MASTER

MASTER HYDRO (PRIVATE) LIMITED

REGISTERED OFFICE: FURNITURE MARKER DIR, DISTRICT UPPER DIR, KHYBER PAKHTUNKHWA, DIR, PROVINCIALLY ADMINISTRATED TRIBAL AREAS (P.A.T.A) 18000

POSTAL ADDRESS: 82 - C-1, GULBERG III, LAHORE.

TEL: +92-42-35752620-22, +92-42-35758524-26
UAN: +92-42-111-666-555. FAX: +92-42-35751905

Date: 05-July-2018

The Registrar,
National Electric Power Regulatory Authority
NEPRA Tower Attaturk Avenue (East),
Sector G-5/1, Islamabad.

Subject: Submission of application for Generation License for Master Hydro Power (Private) Limited for its 99 MW (102.3 MW gross) Arkari Gol Hydro Power Project

Dear Sir,

Master Textile Mills Limited ("**MTML**") was notified by Pakhtunkhwa Energy Development Organization as the first ranked bidder vide letter reference 2473-76/PEDO/DRE/MASTER dated October 23, 2017 for the Arkari Gol Hydro Power Project (the "**Project**") as a result of the competitive bidding process for the award of the Project. Therefore, MTML has incorporated a special purpose vehicle Master Hydro (Private) Limited ("**MHPL**") to undertake the development of the Project.

We would like to submit herewith our Application for Issuance of Generation License for MHPL. The required documents pursuant to the provisions of National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations, 1999 are attached herewith this application.

A Pay Order bearing number 0525754 dated 04-07-2018 of Pakistani Rupees 782,440/- as nonrefundable license application fee calculated in accordance with Schedule 11 to the National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations, 1999, is also attached herewith.

The application for the Generation License (including its Annexures) is submitted in triplicate.

Yours sincerely,

For and on behalf of
Master Hydro (Private) Limited

Master Hydro (Private) Limited

Rumman Arshad Dar
Chief Operating Officer

For information
— DRO/D Reg-I
Coord:
— SA(Tech)
— SAT-I
— DG(M&E)
— ADG(Lic)
— LA(Lic)
— MF

06 07 18
Chairman
M(T)
M(M&E)
M(Lic)

Received alongwith two copies & Chq. amounting Rs 782,440/-

REGISTRAR
Dy. No. 6803
Dated: 06-07-18

Application for Generation License

By Master Hydro (Private) Limited

For 99 MW (102 MW gross) Arkari Gol Hydropower Project in District Chitral, KPK

Before:

National Electric Power Regulatory Authority

July 6, 2018

Contents

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CONTENTS

SECTION - 1

Request for Generation License

1 REQUEST FOR GENERATION LICENSE

Under the Regulation of Generation, Transmission and Distribution of Electric Power Act (XL of) 1997 (the **NEPRA Act**) and the National Electric Power Regulatory Authority Licensing (Generation) Rules 2000 (the **Licensing Rules**), the National Electric Power Regulatory Authority (**NEPRA**) is responsible for and has authority to *inter alia* grant licenses for the generation of electric power and other terms and conditions for the supply of electricity through generation. The National Electric Power Regulatory Authority Licensing (Application & Modification Procedure) Regulations,1999 (**The Licensing Regulations**), specify the procedure to be adopted for application to NEPRA for grant of generation License.

Pursuant to Sections 7(2)(a) and 15 of the NEPRA Act, read with other enabling provisions of the NEPRA Act,the Licensing Rules and the Licensing Regulations, and in accordance with the KP Hydropower Policy 2016 (the **Policy**); Master Hydro (Private) Limited (the **Project Company** or the **Applicant**) hereby submits for NEPRA's kind and gracious consideration, the application for the grant of a generation license along with supporting documents (the **Generation License Application**) for its 99 MW (102 MW gross) hydropower generation facility to be located at District Chitral, KPK, Pakistan (the **Project**).

Given the advanced stage of the Project, NEPRA is kindly requested to process this Generation License Application at the earliest, thereby enabling the Project Company to proceed further with the development process.

This Generation License Application is submitted in triplicate.

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SECTION - 2

The Project

2 THE PROJECT

2.1 Project Status

The 99 MW (102 MW gross) Arkari Gol hydropower project was identified as part of a comprehensive study conducted by the Government of Khyber Pakhtunkhwa in collaboration with the German Agency for Technical Cooperation. In 2013-14, an extensive site investigation was conducted by the Pakhtunkhwa Energy Development Organisation (**PEDO**) which included field reconnaissance, topographical survey, hydrological and geological investigations and engineering and design studies. Based on the results of field investigations, the Project was considered viable for development and the results were compiled into a Project Feasibility Study (the **PFS**). In line with NEPRA's guidelines for competitive bidding for award of solicited sites, PEDO initiated a single stage two-envelope competitive bidding process for award of the Project. Pre-qualified bidders were required to submit both a technical proposal and a commercial proposal, based on the design outlined in the Project Feasibility Study.

A summary of the bidding process conducted by PEDO is outlined in table **??** below.

In compliance with the requirements of the RFP, Master Textile Mills Limited (**MTML** or the **Main Sponsor**) submitted its technical and commercial proposals (the **Bid**) to PEDO for evaluation. As a result of the bidding process, MTML was notified by PEDO as the first ranked bidder for the Project. Master Hydro (Private) Limited (**MHPL**), was incorporated on August 09, 2017 to develop, own and operate the Project.

Subject to approval of the tariff petition and generation license by NEPRA, the indicative time lines for subsequent project development milestones are outlined below:

Date	Activity
July 2018	Submission of Tariff Petition to NEPRA
Aug 2018	Issuance of Letter of Award
Sept 2018	Issuance of Letter of Support
Apr 2019	Financial Close
Mid 2023	Expected COD

Table 2.1: Way forward

RAP
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Date	Activity
Mar 2016	Project advertised by PEDO as solicited site and interested parties invited to submit pre-qualification documents
14 Jun 2016	Pre-qualification documents submitted by interested parties
10 Oct 2016	Notification of pre-qualification issued to applicants, and pre-qualified applicants invited to purchase the request for proposal document (**RFP**)
07 Nov 2016	A comprehensive RFP package issued by PEDO, outlining the mechanism to be adopted for award of the Project through competitive bidding
01 Jan 2017	Pre-bid meeting held in Islamabad to clarify queries of pre-qualified applicants
25 Apr 2017	Submission of technical and commercial bids by pre-qualified bidders and bid opening of technical proposals (Envelope I)
19 Jul 2017	Technically responsive bidders notified by PEDO
24 Jul 2017	Bid opening of commercial proposals (Envelope II) of technically responsive bidders
23 Oct 2017	First Ranked Bidders notified by PEDO
19 March 2017	Motion for Leave for Review (MLR) filed by PEDO
27 June 2017	Successful Bidder notified by PEDO

Table 2.2: Summary of Bidding Process

2.2 The Sponsors

Master Textile Mills Limited was incorporated on February 13, 1992 as a private limited company under the Companies Ordinance, 1984 and was subsequently converted into a public limited company in 1992. MTML is principally engaged in the manufacturing and trade of yarn, grey cloth, dyed fabric and stitched garments.

The Main Sponsor is part of Master Group of Industries (the **Group**), one of the most dynamic business groups of Pakistan. The Group started its core business in the bedding industry followed by diversification into textile, automobile, engineering, retail and power sectors. The Group comprises the following key companies:

- Master Textile Mills Limited
- Master Enterprises (Private) Limited
- Dura Industries (Private) Limited
- Procon Engineering (Private) Limited
- Master Motor Corporation (Private)Limited

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- Master Wind Energy Limited
- Master Green Energy Limited
- Master Offisys (Private) Limited
- Celeste Home Fashion (Private) Limited

The Group is committed to play its part in the development of Pakistan's various sectors. Realizing the role of clean energy in development of the nation, Master Group ventured into the power generation sector by developing a 52.8 MW wind power project in Jhimpir, Sindh. Master Wind Energy Limited (**MWEL**) successfully commenced commercial operation in October 2016. The company is expanding its operational base by developing two additional wind energy projects in the wind corridor of District Thatta, as well as installing a solar hybrid set up at the existing MWEL project site. Master Green Energy Limited is the Sponsor's second project in the wind power sector, which is expected to achieve financial close by end 2018. Another 50 MW wind power project, Jamshed Wind Energy Limited is also being developed in Jhimpir, near the MWEL site.

P-AD
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2.3 Project Costs and Funding Plan

A breakup of the cost heads is provided in the tables below, based on the costs submitted as part of the Bid. As indicated in the Bid, the proposed Project cost is USD 214.55 million.

Project Costs	Mil. USD
EPC	150.00
Non EPC	33.79
Interest During Construction	21.06
Insurance	1.50
Financial Charges	6.18
Feasibility Study	2.04
Total	**214.55**

Source of Funds	Mil. USD
DEBT (75%)	
Foreign	95.89
Local	65.03
EQUITY (25%)	53.64
Total Financing	**214.55**

25% of the project costs will be injected by the sponsors as equity, while the remaining 75% will be financed through debt. The sponsors have adequate resources and financial strength to take on development of the Project, as evidenced in section ?? of this document. On the debt financing front, Overseas Private Investment Corporation **(OPIC)** and National Bank of Pakistan **(NBP)** have committed to arrangement of the required foreign and local financing.

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SECTION - 3

Generation License Application

3 Generation License Application

3.1 Application for Generation License[2]

[2]As per form specified in Schedule I of the Licensing Regulations

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MASTER HYDRO (PRIVATE) LIMITED

REGISTERED OFFICE: FURNITURE MARKER DIR, DISTRICT UPPER DIR, KHYBER PAKHTUNKHWA, DIR, PROVINCIALLY ADMINISTRATED TRIBAL AREAS (P.A.T.A) 18000

POSTAL ADDRESS: 82 - C-1, GULBERG III, LAHORE.

TEL: +92-42-35752620-22, +92-42-35758524-26
UAN: +92-42-111-666-555. FAX: +92-42-35751905

The Registrar,

National Electric Power Regulatory Authority

Subject: **Application for a Generation License**

I, Rumman A. Dar, being the duly authorized representative of Master Hydro (Private) Limited by virtue of Board Resolution dated November 3rd, 2017 hereby apply to the National Electric Power Regulatory Authority for the grant of a Generation License to Master Hydro (Private) Limited, pursuant to Section 15 of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997.

I, certify that the documents-in-support attached with this application are prepared and submitted in conformity with the provisions of the National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations,1999, and undertake to abide by the terms and provisions of the above-said regulations. I further undertake and confirm that the information provided in the attached documents-in-support is true and correct to best of my knowledge and belief.

A pay order in the sum of Pakistani Rupees 782,440 /-, being the non-refundable license application fee calculated in accordance with Schedule II to the National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations, 1999, is also attached herewith.

Date: 05-July-2018

Master Hydro (Private) Limited *

Rumman A. Dar
Chief Operating Officer
Master Hydro (Private) Limited

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3.2 Board Resolution authorizing application for Generation License

RAD
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MASTER HYDRO (PRIVATE) LIMITED

Lahore Office: 82 – C-1, Gulberg III, Lahore.
Tel: +92-42-35752620-22, +92-42-35758524-26
UAN: +92-42-111-666-555, Fax: +92-42-35751905

EXTRACT OF THE BOARD RESOLUTION PASSED AND APPROVED BY THE BOARD OF DIRECTORS OF MASTER HYDRO (PRIVATE) LIMITED ON November 3, 2017.

"RESOLVED THAT **Master Hydro (Private) Limited** a company incorporated under the laws of Pakistan with its registered office located at 54 Darul Aman Co-Operative Housing Society, Main Shahra-e-Faisal, Karachi (the "**Company**") be and is hereby authorized to submit an application for Generation License (including any subsequent modifications) for submission to the National Electric Power Regulatory Authority ("**NEPRA**") for grant of Generation License in respect of its 99 MW (102.3 MW Gross) Arkari Gol Hydropower Project located at Chitral District, Khyber Pakhtunkhwa, Pakistan (the "**Project**") and in relation thereto, enter into and execute all required documents, make all filings and pay all applicable fees, in each case, of any nature whatsoever, as required."

"FURTHER RESOLVED THAT in respect of filing of application for Generation License (including any subsequent modifications) for submission to NEPRA, Mr. Rumman Arshad Dar (Chief Operation Officer) be authorized and empowered for and on behalf of the Company to:

(i) review, execute, submit, and hereby deliver the application for Generation License (including any subsequent modifications) and any related documentation required by the NEPRA for the determination of the reference to application for generation license including any contract, documents, affidavits, letters, forms, applications, deeds, guarantees, undertakings, approvals, memoranda, amendments, communications, notices, certificates, requests, statements, and any other instruments in respect to the Generation License;
(ii) represent the Company in all negotiations, representations, presentations, hearings, conferences and/or meetings of any nature whatsoever with any entity (including, but in no manner limited to NEPRA, any private parties, companies, partnerships, individuals, governmental and/or semi-governmental authorities and agencies, ministries, boards, departments, regulatory authorities and/or any other entity of any nature whatsoever);
(iii) sign and execute the necessary documentation, pay the necessary fees, appear before the NEPRA as needed, and do all acts necessary for the completion and processing of the application for Generation License including any modifications;
(iv) do all such acts, matters and things as may be necessary for carrying out the purposes aforesaid and giving full effect to the above resolution/resolutions;"

IN WITNESS THEREOF, I hereunder set my hands as such Secretary and affix the corporate seal of the said Company

Company Secretary

Master Hydro (Private) Limited

RAD
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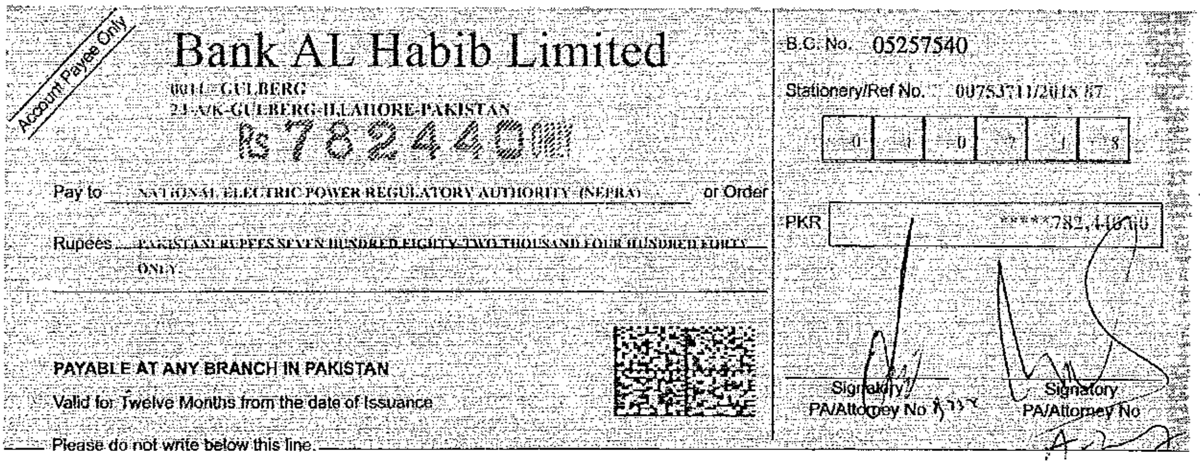
3.3 Application Fee[3]


Account Payee Only

Bank AL Habib Limited

0011 - GULBERG

23-A/K-GULBERG-II,LAHORE-PAKISTAN

Rs 782440

B.C. No. 05257540

Stationery/Ref No.

Pay to NATIONAL ELECTRIC POWER REGULATORY AUTHORITY (NEPRA) or Order

Rupees PAKISTANI RUPEES SEVEN HUNDRED EIGHTY-TWO THOUSAND FOUR HUNDRED FORTY ONLY

PKR *****782,440.00

PAYABLE AT ANY BRANCH IN PAKISTAN

Valid for Twelve Months from the date of Issuance

Signatory PA/Attorney No

Signatory PA/Attorney No

Please do not write below this line

[3]Pay order of Rs. **782,440** /- (Fee with CPI for upto **June 30, 2018**) attached as Application of Generation License Fee for power projects over 100 MW (gross)

Certified True Copy

3.4 Affidavit of authorised representative

Certified True Copy

C090151

200 Rupees ۲۰۰ روپیہ

BEFORE
THE NATIONAL ELECTRIC POWER REGULATORY AUTHORITY

AFFIDAVIT

Affidavit of **Mr. Rumman Arshad Dar** S/o **Mr. Arshad Iqbal Dar**, having CNIC No. 61101-1927558-5 resident of **House # 506-CC, Street # 13, Phase-IV, DHA, Lahore,** and authorized representative of **MASTER HYDRO (PRIVATE) LIMITED**, having its registered office at **FURNITURE MARKET DIR, DISTRICT UPPER DIR, KHYBER PAKHTUNKHWA, DIR, PROVINCIALLY ADMINISTRATED TRIBAL AREAS (P.A.T.A) 18000** (the "**Company**").

I, the above mentioned Deponent, do hereby solemnly affirm and declare that:

1. I am the **Chief Operating Officer** of the Company.
2. I am the authorized representative of the Company by virtue of Board Resolution dated 3rd of November, 2017.
3. The contents of accompanying Generation License Application dated 6 of July, 2018 submitted to the National Electric Power Regulatory Authority ("**NEPRA**") along with the supporting documents are true and correct to the best of my knowledge and belief and nothing material or relevant thereto has been concealed or withheld therefrom.
4. I also affirm that all further documentation and information to be provided by me in connection with the aforesaid Generation License Application shall be true and correct to the best of my knowledge and belief.

DEPONENT

VERIFICATION

It is hereby verified on solemn affirmation at 5th Day of July, 2018, that the contents of the above affidavit are true and correct to the best of my knowledge and belief, and nothing material or relevant thereto has been concealed or withheld therefrom.

DEPONENT

ATTESTED
Notary Public
Distt. Courts Lahore

Certified True Copy

SECTION - 4

Documents in Support

4 Documents in Support

4.1 Regulatory Filings of the Project Company

As required pursuant to Regulation 3(5)(a) of the Licensing Regulations, the following regulatory filings of the Project Company are attached.

- Certified copy of Certificate of Incorporation
- Certified copy of Memorandum & Articles of Association
- Annual Return of the Project Company

Certified True Copy

4.1.1 Certified copy of Certification of Incorporation

Pursuant to Regulation 3(5)(a)(i), please see attached certified copy of Certificate of Incorporation.

CAD
Certified True Copy

A031719

SECP

SECURITIES AND EXCHANGE COMMISSION OF PAKISTAN

COMPANY REGISTRATION OFFICE, KARACHI

CERTIFICATE OF INCORPORATION

[Under section 16 of the Companies Act, 2017 (XIX of 2017)]

Corporate Universal Identification No. 0110719

I hereby certify that MASTER HYDRO (PRIVATE) LIMITED is this day incorporated under the Companies Act, 2017 (XIX of 2017) and that the company is limited by shares.

Given under my hand at Karachi this Ninth day of August, Two Thousand and Seventeen.

Incorporation fee Rs. 5,500/=

(Kashif Mahmood)
Deputy Registrar of Companies

Certified to be True Copy

Deputy Registrar of Companies

Dated 11-08-2017

Certified True Copy

4.1.2 Certified copy of Memorandum and Articles of Association

Pursuant to Regulation 3(5)(a)(ii), please see attached certified copies of Memorandum and Articles of Association.

Certified True Copy

(AMENDED)

THE COMPANIES ACT, 2017 (XIX OF 2017)

(COMPANY LIMITED BY SHARES)

MEMORANDUM

OF

ASSOCIATION

OF

MASTER HYDRO (PRIVATE) LIMITED

SECURITIES AND EXCHANGE COMMISSION OF PAKISTAN
COMPANY REGISTRATION OFFICE
PESHAWAR

Certified True Copy

THE COMPANIES ACT, 2017 (XIX OF 2017)

(COMPANY LIMITED BY SHARES)

MEMORANDUM OF ASSOCIATION

OF

MASTER HYDRO (PRIVATE) LIMITED

1. The name of the company is Master Hydro (Private) Limited.

2. The registered office of the Company will be situated in the Province of Khyber Pakhtunkhwa (KPK).

3. (i) The Company's principal objective is to setup power generation projects and to operate, generate, accumulate and to supply electric power subject to license from regulator. However, Company will not undertake the business of Non-Banking Finance Company and Brokerage business.

(ii) Except for the businesses mentioned in sub-clause (iii) hereunder, the company may engage in all the lawful businesses and shall be authorized to take all necessary steps and actions in connection therewith and ancillary thereto.

(iii) Notwithstanding anything contained in the foregoing sub-clauses of this clause nothing contained herein shall be construed as empowering the Company to undertake or indulge, directly or indirectly in the business of a Banking Company, Non-banking Finance Company (Mutual Fund, Leasing, Investment Company, Investment Advisor, Real Estate Investment Trust management company, Housing Finance Company, Venture Capital Company, Discounting Services, Microfinance or Microcredit business), Insurance Business, *Modaraba* management company, Stock Brokerage business, forex, real estate business, managing agency, business of providing the services of security guards or any other business restricted under any law for the time being in force or as may be specified by the Commission.

(iv) It is hereby undertaken that the company shall not:

(a) engage in any of the business mentioned in sub-clause (iii) above or any unlawful operation;

(b) launch multi-level marketing (MLM), Pyramid and Ponzi Schemes, or other related activities/businesses or any lottery business;

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(c) engage in any of the permissible business unless the requisite approval, permission, consent or license is obtained from competent authority as may be required under any law for the time being in force.

4. The liability of the members is limited.

5. The authorized capital of the company is Rs 1,000,000 (Rupees one million only) divided into 100,000 (one hundred thousand) ordinary shares of Rs. 10/- (Rupees ten only) each.

We, the several persons whose names and addresses are subscribed below, are desirous of being formed into a company, in pursuance of this memorandum of association, and we respectively agree to take the number of shares in the capital of the company as set opposite our respective names:

SR. NO.	NAME AND SURNAME (PRESENT AND FORMER) IN FULL BLOCK LETTERS	CNIC NO. (IN CASE OF FOREIGNER, PASSPORT NO)	FATHER'S/ HUSBAND'S NAME IN FULL	NATIONALITY WITH ANY FORMER	OCCUPATION	RESIDENTIAL ADDRESS IN FULL	NUMBER OF SHARES TAKEN BY EACH SUBSCRIBER	SIGNATURE OF THE SUBSCRIBER
1	MR. NADEEM MALIK	42301-8656497-9	S/O MR. RIAZ MALIK	PAKISTANI	BUSINESS	PLOT NO. 75, KHAYABAN-E-SHAHEEN, PHASE VI, D.H.A, KARACHI	10,000	...Sd...
2	MR. NAJEEB MALIK	35201-3088787-3	S/O MR. RIAZ MALIK	PAKISTANI	BUSINESS	PLOT NO. 321, BLOCK K, PHASE 1, LAHORE CANTT COOPERATIVE HOUSING SOCIETY, LAHORE	10,000	..Sd...
3	MR. SHAHZAD MALIK	352019-295415-7	S/O MR. NAVEED MALIK	PAKISTANI	BUSINESS	126- Y BLOCK, STREET NO. 18, D.H.A. LAHORE	10,000	....Sd...
	Total number of shares taken		*Thirty Thousand shares of Rs. 10 each*				**30,000**	

Dated the 3rd day of August, 2017.

SECURITIES & EXCHANGE COMMISSION OF PAKISTAN REGISTRATION OFFICE

Page 3 of 3

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(Muhammad Nasir Gill)
Deputy Registrar of Companies
Securities and Exchange Commission of Pakistan
CRO, Peshawar 16/4/2018

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THE COMPANIES ACT, 2017 (XIX of 2017)

(PRIVATE COMPANY LIMITED BY SHARES)

Articles of Association

of

MASTER HYDRO (PRIVATE) LIMITED

SECURITIES & EXCHANGE COMMISSION OF PAKISTAN
REGISTRATION OFFICE

KAD
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THE COMPANIES ACT, 2017 (XIX of 2017)

(Private Company Limited by Shares)

ARTICLES OF ASSOCIATION

OF

MASTER HYDRO (PRIVATE) LIMITED

1. The Regulations contained in Table 'A' to the First Schedule to the Companies Act, 2017 (the "Act") shall be the regulations of **MASTER HYDRO (PRIVATE) LIMITED** (the "Company") so far as these are applicable to a private company.

PRIVATE COMPANY

2. The Company is a "Private Company" within the meaning of Section 2(1)(49) of the Act and accordingly:

(1) No invitation shall be made to the public to subscribe for the shares or debentures of the Company.

(2) The number of the members of the Company (exclusive of persons in the employment of the Company), shall be limited to fifty, provided that for the purpose of this provision, where two or more persons hold one or more shares in the company jointly, they shall be treated as single member; and

(3) The right to transfer shares of the Company is restricted in the manner and to the extent herein appearing.

TRANSFER OF SHARES

3. A member desirous to transfer any of his shares shall first offer such shares for sale or gift to the existing members and in case of their refusal to accept the offer, such shares may be transferred to any other person, as proposed by the transferor member, with the approval of the Board of Directors.

DIRECTORS

4. The number of directors shall not be less than two or a higher number as fixed under the provisions of the Act. The following persons shall be the first directors of the Company and shall hold the office upto the date of First Annual General Meeting:

1. Mr. Shahzad Malik
2. Mr. Nadeem Malik
3. Mr. Najeeb Malik

We, the several persons whose names and addresses are subscribed below, are desirous of being

SECURITIES & EXCHANGE COMMISSION OF PAKISTAN
REGISTRATION OFFICE

KAD

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formed into a company, in pursuance of these articles of association, and we respectively agree to take the number of shares in the capital of the company set opposite our respective names:

SR. NO.	NAME AND SURNAME (PRESENT AND FORMER) IN FULL BLOCK LETTERS	CNIC NO. (IN CASE OF FOREIGNER, PASSPORT NO)	FATHER 'S/ HUSBAND'S NAME IN FULL	NATIONALITY WITH ANY FORMER	OCCUPATION	RESIDENTIAL ADDRESS IN FULL	NUMBER OF SHARES TAKEN BY EACH SUBSCRIBER	SIGNATURE OF THE SUBSCRIBER
1	MR. NADEEM MALIK	42301-8656497-9	S/O MR. RIAZ MALIK	PAKISTANI	BUSINESS	PLOT NO. 75, KHAYABAN-E-SHAHEEN, PHASE VI, D.H.A, KARACHI	10,000	...Sd...
2	MR. NAJEEB MALIK	35201-3088787-3	S/O MR. RIAZ MALIK	PAKISTANI	BUSINESS	PLOT NO. 321, BLOCK K, PHASE 1, LAHORE CANTT COOPERATIVE HOUSING SOCIETY, LAHORE	10,000	..Sd...
3	MR. SHAHZAD MALIK	352019-295415-7	S/O MR. NAVEED MALIK	PAKISTANI	BUSINESS	126- Y BLOCK, STREET NO. 18, D.H.A. LAHORE	10,000	....Sd....
Total number of shares taken			*Thirty Thousand shares of Rs. 10 each*				**30,000**	

Dated the 3rd day of August, 2017.

SECURITIES & EXCHANGE COMMISSION OF PAKISTAN ... OFFICE

Certified to be True Copy

(Muhammad ...)
Deputy Registrar of Companies
Securities and Exchange Commission of Pakistan
CRO, Peshawar 16/4/2018

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4.1.3 Certified copy of last filed annual return

Master Hydro (Private) Limited was incorporated on August 9, 2017. Annual Returns will be filed after one operational year.

However, as required pursuant to Regulation 3(5)(a)(iv) of the Licensing Regulations, please see attached an annual return prepared in accordance with the third schedule of the Companies Ordinance.

"THIRD SCHEDULE

(See section 156)

FORM A- ANNUAL RETURN OF COMPANY HAVING SHARE CAPITAL

1	Registration No.	0110719		
2	Name of the Company	MASTER HYDRO (PRIVATE) LIMITED		
3	Form A made upto (Day/Month/Year)	30	06	18
4	Date of AGM (Day/Month/Year)			

PART-A

5	Registered office address:
	FURNITURE MARKET DIR, DISTRICT UPPER DIR, KHYBER PAKHTUNKHWA, DIR, PROVINCIALLY ADMINISTRATED TRIBAL AREAS (P.A.T.A) 18000, Pakistan
6	Email Address: amir.m.butt@master.com.pk
7	Office Tel. No.:2132579980
8	Office Fax No.: 2132570135
9	Nature of Business: POWER GENERATION

10 Authorized Share Capital

Type of Shares	No. of Shares	Amount	Face Value
Ordinary Shares	100,000	10	1,000,000

11 Paid up Share Capital

Type of Shares	No. of Shares	Amount	Issue Price
Ordinary Shares	30,000	10	300,000

12	Amount of indebtedness on the date upto which form A is made in respect of all			
	Mortgages/Charges	NIL		
13	**Particulars of the holding company**			
	Name			
	Registration No.	% Shares Held		
14	**Chief Executive**			
	Name	SHAHZAD MALIK	NIC	3520192954157
	Address	Y-26 STREET NO 13, DHA LAHORE		
15	**Chief Accountant**			
	Name		NIC	
	Address			
16	**Secretary**			
	Name		NIC	
	Address			

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17	**Legal Adviser**
	Name:
	Address:
18	**Auditors**
	Name:
	Address:

19 **List of Directors on the date of Form-A**

Name of Director	Address	Nationality	NIC (Passport No. if foreigner)												
1. SHAHZAD MALIK	Y-26 STREET NO 13, DHA LAHORE	PAKISTAN	3	5	2	0	1	9	2	9	5	4	1	5	7
2.NAJEEB MALIK	PLOT NO. 321, BLOCK-K, PHASE-1, LAHORE CANTT	PAKISTAN	3	5	2	0	1	3	0	8	8	7	8	7	3
3. NADEEM MALIK	HOUSE NO. 75 KHAYABAN-E-SHAHEEN, PHASE VI, DHA KARACHI	PAKISTAN	4	2	3	0	1	8	6	5	6	4	9	7	9
4.															
5.															
6.															
7.															
8.															
9.															

PART-B

20. List of members & debenture holders on the date upto which this Form A is made

Folio	Name	Address	Nationality	No. of shares	NIC (Passport No. if foreigner)												
	Members																
	SHAHZAD MALIK	Y-26 STREET NO 13, DHA LAHORE	PAKISTAN	10,000	3	5	2	0	1	9	2	9	5	4	1	5	7
	NADEEM MALIK	HOUSE NO. 75 KHAYABAN-E-SHAHEEN, PHASE VI, DHA KARACHI	PAKISTAN	10,000	4	2	3	0	1	8	6	5	6	4	9	7	9
	NAJEEB MALIK	PLOT NO. 321, BLOCK-K, PHASE-1, LAHORE CANTT	PAKISTAN	10,000	3	5	2	0	1	3	0	8	8	7	8	7	3

	Debenture holders																

Use separate sheet, if necessary

21.	Transfer of shares (debentures) since last Form A was made			
	Name of Transferor	Name of Transferee	Number of shares transferred	Date of registration of transfer
	Members			
	Debenture holders			

Use separate sheet, if necessary

22. I certify that this return and the accompanying statements state the facts correctly and completely as on the date upto which this Form-A is made

Date		30	06	18		Signature	
						Designation (Please tick)	Chief Executive/Secretary

INSTRUCTIONS FOR FILLING FORM-A

1. The Form shall be made upto the date of last AGM of the Company or the last date of the year where no AGM is held during the year.

2. Under nature of business, please give precisely the specific nature of business in which the company is engaged.

3. Under S. No.20 above, the aggregate number of shares held by each member should be stated, and the aggregates must be added up so as to agree with the number of shares stated against NO. 11.

4. When the shares are of different classes the columns should be subdivided so that the number of each class held, or transferred, is shown separately against S. Nos. 10,11,20 and 21.

5. If the space provided in the Form is insufficient, the required particulars should be listed in a separate statement attached to this return which should be similarly certified and signed.

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6. The return and any statement attached hereto shall be signed by the chief executive or the secretary.

7. In case a body corporate is a member, NIC number may be omitted to be given.

8. In case of foreign nationals, indicate "passport number" in the space provided for "NIC No." Pakistani nationals will only indicate "NIC NO."

9. This form is to be filed within 30 days (45 days in case of listed company) of the date indicated in S.No.3 above.

4.2 Management profiles and CV

Brief Profiles and Curriculum Vitae of applicant's key management, as required pursuant to Regulation 3(5)(b) & Regulation 3(5)(c) of the Licensing Regulations attached herewith.

BOARD OF DIRECTORS

❖ NADEEM MALIK – DIRECTOR

Mr. Nadeem Malik has been associated with the Group for the past 25 years and is a director and major stakeholder in the companies comprising the Master Group. He spearheaded the Group's expansion into the automotive sector, and is currently Managing Director of Procon Engineering (Private) Limited and Master Motor Corporation (Private) Limited. He holds a Bachelor's degree in Business Administration from the University of Southern California.

Professional Experience

Mr. Nadeem Malik specializes in and has extensive experience in the Automotive Industry and has been successfully running his business over a period spanning over 2 decades. He is currently managing director of Procon Engineering (Pvt) Ltd and Master Motor Corporation along with holding directorship in the Master Group companies in Pakistan as detailed below:

o **PROCON ENGINEERING (PVT) LTD** – ***Managing Director***

The year 1988 saw the foundation of PROCON ENGINEERING (PVT) LTD which rapidly grew to be a totally self-reliant composite manufacturing facility, with strength of over 250 engineers and technical staff. Since then PROCON ENGINEERING (PVT) LTD has always been at the forefront as an integral player in the industrialization of Pakistan. PROCON ENGINEERING (PVT) LTD is involved in the manufacture and supply of the following items:

- All type of automobile seats
- Sports car seats for export
- Door trims (molded & flat type)
- Roof headlining (molded, suspended & perforated types)
- Steering wheels
- Rear package tray
- Sun visors
- Fender liner
- Engine under cover
- Armrests
- Floor mats

o **MASTER MOTOR CORPORATION** – ***Managing Director***

Master Motor Corporation has state-of-the-art technology at its newly built plant at Bin Qasim, Karachi. Master Motor Corporation is introducing 4.5 Ton, 3.5 Ton and 2 Ton light duty truck and medium size buses to be followed by a variety of models including medium and heavy duty trucks and large buses.

o **DIRECTOR**

- Master Foam (Pvt) Ltd, Mirpur (Azad Kashmir)
- Dura Industries (Pvt) Ltd, Mirpur (Azad Kashmir)
- Master Polymer Industries (Pvt) Ltd.
- Dura Foam (Pvt) Ltd
- Master Enterprises (Pvt) Ltd, Karachi
- Master Textile Mills Ltd, Lahore
- Master Celeste (Pvt) Ltd, Lahore
- Procon Engineering (Pvt) Ltd
- Master Motorcycles (Pvt) Ltd
- Master Motor Corporation Ltd

BOARD OF DIRECTORS

- Master Tractors (Pvt) Ltd
- Media Flow (Pvt) Ltd
- Master Tex Ltd
- Master Wind Energy Ltd

Education
- O' Level from Cambridge University in 1979.
- Bachelor of Business Management from University of Southern California, LOS Angeles, U.S.A. in 1983.

❖ NAJEEB MALIK – DIRECTOR
Mr. Najeeb Malik has been associated with the Group for over twenty years. He was the driving force behind Master Group's diversification into the textile sector, and is currently Managing Director of Master Textile Mills Limited. He is also a major stakeholder and director of the other Master Group Companies. Mr. Najeeb Malik holds an engineering degree from University of Southern California.

Professional Experience
Mr. Najeeb Malik specializes in textile industry and has been successfully running his business for the last 2 decades. He is currently managing director of Master Textile Mills Ltd along with holding directorship in the Master Group companies in Pakistan as detailed below:

o **MASTER TEXTILE MILLS LIMITED** – ***Managing Director***
MTML was incorporated on February 13, 1992 as a private limited company under the Companies Ordinance, 1984 and was subsequently converted into a public limited company in 1992. MTML is a fully vertically integrated facility, with spinning, weaving, dyeing and garment divisions. It is one of the go-to choices manufacturing choices for international brands.

o **DIRECTOR:**
- Master Foam (Pvt) Ltd, Mirpur (Azad Kashmir).
- Dura Industries (Pvt) Ltd, Mirpur (Azad Kashmir)
- Master Polymer Industries Ltd
- Dura Foam (Pvt) Ltd
- Master Enterprises (Pvt) Ltd, Karachi
- Master Textile Mills Ltd, Lahore
- Master Celeste (Pvt) Ltd, Lahore
- Procon Engineering (Pvt) Ltd
- Master Motorcycles (Pvt) Ltd
- Master Motor Corporation (Pvt) Ltd
- Master Tractors (Pvt) Ltd
- Media Flow (Pvt) Ltd
- Master Tex Ltd
- Master Wind Energy Ltd

Education
- Master's degree in Engineering from University of Southern California, USA

BOARD OF DIRECTORS

❖ SHAHZAD MALIK – DIRECTOR

Mr. Shahzad Malik, a young and enterprising businessman, started his career at Master Group in the core, foam products business. Since taking over, he has revamped the entire product line, expanded beyond Pakistan and updated the look of the Master brand to reflect the modern era. He is also the driving force behind a new foam production facility (2015) at Raiwind, and the inauguration of the Marina Home store in Lahore. Recognising the potential of the wind power sector in Pakistan, Mr. Malik spearheaded Master Group's investment in Master Wind Energy Limited, and is responsible for the management of the MWEL project. As Managing Director, he favours a hand-on approach, which has given him extensive experience and insight into all aspects of wind power projects, from the pre-financial close process of financing, selection of EPC contractors and negotiating the project agreements, to the construction phase of coordinating on the ground activities.

Professional Experience

o Jan 2011 – Present	Managing Director Dura Industries (Pvt.) Ltd., Master Wind Energy Ltd. and Master Green Energy Ltd.

Education

o 2010 – 2011	Masters in Business Administration, Bentley Universities, USA
o 2007 – 2011	Bachelors of Science (Finance), Bentley Universities, USA

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MANAGEMENT PROFILE

❖ RUMMAN ARSHAD DAR – CHIEF OPERATING OFFICER

Mr. Rumman A. Dar has over 12 years of experience in Corporate Finance, Financial Advisory and Investment Banking, with particular expertise in Structured Project Finance, Debt Advisory, Contract Negotiation and Project Development & Implementation. Prior to joining Master Group, he was a Partner at Bridge Factor (boutique financial advisory firm) where he oversaw the firm's power sector clients. In this role, his responsibilities included arrangement of financing and overall project development & implementation (tariffing, concession agreement finalisation, EPC and O&M contract finalisation, etc). He has been involved in the wind industry of Pakistan since it's inception, and contributed to the successful financial close and implementation of numerous wind power projects, including FFC Energy Ltd., Foundation Wind Energy, Sapphire Wind Power Company Ltd., Gul Ahmed Wind Power Ltd. and Master Wind Energy Ltd. Before Bridge Factor, Mr. Dar worked as Director Finance at Cleantech, a local import and distribution company.

Professional Experience

o Jul 2015 – Present	Chief Operating Officer, Master Group Energy Division
o Dec 2008 – Jun 2015	Partner, Bridge Factor
o Mar 2003 – Nov 2008	Director Finance & Accounts, Cleantech (Pvt.) Ltd.
o Oct 2006 – Oct 2009	Director Comcept (Pvt.) Ltd.

Education

o Dec 2007 & Aug 2008	Cleared Level I & II, Chartered Financial Analyst Program (CFA Institute, USA)
o Jan 2007	MBA Finance, Bahria University, Pakistan

❖ SYED SHAHZAD ALI – SENIOR PROJECT MANAGER

Syed Shahzad Ali has over 10 years of experience in the field of Electrical Engineering. He has been a part of several reputable organisations, with varied responsibilities including project management, engineering, technical support and maintenance. Prior to joining Master Wind Energy Ltd., Mr. Ali worked as Project Manager and Electrical Engineer at Al Ajjaj Ltd. Co., a leading electro-mechanical engineering company based in Qatar, where he successfully managed the electrical engineering of the firms numerous development projects, including power generation and transmission. He was responsible for supervising the on-site electrical works of the Master Wind Energy Limited and worked closely with the EPC contractor's electrical team to ensure smooth development activities. Currently, he is the Senior Plant Manager for the Master Wind Energy Limited plant and ensures smooth operations.

Professional Experience

o Nov 2014 – Present	Senior Project Manager, Master Group Energy Division
o Aug 2010 – May 2014	Project Manager/Senior Electrical Engineer, Al Ajjaj Ltd. Co. (Qatar)
o Aug 2008 – Jul 2010	Senior Engineer, Areva T&D (Pvt.) Ltd. Formerly ALSTOM (Pakistan)
o Nov 2007 – Jul 2008	Electrical Engineer, Al Ajjaj Ltd. Co. (Qatar)
o Oct 2006 – Oct 2007	Assistant Manager Electrical

Education

o 2005	Bachelor Tech. (Electrical) (Mehran University of Engineering and Technology)
o 1999	D.A.E. (R, TV and Electronics) (Sindh Board of Technical Education, Karachi)

MANAGEMENT PROFILE

❖ IMRAT AAMIR FAYYAZ – MANAGER, NEW BUSINESS DEVELOPMENT

Ms. Imrat Aamir Fayyaz is an engineering graduate from Cambridge University. She specialized in mechanical engineering, with a particular focus on renewable energy generation technologies. For the past two years, she has been employed at Master Group's Energy Division and has worked closes with the EPC contractor, technical consultants and Original Equipment Manufacturer to ensure smooth and timely installation of all mechanical equipment at our plant. She is currently coordinating development activities for Master Green Energy Limited.

Professional Experience

o Sep 2015 – Present	Manager New Business Development, Master Group Energy Division

Education

o 2014 – 2015	Masters in Engineering (Mechanical) - Cambridge University
o 2011 – 2014	Bachelors in Engineering (Mechanical) - Cambridge University
o 2009 – 2011	Cambridge International A Levels

❖ KHALID USMAN –MANAGER, FINANCE

Mr. Khalid Usman is ACA (VAT Experienced Professional), who worked with Deloitte and performed different assignments including external Audits, Internal Audits, Internal Control Reviews and Compilation of standard Operating Procedures. He also worked with Multinationals, Listed Companies, Deloitte International Clients, Body Corporate, Government Agencies and Private Corporation. Further, he worked for Sitara Chemical Industries Limited and Nishat Chunian as Manager Accounts. Currently, working as Finance Manager at Master Wind Energy Limited.

Professional Experience

o Apr 2015 – Present	Finance Manager , Master Wind Energy Limited
o Jan 2014 – Mar 2015	Manager Accounts, Nishat Chunian Limited
o June 2013 – Jan 2014	Senior Deputy Manager Internal Audit, Sitara Chemical Industries Limited
o June 2009 – May 2013	Senior Supervisor Audit and Business Advisory Services, M. Yousaf Adil Saleem & CO., Lahore (A member firm of Delloitte Touche Tohmatsu Limited)

Education

o 2012 – 2013	Chartered Accountant (ACA) – Institute of Chartered Accountants of Pakistan
o 2007 – 2011	Bachelors of Arts – University of Punjab , Lahore
o 2005 – 2006	FSC Pre- Engineering – Board of Intermediate and Secondary Education, Lahore
o 2002- 2003	Matriculation – Cathedral High School, Lahore

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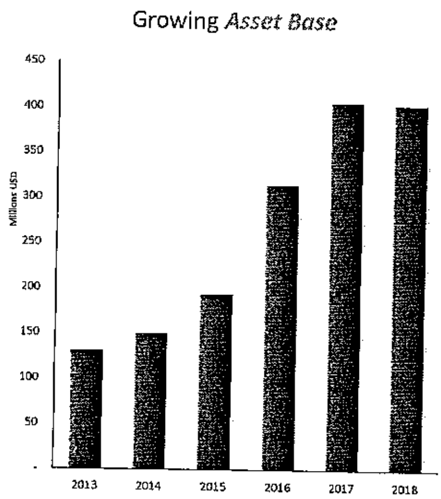
4.3 Evidence of Applicant's technical and financial strength

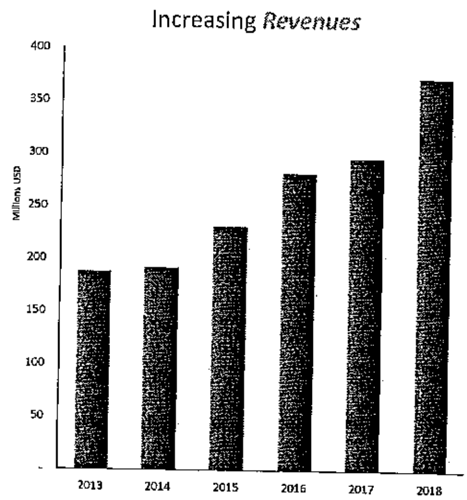
Evidence of Applicant's technical and financial strength attached herewith as required pursuant to Regulation 3(5)(d) of the Licensing Regulations.

4.3.1 Financial Strength of Sponsors

The Applicant is sponsored by Master Group of Industries, one of the most dynamic and diverse business groups in Pakistan. The Group started its operations by entering into the bedding industry in 1963 as a licensee of Bayer A.G. (Germany) to manufacture foam mattresses and became a pioneer in the bedding industry. Today, Master Group has a strong asset base of over US$440 million and an annually increasing group turnover of more than US$400 million. The Group is not only the leading player in the bedding market, but has also diversified over the period into the textile, automobile, engineering and energy sectors. The overall financial strength of Master group is summarised by the graphs below.

Most recent financial statements of Master Textile Mills Limited, Procon Engineering and Master Wind Energy Limited are also provided as further evidence of the Sponsor's financial strength and ability to take on equity investment in the Project.





The sponsor's first venture in the power sector, the 52.8 MW Master Wind Energy Limited project, achieved financial close in March 2015 and commenced commercial operations in October 2016. Master Group has gained invaluable experience during the development and construction of our first wind power project and are positioned to deploy the experience for development of the project.

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4.3.2 Audited Financial Statements of Master Textile Mills Limited

FAO
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Grant Thornton
An instinct for growth™

Grant Thornton Anjum Rahman
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43-Jail Road, Lahore 54000,
Pakistan.
T +92 42 37423 621-23, 37422 987-88
F +92 42 37425 485
www.gtpak.com

AUDITOR'S REPORT TO THE MEMBERS

We have audited the annexed balance sheet of **Master Textile Mills Limited** ("the Company") as at **June 30, 2017** and the related profit and loss account, statement of comprehensive income, cash flow statement and statement of changes in equity together with the notes forming part thereof, for the year then ended and we state that, we have obtained all the information and explanations which, to the best of our knowledge and belief, were necessary for the purposes of our audit.

It is the responsibility of the Company's management to establish and maintain a system of internal control, and prepare and present the above said statements in conformity with the approved accounting standards and the requirements of the Companies Ordinance, 1984. Our responsibility is to express an opinion on these statements based on our audit.

We conducted our audit in accordance with the auditing standards as applicable in Pakistan. These standards require that we plan and perform the audit to obtain reasonable assurance about whether the above said statements are free of any material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the above said statements. An audit also includes assessing the accounting policies and significant estimates made by management, as well as, evaluating the overall presentation of the above said statements. We believe that our audit provides a reasonable basis for our opinion and, after due verification, we report that:

(a) as referred in note 4.21 to the accompanying financial statements, during the year, the Company has adopted TR 32 issued by ICAP prospectively and has classified long term loans obtained from its sponsors amounting to Rs. 558,537,824 as equity. However, the Company has not restated its financial statements as required by such TR and approved accounting standards as applicable in Pakistan. Had prior year financial statements been restated, opening equity would have been increased by Rs. 830,897,646;

(b) in our opinion, proper books of account have been kept by the Company as required by the Companies Ordinance, 1984;

(c) In our opinion:

(i) the balance sheet and profit and loss account together with the notes thereon, except for the matter stated in paragraph (a) above, have been drawn up in conformity with the Companies Ordinance, 1984, and are in agreement with the books of account and are further in accordance with accounting policies consistently applied except as stated in note 4.21 with which we concur;

ii) the expenditure incurred during the year was for the purpose of the Company's business; and

iii) the business conducted, investments made and the expenditure incurred during the year were in accordance with the objects of the Company;

(d) in our opinion and to the best of our information and according to the explanations given to us, except for the effect of matter stated in paragraph (a) above the balance sheet, profit and loss account, statement of comprehensive income, cash flow statement and statement of changes in equity together with the notes forming part thereof, conform with approved accounting standards as applicable in Pakistan, and, give the information required by the Companies Ordinance, 1984, in the manner so required and respectively give a true and fair view of the state of the Company's affairs as at June 30, 2017 and of the profit, total comprehensive income, its cash flows and changes in equity for the year then ended; and

(e) in our opinion, no Zakat was deductible at source under the Zakat and Ushr Ordinance, 1980.

Grant Thornton Anjum Rahman
CHARTERED ACCOUNTANTS
Engagement Partner: Imran Afzal
Lahore
Dated: October 09, 2017

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Balance sheet
As at June 30, 2017

	Note	2017 Rupees	2016 Rupees
Equity and liabilities			
Equity			
Share capital and reserves			
Authorized capital			
50,000,000 (2016: 50,000,000) ordinary shares of Rs. 10/- each		500,000,000	500,000,000
Issued, subscribed and paid-up capital	5	316,002,930	285,850,000
Convertible loan	6	-	301,529,300
Loans from directors	7	558,537,824	-
Reserves	8	3,724,815,821	3,032,503,549
Total equity		4,599,356,575	3,619,882,849
Liabilities			
Non-current			
Long term financing	9	1,090,135,734	626,303,696
Loans from directors	10	-	830,897,646
Deferred liability	11	426,580	546,161
Total non-current liabilities		1,090,562,314	1,457,747,503
Current			
Trade and other payables	12	1,996,246,771	1,970,952,753
Mark-up accrued on loans		62,672,805	36,566,566
Loans from directors	13	168,505,942	-
Short term borrowings	14	3,858,152,415	2,951,979,781
Current portion of long term financing	15	138,541,716	85,564,224
Total current liabilities		6,224,119,649	5,045,063,324
Total liabilities		7,314,681,963	6,502,810,827
Total equity and liabilities		11,914,038,538	10,122,693,676
Contingencies and commitments	16		
Assets			
Non-current			
Property, plant and equipment	17	4,665,779,824	3,975,588,185
Intangible assets	18	20,689,559	26,351,694
Long term deposits		2,864,823	2,801,823
Investment in subsidiary	19	250,000,000	250,000,000
Investment in associate	20	506,048,000	506,048,000
Total non-current assets		5,445,382,206	4,760,789,702
Current			
Stores, spare parts and loose tools	21	92,420,944	102,382,026
Stock-in-trade	22	3,734,560,651	2,801,043,507
Trade debts	23	705,600,101	609,895,495
Loans and advances	24	375,701,132	646,302,269
Prepayments and other receivables	25	13,020,037	18,199,920
Tax refunds due from government	26	1,481,791,294	1,059,312,629
Short term investment	27	30,000,000	30,000,000
Cash and bank balances	28	35,562,173	94,768,128
Total current assets		6,468,656,332	5,361,903,974
Total assets		11,914,038,538	10,122,693,676

The annexed notes 1 to 43 form an integral part of these financial statements.

CHIEF EXECUTIVE OFFICER

DIRECTOR

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Profit and loss account
For the year ended June 30, 2017

	Note	2017 Rupees	2016 Rupees
Sales	29	10,202,640,623	9,149,735,148
Cost of sales	30	(8,838,794,882)	(8,037,404,386)
Gross profit		1,363,845,741	1,112,330,762
Distribution cost	31	(485,079,749)	(383,941,909)
Administrative expenses	32	(212,410,703)	(196,597,636)
Other expenses	33	(20,348,100)	(22,330,098)
Other income	34	46,115,639	11,944,126
Operating profit		692,122,828	521,405,245
Finance cost	35	(271,186,926)	(211,628,676)
Profit before tax		420,935,902	309,776,569
Taxation	36	-	(56,375,845)
Profit after taxation		420,935,902	253,400,724

The annexed notes 1 to 43 form an integral part of these financial statements.

CHIEF EXECUTIVE OFFICER

DIRECTOR

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Statement of comprehensive income
For the year ended June 30, 2017

	Note	2017 Rupees	2016 Rupees
Profit after taxation		**420,935,902**	253,400,724
Other comprehensive income for the year			
Items that will not be reclassified to profit or loss		-	-
Items that may be reclassified subsequently to profit or loss		-	-
Other comprehensive income for the year		-	-
Total comprehensive income for the year		**420,935,902**	253,400,724

The annexed notes 1 to 43 form an integral part of these financial statements.

CHIEF EXECUTIVE OFFICER

DIRECTOR

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Cash flow statement
For the year ended June 30, 2017

	2017 Rupees	2016 Rupees
Cash flows from operating activities		
Profit for the year before taxation	420,935,902	309,776,569
Adjustments for:		
Depreciation	392,519,500	311,102,921
Amortization	5,662,135	890,983
Finance cost	271,186,926	211,628,676
Provision for doubtful debts	-	5,046,227
Loss / (Gain) on disposal of property, plant and equipment	90,068	(10,816,222)
Profit before working capital changes	1,090,394,531	827,629,154
(Increase) / decrease in current assets		
Stores, spare parts and loose tools	9,961,082	6,871,153
Stock-in-trade	(933,517,144)	(189,295,436)
Trade debts	(95,704,606)	251,480,819
Loans and advances	270,601,137	(103,298,926)
Prepayments and other receivables	5,179,883	6,707,701
Tax refunds due from government	(257,140,502)	(211,571,922)
Increase / (decrease) in current liabilities		
Trade and other payables	25,294,018	274,325,945
Net changes in working capital	(975,326,132)	35,219,334
Cash generated from operations	115,068,399	862,848,488
Finance cost paid	(245,080,687)	(239,938,555)
Income taxes paid	(165,338,164)	(139,346,947)
Gratuity paid	(119,581)	-
Net cash (used in) / from operating activities	(295,470,033)	483,562,986
Cash flows from investing activities		
Disposal proceeds from fixed assets	12,934,537	43,372,283
Purchase of property, plant and equipment	(1,095,735,743)	(856,466,389)
Long term investment made in subsidiary	-	(250,000,000)
Increase in long term deposits	(63,000)	(302,006)
Net cash used in investing activities	(1,082,864,206)	(1,063,396,112)
Cash flows from financing activities		
Net proceeds of loans obtained from financial institutions	516,809,530	310,897,816
Net (repayment of) / proceeds of loans from directors	(103,853,880)	236,899,981
Net increase in short term borrowings	906,172,634	32,331,129
Net cash from financing activities	1,319,128,284	580,128,926
Net (decrease) / increase in cash and cash equivalents	(59,205,955)	295,800
Cash and cash equivalents at the beginning of the year	94,768,128	94,472,328
Cash and cash equivalents at the end of the year	35,562,173	94,768,128

The annexed notes 1 to 43 form an integral part of these financial statements.

CHIEF EXECUTIVE OFFICER

DIRECTOR

RAD
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Statement of changes in equity
For the year ended June 30, 2017

	Issued, subscribed and paid up share capital	Convertible loan	Reserves				Loan from sponsors	Total equity
			Capital reserve	Revenue reserves		Total reserves		
			Share premium	General reserve	Unappropriated profit			
	(Rupees)							
	A	B	C	D	E	F = C + D + E	G	H = A + B + F + G
Balance at July 01, 2015	285,850,000	301,529,300	150,360,507	490,000,000	2,138,742,318	2,779,102,825	-	3,366,482,125
Profit for the year	-	-	-	-	253,400,724	253,400,724	-	253,400,724
Other comprehensive income for the year	-	-	-	-	-	-	-	-
Total comprehensive income for the year	-	-	-	-	253,400,724	253,400,724	-	253,400,724
Balance at June 30, 2016	285,850,000	301,529,300	150,360,507	490,000,000	2,392,143,042	3,032,503,549	-	3,619,882,849
Issuance of shares during the year	30,152,930	(301,529,300)	271,376,370	-	-	271,376,370		-
Profit for the year					420,935,902	420,935,902		420,935,902
Other comprehensive income for the year	-	-	-	-	-	-		-
Total comprehensive income for the year	30,152,930	(301,529,300)	271,376,370	-	420,935,902	692,312,272	-	420,935,902
Reclassification of Sponsor Loan	-	-	-	-	-	-	558,537,824	558,537,824
Balance at June 30, 2017	316,002,930	-	421,736,877	490,000,000	2,813,078,944	3,724,815,821	558,537,824	4,599,356,576

The annexed notes 1 to 43 form an integral part of these financial statements.

CHIEF EXECUTIVE OFFICER

DIRECTOR

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Notes to the financial statements
For the year ended June 30, 2017

1 LEGAL STATUS AND NATURE OF BUSINESS

Master Textile Mills Limited (the "Company") was incorporated in Pakistan on February 13, 1992 as a private limited company under the Companies Ordinance, 1984. Subsequently on October 25, 1992, it was converted into a public limited company. The Company is principally engaged in manufacturing and trading of yarn, greige cloth, dyed fabric, denim fabric and stitched garments. The registered office and factory of the Company are situated at Dars Road, Off Raiwind Manga Mandi Road, Distt. Kasur, Pakistan.

2 BASIS OF PREPARATION

2.1 Separate financial statements

These unconsolidated financial statements are the separate financial statements of the Company in which investment in subsidiary is accounted for on the basis of direct equity interest rather than on the basis of reported results and net assets of the investee. Consolidated financial statements of the Company are prepared and presented separately.

The Company has following long term investment:

	2017	2016
	(Direct holding percentage)	
Subsidiary Company		
Master Power (Private) Limited	100	100

2.2 Statement of compliance

These financial statements have been prepared in accordance with approved accounting standards as applicable in Pakistan. Approved accounting standards comprise of such International Financial Reporting Standards (IFRSs) issued by the International Accounting Standards Board as are notified under the Companies Ordinance, 1984, provisions of and directives issued under the Companies Ordinance, 1984 and Islamic Financial Accounting Standards (IFASs) issued by Institute of Chartered Accountants of Pakistan. In case requirements differ, the provisions or directives of the Companies Ordinance, 1984 shall prevail.

2.3 Standards, amendments or interpretations that became effective during the year

The Company has adopted following new standards and amendments to published standards which became effective during the current year:

Standard or Interpretation	Effective Date
IAS 1 Presentation of Financial Statements - Disclosure Initiative (Amendment)	1-Jan-16
IAS 16 Property, Plant and Equipment and IAS 38 Intangible Assets- Clarification of Acceptable Methods of Depreciation and Amortization (Amendment)	1-Jan-16
IFRS 10 Consolidated Financial Statements, IFRS 12 Disclosure of Interests in Other Entities and IAS 28 Investment in Associates – Investment Entities: Applying the Consolidation Exception (Amendment)	1-Jan-16
IAS 16 Property, Plant and Equipment and IAS 41 Agriculture - Agriculture: Bearer Plants (Amendment)	1-Jan-16
Annual Improvements to IFRSs 2012 - 2014 Cycle	1-Jan-16

The adoption of above amendments to IAS and IFRS did not have any significant effect on these financial statements except few additional disclosures.

2.4 Standards that are not yet effective

The following standards and amendments with respect to the approved accounting standards as applicable in Pakistan would be effective from the dates mentioned below against the respective standard or interpretation:

Standard	Effective Date
IFRS 2 Share-based Payment – Classification and Measurement of Share-based Payment Transactions (Amendments)	1-Jan-18
IFRS 9 Financial Instruments (2014) and consequent amendments to IFRS 4 Insurance Contracts	1-Jan-18
IFRS 10 Consolidated Financial Statements, IFRS 12 Disclosure of Interests in Other Entities and IAS 28 Investment in Associates and Joint Ventures – Investment Entities: Applying the Consolidation Exception (Amendments)	Not yet finalized
IFRS 15 Revenue from Contracts with Customers	1-Jan-18
IAS 7 Financial Instruments: Disclosures - Disclosure Initiative - (Amendment)	1-Jan-17
IAS 12 Income Taxes – Recognition of Deferred Tax Assets for Unrealized Losses	1-Jan-17
IFRIC 22 Foreign Currency Transactions and Advance Consideration	1-Jan-18
IFRIC 23 Uncertainty Over Income Tax Treatment	1-Jan-19
IFRS 12 Annual Improvements to IFRS 2014-2016	1-Jan-17
IFRS 1 and IAS 28 - Annual Improvements to IFRSs 2014-2016	1-Jan-18
IAS 40 Transfers of Investment Property (Amendments to IAS 40)	1-Jan-18

Similarly, recently Companies Ordinance, 1984 has been repealed through inclusion of the Companies Act 2017. New disclosure requirements relating to this Act would be applicable from June 01, 2017.

The Company is in process of assessing impact of these amendments to the published standards, interpretations and Companies Act 2017 on the financial statements of the Company.

Notes to the financial statements
For the year ended June 30, 2017

2.5 **Standards, amendments and interpretations to the published standards that are not yet notified by the Securities and Exchange Commission of Pakistan (SECP)**

In addition to the above, following standards have been issued by IASB which are yet to be notified by the SECP for purpose of applicability in Pakistan;

Standard		Effective Date
IFRS 14	Regulatory Deferral Accounts	January 1, 2016
IFRS 16	Leases	January 1, 2019
IFRS 17	Insurance Contracts	January 1, 2021

2.6 **Accounting convention**

These financial statements have been prepared under the historical cost convention except as stated in required Standards.

2.7 **Functional and presentation currency**

These financial statements are presented in Pak Rupees which is the Company's functional and presentation currency. All financial information presented in Pak Rupees has been rounded to the nearest Rupee unless otherwise stated.

3 ACCOUNTING ESTIMATES AND JUDGEMENTS

The preparation of financial statements in conformity with approved accounting standards requires the use of certain critical accounting estimates. It also requires the management to exercise its judgment in the process of applying the Company's accounting policies. Estimates and judgments are continually evaluated and are based on historical experience, including expectation of future events that are believed to be reasonable under the circumstances. The areas where various assumptions and estimates are significant to the Company's financial statements or where judgments were exercised in application of accounting policies are discussed below:

-assumptions and estimates used in determining the recoverable amount, residual values and useful lives of property, plant and equipment;
-assumptions and estimates used in writing down items of stock in trade to their net realizable value;
-assumptions and estimates used in calculating the provision for impairment for trade debts;
-assumptions and estimates used in the recognition of income taxes; and
-assumptions and estimates used in disclosure and assessment of provision for contingencies.

4 SIGNIFICANT ACCOUNTING POLICIES

4.1 **Staff retirement benefits**

The Company operates an approved funded provident fund scheme for all its permanent employees who have completed minimum qualifying period of service as defined under the respective scheme. Equal monthly contributions are made both by the Company and the employees at the rate of 8.33% of basic salary.

4.2 **Property, plant and equipment**

Operating fixed assets

Property, plant and equipment except freehold land are stated at cost less accumulated depreciation and impairment in value including any costs directly attributable in bringing the assets to the location and condition necessary for it to be capable of operating in the manner intended by the Company's management.

Depreciation is charged to income applying the reducing balance method over the estimated useful life at the rates specified in property, plant and equipment note 16.1.

Depreciation on additions is charged from the date in which the property, plant and equipment is acquired, capitalized or on commencement of commercial production while no depreciation is charged from the date in which property, plant and equipment is disposed off.

The assets' residual values and useful lives are reviewed at each financial year end, and adjusted if impact on depreciation is significant.

Maintenance and normal repairs are charged to income as and when incurred. Major renewals and improvements are capitalized and the assets so replaced, if any, are retired.

Gain or loss on disposal of property, plant and equipment is taken to profit or loss.

Capital work in progress

Capital work in progress is stated at cost less impairment, if any. Cost of property, plant and equipment consists of historical cost, borrowing costs pertaining to the erection / construction period and other directly attributable costs of bringing the assets to their working condition or for commencement of commercial production. All expenditure connected with specific assets incurred during installation and construction period are carried under capital work in progress. These are transferred to specific assets as and when these assets are available for use.

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Notes to the financial statements
For the year ended June 30, 2017

4.3 Intangibles

An intangible asset is an identifiable non-monetary asset without physical substance.

Intangible assets are recognized when it is probable that the expected future economic benefits will flow to the entity and the cost of the assets can be measured reliably. Cost of the intangible asset includes purchase cost and directly attributable expenses incidental to bring the asset for its intended use.

Costs associated with maintaining computer software are recognized as an expense as and when incurred.

Intangible assets are stated at cost less accumulated amortization and accumulated impairment losses, if any. Amortization is charged over the estimated useful life of the asset on a systematic basis applying the straight line method.

Useful lives of intangible operating assets are reviewed, at each balance sheet date and adjusted if the impact of amortization is significant.

4.4 Stores, spare parts and loose tools

These are stated at lower of NRV and cost using moving average method except goods in transit which are stated at invoice value plus other charges incurred thereon.

4.5 Stock in trade

These are valued at the lower of cost and net realizable value applying the following basis:

Raw material	Weighted Average
Work in process	Average manufacturing cost
Finished goods	Average manufacturing cost
Packing material	Weighted Average
Waste	Net realizable value

Raw material in transit is stated at invoice price plus other charges paid thereon up to the balance sheet date.

Average manufacturing cost in relation to work in process and finished goods consists of direct material, labour and a proportion of manufacturing overheads based on normal capacity.

Net realizable value signifies the estimated selling price in the ordinary course of business less estimated costs of completion and estimated costs necessary to make the sale.

4.6 Investments

Investments which could not be classified as held for trading or held-to-maturity are classified as available for sale. These are stated at fair value and changes in carrying values are recognized in equity until investment is sold or determined to be impaired at which time the cumulative gain or loss previously recognized in equity is included in profit or loss for the year.

Investments in equity instruments that do not have a quoted market price in an active market and whose fair value cannot be reliably measured are stated at cost less any identified impairment.

4.7 Investment in associate

Entities in which the Company has significant influence but not control and which are neither its subsidiaries nor joint ventures are associates. These investments are recognized at cost.

4.8 Loans and advances

These are stated at cost which represents the fair value of the consideration less any identified impairment.

4.9 Trade debts

Trade debts originated by the Company are recognized and carried at original invoice amount less allowance for any uncollectible amounts. An estimate for doubtful debt is made when collection of the full amount is no longer probable. Known bad debts are written off as incurred.

4.10 Trade and other payables

Creditors relating to trade and other payables are carried at cost which is the fair value of the consideration to be paid in future for goods and services received, whether or not billed to the Company.

4.11 Mark up bearing borrowings and borrowing costs

Mark up bearing borrowings are recognized initially at cost, less attributable transaction costs. Subsequent to initial recognition, mark up bearing borrowings are stated at original cost less subsequent repayments, while the difference between the cost (reduced for periodic payments) and redemption value is recognized in the profit or loss over the period of borrowings on an effective mark up basis.

Borrowing costs directly attributable to the acquisition, construction or production of qualifying assets, which are assets that necessarily take a substantial period of time to get ready for their intended use or sale, are added to the costs of those assets, until such time as the assets are ready for their intended use or sale.

4.12 Foreign currencies

Transactions in currencies other than Pak Rupees are recorded at the rates of exchange prevailing on the dates of the transactions. At each balance sheet date, monetary assets and liabilities that are denominated in foreign currencies are retranslated at the rates prevailing on the balance sheet date except where forward exchange contracts have been entered into wherein the rates contracted for are used.

Gains and losses arising on retranslation are included in profit or loss for the year.

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Notes to the financial statements
For the year ended June 30, 2017

4.13 Investment in subsidiary

Investment in subsidiary is recognized at cost. At subsequent reporting dates, the recoverable amount is estimated to determine the extent of impairment loss, if any, and carrying amount of investment is adjusted accordingly. Impairment loss is recognized as expense. Where impairment loss subsequently reverse, the carrying amount of investment is increased to the revised recoverable amount but limited to the extent of initial cost of investment. A reversal of impairment loss is recognized in the profit and loss account.

4.14 Revenue recognition

Revenue is measured at the fair value of the consideration received or receivable and represents amounts receivable for goods and services provided in the normal course of business.

- Local sales are recorded on dispatch of goods to customers.
- Export sales are accounted for on shipment basis.
- Rebate income is recognized on accrual basis.
- Interest income is recognized on time proportion basis.
- Gain or loss arising on sale of investments is taken into income in the year in which they arise.
- Dividend income is recognized when the Company's right to receive payment is established.
- Conversion income is recognized when the services are rendered.

4.15 Financial instruments

Financial assets

Financial assets are recognized when the Company becomes a party to the contractual provisions of the financial instrument and are measured initially at fair value adjusted by transaction costs. Subsequent measurement of financial assets are described below. Financial assets are derecognized when the contractual rights to the cash flows from the financial asset expire, or when the financial asset and all substantial risks and rewards are transferred.

For the purpose of subsequent measurement financial assets of the Company are classified into the followings:

a) Loans and receivables

Loans and receivables are non-derivative financial assets with fixed or determinable payments that are not quoted in an active market. After initial recognition, these are measured at amortized cost using the effective interest method, less provision for impairment. Discounting is omitted where the effect of discounting is immaterial. These are included in current assets, except for maturities for greater than twelve months after the balance sheet date, which are classified as non-current assets. Loans and receivables with less than twelve months maturities are classified as current assets. The Company's cash and cash equivalents, trade debts, advances, deposits and other receivables fall into this category of financial instruments. Loans and receivables are subject to review for impairment at each reporting date to identify whether there is objective evidence that the financial asset is impaired.

b) Available-for-sale financial assets

Available for sale financial assets are non-derivatives that are either designated in this category or not classified in any of the categories of loans and receivables, financial assets at fair value through profit or loss, and financial assets held to maturity. They are included in non-current assets unless management intends to dispose of the investments within twelve months from the end of reporting period. Available-for-sale financial assets are classified as short term investments in the balance sheet.

After initial recognition, available-for-sale investments are measured at fair value in accordance with IAS 39 "Financial Instruments: Recognition and Measurement". Investments in equity instruments that do not have a quoted market price in an active market and whose fair value can not be measured reliably are measured at cost. Gains or losses on available-for-sale investments are recognized through other comprehensive income until the investment is sold or de-recognized, at which time the cumulative gain or loss previously reported is included in profit or loss.

Dividends on available-for-sale equity instruments are recognized in the profit or loss when the Company's right to receive payments is established.

Financial assets are de-recognized when the rights to receive cash flows from the assets have expired or have been transferred and the Company has transferred substantially all risks and rewards of ownership.

The Company assesses at each balance sheet date whether there is objective evidence, that a financial asset or group of financial assets is impaired. If any such evidence exists for 'available-for-sale' financial assets, the cumulative loss is removed from equity and recognized in profit or loss. Impairment losses recognized in profit or loss on equity instruments are not reversed through profit and loss account.

Financial liabilities

The Company's financial liabilities include borrowings and trade and other payables.

Financial liabilities are measured initially at fair value, less attributable transaction costs. Financial liabilities are measured subsequently at amortized cost using the effective interest method.

Borrowing costs directly attributable to the acquisition, construction or production of qualifying assets, if any, are added to the cost of those assets, until such time as the assets are substantially ready for their intended use or sale. Investment income earned on the temporary investment of specific borrowings, if any, pending their expenditure on qualifying asset is deducted from the borrowing costs eligible for capitalization. All other borrowing costs are recognized as expense in the period in which they are incurred.

A financial asset and financial liability is offset and the net amount is reported in the balance sheet if the Company has a legal enforceable right to set off the transaction and also intends either to settle on a net basis or to realize the asset and settle the liability simultaneously.

Notes to the financial statements
For the year ended June 30, 2017

4.16 Off-setting of financial instruments

Financial assets and liabilities are offset and the net amount is reported in the financial statements only when the Company has a legally enforceable right to offset the recognized amounts and the Company intends either to settle on a net basis or to realize the asset and settle the liability simultaneously.

4.17 Taxation

Current

The charge for current taxation is based on taxable income at the current rates of taxation after taking into account applicable tax credits, rebates and exemption available, if any, and tax paid on presumptive basis.

Deferred

Deferred tax is provided using the balance sheet liability method for all temporary differences at the balance sheet date between tax bases of assets and liabilities and their carrying amounts for financial reporting purposes.

Deferred income tax asset is recognized for all deductible temporary differences and carry forward of unused tax losses, if any, to the extent that it is probable that taxable profits will be available against which such temporary differences and tax losses can be utilized. Deferred tax liabilities are recognized for all major taxable temporary differences.

Deferred income tax assets and liabilities are measured at the tax rates that are expected to apply to the period when the asset is

realized or the liability is settled, based on tax rates that have been enacted or substantively enacted at the balance sheet date.

Deferred tax is charged or credited to the income statement, except in the case of items credited or charged to equity in which case it is included in equity.

4.18 Provisions

Provisions are recognized when the Company has a present legal or constructive obligation as a result of past events and it is probable that out flow of resources embodying economic benefits will be required to settle the obligation and a reliable estimate of the amount can be made. However, provisions are reviewed at each balance sheet date and adjusted to reflect the current best estimate.

4.19 Cash and cash equivalents

For the purpose of cash flow statement, cash and cash equivalents comprise cash in hand and bank balances and other short term highly liquid investments that are readily convertible to known amounts of cash and which are subject to an insignificant risk of change in value.

4.20 Ijarah

Ijarah (Lease) payments under an Ijarah (Lease) are recognized as an expense in the income statement on a straight line basis over the Ijarah (Lease) term.

4.21 Interest free loans from directors (at discretion of Company)

During the year, due to adoption of Technical Release 32 (TR-32) issued by the Institute of Chartered Accountant of Pakistan (ICAP) dated 25th January 2016, such loans have been classified as part of equity. These have been measured at fair value.

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Notes to the financial statements
For the year ended June 30, 2017

	Note	2017 Rupees	2016 Rupees
5 ISSUED, SUBSCRIBED AND PAID UP CAPITAL			
5.1 Authorized share capital			
50,000,000 (2016: 50,000,000) ordinary shares of Rs. 10 each		500,000,000	500,000,000
5.2 Issued, subscribed and paid-up capital			
30,040,828 (2016: 27,025,535) ordinary shares of Rs. 10 each fully paid in cash		300,408,280	270,255,350
1,559,465 (2016: 1,559,465) ordinary shares of Rs. 10 each fully paid for consideration other than cash		15,594,650	15,594,650
Total		316,002,930	285,850,000

5.3 25,032,453 (2016: 25,032,453) ordinary shares are held by the associated undertakings.

6 CONVERTIBLE LOAN

This represents advance that is convertible into 3,015,293 shares at sole discretion of the Company. During the year, the company has issued ordinary shares @ Rs. 100 each including Rs. 90 as premium per share.

7 LOANS FROM DIRECTORS - UNSECURED

	Note	2017 Rupees	2016 Rupees
Loan from directors (related party)		558,537,824	
Total loans form directors	7.1	558,537,824	-

7.1 The loans are interest free and are repayable on the discretion of the Company. Accordingly, the loan is accounted for as equity in accordance with reference under TR- 32 issued by ICAP.

8 RESERVES

	Note	2017 Rupees	2016 Rupees
Capital reserve	8.1	421,736,877	150,360,507
Revenue reserves		3,303,078,944	2,882,143,042
Total Reserves		3,724,815,821	3,032,503,549

8.1 This represents share premium reserve. During the year, the Company has issued shares at premium @ 90 per share amounting to Rs. 271.376 million.

9 LONG TERM FINANCING

From banking companies - secured

	Repayment commencement period	Sanctioned limit (Rupees)	Interest rate	Installments	2017 Rupees	2016 Rupees
Bank Al Habib Limited						
LTF-EOP-own source	Oct-08	119.42 M	6MK+1%	Semi-annually	76,026,950	140,216,175
LTFF	Dec-09	449.934 M	SBP+1%	Semi-annually	199,934,000	50,064,000
Pak Brunei Investment Company Limited						
LTF-EOP-own source	Oct-18	158.07 M	1MK+1%	Semi-annually	-	158,066,746
LTFF	Oct-18	777 M	SBP+1%	Semi-annually	673,063,000	62,492,500
The Bank of Punjab						
LTFF	Oct-17	268.966 M	SBP+1.25%	Semi-annually	268,966,000	268,966,000
Meezan Bank Limited						
Dim. Musharika	Jan-16	53.29 M	6MK+1.5%	Semi-annually	10,687,500	32,062,500
Total - long term financing					1,228,677,450	711,867,920
Current portion of long term borrowings					(138,541,716)	(85,564,224)
Total long term portion					1,090,135,734	626,303,696

9.1 These represent long term financing obtained from commercial banks. Markup is payable on quarterly basis. These loans are secured against registered mortgage over the property, plant and equipment of the Company, first pari passu charge/hypothecation over current assets of the Company and personal guarantees of the directors. Further, these are also secured against corporate guarantee given by M/s N.M Enterprises (Private) Limited (Associated undertaking) and registered hypothecation / mortgage over fixed assets amounting to Rs. 350 million of M/s N.M Enterprises (Private) Limited.

10 LOANS FROM DIRECTORS - UNSECURED

This represents interest free loans given to the Company by the directors.

11 DEFERRED LIABILITIES

The Company had operated an unfunded gratuity scheme up to January 31, 2003 covering all its employees who had completed prescribed qualifying period of service. The unfunded gratuity scheme has been substituted by the provident fund scheme operated by the Company for all employees as defined in note 4.1. This balance of gratuity payable represents the entitlement of current employees as at January 31, 2003 as reduced by the payments made to employees who have left the Company since then.

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		Note	2017 Rupees	2016 Rupees
12	**TRADE AND OTHER PAYABLES**			
	Creditors		542,816,730	675,494,187
	Murabaha	12.1 & 12.2	479,510,434	415,222,349
	Advances from customers		292,191,920	386,450,297
	Accrued liabilities		96,163,983	18,248,755
	Payable to Provident Fund Trust		360,528,097	252,092,827
	Payable to Workers' Profit Participation Fund		20,258,032	16,008,127
	Payable to Workers Welfare Fund		-	36,033,292
	Commission payable		149,130,898	113,231,913
	Others	12.3	55,646,677	58,171,006
	Total		1,996,246,771	1,970,952,753

12.1 These are secured against collaterals mentioned in note 13.1.

12.2 Profit on Murabaha investment is in range of 6.56% to 7.61% (2016: 3.50% to 8.26%).

12.3 These include payables towards associated undertakings amounting to Rs. 30,585,494 (2016: Rs. 20,454,647).

		Note	2017 Rupees	2016 Rupees
13	**LOANS FROM DIRECTORS - UNSECURED**			
	Loan from directors (related party)		168,606,942	-
	Total loans form directors	13.1	168,606,942	-

13.1 These loans are repayable on demand by the Directors. Accordingly, the loan is accounted for as loan in accordance with TR-32 issued by ICAP.

		Note	2017 Rupees	2016 Rupees
14	**SHORT TERM BORROWINGS**			
	From banking companies - secured			
	State Bank of Pakistan (SBP) refinances	14.1 & 14.3	2,773,300,000	2,404,687,070
	Short term running finances	14.1 & 14.4	262,347,794	174,433,948
	Other short term finances	14.1 & 14.5	727,034,244	248,055,970
	Subtotal		3,762,682,038	2,827,176,988
	Overdrawn balances	14.2	95,470,377	124,802,793
	Total		3,858,152,415	2,951,979,781

14.1 The Company has arranged facilities from different financial institutions. These facilities are secured against pledge / hypothecation of stocks, lien on confirmed exports and local L/C documents, promissory notes, registered mortgage over property, plant and equipment, pari passu charge on current assets and personal guarantees of directors. Further, these are also secured against corporate guarantee given by M/s N.M Enterprises (Private) Limited (associated undertaking) along with registered hypothecation / mortgage charge over fixed assets of M/s N.M Enterprises (Private) Limited amounting to Rs. 350 million. These form part of total credit facilities of Rupees 5,650 million (2016: Rupees 4,525 million).

14.2 These overdrawn balances have been arisen on account of cheques issued just prior to the year end. However, concerned banks statements show favourable balances at the year end.

14.3 Mark-up on such loans is in range of 2.75% to 3.50% (2016: 3.35% to 3.50%).

14.4 Mark-up on such loans is in range of 6.44% to 7.91% (2016: 7.10% to 8.50%).

14.5 Mark-up on such loans is in range of 6.57% to 7.52% (2016: 6.9% to 7.94).

		Note	2017 Rupees	2016 Rupees
15	**CURRENT PORTION OF LONG TERM BORROWINGS**			
	Long term borrowings	9	138,541,716	85,564,224
	Total		138,541,716	85,564,224

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16 CONTINGENCIES AND COMMITMENTS

16.1 CONTINGENCIES

i) A suit is pending before the Civil Judge, Lahore against Pakistan Cargo (Private) Limited for recovery of total consignment amounting to US$ 36,718 along with cost of funds at the rate of 10% per annum and damages to the extent of Rs. 2.0 million (2016: US$ 36,718 and Rs. 2.0 million). The Company is expecting a positive decision.

ii) A suit is pending before the Civil Judge, Kasur filed by Umair Traders against Master Textile Mills Limited for recovery of advance paid of Rs. 1,031,879 (2016: Rs 1,031,879) along with admissible markup. The case is pending for plaintiff evidence. The management is hopeful for a favourable decision.

iii) A suit is pending regarding the Gas Infrastructure Development Cess (GIDC ACT 2015) on Gas Bills amounting to Rs. 117,937,303/- (2016: Rs 117,937,303/-). This has been challenged and presently, the recovery (GIDC ACT 2015) has been stayed by the Karachi High Court. SNGPL has also filed appeal against such interim order. The Company is confident of favourable outcome and accordingly, no provision has been made in these financial statements.

iv) A suit is pending regarding the Gas Tariff Difference on Gas bills. This has been challenged and presently, the recovery of Gas Bill has been stayed by the Lahore High Court, Lahore. The Company is confident of favourable outcome and accordingly, no provision has been made in these financial statements.

v) The Assistant Commissioner Inland Revenue (ACIR) penalized the Company for late filing and raised impugned demand of Rs. 2,351,101/-. This order was also confirmed by the Commissioner Inland Revenue Appeals (CIR-A). The Company being aggrieved from the aforesaid Appellate order, filled 2nd appeal before the Appellate Tribunal Inland Revenue (ATIR) which is pending for hearing. The Company is confident of favourable outcome and accordingly, no provision has been made in these financial statements.

vi) The Company was selected for Tax Audit u/s 177 through a random ballot conducted by the FBR for audit of the Income Tax affairs for the Tax Year 2011. Proceedings were finalized by the DCIR, u/s 122(1)/122(5) of the Ordinance wherein, certain additions were made which resulted into taxable income of Rs. 192,003,243/- as against the declared taxable income of Rs. 8,546,979/- thus, creating additional impugned demand of Rs. 3,398,975/-. The Company filed appeal before CIR-A against the impugned order which is pending for hearing. The Company is confident of favourable outcome and accordingly, no provision has been made in these financial statements.

vii) Additional Commissioner Inland Revenue finalized proceedings u/s 122(5A) for the said tax year 2009 considering the assessment u/s 120 to be erroneous & prejudicial to the interest of revenue and made certain additions which resulted into taxable income of Rs. 40,424,228/-. The Company filed appeal before ATIR Lahore against the impugned order which is pending for hearing. The Company is confident of favourable outcome and accordingly, no provision has been made in these financial statements.

		Note	2017 Rupees	2016 Rupees
16.2	**COMMITMENTS**			
i)	Letters of credit for plant and machinery		-	73,935,332
ii)	Ijarah rentals	16.2.1	19,562,168	31,070,786
iii)	Letters of credit for raw material & stores and spares		-	53,257,695
iv)	Letters of guarantee		167,230,000	152,118,000
Total			186,792,168	310,381,813

16.2.1 Future Ijrah payments under Ijarah and the period in which these payments will become due are as follows:

	Note	2017 Rupees	2016 Rupees
Not later than one year		7,910,148	8,166,952
Later than one year and not later than five years		11,652,020	22,904,834
Total		19,562,168	31,070,786

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	Note	2017 Rupees	2016 Rupees
17 PROPERTY, PLANT AND EQUIPMENT			
Operating fixed assets	17.1	4,253,457,166	3,218,749,756
Capital work in progress	17.3	412,322,668	756,838,429
Total		4,665,779,824	3,975,588,185

17.1 Operating fixed assets

2017

Particulars	Cost: As at July 01, 2016	Cost: additions / (deletions) during the year	Cost: As at June 30, 2017	Rate	Depreciation: As at July 01, 2016	Depreciation: For the year	Depreciation: On adjustments / disposal	Depreciation: As at June 30, 2017	Written down value as at June 30, 2017
	Rupees								
Freehold land	181,030,240	-	181,030,240	-	-	-	-	-	181,030,240
Building	1,091,508,089	99,953,096	1,191,461,185	10%	522,943,086	62,657,351	-	585,600,438	605,860,749
Plant and machinery	4,433,972,952	1,303,223,972 (39,012,734)	5,698,184,190	10%	2,040,559,120	316,028,233	(25,988,129)	2,330,599,224	3,367,584,966
Vehicles	76,686,066	19,586,451	96,270,517	20%	52,598,796	6,033,372	-	58,632,168	37,638,349
Office equipment	14,347,657	1,571,618	15,919,275	10%	6,394,757	851,848	-	7,246,605	8,672,670
Furniture and fittings	44,904,958	9,105,273	54,010,231	10%	14,929,192	3,488,871	-	18,418,063	35,592,168
Computers and accessories	22,781,704	4,963,891	27,745,595	30%	15,531,637	2,744,532	-	18,276,169	9,469,426
Air conditioners	9,600,545	1,848,214	11,448,759	10%	3,124,868	716,293	-	3,840,161	7,608,598
	5,874,831,211	1,440,251,515 (39,012,734)	7,276,069,992		2,656,081,455	392,519,500	(25,988,129)	3,022,612,826	4,253,457,166
June 30, 2017	5,874,831,211	1,401,238,781	7,276,069,992		2,656,081,455	392,519,500	(25,988,129)	3,022,612,826	4,253,457,166

2016

Particulars	Cost: As at July 01, 2015	Cost: additions / (deletions) during the year	Cost: As at June 30, 2016	Rate	Depreciation: As at July 01, 2015	Depreciation: For the year	Depreciation: On adjustments / disposal	Depreciation: As at June 30, 2016	Written down value as at June 30, 2016
	Rupees								
Freehold land	186,830,240	- (5,800,000)	181,030,240	-	-	-	-	-	181,030,240
Building	1,067,450,566	24,057,523	1,091,508,089	10%	461,084,559	61,858,525	-	522,943,085	568,565,004
Plant and machinery	4,169,472,743	369,430,650 (24,930,447)	4,433,972,952	10%	1,864,798,894	237,036,734	(61,278,508)	2,040,559,120	2,393,413,832
Vehicles	80,351,997	2,247,500 (5,914,431)	76,685,066	20%	49,102,854	6,060,565	(2,624,644)	52,538,796	24,086,270
Office equipment	12,672,249	1,675,408	14,347,657	10%	5,667,583	727,174	-	6,394,757	7,952,900
Furniture and fittings	33,043,260	11,861,678	44,904,958	10%	12,506,474	2,422,718	-	14,929,192	29,975,766
Computers and accessories	20,474,574	2,330,330 (23,200)	22,781,704	30%	13,098,140	2,452,590	(19,093)	15,531,637	7,250,067
Air conditioners	7,824,320	1,796,668 (20,647)	9,600,545	10%	2,592,694	544,593	(12,419)	3,124,868	6,475,677
	5,567,919,975	403,399,961 (96,488,725)	5,874,831,211		2,406,911,198	311,102,921	(63,932,664)	2,656,081,455	3,218,749,756
June 30, 2016	5,567,919,975	306,911,236	5,874,831,211		2,406,911,198	311,102,921	(63,932,664)	2,656,081,455	3,218,749,756

17.1.1 This includes borrowing cost capitalized amounting to Rs. 2.42 million. (2016. Rs. Nil)

	Note	2017 Rupees	2016 Rupees
17.2 Depreciation for the year has been allocated as under :			
Cost of sales	30	378,685,584	298,896,261
Administrative expenses	32	13,833,916	12,206,660
Total		392,519,500	311,102,921

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Notes to the financial statements
For the year ended June 30, 2017

		Note	2017 Rupees	2016 Rupees
17.3	**Capital work in progress**			
	Opening balance			
	Building		101,408,602	28,697,845
	Plant and machinery		655,429,827	275,074,156
			756,838,429	303,772,001
	Additions during the year			
	Building		23,401,463	95,960,376
	Plant and machinery		895,301,825	728,615,512
			918,703,288	824,575,888
	Transferred to operating fixed assets			
	Building		(92,313,878)	(23,249,619)
	Plant and machinery		(1,170,905,181)	(348,259,841)
			(1,263,219,059)	(371,509,460)
	Closing balance			
	Building		32,496,187	101,408,602
	Plant and machinery		379,826,471	655,429,827
	Total		412,322,658	756,838,429

18 INTANGIBLE ASSETS

Operating intangible assets	20,689,559	26,351,694
Total	20,689,559	26,351,694

2017

Particulars	Cost			Amortization	Amortization			Net book value
	As at July 01, 2016	Additions	As at June 30, 2017		As at July 01, 2016	For the year	As at June 30, 2017	
	Rupees			%	Rupees			
Computer software	1,200,000	-	1,200,000	33%	833,000	367,000	1,200,000	-
ERP-Oracle	26,475,677	-	26,475,677	20%	490,983	5,295,135	5,786,118	20,689,559
June 30, 2017	27,675,677	-	27,675,677		1,323,983	6,662,135	6,986,118	20,689,559

2016

Particulars	Cost			Amortization	Amortization			Net book value
	As at July 01, 2015	Additions	As at June 30, 2016		As at July 01, 2015	For the year	As at June 30, 2016	
	Rupees			%	Rupees			
Computer software	1,200,000	594,512	1,794,512	33%	433,000	459,930	892,930	901,582
ERP-Oracle	-	25,881,165	25,881,165	20%	-	431,353	431,353	25,449,812
June 30, 2016	1,200,000	26,475,677	27,675,677		433,000	890,983	1,323,953	26,351,694

	Note	2017 Rupees	2016 Rupees
19 INVESTMENT IN SUBSIDIARY			
Investment in Master Power (Private) Limited		250,000,000	250,000,000
Total		250,000,000	250,000,000

19.1 This represents the Company's investment in wholly owned subsidiary, "Master Power (Private) Limited". The Company holds 100% (2016: 100%) shares in the Master Power (Private) Limited. The breakup value per share based on audited accounts amounts to Rs. 1373.90 per share (2016: Rs.-6.93) at June 30, 2017. Two shares are held in the name of Directors of the Master Power (Private) Limited nominated by Master Textile Mills Limited (the Parent Company).

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		Note	2017 Rupees	2016 Rupees
20	**INVESTMENT IN ASSOCIATE**			
	Master Wind Energy Limited	20.1	506,048,000	506,048,000
	Total		506,048,000	506,048,000

20.1 This represents the Company's investment in the associate company, Master Wind Energy Limited. The Company has common directorship with the associate and holds 15% (2016: 15%) equity in the associate. The breakup value per share based on audited accounts works out to Rs. 1,170.75 (2016: Rs. 992.09 per share) at June 30, 2017. The summarized financial information of Master Wind Energy Limited, extracted from its audited financial statements for the year ended 30 June 2017 and June 30, 2016, are as follows:

	Note	2017 Rupees	2016 Rupees
Associate's balance sheet:			
Current assets		4,274,477,344	687,100,343
Non-current assets		11,553,856,164	10,536,393,228
Current liabilities		2,556,506,090	791,750,201
Non-current liabilities		9,322,118,639	7,093,776,336
Associate's revenue and profit			
Revenue		1,723,823,193	-
Profit before taxation for the year		610,290,427	4,243,949
Profit / (loss) after taxation for the year		602,743,845	(5,216,695)

		Note	2017 Rupees	2016 Rupees
21	**STORES, SPARE PARTS AND LOOSE TOOLS**			
	Stores		45,153,988	45,589,635
	Spare parts		45,959,984	54,970,970
	Loose tools		1,306,972	1,821,421
	Total		92,420,944	102,382,026
22	**STOCK IN TRADE**			
	Raw materials		1,275,946,642	910,269,348
	Work in process		545,564,715	441,591,002
	Finished goods and waste	22.1	1,913,049,294	1,449,183,157
	Total		3,734,560,651	2,801,043,507

22.1 These include goods in transit amounting to Rs. 30,002,894 (2016: Rs.79,255,380).

		Note	2017 Rupees	2016 Rupees
23	**TRADE DEBTS - considered good**			
	Export - secured against letters of credit		431,496,287	370,751,839
	Local - unsecured	23.1	280,405,143	245,444,985
			711,901,430	616,196,824
	Less: Provision for doubtful debts		(6,301,329)	(6,301,329)
	Total		705,600,101	609,895,495

23.1 These include Rs. 38,886,337 (2016: Rs. 52,761,686) receivable from related parties. Aging of related parties balances are as mentioned below:

	2017				2016			
Related Parties	1 to 30 days	31 to 180 days	past due 180 days	Total	1 to 30 days	31 to 180 days	past due 180 days	Total
Dura Industries Limited	186,340	2,894,308	26,276,051	28,356,699	32,842,952	949,626	-	33,792,578
Master Enterprises (Private) Limited	-	-	1,409,405	1,409,405	-	-	1,409,405	1,409,405
Master Synthetic (Private) Limited	-	82,391	9,038,842	9,121,233	147,319	6,680,342	8,757,478	15,585,139
Master Wind Energy (Private) Limited	-	-	-	-	-	-	1,586,227	1,586,227
N.M Corporation (Private) Limited	-	-	-	-	388,337	-	-	388,337
	186,340	2,976,699	36,724,298	38,886,337	33,378,608	7,629,968	11,753,110	52,761,686

Notes to the financial statements
For the year ended June 30, 2017

	Note	2017 Rupees	2016 Rupees
24 LOANS AND ADVANCES			
Advances - unsecured and considered good:			
to suppliers		350,396,000	606,432,453
to employees - against expense		25,305,132	23,118,900
		375,701,132	629,551,353
Letters of credit - considered good		-	16,750,916
Total		375,701,132	646,302,269

	Note	2017 Rupees	2016 Rupees
25 PREPAYMENTS AND OTHER RECEIVABLES			
Short term prepayments		3,701,310	3,474,933
Insurance claim receivable		2,705,254	1,352,244
Other receivables	25.1	6,613,473	13,372,743
Total		13,020,037	18,199,920

25.1 This includes receivable amounting to Rs. 1,919,206 (2016: Rs. 1,919,206) deposited with Collector of Customs pursuant to interim order for deposit of one fourth of impugned liability which was subsequently decided in favor of the Company.

	Note	2017 Rupees	2016 Rupees
26 TAX REFUNDS DUE FROM GOVERNMENT			
Advance income tax - net		461,052,513	295,714,350
Sales tax refundable - net		681,795,087	591,222,646
Special excise duty receivable		4,728,093	13,634,781
Duty drawback receivable		193,946,775	-
Export rebate receivable		140,269,826	158,740,852
Total		1,481,791,294	1,059,312,629

	Note	2017 Rupees	2016 Rupees
27 SHORT TERM INVESTMENT			
Available for sale (un-quoted)			
Al Hamra Avenue (Private) Limited			
3,000,000 (2016: 3,000,000) fully paid ordinary shares of Rs. 10 each		30,000,000	30,000,000
Total		30,000,000	30,000,000

27.1 Short term investment is in an un-quoted company and is stated at cost.

	Note	2017 Rupees	2016 Rupees
28 CASH AND BANK BALANCES			
Cash with banks on:			
- current accounts		19,582,259	58,884,246
- deposit accounts	28.1	104,460	10,587,423
		19,686,719	69,471,669
Cash in hand		15,875,454	25,296,459
Total		35,562,173	94,768,128

28.1 Rate of profit on bank deposits ranges from 3% to 5% (2016: 3% to 5%) per annum.

	Note	2017 Rupees	2016 Rupees
29 SALES			
Exports	29.1	7,860,228,807	7,166,003,613
Local	29.2	2,412,121,772	1,999,207,961
Waste sales - local		84,495,481	66,679,504
		10,356,845,060	9,231,891,078
Less: Commission on export sales		148,010,403	76,644,951
Commission on local sales		6,194,034	5,510,979
		154,204,437	82,155,930
Total		10,202,640,623	9,149,735,148

29.1 It includes net foreign currency exchange gain amounting to Rs. 1,365,063 (2016: Rs. 4,912,007).

29.2 It includes indirect exports amounting to Rs. 714,668,897 (2016: Rs. 296,515,040).

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Notes to the financial statements
For the year ended June 30, 2017

	Note	2017 Rupees	2016 Rupees
30 COST OF SALES			
Raw material consumed	30.1	6,240,398,368	5,204,694,389
Salaries, wages and other benefits		1,321,276,737	1,033,021,308
Rent, rates and taxes		1,676,172	2,224,474
Sizing material consumed		77,080,485	51,776,295
Fuel and power		1,122,964,420	983,936,973
Packing material consumed		158,680,262	131,247,745
Stores and spares consumed		220,798,388	242,676,391
Freight and octroi		31,168,267	25,315,627
Vehicle running and maintenance		4,987,451	4,273,524
Printing and stationery		2,869,056	2,441,156
Repairs and maintenance		16,386,164	14,142,335
Insurance		34,260,400	36,199,397
Stitching and processing charges		89,765,119	65,025,638
Factory expenses		23,685,144	33,722,339
Depreciation	17.2	378,685,583	298,696,261
		9,724,682,016	8,130,291,850
Adjustment of work-in-process			
Opening stock		441,591,002	348,813,860
Closing stock		(545,564,715)	(441,591,002)
		(103,973,713)	(92,777,142)
Adjustment of finished goods			
Opening stock		1,449,183,157	1,494,183,139
Closing stock		(1,913,049,294)	(1,449,183,157)
		(463,866,137)	44,999,982
Less: Export rebate & duty draw back		(318,047,284)	(45,110,304)
Total		8,838,794,882	8,037,404,386

30.1 Raw material consumed

	2017 Rupees	2016 Rupees
Opening stock	910,269,348	768,751,072
Add: Purchases	6,606,076,662	5,346,212,665
	7,516,346,010	6,114,963,737
Less: Closing stock	(1,275,946,642)	(910,269,348)
Total	6,240,398,368	5,204,694,389

	Note	2017 Rupees	2016 Rupees
31 DISTRIBUTION COST			
Salaries, wages and other benefits		144,726,746	104,114,466
Ocean and air freight		96,866,490	61,425,308
Freight and forwarding		42,664,464	42,282,148
Export expenses		87,082,628	85,836,459
Telephone and telegram		860,675	1,681,629
Traveling and conveyance		35,097,639	28,816,428
Vehicle running and maintenance		499,566	385,121
Insurance		2,324,482	2,323,895
Postage and courier		29,316,859	25,349,056
Advertisement and publicity		8,754,449	15,635,505
Others		36,886,832	16,091,985
Total		485,079,748	383,941,909

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Notes to the financial statements
For the year ended June 30, 2017

	Note	2017 Rupees	2016 Rupees
32 ADMINISTRATIVE EXPENSES			
Chief executive's remuneration	32.1	-	6,000,000
Salaries and other benefits		147,324,048	133,602,974
Postage and communication		27,198	12,144
Vehicles running and maintenance		5,652,817	4,086,393
Traveling and conveyance		330,305	506,765
Printing and stationery		2,353,778	3,526,055
Repairs and maintenance		3,870,365	899,353
News papers and periodicals		6,350	8,496
Auditors' remuneration		1,000,000	900,000
Legal and professional charges		1,756,738	1,747,184
Fee and subscription		6,160,402	3,957,630
Advertisement		293,916	64,510
Provision for doubtful debts		-	5,046,227
Office expenses		3,580,659	2,308,281
Insurance		6,210,389	3,600,701
Ijarah rentals		7,995,568	7,001,958
Others		6,352,129	10,031,322
Depreciation and amortization	17.2	19,496,051	13,097,643
Total		212,410,703	198,597,636

32.1 This represents remuneration given to the chief executive of the Company.

	Note	2017 Rupees	2016 Rupees
33 OTHER EXPENSES			
Workers' Profit Participation Fund		20,258,032	16,008,127
Workers' Welfare Fund		-	6,321,971
Loss on disposal of property, plant and equipment		90,068	-
Total		20,348,100	22,330,098

	Note	2017 Rupees	2016 Rupees
34 OTHER INCOME			
Income from financial assets			
Profit on bank deposits		140,012	691,363
Income from assets other than financial assets			
Gain on disposal of property, plant and equipment		-	10,816,222
Foreign currency translation differences - net		3,942,335	238,241
Rental income		6,000,000	198,300
Reversal of prior years Workers Welfare Fund		36,033,292	-
Total		46,115,639	11,944,126

	Note	2017 Rupees	2016 Rupees
35 FINANCE COST			
Mark-up / profit on long term financing		37,284,891	26,259,481
Mark-up / profit on short term borrowings and murabaha		174,263,499	134,250,337
Interest on provident fund		7,040,989	7,651,958
Bank charges and others		52,597,547	43,466,900
Total		271,186,926	211,628,676

36 TAXATION

36.1 During the year, no current tax liability has been recognized as the Company has availed tax credit u/s 65- B of the Income Tax Ordinance, 2001. Therefore, tax reconciliation has also not been re-produced in these financial statements.

36.2 The Company has not recognized its deferred tax asset / liability because its current year taxable income falls under final tax regime and the Company also expects same trend in future tax years as well.

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37 FINANCIAL INSTRUMENTS AND RELATED DISCLOSURES

The Company has exposures to the following risks from its use of financial instruments:

- Credit risk
- Liquidity risk
- Market Risk

The Board of Directors has overall responsibility for the establishment and oversight of the Company's risk management framework. The Board is also responsible for developing and monitoring the Company's risk management policies.

37.1 Credit risk and concentration of credit risk

Credit risk represents the accounting loss that would be recognized at the reporting date if counter parties fail completely to perform as contracted.

Credit risk arises principally from loans and advances, trade debts, deposits, other receivables and bank balances. Out of total financial assets of Rs. 789.647 million (2016: Rs. 758.492 million), the financial assets that are subject to credit risk amounted to Rs. 773.772 million (2016: Rs. 733.195 million).

The Company monitors the credit quality of the financial assets with reference to the historical performance of such assets and available external credit ratings.

The credit quality of financial assets that are neither past due nor impaired can be assessed by reference to external credit ratings or to historical information about counterparty default rate. The table below shows the bank balances and investment held with some major counterparties at the balance sheet date.

Banks	Rating Short term	Rating Long term	Agency	2017 Rupees	2016 Rupees
Bank Al Habib Limited	A 1+	AA+	PACRA	1,965,940	19,485,260
Allied Bank Limited	A 1+	AA+	PACRA	419,756	223,170
Bank Alfalah Limited	A 1+	AA	PACRA	4,694,224	639,918
MCB Bank Limited	A 1+	AAA	PACRA	11,447	11,447
United Bank Limited	A - 1+	AAA	JCR-VIS	888,900	307,444
Meezan Bank Limited	A - 1+	AA	JCR-VIS	1,984,810	7,604,441
Askari Bank Limited	A - 1+	AA	JCR-VIS	177,514	618,980
Habib Metropolitan Bank Limited	A 1+	AA+	PACRA	5,118,687	891,958
Habib Bank Limited	A - 1+	AAA	JCR-VIS	3,364,386	2,964,714
The Bank of Punjab	A 1+	AA-	PACRA	357,603	698,447
Dubai Islamic Bank Pakistan Limited	A - 1	A+	JCR-VIS	1,866	1,855
NIB Bank Limited	A 1+	AA-	PACRA	630,898	905,607
Pak Brunei Investment Company Limited	A 1+	AA+	PACRA	-	34,456,500
Chase Bank USA	Not available			81,918	81,918
Total				19,888,719	69,471,669

The aging of trade receivables at the reporting date is:

	Note	2017 Rupees	2016 Rupees
Past due but not impaired			
1 to 30 days		251,519,838	237,464,336
31 to 150 days		105,698,624	101,442,564
past due 150 days		130,818,313	93,674,023
		487,936,775	432,580,923
Not yet due		217,663,326	177,314,572
Total		705,600,101	609,895,495

37.2 Liquidity risk

Liquidity risk is the risk that the Company will not be able to meet its financial obligations as they fall due. The Company's approach to managing liquidity is to ensure as far as possible to always have sufficient liquidity to meet its liabilities when due. The Company's approach to managing liquidity is to ensure, as far as possible, that it will always have sufficient liquidity to meet its obligations when due, under both normal and stressed conditions, without incurring unacceptable losses or risking damage to the Company's reputation. The Company uses different methods which assists it in monitoring cash flow requirements. Typically the Company ensures that it has sufficient cash on demand to meet expected operational expenses for a reasonable period, including the servicing of financial obligation.

The following are contractual maturities of financial liabilities as at 30 June 2017:

	Carrying amount Rupees	Less than one year Rupees	One to five years Rupees	More than five years Rupees
Long term financing	1,228,677,460	138,541,716	1,090,135,734	-
Short term loans from directors	168,606,942	168,606,942	-	
Short term financing	3,858,162,415	3,858,162,415	-	-
Trade and other payables	1,996,249,771	1,996,249,771	-	-
Markup accrued on loans	62,672,805	62,672,805	-	-
Total	7,314,256,383	6,224,119,649	1,090,135,734	-

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Notes to the financial statements
For the year ended June 30, 2017

The following are contractual maturities of financial liabilities as at 30 June 2016:

	Carrying amount Rupees	Less than one year Rupees	One to five years Rupees	More than five years Rupees
Long term financing	711,867,920	85,564,224	626,303,696	-
Short term financing	2,951,979,781	2,951,979,781	-	-
Loans from directors	830,897,846	-	830,897,846	-
Trade and other payables	1,970,952,753	1,970,952,753	-	-
Markup accrued on loans	36,566,566	36,566,566	-	-
Total	6,502,264,666	5,045,063,324	1,457,201,342	-

37.3 **Market risk**

Market risk is the risk that changes in market price, such as foreign exchange rates, interest rates and equity prices will effect the Company's income or the value of its holdings of financial instruments.

a) Currency risk

Currency risk is the risk that the fair value or future cash flows of a financial instruments will fluctuate because of changes in foreign exchange rates.

The Company is exposed to currency risk on import of raw materials, stores, spares, machinery and export of goods mainly denominated in US dollars. The Company's exposure to foreign currency risk is as follows:

	2017	2016
Foreign debtors-USD	3,617,685	2,924,075
Foreign creditors including foreign commission payable-USD	-	-
The following significant exchange rates have been applied:		
Rupees per USD		
Average rate	104.22	104.66
Reporting date rate	104.80	104.50

As at year end, had exchange of USD depreciated or appreciated against the currency with all other variables held constant, the change in post tax profit / (loss), mainly as a result of foreign exchange gain / loss on translation of foreign currency denominated payables, would have been as follows:

	% change	2017	2016
Debtors US $	10	361,769	292,408
Creditors US $	10	-	-

b) Interest rate risk

Interest rate risk is the risk that the value of a financial instrument will fluctuate due to changes in the market interest rates.

At the reporting date, the variable interest / markup rate profile of the Company's significant interest bearing financial instruments was as follows:

Variable rate instruments	2017 Effective markup rate %	2016 Effective markup rate %	June 2017 Carrying value in Rupees	June 2016 Carrying value in Rupees
Financial liabilities				
Long term financing	7.23% to 7.86%	7.24% to 7.86%	86,714,450	330,345,420
Short term financing	6.44% to 7.91%	7.10% to 8.50%	989,382,038	422,489,918
Murabaha	6.86% to 7.61%	3.5% to 8.26%	479,510,434	415,222,349
Total			1,555,606,922	1,168,057,687
Financial assets				
Cash at bank - deposit accounts	1.50% to 2.75%	1.50% to 2.75%	104,460	10,587,423
Total			104,460	10,587,423

At reporting date, fixed markup rate profile of the Company's significant interest bearing financial instruments was as follows:

Fixed rate instruments	2017 Effective markup rate %	2016 Effective markup rate %	June 2017 Carrying value in Rupees	June 2016 Carrying value in Rupees
Financial liabilities				
Long term financing	3% to 3.75%	3% to 7.86%	1,141,963,000	381,522,500
Short term financing	2.75% to 3.60%	3.35% to 3.5%	2,773,300,000	2,404,687,070
Total			3,915,263,000	2,786,209,570

Cash flow sensitivity analysis for variable rate instruments

A change of 100 basis points in interest rates at the reporting date would have increased / (decreased) profit for the year by the amounts shown below. This analysis assumes that all other variables remain constant. The analysis is performed on the same basis for 2016.

	Profit and loss 100 bp	
	Increase	Decrease
As at June 30, 2017		
Cash flow sensitivity - variable rate financial liabilities	15,556,069	(15,556,069)
As at June 30, 2016		
Cash flow sensitivity - variable rate financial liabilities	11,680,577	(11,680,577)

The sensitivity analysis prepared is not necessarily indicative of the effects on profit for the year and assets / liabilities of the Company.

c) Equity price risk

Other price risk represents the risk that the fair value or future cash flows of a financial instrument will fluctuate because of changes in market prices (other than those arising from interest rate risk or currency risk), whether those changes are caused by factors specific to the individual financial instrument or its issuer, or factors affecting all similar financial instruments traded in the market. The Company is exposed to equity price risk as the Company holds investment in Master Power (Private) Limited, Master Wind Energy Limited and Al Hamra Avenue (Private) Limited (Note 18, 19 and Note 26 respectively) whose fair value or future cash flows will fluctuate because of changes in fair value.

37.4 Financial instruments by categories

	Cash & cash equivalents		Available for Sale		Loans and receivables		Total	
	June 2017	June 2016	June 2017	June 2016	June 2017	June 2016	June 2017	June 2016
	Rupees							
Financial assets								
Trade debts	-	-	-	-	711,901,430	616,196,824	711,901,430	616,196,824
Long term deposits	-	-	-	-	2,864,823	2,801,823	2,864,823	2,801,823
Short term investments	-	-	30,000,000	30,000,000	-	-	30,000,000	30,000,000
Other receivables	-	-	-	-	6,613,473	13,372,743	6,613,473	13,372,743
Cash and bank balances	35,562,173	94,768,128	-	-	-	-	35,562,173	94,768,128
Total	35,562,173	94,768,128	30,000,000	30,000,000	721,379,726	632,371,390	786,941,899	757,139,516

	Financial liabilities at amortised cost	
	June 2017	June 2016
	Rupees	Rupees
Financial liabilities		
Long term financing	1,223,677,460	711,867,920
Short term financing	3,752,682,038	2,827,175,989
Trade and other payables	1,985,248,771	1,970,952,753
Markup accrued	62,672,805	36,568,566
Total	7,059,279,094	5,546,564,227

37.5 Fair value of financial instruments

Fair value is the amount that would be received on sale of an asset or paid on transfer of a liability in an orderly transaction between market participants at the measurement date. Consequently, differences can arise between carrying values and fair value estimates. Underlying the definition of fair value is the presumption that the Company is a going concern without any intention requirement to curtail materially the scale of its operations or to undertake a transaction on adverse terms.

IFRS 13, 'Fair value Measurements' requires the Company to classify fair value measurements using fair value hierarchy that reflects the significance of the inputs used in making the measurements. The fair value hierarchy has the following levels;

Level 1: quoted prices (unadjusted) in active markets for identical assets or liabilities;

Level 2: inputs other than quoted prices included within Level 1 that are observable for the assets or liability, either directly (i.e. as prices) or indirectly (i.e. derived from prices); and

Level 3: inputs for the assets or liability that are not based on observable market data (unobservable inputs).

Notes to the financial statements
For the year ended June 30, 2017

37.5.1 The following table show the categories as well as carrying amounts and fair values of financial assets according to there respective category, including their levels in the fair value hierarchy for financial instruments measured at fair value. It does not include fair value information for financial assets not measured at fair value if the carrying amount is reasonable approximation of fair value.

Description	Carrying amount					Fair Value			
	Cash and cash equivalents	Loans and receivables	Available for sale instruments	Fair value through profit or loss	Total	Level 1	Level 2	Level 3	Total
June 30, 2017									
Financial assets measured at fair value									
Short term investments	-	-	30,000,000	-	30,000,000	-	-	30,000,000	30,000,000
Financial assets not measured at fair value									
Non-current assets									
Long term deposits	-	2,862,823	-	-	2,862,823	-	-	-	-
Current assets									
Trade debts-unsecured	-	280,406,143	-	-	280,406,143	-	-	-	-
Loans and advances	-	25,306,132	-	-	25,306,132	-	-	-	-
Other receivables	-	6,613,473	-	-	6,613,473	-	-	-	-
Cash and bank balances	35,562,173	-	-	-	35,562,173	-	-	-	-
	35,562,173	315,188,571	30,000,000	-	380,750,744	-	-	30,000,000	30,000,000
June 30, 2016									
Financial assets measured at fair value									
Short term investments	-	-	30,000,000	-	30,000,000	-	-	30,000,000	30,000,000
Financial assets not measured at fair value									
Non-current assets									
Long term deposits	-	2,801,823	-	-	2,801,823	-	-	-	-
Current assets									
Trade debts-unsecured	-	245,444,985	-	-	245,444,985	-	-	-	-
Loans and advances	-	23,118,900	-	-	23,118,900	-	-	-	-
Other receivables	-	13,372,743	-	-	13,372,743	-	-	-	-
Cash and bank balances	94,768,128	-	-	-	94,768,128	-	-	-	-
	94,768,128	284,738,451	30,000,000	-	409,506,579	-	-	30,000,000	30,000,000

37.5.2 The Company does not hold any financial liability at fair value.

37.6 Capital risk management

The Company's objectives when managing capital are to safeguard the entity's ability to continue as a going concern, so that it can continue to provide adequate returns for shareholders and benefits for other stakeholders; and to maintain a strong capital base to support the sustained development of its businesses.

The Company manages its capital structure which comprises capital and reserves by monitoring return on net assets and makes adjustments to it in the light of changes in economic conditions. In order to maintain or adjust the capital structure, the Company may adjust the amount of dividend paid to shareholders, appropriation of amounts to capital reserves and / or issue new shares.

Consistent with others in the industry, the Company manages its capital risk by monitoring its debt levels and liquid assets and keeping in view future investment requirements and expectations of the shareholders. Debt is calculated as total borrowings ("long term loan" and "short term borrowings" as shown in the balance sheet). Total capital comprises shareholders' equity as shown in the balance sheet under "share capital and reserves".

The salient information relating to capital risk management of the Company as of June 30, 2017 and 2016 were as follows:

	Note	2017 Rupees	2016 Rupees
Total borrowings (including murabaha)		5,666,340,299	4,909,967,696
Less: Cash and cash equivalents		(35,562,173)	(94,768,128)
Net debt		5,630,778,126	4,815,199,568
Total equity		4,499,356,575	3,619,882,849
Total capital		10,130,134,701	8,435,082,417
Gearing ratio (%)		55.58	57.09

Notes to the financial statements
For the year ended June 30, 2017

38 **RELATED PARTIES DISCLOSURES**

Related parties comprise subsidiary, associates, associated undertakings, companies where directors also hold interest, directors as the employee, provident fund and key management personnel of the Company. Transactions and balances with related parties other than remuneration and benefits to key management personnel under the terms of their employment are as follows:

	Relationship	2017 Rupees	2016 Rupees
Receivables from related parties			
Dura Industries (Private) Limited	Associated undertaking	28,355,699	33,792,578
N. M. Corporation (Private) Limited	Associated undertaking	-	388,337
Master Enterprises (Private) Limited	Associated undertaking	1,409,406	1,409,405
Master Synthetic (Private) Limited	Associated undertaking	9,121,233	16,585,139
Master Wind Energy (Private) Limited	Associated undertaking	-	1,586,227
Payable to Related parties	Associated undertaking	30,585,494	20,454,647
Payable to Provident Fund		360,528,097	252,092,827
Loans from directors		727,043,766	830,897,646
Total		1,157,043,694	1,156,206,806

Name of the entity	Nature of transactions	2017 Rupees	2016 Rupees
Transactions with related parties			
Associated undertakings	Sale of goods	180,476,439	160,523,438
Associated undertakings	Sale of machinery	8,878,977	-
Associated undertakings	Purchases	6,073,445	1,790,466
Associated undertakings	Rental Income	6,000,000	-
Provident Fund	Contribution made	102,712,774	82,690,240
Subsidiary	Investment made	-	250,000,000
Total		304,139,635	495,004,144

39 **REMUNERATION OF CHIEF EXECUTIVE OFFICER**

Description	2017 Chief executive officer	2016 Chief executive officer
Managerial remuneration	-	6,000,000
Total	-	6,000,000
No. of persons	1	1

39.1 The Chief Executive Officer of the Company is also provided with Company maintained vehicle.

40 **PROVIDENT FUND RELATED DISCLOSURES**

The following information is based on latest un-audited financial statements of the Fund:

	2017	2016
Size of the fund - Total assets	332,366,242	335,595,093
Cost of investments made	-	-
Percentage of investments made	0%	0%
Fair value of investments	-	-

40.1 The break-up of fair value of investments is:

	2017 Rupees	2017 %	2016 Rupees	2016 %
Bank balances	3,117,914	1%	21,106,465	6%
Total	3,117,914	1%	21,106,465	6%

41 **NUMBER OF EMPLOYEES**

The total average number of employees during the year and as at June 30, 2017 and 2016 respectively are as follows:

	2017	2016
Average number of employees during the year	4,113	4,225
Total number of employees as at June 30	4,940	4,120

42 **GENERAL**

Corresponding figures have been re-arranged / and reclassified where ever considered necessary for the purpose of better presentation. However, no significant reclassification has been made in these financial statements. Except as stated in note 7 & 13.

43 **DATE OF AUTHORIZATION**

These financial statements have been approved by the board of directors of the Company on October 09, 2017

CHIEF EXECUTIVE OFFICER

DIRECTOR

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4.3.3 Audited Financial Statements of Procon Engineering (Pvt.) Limited

PROCON ENGINEERING (PRIVATE) LIMITED
FINAL ACCOUNTS
FOR THE YEAR ENDED JUNE 30, 2017

RAO & COMPANY
CHARTERED ACCOUNTANTS

TELEPHONES
32412778 & 32412779
FAX: 32419452
TELEGRAMS
AKOUNTVIEW

4, Karachi Chambers
Hasrat Mohani Road,
P.O. Box 5061
Karachi-2
PAKISTAN

AUDITORS' REPORT TO THE MEMBERS

We have audited the annexed balance sheet of **PROCON ENGINEERING (PRIVATE) LIMITED** as at June 30, 2017 and the related profit and loss account, statement of comprehensive income, cash flow statement and statement of changes in equity together with the notes forming part thereof, for the year then ended and we state that we have obtained all the information and explanations which, to the best of our knowledge and belief, were necessary for the purposes of our audit.

It is the responsibility of the Company's management to establish and maintain a system of internal control, and prepare and present the above said statements in conformity with the approved accounting standards and the requirements of the Companies Ordinance, 1984. Our responsibility is to express an opinion on these statements based on our audit.

We conducted our audit in accordance with the auditing standards as applicable in Pakistan. These standards require that we plan and perform the audit to obtain reasonable assurance about whether the above said statements are free of any material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the above said statements. An audit also includes assessing the accounting policies and significant estimates made by management, as well as, evaluating the overall presentation of the above said statements. We believe that our audit provides a reasonable basis for our opinion and, after due verification, we report that:

a) The Company operates an unfunded gratuity scheme covering all of its permanent employees who are eligible under the scheme. However, instead of making provision annually to cover the obligations under the scheme , the Company accounts for gratuity as an expense at the time of making payment to an outgoing employee. International Accounting Standard -19 "Employee Benefits" requires such liability to be recorded on the basis of projected unit credit method. In the absence of measurement of liability on projected unit credit method , the impact on these financial statements could not be quantified;

b) In our opinion, proper books of account have been kept by the Company as required by the Companies Ordinance, 1984;

c) in our opinion:

   I. except for the matters discussed in paragraph (a) above the balance sheet and profit and loss account, together with the notes thereon have been drawn up in conformity with the Companies Ordinance, 1984, and are in agreement with the books of account and are further in accordance with accounting policies consistently applied;

   II. the expenditure incurred during the year was for the purpose of the Company's business; and

   III. the business conducted, investments made and the expenditure incurred during the year were in accordance with the objects of the Company;

d) in our opinion and to the best of our information and according to the explanations given to us, except for the effects of adjustment that could have been on the financial statements of the matters discussed in paragraph (a) above, the balance sheet, profit and loss account, statement of comprehensive income, cash flow statement and statement of changes in equity, together with the notes forming part thereof conform with approved accounting standards as applicable in Pakistan, and, give the information required by the Companies Ordinance, 1984, in the manner so required and respectively give a true and fair view of the state of the Company's affairs as at June 30, 2017, and of the profit, total comprehensive income, its cash flows and changes in equity for the year then ended; and

e) in our opinion, no Zakat was deductible at source under the Zakat & Ushr Ordinance, 1980 (XVIII of 1980).

Chartered Accountants
Engagement Partner: Khalid Adeeb
Karachi.

07 OCT 2017

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PROCON ENGINEERING (PRIVATE) LIMITED
BALANCE SHEET
AS AT JUNE 30, 2017

	Note	2017 Rupees	2016 Rupees
ASSETS			
Non-current assets			
Property, plant and equipment	4	1,140,716,856	871,038,019
Intangible assets	5	7,508,295	5,235,982
Long term investment	6	585,160,278	502,281,567
Long term deposits	7	8,581,195	7,538,397
		1,741,966,624	1,386,093,965
Current assets			
Store and spares		12,678,117	5,311,166
Stock-in-trade	8	1,448,450,580	562,146,416
Trade receivables	9	331,723,359	349,478,502
Short term advances	10	617,161,358	272,997,308
Prepayments and other receivables	11	8,182,799	10,032,826
Tax refunds due from the Government		54,325,728	52,835,267
Cash and bank balances	12	15,269,716	38,160,212
		2,487,791,657	1,290,961,697
		4,229,758,281	2,677,055,662
EQUITY AND LIABILITIES			
Share capital and reserves			
Authorized capital			
500,000 (2016: 500,000) Ordinary shares of Rs.100 each		50,000,000	50,000,000
Issued, subscribed and paid-up capital	13	30,000,000	30,000,000
General reserves		150,000,000	150,000,000
Loan from directors		146,323,965	-
Unappropriated profit		1,026,347,329	631,668,722
		1,352,671,294	811,668,722
Non-current liabilities			
Long-term borrowings	14	517,061,457	815,613,466
Deferred taxation	15	84,485,072	70,876,669
		601,546,529	886,490,135
Current liabilities			
Trade, accrued and other payables	16	988,880,239	736,682,497
Accrued mark-up	17	68,060,898	56,140,919
Short term borrowings	18	1,131,098,265	95,945,863
Due to related parties	19	2,184,144	20,463,768
Provision for taxation		85,316,912	69,663,758
		2,275,540,458	978,896,805
Contingencies and commitments	20		
		4,229,758,281	2,677,055,662

The annexed notes from 1 to 35 form an integral part of these financial statements.

CHIEF EXECUTIVE　　　　　　DIRECTOR

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PROCON ENGINEERING (PRIVATE) LIMITED
PROFIT AND LOSS ACCOUNT
FOR THE YEAR ENDED JUNE 30, 2017

	Note	2017 Rupees	2016 Rupees
Sales	21	8,236,783,503	6,926,082,230
Cost of sales	22	(7,286,583,591)	(6,195,393,559)
Gross profit		950,199,912	730,688,671
Selling and distribution expenses	23	(76,962,692)	(48,648,931)
Administrative and general expenses	24	(384,877,738)	(272,141,118)
		(461,840,430)	(320,790,050)
Operating profit		488,359,482	409,898,622
Finance cost	25	(48,492,426)	(25,852,152)
		439,867,056	384,046,470
Other income	26	1,474,697	2,466,938
Other charges	27	(31,636,778)	(38,418,994)
		(30,162,081)	(35,952,056)
		409,704,975	348,094,414
Share of profit / (loss) from associate		82,878,711	(3,766,433)
Profit before taxation		492,583,686	344,327,981
Taxation	28	(97,905,079)	(87,227,622)
Profit after taxation		394,678,607	257,100,359
Earning per share-basic and diluted	29	1,315.60	857.00

The annexed notes from 1 to 35 form an integral part of these financial statements.

CHIEF EXECUTIVE **DIRECTOR**

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PROCON ENGINEERING (PRIVATE) LIMITED
STATEMENT OF COMPREHENSIVE INCOME
FOR THE YEAR ENDED JUNE 30, 2017

	2017 Rupees	2016 Rupees
Profit after taxation for the year	394,678,607	257,100,359
Other comprehensive income	-	-
Total comprehensive income for the year	394,678,607	257,100,359

The annexed notes from 1 to 35 form an integral part of these financial statements.

CHIEF EXECUTIVE

DIRECTOR

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PROCON ENGINEERING (PRIVATE) LIMITED
CASH FLOW STATEMENT
FOR THE YEAR ENDED JUNE 30, 2017

	Note	2017 Rupees	2016 Rupees
CASH FLOWS FROM OPERATING ACTIVITIES			
Net profit before taxation		492,583,686	344,327,981
Adjustment for:			
Depreciation	4.1	155,545,023	104,048,028
Amortization on software	5	5,027,687	2,248,520
Finance cost	25	48,492,426	25,852,152
Share in post acquisition (profit) / loss from associate	6	(82,878,711)	3,766,433
Gain on disposal of property, plant and equipment	26	(713,724)	(1,102,717)
Unrealised Foreign currency exchange loss	27	1,447,991	13,915,111
		126,920,692	148,727,527
		619,504,378	493,055,508
Changes in Working Capital			
(Increase) / decrease in current assets			
Store and spares		(7,366,951)	(505,366)
Stock-in-trade		(886,304,164)	(116,635,906)
Trade receivables		17,755,143	21,513,352
Short term advances		(165,265,877)	(105,105,256)
Prepayments and other receivables		1,850,027	(358,952)
		(1,039,331,822)	(201,092,128)
		(419,827,444)	291,963,380
Increase / (decrease) in current liabilities			
Trade, accrued and other payables		252,197,742	198,675,893
Due to related parties		(18,279,624)	(40,654,868)
		233,918,118	158,021,025
Cash generated from operations		(185,909,326)	449,984,405
Finance cost paid		(36,572,447)	(20,783,390)
Income tax paid		(249,032,156)	(87,834,392)
Long term deposit		(1,042,798)	100,600
		(286,647,401)	(108,517,182)
Net cash generated from operating activities		(472,556,727)	341,467,223
CASH FLOWS FROM INVESTING ACTIVITIES			
Addition in property, plant and equipment		(425,475,136)	(284,151,165)
Addition in intangible assets		(7,300,000)	(4,050,000)
Proceeds from disposal of property, plant and equipment		965,000	1,510,718
Investment in DSCs		-	3,000
Net cash (used in) investing activities		(431,810,136)	(286,687,447)
CASH FLOWS FROM FINANCING ACTIVITIES			
Repayment of liabilities against asset subject to finance lease		-	(518,022)
Long term borrowings received / (repaid) during the year - net		106,570,000	(80,192,580)
Short term borrowings		774,906,367	40,811,188
Net cash (used in) financing activities		881,476,367	(39,899,414)
Net (decrease) / increase in cash and cash equivalents		(22,890,496)	14,880,362
Cash and cash equivalents at beginning of the year		38,160,212	23,279,850
Cash and cash equivalents at end of the year	12	15,269,716	38,160,212

The annexed notes from 1 to 35 form an integral part of these financial statements.

CHIEF EXECUTIVE

DIRECTOR

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PROCON ENGINEERING (PRIVATE) LIMITED
STATEMENT OF CHANGES IN EQUITY
FOR THE YEAR ENDED JUNE 30, 2017

	Issued, subscribed and paid up	General reserves	Loan from directors	Unappropriated profit	Total
Balance as on June, 30, 2015	30,000,000	150,000,000	-	374,568,363	554,568,363
Total comprehensive income for the year	-	-	-	257,100,359	257,100,359
Transactions with owners	-	-	-	-	-
Balance as on June, 30, 2016	30,000,000	150,000,000	-	631,668,722	811,668,722
Total comprehensive income for the year	-	-	-	394,678,607	394,678,607
Transactions with owners					
Long term borrowing transferred from non-current liabilities (note 14)	-	-	146,323,965	-	146,323,965
Balance as on June, 30, 2017	30,000,000	150,000,000	146,323,965	1,026,347,329	1,352,671,294

The annexed notes from 1 to 35 form an integral part of these financial statements.

CHIEF EXECUTIVE

DIRECTOR

1 STATUS AND NATURE OF BUSINESS

The Company was incorporated in Pakistan under the Companies Ordinance, 1984 on October 13, 1988. The Company is engaged in manufacturing of automotive parts and components. The registered address of the Company is 54- Darul Aman Co-operative Housing Society Shahrah-e-Faisal Karachi.

2 STATEMENT OF COMPLIANCE

These financial statements have been prepared in accordance with approved accounting standards as applicable in Pakistan. Approved accounting standards comprise of such International Financial Reporting Standards (IFRSs) issued by the International Accounting Standards Board as are notified under the Companies Ordinance, 1984 and provisions of and directives issued under the Companies Ordinance, 1984. In case the requirements differ, the provisions or directives of the Companies Ordinance, 1984 shall prevail.

During the year, the Companies Act, 2017 (the Act) has been promulgated, however, Securities and Exchange Commission of Pakistan (SECP) vide its circular no. 17 of 2017 dated July 20, 2017 communicated commission's decision that the companies whose financial year close on or before 30 June 2017 shall prepare their financial statements in accordance with the provisions of the repealed Companies Ordinance, 1984.

3 SUMMARY OF SIGNIFICANT ACCOUNTING POLICIES

3.1 Basis of preparation

These financial statements have been prepared under the historical cost convention except as other wise stated in the respective policies and notes given hereunder.

In these financial statements, except for the amounts reflected in the cash flow statement, all transactions have been accounted for on accrual basis.

3.2 Functional and presentation currency

These financial statements are presented in Pakistan Rupees which is the functional currency of the Company.

3.3 Changes in accounting standards and interpretations

a) Standards, interpretations and amendments to published approved accounting standards that are effective and relevant

Following amendments to existing standards and interpretations have been published and are mandatory for accounting periods beginning on January 01, 2016 and are considered to be relevant to the company's operations:

IAS 1, 'Presentation of Financial Statements' aims to improve presentation and disclosure in financial reports by emphasising the importance of understandability, comparability and clarity in presentation.

The amendments provide clarification on number of issues including:

- Materiality – an entity should not aggregate or disaggregate information in a manner that obscures useful information. Where items are material, sufficient information must be provided to explain the impact on the financial position or performance.
- Disaggregation and subtotals – line items specified in IAS 1 may need to be disaggregated where this is relevant to an understanding of the entity's financial position or performance. There is also new guidance on the use of subtotals.

- Notes – confirmation that the notes do not need to be presented in a particular order.

- Other Comprehensive Income (OCI) – arising from investments accounted for under the equity method - the share of the OCI arising from equity - accounted investments is grouped based on whether the items will or will not subsequently be reclassified to profit or loss. Each group should then be presented as a single line item in the statement of comprehensive income.

The above do not have any significant impact on these financial statements.

b) **Standards, interpretations and amendments to published approved accounting standards that are effective but not relevant**

The new standards, amendments and interpretations that are mandatory for accounting periods beginning on or after January 01, 2016 are considered not to be relevant to Company's financial statements and hence have not been detailed here.

c) **Standards, interpretations and amendments to published approved accounting standards that are not yet effective but relevant**

Following new amendment to published standard is effective for accounting periods beginning on or after January 1, 2017 and is considered to be relevant for Company's financial statements.

IAS 7, 'Cashflow statements' - This amendment requires disclosure to explain changes in liabilities for which cash flows have been, or will be classified as financing activities in the statement of cash flows. The amendment is part of the IASB's Disclosure Initiative. In the first year of adoption, comparative information need not be provided.

3.4 Significant accounting estimates and judgments

The preparation of financial statements in conformity with approved accounting standards requires the use of certain critical accounting estimates. It also requires management to exercise judgment, estimates and assumptions in the process of applying accounting policies and the reported amounts of assets, liabilities, income and expenses. Actual results may differ from these estimates.

Estimates and underlying assumptions are reviewed on an on going basis. Revisions to accounting estimates are recognized in the period in which the estimates are revised and in any future periods affected.

In the process of applying the Company's accounting policies, management has made the following estimates and judgments, which are significant to the financial statements:

(i) Property, plant and equipment
(ii) Trade debts
(iii) Taxation
(iv) Valuation of stock in trade

3.5 Revenue recognition

Revenue is recognised when it is probable that the economic benefits associated with the transaction will flow to the company and the amount of revenue and the associated cost incurred or to be incurred can be measured reliably.

(i) sale of goods is recognised when the goods are invoiced and risk and rewards transferred.

(ii) all other income are recorded as and when accrued.

3.6 Property, plant and equipment

Owned

Property, plant and equipment are stated at cost less accumulated depreciation and impairment. Depreciation is charged to Income applying the diminishing balance method at the rates specified in note 4. Depreciation is charged on all property, plant and equipment from the month they are available for use till the month they are disposed of. Any gain or loss on disposal of property, plant and equipment are taken in profit and loss account in the year of disposal. Minor repairs and maintenance are charged to current expenses. Major renewals and improvements are capitalized.

Leased

Leases that transfer substantially all the rewards and risks of ownership of assets to the company are accounted for as finance leases. At the inception of a finance lease, the cost of the leased asset is capitalised at the fair value of the leased asset or, if lower, at the present value of the minimum lease payments. Lease payments are apportioned between the finance charges and reduction of the lease liability so as to achieve a constant rate of interest on the remaining balance of the liability. Finance charges are charged to the income statement. The lessor gives an option to purchase assets at the end of lease term.

3.7 Investment in associate

Entities in which the Company has significant influence but not control and which are neither its subsidiaries nor joint ventures are associates and are accounted for by using the equity method of accounting.

These investments are initially recognized at cost, thereafter the carrying amount is increased or decreased to recognize the Company's share of profit or loss of associates. Share of post acquisition profit or loss of associates is accounted for in the Company's profit or loss. Distribution received from investee, reduces the carrying amount of investment. The Company's share of changes recognized in other comprehensive income by the associate are recognized by the Company in other comprehensive income.

3.8 Stores, spares and loose tools

Stores, spares and loose tools are valued at weighted average cost except for items in transit which are stated at cost incurred upto the balance sheet date. For items which are slow moving and / or identified as surplus to the Company's requirements, adequate provision is made for any excess book value over estimated realizable value. The Company reviews the carrying amount of stores and spares on a regular basis and provision is made for obsolescence.

3.9 Stock-in-trade

These are valued at lower of cost and net realizable value. Cost is determined by first-in first-out method.

Cost of stock-in-transit comprises bank charges and any other cost incurred till balance sheet date. Cost of Work-in-Progress and finished goods include prime cost and appropriate portion of manufacturing expenses.

Net realizable value signifies the estimated selling price in the ordinary course of business less costs necessarily to be incurred in order to make the sale.

3.10 Trade and other receivables

Trade receivables are recognized and carried at original invoice amount less an allowance for any uncollectible amounts. Known bad debts, if any, are written off and provision is made against debts considered doubtful.

3.11 Advances, deposits and prepayments

These are stated at cost.

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3.12 Cash and cash equivalents

Cash and cash equivalents are carried in the balance sheet at cost. For the purpose of cash flow statement, cash and cash equivalents comprise cash in hand, cash with banks on current, saving and deposit accounts and other short term highly liquid investments that are readily convertible to known amounts of cash and which are subject to insignificant risk of change in value.

3.13 Related party transactions

All transactions involving related parties arising in the normal course of business are conducted at arm's length at normal commercial rates on the same terms and conditions as third party transactions using valuation modes, as admissible, except in extremely rare circumstances where, subject to the approval of the Board of Directors, it is in the interest of the Company to do so.

The Company classifies its financial assets in the following categories: at fair value through profit and loss, held to maturity, loans and receivables, and available-for-sale. The classification depends on the purpose for which the financial assets were acquired. Management determines the classification of its financial assets at initial recognition.

3.14 Financial instruments – classification, recognition, measurement, derecognition and offsetting

Financial assets at fair value through profit or loss

Financial assets at fair value through profit or loss are financial assets held for trading. A financial asset is classified in this category if acquired principally for the purpose of selling in the short term. Derivatives are also categorized as held for trading unless they designated as hedges. Assets in this category are classified as current assets.

Loans and receivables

Loans and receivables are non-derivatives financial assets with fixed or determinable payments that are not quoted in an active market. They are included in the current assets, except for the maturities greater than 12 months after the end of the reporting period, which are classified as non-current assets.

Held to maturity financial assets

Held to maturity financial assets are non-derivative financial assets with fixed or determinable payments and maturity where management has a positive intention and ability to hold till maturity.

Available for sale financial assets

Available for sale financial assets are non-derivatives that are either designated in this category or not classified in any of other categories. These are included in non-current assets unless the investment matures or management intends to dispose of the financial assets within 12 months of the balance sheet date.

Regular way purchases and sales of financial assets are recognised on the trade date - the date on which the Company commits to purchase or sell the asset. Financial assets are initially recognised at fair value plus transaction costs for all financial assets not carried at fair value through profit or loss. Financial assets carried at fair value through profit or loss are initially recognised at fair value and transaction costs are expensed in the profit and loss account. Financial assets are derecognised when the right to receive cash flows from the investments have expired or have been transferred and the Company has transferred substantially all risks and rewards of ownership. Available for sale financial assets and financial assets at fair value through profit or loss are subsequently carried at fair value. Loans and receivables and held to maturity financial assets are carried at amortized cost using the effective interest rate method.

Financial liabilities are recognized at the time when the Company becomes a party to the contractual provisions of the instrument. A financial liability is derecognised when the obligation under the liability is discharged or cancelled or expires. When an existing financial liability is replaced by another from the same lender on substantially different terms or the terms of an existing liability are substantially modified, such an exchange or modification is treated as a derecognition of the original liability and the recognition of a new liability, and the difference in the respective carrying amounts is recognised in the statement of comprehensive income.

A financial asset and financial liability is offset and the net amount is reported in the balance sheet if the Company has a legally enforceable right to set-off the recognized amounts and the Company intends either to settle on a net basis or to realize the asset and discharge the liability simultaneously. Corresponding income on assets and charge on liability is also offset.

3.15 Derivative financial instruments and hedging activities

Derivatives are initially recognised at fair value on the date a derivative contract is entered into and are subsequently re-measured at their fair value. The method of recognizing the resulting gain or loss depends on whether the derivative is designated as a hedging instrument, and if so, the nature of the item being hedged. The Company designates certain derivatives as either:

- Hedges of the fair value of recognized assets or liabilities or a firm commitment (fair value hedge); or
- Hedges of a particular risk associated with a recognized asset or liability or a highly probable forecast transaction (cash flow hedge).

Fair value hedge
Changes in the fair value of derivatives that are designated and qualify as fair value hedges are recorded in the profit and loss account, together with any changes in the fair value of the hedged asset or liability that are attributable to the hedged risk.

Cash flow hedge
On an ongoing basis, the Company assesses whether each derivative continues to be highly effective in offsetting changes in the cash flows of hedged items. If and when a derivative is no longer expected to be highly effective, hedge accounting is discontinued.

The effective portion of changes in fair value of derivatives that are designated and qualify as cash flow hedges is recognized in other comprehensive income. The gain or loss relating to the ineffective portion is recognized immediately in the profit and loss account.

3.16 Offsetting

Financial assets and liabilities are offset and the net amount is reported in the balance sheet, if the Company has a legally enforceable right to setoff the recognised amounts and the Company intends to settle either on a net basis or realise the asset and settle the liability simultaneously.

3.17 Impairment of assets

An assessment is made at each balance sheet date to determine whether there is any indication of impairment or reversal of previous impairment, including items of property, plant and equipment and intangible assets. In the event that an asset's carrying amount exceeds its recoverable amount, the carrying amount is reduced to recoverable amount and an impairment loss is recognised in the income statement. A previously recognised impairment loss is reversed only if there has been a change in the estimates used to determine the recoverable amount, however not to an amount higher than the carrying amount that would have been determined (net of amortisation or depreciation), had no impairment losses been recognised for the asset in prior years. Reversal of impairment loss is restricted to the original cost of the asset.

3.18 Provisions

Provisions are recognised when the Company has a present legal or constructive obligation as a result of past events, it is probable that an out flow of resources embodying economic benefits will be required to settle the obligation and a reliable estimate can be made of the amount of obligation.

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3.19 Foreign currency transactions

Foreign currency transactions are recorded at the exchange rate applicable at the transaction date. Monetary assets and liabilities are translated into rupees using exchange rates applicable at the balance sheet date. All gains and losses on settlement and translation at year end are recognised in the profit and loss account.

3.20 Borrowing cost

Borrowing costs are recognised as an expenses in the period in which these are incurred except to the extent of borrowing costs that are directly attributable to the acquisition, construction or production of a qualifying assets. Such borrowing costs are capitalized as part of the cost of the asset.

3.21 Warranty obligations

The Company recognises the estimated liability, on an accrual basis, to repair or replace products under warranty at the balance sheet date, and recognises the estimated product warranty costs in the profit and loss account when the sale is recognised.

3.22 Staff retirement benefits - Gratuity

The Company operates an unfunded gratuity scheme covering all of its permanent employees who are eligible under the scheme. However, instead of making provision annually to cover the obligations under the scheme, the Company accounts for gratuity as an expense at the time of making payment to an outgoing employee.

3.23 Trade, accrued and others payable

Liabilities for trade and other payables are carried at cost, which is the fair value of the consideration to be paid in future for goods and services received.

3.24 Taxation

Current

Provision for current taxation is based on taxable income at current rates of taxation after taking into account tax rebates and tax credit available, if any. The company provides for deferred taxation on liability method for all major temporary differences, if any. Net deferred tax debits, if any, on account of temporary differences have not been recognized.

Deferred

Deferred taxation is recognized, using the balance sheet liability method, providing for all temporary differences between the carrying amounts of assets and liabilities for financial reporting purposes and the amounts used for taxation purposes. The amount of deferred tax recognized is based on the expected manner of the realization or settlement of the carrying amount of assets and liabilities, using rates of taxation enacted or substantially enacted at the balance sheet date.

Deferred tax asset is recognized only to the extent that it is probable that future taxable profit will be available and the credits can be utilized.

3.25 Earnings per share

The Company presents basic and diluted earnings per shares (EPS) data. Basic EPS is calculated by dividing the profit or loss attributable to shareholders of the Company by the weighted average number of ordinary shares outstanding during the period. Diluted EPS is determined by adjusting the profit or loss attributable to shareholders and the weighted average number of ordinary shares outstanding, adjusted for the effects of all dilutive potential ordinary shares.

3.26 Loan from directors

Loan from director is accounted for by using Technical Release-32 "Accounting Directors Loan" (TR 32) issued by the Institute of Chartered Accountant of Pakistan (ICAP) on 25th January 2016 which provided specific guidance on Director's loan that are interest free:

- Director's loan that is interest free and payable at the discretion of the Company is to be recorded as equity at face value and is not to be subsequently remeasured.
- Director's loan that is interest free and payable on demand is to be recorded under current liabilities.

4 PROPERTY, PLANT AND EQUIPMENTS

	Note	2017 Rupees	2016 Rupees
Operating fixed assets	4.1	1,060,798,970	848,724,231
Capital work-in-progress	4.2	79,917,886	22,313,788
		1,140,716,856	871,038,019

4.1 OPERATING FIXED ASSETS

Particulars	Cost as on July 01, 2016	Additions / (deletions) / *transfers	Cost as at June 30, 2017	Accumulated depreciation as at July 01, 2016	Depreciation / (adjustment) for the year	Accumulated depreciation as at June 30, 2017	Written down value at June 30, 2017	Rate %
Owned								
Lease-hold land	54,561,701	-	54,561,701	-	16,368,510	16,368,510	38,193,191	
S.F. units	9,365,899	3,258,118	12,624,017	-	-	-	12,624,017	
Building	239,272,765	5,306,866 6,541,152*	261,120,784	147,329,040	9,890,700	157,219,740	93,901,044	10
Plant and machinery	1,224,283,270	252,895,910 22,582,596*	1,499,761,776	624,265,201	107,740,017	732,005,218	767,756,559	15
Furniture, fixture and equipments	61,399,437	35,093,564	96,493,001	36,152,421	5,467,523	41,619,944	54,873,057	15
Motor boat	815,000	-	815,000	786,920	4,212	791,132	23,868	15
Computers	27,923,194	4,450,459	32,373,653	17,126,574	3,964,647	21,091,221	11.282,432	30
Data communication system	2,752,185	-	2,752,185	2,215,475	80,506	2,295,982	456,203	15
Motor vehicles	101,895,341	37,742,372 (1,973,655)	137,664,058	45,668,930	12,028,907 (1,722,379)	55,975,458	81,688,600	15
2017 Rupees	1,722,268,792	338,747,290 29,123,748* (1,973,655)	2,088,166,175	873,544,561	155,545,023 (1,722,379)	1,027,367,205	1,060,798,970	

Particulars	Cost as on July 01, 2015	Additions / (deletions) / *transfers	Cost as at June 30, 2016	Accumulated depreciation as at July 01, 2015	Depreciation / (adjustment) for the year	Accumulated depreciation as at June 30, 2016	Written down value at June 30, 2016	Rate %
Owned								
Lease-hold land	53,481,701	1,080,000	54,561,701	-	-	-	54,561,701	
S.F. units	8,565,899	800,000	9,365,899	-	-	-	9,365,899	
Building	237,969,595	1,303,170	239,272,765	137,209,806	10,119,234	147,329,040	91,943,725	10
Plant and machinery	981,086,012	243,197,258	1,224,283,270	542,357,269	81,907,931	624,265,201	600,018,069	15
Furniture, fixture and equipments	52,219,926	9,179,511	61,399,437	32,756,822	3,395,599	36,152,421	25,247,016	15
Motor boat	815,000	-	815,000	781,965	4,955	786,920	28,080	15
Computers	21,997,157	5,926,037	27,923,194	13,706,378	3,420,196	17,126,574	10,796,620	30
Data communication system	2,752,185	-	2,752,185	2,120,762	94,713	2,215,475	536,710	15
Motor vehicles	79,431,964	18,264,829 6,711,665* (2,513,117)	101,895,341	37,058,526	5,105,398 5,610,122* (2,105,116)	45,668,930	56,226,411	15
	1,438,319,439	279,750,805 (2,513,117) 6,711,665*	1,722,268,792	765,991,528	104,048,028 (2,105,116) 5,610,122*	873,544,561	848,724,231	
Leased assets								
Motor vehicles	6,711,665	(6,711,665)*	-	5,610,122	(5,610,122)*	-	-	15
	6,711,665	(6,711,665)	-	5,610,122	(5,610,122)	-		
	1,445,031,104	279,750,805 (2,513,117)	1,722,268,792	771,601,650	104,048,028 (2,105,116)	873,544,561	848,724,231	

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	Note	2017 Rupees	2016 Rupees
4.1.1 Allocation of depreciation			
Cost of Sales	22	133,939,227	92,027,165
Administration and general expenses	24	21,545,796	12,020,862
		155,545,023	104,048,028

4.2 Capital work in progress

	Note	2017 Rupees	2016 Rupees
Opening balance as at July 01		22,313,788	17,913,428
Additions			
- Building		53,261,340	19,821,800
- Plant and machinery		33,466,505	-
		86,727,846	19,821,800
Less: Transferred to operating fixed assets			
- Building		(6,541,152)	-
- Plant and machinery		(22,582,596)	(15,421,440)
		(29,123,747)	(15,421,440)
Closing balance as at June 30		79,917,886	22,313,788

5 INTANGIBLE ASSETS

	Note	2017 Rupees	2016 Rupees
Software			
Cost			
As at 1st July		8,958,062	4,908,062
Addition		7,300,000	4,050,000
		16,258,062	8,958,062
Amortization			
As at 1st July		(3,722,080)	(1,473,560)
Amortization during the year	24	(5,027,687)	(2,248,520)
		(8,749,767)	(3,722,080)
		7,508,295	5,235,982
Rate		33.3%	33.3%

6 LONG TERM INVESTMENT
Investment in associate

Master Wind Energy Limited
506,048 ordinary shares of Rs.1,000 each
Ownership interest 15% (2016: 15%)

	Note	2017 Rupees	2016 Rupees
Cost of investment	6.1	506,048,000	506,048,000
Share of post acquisition profit/ (loss)			
Opening		(3,766,433)	-
Share of profit / (loss) for the year		82,878,711	(3,766,433)
		79,112,278	(3,766,433)
		585,160,278	502,281,567

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6.1 Master Wind Energy Limited is engaged in the business of supplying general electric power and to setup and operate wind energy generation project.

6.2 The Company's shareholding in associate is below 20%, however, the Company exercises significant influence by virtue of common directorship.

6.3 **Summarised financial information of associate as per audited financial statements for the year ended 30 June 2017:**

	Note	2017 Rupees	2016 Rupees
Associate's balance sheet:			
Current assets		4,274,477,344	687,100,343
Non-current assets		11,553,856,164	10,535,393,228
Current liabilities		2,556,506,090	791,750,201
Non-current liabilities		9,322,116,539	7,083,776,336
Associate's revenue and profit			
Revenue		1,723,823,193	-
Profit before taxation for the year		610,290,427	4,243,949
Profit / (loss) after taxation for the year		602,743,845	(5,216,695)

7 LONG TERM DEPOSIT

Deposits - considered good		
Sui Southern Gas Company	715,127	715,127
Pakistan Telecommunication Company Limited	77,615	77,615
S.F Units	350,000	350,000
K- Electric Limited	5,925,731	5,925,731
Other deposit	1,512,722	469,924
	8,581,195	7,538,397

8 STOCK-IN-TRADE

Raw material and components	988,017,700	438,092,701
Work in process	139,679,555	63,701,262
Goods-in-transit	320,753,325	60,352,453
	1,448,450,580	562,146,416

	Note	2017 Rupees	2016 Rupees
9 TRADE RECEIVABLES			
Unsecured, considered good		331,723,359	349,478,502

9.1 This includes the related party balances of amounting Rs.51,785,382/- (2016 : Rs. 28,412,951).

	Note	2017 Rupees	2016 Rupees
10 SHORT TERM ADVANCES - unsecured, considered good			
Advances to staff		15,906,503	12,813,804
Advance against import		13,239,810	2,142,082
Advances for purchases		24,581,616	32,802,755
Advance sales tax		234,164,182	74,867,593
Advance income tax		329,269,247	150,371,074
		617,161,358	272,997,308
11 PREPAYMENTS AND OTHER RECEIVABLES			
Prepayments		2,306,200	390,356
Other receivables		1,815,103	6,071,208
Due from associated undertakings	11.1	4,061,496	3,571,262
		8,182,799	10,032,826

11.1 Represents inter company current account balances which are in the normal course of business.

	2017 Rupees	2016 Rupees
12 CASH AND BANK BALANCES		
Cash in hand	7,541,386	33,510,578
Cash at bank		
- current account	7,728,330	4,649,634
	15,269,716	38,160,212

13 ISSUED, SUBSCRIBED AND PAID - UP CAPITAL

2017 No. of shares	2016 No. of shares		2017 Rupees	2016 Rupees
40	40	Ordinary shares of Rs.100 each fully paid up in cash	4,000	4,000
299,960	299,960	Ordinary shares of Rs.100 each fully paid up as Bonus Share	29,996,000	29,996,000
300,000	300,000		30,000,000	30,000,000

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	Note	2017 Rupees	2016 Rupees

14 LONG TERM BORROWING- unsecured

	Note	2017 Rupees	2016 Rupees
Dublin Investments Limited	14.1	517,061,457	515,613,466
From related parties	14.2	-	300,000,000
		517,061,457	815,613,466

14.1 This represents foreign currency loan obtained from an investment company for business purpose and the facility is payable in eleven equal semi annual instalments commencing from June 30, 2018 and having mark-up at the rate LIBOR plus 1% per annum, mark-up payable on semi annually basis starting from the date of first drawn.

14.2 From related parties

	2017 Rupees	2016 Rupees
Directors	-	314,203,959
Other related parties	-	(14,203,959)
	-	300,000,000

These represent unsecured and interest free loan to the Company by its directors. In the absence of specific terms of the loan and guidance available, the Company had recognized this loan at cost. However, during the year, the Company has entered into an agreement with the directors of the Company, in pursuance of which Rs. 145,000,000 of loan is repayable at the discretion of the Company. Accordingly, the Company has recognized this loan as equity and presented under share capital and reserves. Remaining Rs. 261,570,000 of loan is payable on demand of directors and hence transferred to short term borrowings.

	Note	2017 Rupees	2016 Rupees
15 DEFERRED TAXATION	15.1	84,485,072	70,876,669

15.1 This represents temporary differences in respect of accelerated tax depreciation allowance.

16 TRADE, ACCRUED AND OTHER PAYABLES

	2017 Rupees	2016 Rupees
Trade creditors	802,161,490	373,607,131
Mobilization advances	10,062,345	164,996,132
Accrued expenses	132,158,430	171,972,658
Workers' profit participation fund	21,994,688	18,629,915
Workers' welfare fund payable	8,194,099	5,873,968
Advance from customers	14,309,188	1,602,693
	988,880,239	736,682,497

17 ACCRUED MARK-UP

	2017 Rupees	2016 Rupees
Short term borrowings	11,903,878	1,152,936
Interest on director loan	49,674,885	49,674,885
Tooling advance	497,284	-
Finance charge on finance lease	-	555,671
Long term borrowings	5,984,851	4,757,427
	68,060,898	56,140,919

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	Note	2017 Rupees	2016 Rupees
18 SHORT TERM BORROWINGS			
From banks - secured			
Running finance	18.1	856,648,271	81,741,904
From related parties - unsecured			
Directors	18.2	233,704,961	14,203,959
Other related parties	18.2	40,745,033	-
		274,449,994	14,203,959
		1,131,098,265	95,945,863

18.1 These facilities have been obtained from various banks under mark-up arrangements against aggregate sanctioned limit of Rs. 1,100 million (2016: 802 million). These facilities carry mark-up at 3 % avg. KIBOR plus bank premium(2016: 3 % avg. KIBOR plus agreed bank premium) per annum payable quarterly. The aggregate running finance facilities are secured against hypothecation charges over the Company's stock and book debts and personal guarantees of all directors of the Company.

18.2 These represent unsecured and interest free loan which are payable on demand.

19 DUE TO RELATED PARTY- unsecured

	2017 Rupees	2016 Rupees
Advance from associated undertaking	2,184,144	20,463,768

20 CONTINGENCIES AND COMMITMENTS

20.1 Contingency

There is no contingency as at balance sheet date. (2016: Nil)

20.2 Commitments

- Commitments in respect of letter of credits amounting to Rs.824.516 million (2016: Rs.559.036 million).

- Commitments in respect of letter of acceptances amounting to Rs.106.057 million (2016: Rs.34.303 million).

- Commitments in respect of bank guarantee amounting to Rs.15.665 million (2016: Rs.14.980 million).

		Note	2017 Rupees	2016 Rupees
21	**SALES - Net**			
	Gross sales		9,471,989,660	7,957,292,384
	Scrap sales		128,863,250	75,282,341
			9,600,852,910	8,032,574,725
	Less:			
	Sales discount and return		4,304,949	13,397,171
	Sales tax		1,359,764,458	1,093,095,324
			1,364,069,406	1,106,492,495
			8,236,783,503	6,926,082,230
22	**COST OF SALES**			
	Raw material consumed			
	Opening stock as at July 01		438,092,701	246,473,361
	Purchases			
	- Import		4,697,089,794	3,721,335,928
	- Local		2,179,575,807	1,823,157,484
			6,876,665,601	5,544,493,412
	Raw material available for consumption		7,314,758,302	5,790,966,773
	Closing stock as at June 30		(988,017,700)	(438,092,701)
			6,326,740,602	5,352,874,072
	Other manufacturing expenses			
	Salaries, wages and benefits		631,431,183	450,532,358
	Electricity, power and gas		88,699,215	89,418,610
	Rent, rates and taxes		11,609,874	4,774,301
	Stores and spares		52,979,922	41,817,394
	Repair and maintenance		71,945,444	47,797,008
	Miscellaneous		7,132,113	6,869,023
	Water expenses		3,472,574	3,826,240
	Development		5,418,534	3,706,607
	Weaving, painting and galvanizing		21,681,304	13,706,916
	Insurance		7,451,891	5,162,391
	Depreciation	4.1.1	133,999,227	92,027,165
			1,035,821,281	759,638,012
	Cost of goods manufactured during the year		7,362,561,883	6,112,512,084
	Opening stock - work-in-process		63,701,262	146,582,736
	Closing stock - work-in-process		(139,679,555)	(63,701,262)
			(75,978,293)	82,881,475
			7,286,583,591	6,195,393,559
23	**SELLING AND DISTRIBUTION EXPENSES**			
	Freight and forwarding		32,970,532	25,512,487
	Advertisement and publicity		1,477,713	1,329,439
	Technical assistance fee		42,514,447	21,807,005
			76,962,692	48,648,931

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		Note	2017 Rupees	2016 Rupees
24	**ADMINISTRATIVE AND GENERAL EXPENSES**			
	Salaries and benefits		173,544,244	127,323,652
	Directors remuneration		8,400,000	6,000,000
	Office electricity		5,887,210	5,395,693
	Telephone and telex		5,954,602	4,149,912
	Printing and stationery		6,132,889	3,739,008
	Legal and professional		3,442,277	1,579,043
	Audit fee		432,000	432,000
	Conveyance and travelling		45,557,257	31,396,218
	Entertainment		7,023,058	5,418,888
	Staff welfare		11,486,933	10,159,425
	Hajj expenses		195,189	299,941
	Medical and first aid.		3,526,703	1,044,358
	Office equipment repair and maintenance		4,264,638	2,505,786
	Fee and subscription		1,717,953	2,585,406
	Rent, rates and taxes		266,528	418,348
	Miscellaneous		1,916,461	3,494,827
	Repair and maintenance building		4,597,253	2,288,541
	Transportation charges		43,940,097	26,673,573
	Vehicle running expenses		21,501,044	13,847,443
	Depreciation	4.1.1	21,545,796	12,020,862
	Security		8,517,919	9,119,675
	Amortization	5	5,027,687	2,248,520
			384,877,738	272,141,118
25	**FINANCE COST**			
	Interest on bank loan and overdraft		36,247,724	15,504,909
	Interest on long term borrowings		10,978,640	9,082,859
	Bank charges		1,266,061	1,264,384
			48,492,426	25,852,152
26	**OTHER INCOME**			
	Income from financial assets			
	Profit on bank deposit		400,973	1,004,221
	Profit on disposal of property, plant and equipment		713,724	1,102,717
			1,114,697	2,106,938
	Income from non financial assets			
	Rental income		360,000	360,000
			1,474,697	2,466,938
27	**OTHER CHARGES**			
	Workers' profit participation fund		21,994,688	18,629,915
	Workers' welfare fund		8,194,099	5,873,968
	Loss on foreign currency translation		1,447,991	13,915,111
			31,636,778	38,418,994

	2017 Rupees	2016 Rupees
28 TAXATION		
- Current year	85,316,912	69,663,758
- Prior year	(1,020,236)	-
- Deferred	13,608,403	17,563,864
	97,905,079	87,227,622

Reconciliation between accounting profit and tax expense

	2017 Rupees	2016 Rupees
Accounting profit for the year before tax	492,583,686	344,327,981
Tax rate	31%	32%
Tax on accounting profit	152,700,943	110,184,954
Prior year adjustment	(1,020,236)	-
Impact of tax credit on BMR (65B)	(85,398,337)	(75,391,150)
Others	31,622,709	52,433,818
Tax expense	97,905,079	87,227,622

The Company's income for tax year 2016 has been selected for audit under section 214D of the Income Tax Ordinance, 2001. The Deputy Commissioner IR has raised the demand of Rs. 13,738,022 in its order dated 03 July 2017. The Company has filed appeal against the said order before Commissioner Inland Revenue, the proceedings of which were pending till the date of the finalization of these financial statements. The management is hopeful for favourable outcome, therefore, no adjustment in respect of said demand has been made in these financial statements.

29 EARNING PER SHARE - basic and diluted

	2017	2016
Net profit for the year	394,678,607	257,100,359
	---------------- Number of shares -------------	
Weighted average ordinary shares outstanding during the year	300,000	300,000
	------------------ Rupees ------------------	
Earning per share - basic and dilute	1,316	857

30 REMUNERATION OF CHIEF EXECUTIVE, DIRECTOR AND EXECUTIVES

The aggregate amount charged in the accounts for remuneration, including all benefits, to the Directors and Executives of the Company were as follows:

	DIRECTOR	CHIEF EXECUTIVE	DIRECTOR	CHIEF EXECUTIVE
	2017		2016	
Basic salary	8,400,000	4,062,000	6,000,000	3,690,000
Leave encashment	-	301,466	-	223,867
Bonus	-	307,500	-	146,000
Gratuity	-	-	-	522,000
	8,400,000	4,670,966	6,000,000	4,581,867
Number of person(s)	1	1	1	1

31 FINANCIAL INSTRUMENT AND RISK MANAGEMENT

The Company is exposed to the following financial risks from the use of financial instruments ;

- Market risk including currency risk and interest rate risk.
- Credit risk
- Liquidity risk.
- Operational risk.

This note presents information about the Company's exposure to each of the above risk, the Company's objectives, policies and procedures for measuring and managing risk, and the Company's management of capital. Further quantitative disclosures are included throughout these financial

The Company risk management policies are established to identify and analyze the risks faced by the Company, to set appropriate risk limits and controls, and to monitor risks and adherence to limits. The Company overall risk management programme focuses on the unpredictability of financial markets and seeks to minimize potential adverse effects on the Company's financial performance.

The Company's senior management provides policies for overall risk management, as well as policies covering specific areas such as foreign exchange risk, interest rate risk, credit risk, financial instruments and investment of excess liquidity. It is the Company policy that no trading in

The Board of Directors reviews and agrees policies for managing each of these risks which are summarized below :

31.1 Market risk

Market risk is the risk that fair value of future cash flows will fluctuate because of changes in market prices. The Company has exposed to market risks such as interest rate risk. Financial instruments affected by market risk include long-term financing and short-term borrowings.

a) Foreign currency risk

Foreign currency risk is the risk that the value of a financial instrument will fluctuate due to changes in foreign exchange rates. Foreign currency risk arises mainly where receivables and payables exist due to transactions with foreign buyers and suppliers.

	2017 Rupees	2016 Rupees
Long-term borrowing	517,061,457	815,613,466
	Reporting Date Rate	
AED to PKR- Buy	28.59	28.51

Sensitivity analysis:

At reporting date, if the PKR had strengthened by Rupee one against the AED with all other variables held constant, post-tax profit for the year would have been increased/(decreased) by Rs. 18.085 million (2016: Rs.5.16 million)

The sensitivity analysis prepared is not necessarily indicative of the effects on profit/ (loss) for the year and assets / liabilities of the Company.

b) Interest rate risk

Interest rate risk is the risk that fair value or future cash flows of the financial instruments will fluctuate due to change in the market interest rates. The Company interest rate risk arises from short-term borrowings obtained with floating rates. All the borrowings of the Company are obtained in functional currencies. Applicable interest rates of financial instruments are given in respective notes.

Change in interest rate by 1% may have a positive or negative impact of approximately Rs. 5.17 million (2016: Rs. 0.55 million) in profit and loss account before taxation. The analysis is based on closing balances on the assumption that all other variables remain constant.

31.2 Credit risk

Credit risk is the risk that one party to a financial instrument will fail to discharge an obligation and cause the other party to incur a financial loss. Concentration of credit risk arises when a number of counterparties are engaged in similar business.

The maximum exposure to credit risk at the reporting date is as follows :

	2017 Rupees	2016 Rupees
Long-term deposits	8,581,195	7,538,397
Trade receivables - unsecured	331,723,359	349,478,502
Short term advances	15,906,503	12,813,804
Prepayments and other receivables	5,876,599	9,642,470
Bank balances	7,728,330	4,649,634

a) Credit quality of financial assets

The credit policy of financial assets that are neither past nor impaired can be assessed by reference to external credit ratings or to historical information about counterparty default rates:

Trade debts		
Customers with no default in the past one year	331,723,359	349,478,502
Short term advances		
Counter parties without credit rating	15,906,503	12,813,804
Prepayments and other receivables		
Counter parties without credit rating	5,876,599	9,642,470
Bank balances		
A1 +	7,728,330	4,649,634

	Rating Agency	Rating Short term	Rating Medium to long term	2017	2016
Balances with banks					
Bank Al Habib Limited	PACRA	A1+	AA+	4,478,876	914,783
Habib Bank Limited	JCR-VIS	A-1+	AAA	153,621	135,834
Habib Metropolitan Bank Limited	PACRA	A1+	AA+	16,979	250,855
Bank Al Falah Limited	PACRA	A1+	AA	21,048	21,047
National Bank of Pakistan	JCR-VIS	A-1+	AAA	2,589	2,744,679
Meezan Bank Limited	JCR-VIS	A-1+	AA	3,002,070	296,757
Summit Bank Limited	JCR-VIS	A-1	A-	251	251
Faysal Bank Limited	PACRA	A1+	AA	30	30
Muslim Commercial Bank Limited	PACRA	A1+	AAA	52,867	285,397
				7,728,330	4,649,634
				2017 Rupees	**2016 Rupees**
Accrued mark up					
Bank Al Habib Limited	PACRA	A1+	AA+	9,218,682	760,956
Habib Bank Limited	JCR-VIS	A-1+	AAA	1,416,715	237,792
Habib Metropolitan Bank Limited	PACRA	A1+	AA+	1,182,100	154,188
Meezan Bank Limited - Murabaha loan				86,381	-
				11,903,878	1,152,936
Short term running finance					
Bank Al Habib Limited	PACRA	A1+	AA+	705,317,296	65,813,127
Habib Bank Limited	JCR-VIS	A-1+	AAA	112,715,914	15,928,777
Meezan Bank Limited - Murabaha loan				11,936,025	-
Habib Metropolitan Bank				26,679,036	-
				856,648,271	81,741,904

31.3 Liquidity risk

Liquidity risk is the risk that the Company will not be able to meet its financial obligation as they fall due.

The Company applies prudent liquidity risk management by maintaining sufficient cash and the availability of funding through an adequate amount of committed credit facilities. Table below summarizes the maturity profile of the Company's financial liabilities at the following reporting dates based on contractual undiscounted payments. Balances due within 12 months equal their carrying balances as the impact of discounting is not significant.

	Interest bearing			Non-interest bearing				
	Less than one year	One to five years	Sub total	Less than One year	One to five years	Sub total	2017	2016
	Rupees							
Financial liabilities:								
Long-term borrowing	-	517,061,457	517,061,457	-	-	-	517,061,457	815,613,466
Trade, accrued and other payables	-	-	-	944,382,264	-	944,382,264	944,382,264	710,675,921
Accrued mark-up	-	-	-	68,060,898	-	68,060,898	68,060,898	56,140,919
Short-term running finance	856,648,271	-	856,648,271	274,449,994	-	274,449,994	1,131,098,265	95,945,863
Due to related parties	-	-	-	2,184,144	-	2,184,144	2,184,144	20,463,768
	856,648,271	517,061,457	1,373,709,728	1,289,077,300	-	1,289,077,300	2,662,787,028	1,698,739,937

Effective interest rates for the monetary financial assets and liabilities are mentioned in the respective notes to the financial statements.

31.4 Fair value of financial instruments

Fair value is the amount for which an asset could be exchanged, or a liability settled, between knowledgeable and willing parties in an arm's length transaction. Consequently, differences can arise between carrying values and the fair value estimates.

Underlying the definition of fair value is the presumption that the Company is a going concern without any intention or requirement to curtail materially the scale of its operations or to undertake a transaction on adverse terms.

Fair value of all financial assets and financial liabilities are estimated to approximate their respective carrying amount.

31.5 Capital risk management

The primary objective of the Company's capital management is to maintain healthy capital ratios, strong credit rating and optimal capital structures in order to ensure ample availability of finance for its existing and potential investment projects, to maximize shareholders value and

The Company manages its capital structure and makes adjustment to it, in light of changes in economic conditions. In order to maintain or adjust the capital structure, the Company may adjust the amount of dividends paid to shareholders, return capital to shareholders or issue new shares. No changes were made in the objectives, policies and processes during the year ended June 30, 2016.

The Company monitors capital using a gearing ratio, which is net debt divided by total capital plus net debt. The Company includes within net debt, interest bearing loans and borrowings including any finance cost thereon, trade and other payables, less cash and bank balances. Capital signifies equity as shown in the balance sheet plus net debt.

During the year, the Company strategy was to maintain gearing. The gearing ratios as at June 30, 2017 and 2016 were as follows:

	2017	2016
	Rupees	Rupees
Long term borrowing	517,061,457	815,613,466
Cash and bank balances	(15,269,716)	(38,160,212)
Net debts	501,791,741	777,453,254
Share capital	30,000,000	30,000,000
General reserves	150,000,000	150,000,000
Loan from directors	146,323,965	-
Unappropriated profit	1,026,347,329	631,668,722
Total equity	1,352,671,294	811,668,722
Total Capital	1,854,463,035	1,589,121,976
Gearing Ratio	0.27	0.49

The Company finances its expansions projects through equity, borrowings and management of its working capital with a view to maintaining an appropriate mix between various sources of finance to minimize risk.

31.6 Operational Risk

Operation risk is the of direct or indirect loss arising from a wide variety of causes associated with processes, technology and infrastructure supporting the Company's operations either internally within the Company or externally at the Company's services providers, and from external factor other than credit, market and liquidity risk such as those arising from legal and regulatory requirements and generally accepted standards of investment management behaviour, Operational risks arise from all of the Company's activities.

The Company's objective is to manage operational risk so as to balance limiting of financial losses and damage to its reputation with achieving its objective of generating returns for stakeholders.

The primary responsibility for the development and implementation of controls over operational risk rests with the board of directors. The responsibility encompasses the control in the following areas:

- requirement for appropriate segregation of duties between various function, roles and responsibilities;
- requirement for the reconciliation and monitoring of transaction ;
- compliance with regulatory and other legal requirement;
- documentation of control and procedures;
- requirement for the periodic assessment of operational risks faced, and adequacy of control and procedures to address the risk identified;
- ethical and business standard; and
- risk mitigation, including insurance where this effective.
- senior management ensures that the Company's staff have adequate training and experience and fosters effective communication related to operational risk management.

32. TRANSACTIONS WITH RELATED PARTIES

All transactions involving related parties arising in the normal course of business are conducted at arm's length. The related parties and associated undertakings comprise local associated companies, staff retirement funds, directors and key management personnel. Transactions with related parties during the year, if any, disclosed elsewhere in these financial statements, are as follows:

	2017 Rupees	2016 Rupees
Loan from Directors and family members		
Acquired during the year	284,570,000	651,796,000
Repaid during the year	178,000,000	775,806,101
Associated companies		
Sales	193,970,059	148,050,374
Purchases	237,602,552	381,689,566
Rent	7,860,000	360,000

33 NUMBER OF EMPLOYEES

	2017	2016
Number of employees as at June 30	1,561	786
Average number of employees during the year	1,174	679

34 CORRESPONDING FIGURES

The comparative figures have been rearranged and/or reclassified, wherever necessary, for the purpose of comparison in the financial statements.

35 GENERAL

35.1 Figures have been rounded off to the nearest rupees, unless otherwise stated.

35.2 These financial statements were authorized for issue by the Board of Directors in their meeting held on 07 OCT 2017.

CHIEF EXECUTIVE

DIRECTOR

4.3.4 Audited Financial Statements of Master Wind Energy Limited

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MASTER WIND ENERGY LIMITED

FINANCIAL STATEMENTS FOR THE YEAR ENDED JUNE 30, 2017

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AUDITORS' REPORT TO THE MEMBERS

We have audited the annexed balance sheet of Master Wind Energy Limited (the 'company') as at June 30, 2017 and the related profit and loss account, statement of comprehensive income, cash flow statement and statement of changes in equity together with the notes forming part thereof, for the year then ended and we state that we have obtained all the information and explanations which, to the best of our knowledge and belief, were necessary for the purposes of our audit.

It is the responsibility of the company's management to establish and maintain a system of internal control, and prepare and present the above said statements in conformity with the approved accounting standards and the requirements of the Companies Ordinance, 1984. Our responsibility is to express an opinion on these statements based on our audit.

We conducted our audit in accordance with the auditing standards as applicable in Pakistan. These standards require that we plan and perform the audit to obtain reasonable assurance about whether the above said statements are free of any material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the above said statements. An audit also includes assessing the accounting policies and significant estimates made by management, as well as, evaluating the overall presentation of the above said statements. We believe that our audit provides a reasonable basis for our opinion and, after due verification, we report that:

(a) in our opinion, proper books of account have been kept by the company as required by the Companies Ordinance, 1984;

(b) in our opinion:

   (i) the balance sheet and profit and loss account together with the notes thereon have been drawn up in conformity with the Companies Ordinance, 1984, and are in agreement with the books of account and are further in accordance with accounting policies consistently applied;

   (ii) the expenditure incurred during the year was for the purpose of the company's business; and

   (iii) the business conducted, investments made and the expenditure incurred during the year were in accordance with the objects of the company;

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(c) in our opinion and to the best of our information and according to the explanations given to us, the balance sheet, profit and loss account, cash flow statement and statement of changes in equity together with the notes forming part thereof conform with approved accounting standards as applicable in Pakistan, and, give the information required by the Companies Ordinance, 1984, in the manner so required and respectively give a true and fair view of the state of the company's affairs as at June 30, 2017 and of the profit, total comprehensive income, its cash flows and changes in equity for the year then ended; and

(d) in our opinion, no Zakat was deductible at source under the Zakat and Ushr Ordinance, 1980 (XVIII of 1980).

Chartered Accountants

Lahore, August 25, 2017

Engagement Partner: Muhammad Masood

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MASTER WIND ENERGY LIMITED
BALANCE SHEET AS AT JUNE 30, 2017

	Note	2017 Rupees	2016 Rupees
EQUITY AND LIABILITIES			
SHARE CAPITAL AND RESERVES			
Authorised share capital			
3,400,000 (2016: 3,400,000) ordinary shares of Rs 1,000 each		3,400,000,000	3,400,000,000
Issued, subscribed and paid up share capital			
3,373,650 (2016: 3,373,650) ordinary shares of Rs 1,000 each	5	3,373,650,000	3,373,650,000
Revenue reserve: Un-appropriated profit/(accumulated loss)		576,060,879	(26,682,966)
		3,949,710,879	3,346,967,034
NON-CURRENT LIABILITY			
Long term finances - secured	6	9,322,116,539	7,083,776,336
CURRENT LIABILITIES			
Current portion of long term finances - secured	6	855,338,112	157,409,546
Trade and other payables	7	1,606,701,692	568,663,699
Accrued markup on long term finances - secured		89,752,128	60,211,926
Provision for taxation		4,714,158	5,465,030
		2,556,506,090	791,750,201
CONTINGENCIES AND COMMITMENTS	8		
		15,828,333,508	11,222,493,571
ASSETS			
NON-CURRENT ASSETS			
Property, plant and equipment	9	11,553,856,164	10,531,644,004
Long term prepayments	10	-	3,749,224
		11,553,856,164	10,535,393,228
CURRENT ASSETS			
Stores and spares	11	46,569,392	-
Trade debts	12	970,662,720	-
Advances, deposits, prepayments and other receivables	13	155,051,937	271,920,313
Income tax recoverable		11,252,256	-
Cash and bank balances	14	3,090,941,039	415,179,030
		4,274,477,344	687,100,343
		15,828,333,508	11,222,493,571

The annexed notes 1 to 30 form an integral part of these financial statements.

Chief Executive

Director

MASTER WIND ENERGY LIMITED

PROFIT AND LOSS ACCOUNT FOR THE YEAR ENDED JUNE 30, 2017

	Note	2017 Rupees	2016 Rupees
Sales-net	15	1,723,823,193	-
Cost of sales	16	(523,228,046)	-
Gross profit		1,200,595,147	-
Administrative expenses	17	(77,110,971)	(37,211,247)
Other income	18	44,009,570	41,657,061
Finance cost	19	(557,203,319)	(201,865)
Profit before taxation		610,290,427	4,243,949
Taxation	20	(7,546,582)	(9,460,644)
Profit/(loss) for the year		602,743,845	(5,216,695)

The annexed notes 1 to 30 form an integral part of these financial statements.

Chief Executive

Director

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MASTER WIND ENERGY LIMITED

STATEMENT OF COMPREHENSIVE INCOME FOR THE YEAR ENDED JUNE 30, 2017

	2017 Rupees	2016 Rupees
Profit/(loss) for the year	602,743,845	(5,216,695)
Other comprehensive income:		
Items that may be reclassified subsequently to profit or loss	-	-
Items that will not be reclassified subsequently to profit or loss	-	-
	-	-
Total comprehensive income/(loss) for the year	602,743,845	(5,216,695)

The annexed notes 1 to 30 form an integral part of these financial statements.

AM

Chief Executive **Director**

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MASTER WIND ENERGY LIMITED

CASH FLOW STATEMENT FOR THE YEAR ENDED JUNE 30, 2017

	Notes	2017 Rupees	2016 Rupees
Cash flows from operating activities			
Cash generated from operations	21	1,761,556,314	232,883,500
Long term prepayments-net		-	(2,331,801)
Finance cost paid		(682,421,069)	(8,160)
Income tax paid		(19,549,710)	(6,014,757)
Net cash inflow from operating activities		1,059,585,535	224,528,782
Cash flows from investing activities			
Fixed capital expenditure		(1,310,321,173)	(7,440,384,294)
Profit on bank deposits received		34,617,498	-
Net cash outflow from investing activities		(1,275,703,675)	(7,440,384,294)
Cash flows from financing activities			
Proceeds from long term finances acquired		3,114,600,000	7,513,000,001
Repayment of long term finances		(222,468,514)	-
Net cash inflow from financing activities		2,892,131,486	7,513,000,001
Net increase in cash and cash equivalents		2,676,013,346	297,144,489
Cash and cash equivalents at the beginning of the year		415,170,030	118,071,744
Exchange losses on cash and cash equivalents		(242,337)	(46,203)
Cash and cash equivalents at the end of the year	14	3,090,941,039	415,170,030

The annexed notes 1 to 30 form an integral part of these financial statements.

Chief Executive **Director**

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MASTER WIND ENERGY LIMITED

STATEMENT OF CHANGES IN EQUITY FOR THE YEAR ENDED JUNE 30, 2017

	Rupees		
	Issued, subscribed and paid up share capital	Revenue reserve: (accumulated loss)/ un-appropriated profit	Total
Balance as on July 1, 2015	3,373,650,000	(21,466,271)	3,352,183,729
Loss for the year	-	(5,216,695)	(5,216,695)
Other comprehensive income for the year	-	-	-
Total comprehensive loss for the year	-	(5,216,695)	(5,216,695)
Total contributions by and distributions to owners of the company recognised directly in equity	-	-	-
Balance as on June 30, 2016	3,373,650,000	(26,682,966)	3,346,967,034
Profit for the year	-	602,743,845	602,743,845
Other comprehensive income for the year	-	-	-
Total comprehensive income for the year	-	602,743,845	602,743,845
Total contributions by and distributions to owners of the company recognised directly in equity	-	-	-
Balance as on June 30, 2017	3,373,650,000	576,060,879	3,949,710,879

The annexed notes 1 to 30 form an integral part of these financial statements.

Chief Executive **Director**

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MASTER WIND ENERGY LIMITED

NOTES TO AND FORMING PART OF THE FINANCIAL STATEMENTS FOR THE YEAR ENDED JUNE 30, 2017

1. The company and its activities

Master Wind Energy Limited (the 'company') was incorporated on May 03, 2005, as a private limited company under the Companies Ordinance, 1984. The company has been converted from private to public limited company with effect from July 01, 2011. The registered office of the company is situated at Master House, 54 Darul Aman Co-Operative Housing Society, Shahrah-e-Faisal, Karachi and the company's wind power plant has been set up at Jhimpir, District Thatta, Sindh on land that is leased to the company by Alternative Energy Development Board ('AEDB'), Government of Pakistan.

The company's principal objective is to carry on the business of supplying general electric power and to setup and operate wind power generation projects to generate, accumulate, distribute and supply electricity.

The company has set up a wind power station of 52.80 MW gross capacity at the above mentioned location and achieved Commercial Operations Date ('COD') on October 14, 2016. The company's tariff has been determined by National Electric Power Regulatory Authority (NEPRA) through order dated April 23, 2014. The company has an Energy Purchase Agreement ('EPA') with its sole customer, National Transmission and Despatch Company Limited ('NTDC') for twenty years which commenced from the COD.Further, NEPRA has issued a 'Generation License' to the company on December 26, 2011 for a term of twenty years which commenced from the COD.

2. Basis of preparation

2.1 These financial statements have been prepared in accordance with approved accounting standards as applicable in Pakistan. The Companies Ordinance, 1984 has been repealed after the enactment of the Companies Act, 2017. However, as allowed by the Securities and Exchange Commission of Pakistan ('SECP') vide Circular No. CLD/CCD/PR(11)/2017 dated July 20, 2017 and further clarified through its press release dated July 20, 2017, companies whose financial year, including quarterly and other interim period, closes on or before June 30, 2017, shall prepare financial statements in accordance with the provisions of Companies Ordinance, 1984. Accordingly approved accounting standards comprise of such International Financial Reporting Standards ('IFRSs') issued by the International Accounting Standards Board ('IASB') and Islamic Financial Accounting Standards ('IFASs') issued by Institute of Chartered Accountants of Pakistan as are notified under the Companies Ordinance, 1984, (the 'Ordinance') provisions of and directives issued under the Ordinance. Wherever the requirements of the Ordinance or directives issued by SECP differ with the requirements of IFRSs, or IFASs, the requirements of the Ordinance or the requirements of the said directives prevail.

2.2 Initial application of standards, amendments or an interpretation to existing standards

The following amendments to existing standards have been published that are applicable to the company's financial statements covering annual periods, beginning on or after the following dates:

2.2.1 Standards, amendments to published standards and interpretations that are effective in the

Certain standards, amendments and interpretations to approved accounting standards are effective in the current year but are considered not to be relevant or to have any significant effect on the company's operations (although they may affect the accounting for future transactions and events) and are, therefore, not detailed in these financial statements.

2.2.2 Exemption from applicability of certain interpretations to standards

SECP through SRO 24(I)/2012 dated January 16, 2012 has granted exemption from the application of International Financial Reporting Interpretation Committee (IFRIC) 4 'Determining whether an Arrangement contains a Lease' and IFRIC 12 'Service Concession Arrangements' to all companies. However, the SECP made it mandatory to disclose the impact of the application of IFRIC 4 or IFRIC 12 on the results of the companies. This interpretation provides guidance on determining whether arrangements that do not take the legal form of a lease should, nonetheless, be accounted for as a lease in accordance with IAS 17, 'Leases'.

Under IFRIC 4, the consideration required to be made by the lessee for the right to use the asset is to be accounted for as a finance lease under International Accounting Standard ('IAS') 17 'Leases'. The company's wind power plant's control due to purchase of total output by NTDC appears to fall under the scope of IFRIC 4. Consequently, if the company were to follow IFRIC - 4 and IAS - 17, the effect on the financial statements would be as follows:

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	2017 Rupees
De-recognition of property, plant and equipment	(11,417,013,819)
Recognition of lease debtor	11,664,863,912
Increase in un-appropriated profit at the beginning of the year	-
Increase in profit for the year	247,850,093
Increase in un-appropriated profit at the end of the year	247,850,093

2.2.3 **Standards, amendments and interpretations to existing standards that are not yet effective and have not been early adopted by the company**

There are certain standards, amendments to the approved accounting standards and interpretations that are mandatory for the company's accounting periods beginning on or after July 1, 2017 but are considered not to be relevant or to have any significant effect on the company's operations and are, therefore, not detailed in these financial statements.

3. **Basis of measurement**

3.1 These financial statements have been prepared under the historical cost convention.

3.2 The company's significant accounting policies are stated in note 4. Not all of these significant policies require the management to make difficult, subjective or complex judgment or estimates. The following is intended to provide an understanding of the policies the management considers critical because of their complexity, judgment of estimation involved in their application and their impact on these financial statements. Estimates and judgments are continually evaluated and are based on historical experience, including expectations of future events that are believed to be reasonable under the circumstances. These judgments involve assumptions or estimates in respect of future events and the actual results may differ from these estimates that have been explained as follows :

a) **Useful lives and residual values of property, plant and equipment**

The company reviews the useful lives and residual values of property, plant and equipment on regular basis. Any change in estimates in future years might affect the carrying amounts of the respective items of property, plant and equipment with a corresponding effect on the depreciation charge and impairment.

3.3 **Change in accounting estimate**

During the year, the company's management has carried out a comprehensive review of the expected pattern of consumption of the future economic benefits embodied in certain assets and as a result of this review, has revised its depreciation method for such assets. Previously, the company depreciated its furniture and fixtures, computer equipment, office equipment and vehicles on the reducing balance method over their estimated useful lives. Now, the company charges depreciation on these assets based on the straight line method over their estimated remaining useful lives. Such a change has been accounted for as a change in an accounting estimate in accordance with IAS 8 'Accounting Policies, Changes in Accounting Estimates and Errors'. The effect of this change in the accounting estimate on the profit before taxation for the year ended June 30, 2017, carrying amount of operating fixed assets as at that date and future profits before taxation is not material hence, has not been detailed in these financial statements.

4. **Significant accounting policies**

The significant accounting policies adopted in the preparation of these financial statements are set out below. These policies have been consistently applied to all years presented.

4.1 **Taxation**

Current

The profits and gains of the company derived from electric power generation are exempt from tax in terms of Clause (132) of Part I of the Second Schedule to the Income Tax Ordinance, 2001, subject to the conditions and limitations provided therein.

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Under clause (11A) of Part IV of the Second Schedule to the Income Tax Ordinance, 2001, the company is also exempt from levy of minimum tax on 'turnover' under section 113 of the Income Tax Ordinance, 2001. However, full provision is made in the profit and loss account on income from sources not covered under the above clauses at current rates of taxation after taking into account tax credits and rebates available, if any.

Deferred

Deferred tax is accounted for using the balance sheet liability method in respect of all temporary differences arising from differences between the carrying amount of assets and liabilities in the financial statements and the corresponding tax bases used in the computation of the taxable profit. However, the deferred tax is not accounted for if it arises from initial recognition of an asset or liability in a transaction other than a business combination that at the time of transaction neither affects accounting nor taxable profit or loss. Deferred tax liabilities are generally recognised for all taxable temporary differences and deferred tax assets are recognised to the extent that it is probable that taxable profits will be available against which the deductible temporary differences, unused tax losses and tax credits can be utilised.

Deferred tax is calculated at the rates that are expected to apply to the period when the differences reverse based on tax rates that have been enacted or substantively enacted by the balance sheet date. Deferred tax is charged or credited in the profit and loss account, except in the case of items credited or charged to equity in which case it is included in equity.

Deferred tax has not been provided in these financial statements as the company's management believes that the temporary differences will not reverse in the foreseeable future due to the fact that the profits and gains of the company derived from electric power generation are exempt from tax subject to the conditions and limitations provided for in terms of clause (132) of Part I of the Second Schedule to the Income Tax Ordinance, 2001.

4.2 Employees' retirement benefits and other obligations

The main features of the schemes operated by the company for its employees are as follows:

4.2.1 Defined contribution plan

The company operates a defined contributory provident fund for all its permanent employees. Contributions are made equally by the company and the employees at the rate of 6.67% per annum of the gross salary subject to completion of minimum qualifying period of service as determined under the rules of the fund.The company has no further payment obligations once the contributions have been paid.

4.3 Property, plant and equipment

4.3.1 Operating fixed assets

Operating fixed assets are stated at cost less accumulated depreciation and any identified impairment loss.

Depreciation on all items of operating fixed assets is charged to profit and loss account on the straight line method so as to write off the cost of an asset over its estimated useful life at the annual rates mentioned in note 9.1 to these financial statements after taking into account their residual values.

The assets' residual values and useful lives are reviewed, at each financial year end, and adjusted if impact on depreciation is significant. The company's estimate of the residual value of its operating fixed assets as at June 30, 2017 has not required any adjustment as its impact is considered insignificant.

An asset's carrying amount is written down immediately to its recoverable amount if the asset's carrying amount is greater than its estimated recoverable amount (note 4.4).

Subsequent costs are included in the asset's carrying amount or recognised as a separate asset, as appropriate, only when it is probable that future economic benefits associated with the item will flow to the company and the cost of the item can be measured reliably. All other repair and maintenance costs are charged to income during the period in which they are incurred.

The gain or loss on disposal or retirement of an asset represented by the difference between the sale proceeds and the carrying amount of the asset is recognised as an income or expense.

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4.3.2 Capital work-in-progress

Capital work-in-progress is stated at cost less any identified impairment loss. All expenditure connected with specific assets incurred during installation and construction period are carried under capital work-in-progress. These are transferred to operating fixed assets as and when these are available for use.

4.3.3 Major spare parts and stand-by equipment

Major spare parts and stand-by equipment qualify as property, plant and equipment when an entity expects to use them during more than one year. Transfers are made to operating assets category as and when such items are available for use.

4.4 Impairment of non-financial assets

Assets that have an indefinite useful life - for example, goodwill or intangible assets not ready to use - are not subject to amortisation and are tested annually for impairment, or more frequently if events or changes in circumstances indicate that they might be impaired. Assets that are subject to amortisation are reviewed for impairment whenever events or changes in circumstances indicate that the carrying amount may not be recoverable. An impairment loss is recognised for the amount by which the asset's carrying amount exceeds its recoverable amount. The recoverable amount is the higher of an asset's fair value less costs to sell and value in use. For the purposes of assessing impairment, assets are grouped at the lowest levels for which there are separately identifiable cash flows (cash-generating units). Non-financial assets other than goodwill that suffered an impairment are reviewed for possible reversal of the impairment at each reporting date.

4.5 Advances, deposits, prepayments and other receivables

Advances and receivables are stated initially at fair value and subsequently measured at amortised cost using the effective interest rate method less provision for impairment, if any. Provision for impairment is established where there is objective evidence that the company will not be able to collect all amounts due according to the original terms of the receivables. The amount of the provision is charged to the profit or loss. Advances and receivables are written off when considered irrecoverable.

4.6 Cash and cash equivalents

Cash and cash equivalents includes cash in hand and with banks on current and deposit accounts.

4.7 Financial assets

4.7.1 Classification

The company classifies its financial assets in the following categories: at fair value through profit or loss, loans and receivables, available for sale and held to maturity. The classification depends on the purpose for which the financial assets were acquired. Management determines the classification of its financial assets at the time of initial recognition.

a) Financial assets at fair value through profit or loss

Financial assets at fair value through profit or loss are financial assets held for trading and financial assets designated upon initial recognition as at fair value through profit or loss. Derivatives are also categorised as held for trading unless they are designated as hedges. A financial asset is classified as held for trading if acquired principally for the purpose of selling in the short term. Assets in this category are classified as current assets if expected to be settled within twelve months, otherwise, they are classified as non-current.

b) Loans and receivables

Loans and receivables are non-derivative financial assets with fixed or determinable payments that are not quoted in an active market. They are included in current assets, except for maturities greater than twelve months after the balance sheet date, which are classified as non-current assets. Loans and receivables comprise other receivables and cash and cash equivalents in the balance sheet.

c) Available-for-sale financial assets

Available-for-sale financial assets are non-derivatives that are either designated in this category or not classified in any of the other categories. They are included in non-current assets unless management intends to dispose of the investments within twelve months from the balance sheet date.

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d) **Held to maturity**

Financial assets with fixed or determinable payments and fixed maturity, where management has the intention and ability to hold till maturity are classified as held to maturity and are stated at amortised cost.

4.7.2 **Recognition and measurement**

All financial assets are recognised at the time when the company becomes a party to the contractual provisions of the instrument. Regular purchases and sales of investments are recognised on trade-date – the date on which the company commits to purchase or sell the asset. Financial assets are initially recognised at fair value plus transaction costs for all financial assets not carried at fair value through profit or loss. Financial assets carried at fair value through profit or loss are initially recognised at fair value and transaction costs are expensed in the profit or loss. Financial assets are derecognised when the rights to receive cash flows from the assets have expired or have been transferred and the company has transferred substantially all the risks and rewards of ownership. Available-for-sale financial assets and financial assets at fair value through profit or loss are subsequently carried at fair value. Loans and receivables and held-to-maturity investments are carried at amortised cost using the effective interest rate method.

Gains or losses arising from changes in the fair value of the 'financial assets at fair value through profit or loss' category are presented in the profit or loss in the period in which they arise. Dividend income from financial assets at fair value through profit or loss is recognised in the profit or loss as part of other income when the company's right to receive payments is established.

Changes in the fair value of securities classified as available-for-sale are recognised in other comprehensive income. When securities classified as available-for-sale are sold or impaired, the accumulated fair value adjustments recognised in equity are included in the profit or loss as gains and losses from investment securities. Interest on available-for-sale securities calculated using the effective interest method is recognised in the profit or loss. Dividends on available-for-sale equity instruments are recognised in the profit or loss when the company's right to receive payments is established.

The fair values of quoted investments are based on current prices. If the market for a financial asset is not active (and for unlisted securities), the company measures the investments at cost less impairment in value, if any.

The company assesses at each balance sheet date whether there is objective evidence that a financial asset or a group of financial assets is impaired. If any such evidence exists for available-for-sale financial assets, the cumulative loss is removed from equity and recognised in the profit or loss. Impairment losses recognised in the profit or loss on equity instruments are not reversed through the profit or loss. Impairment testing of trade debts and other receivables is described in note 4.12 to these financial statements.

4.8 **Financial liabilities**

All financial liabilities are recognised at the time when the company becomes a party to the contractual provisions of the instrument.

A financial liability is derecognised when the obligation under the liability is discharged or cancelled or expired. Where an existing financial liability is replaced by another from the same lender on substantially different terms, or the terms of an existing liability are substantially modified, such an exchange or modification is treated as a derecognition of the original liability and the recognition of a new liability, and the difference in respective carrying amounts is recognised in the profit or loss account.

4.9 **Offsetting of financial assets and financial liabilities**

Financial assets and financial liabilities are offset and the net amount is reported in the financial statements only when there is a legally enforceable right to set off the recognised amount and the company intends either to settle on a net basis or to realise the assets and to settle the liabilities simultaneously.

4.10 **Borrowings**

Borrowings are recognised initially at fair value, net of transaction costs incurred. Borrowings are subsequently stated at amortised cost, any difference between the proceeds (net of transaction costs) and the redemption value is recognised in the profit or loss over the period of the borrowings using the effective interest method.

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Finance costs are accounted for on an accrual basis and are shown as accrued finance cost to the extent of the amount remaining unpaid.

Borrowings are classified as current liabilities unless the company has an unconditional right to defer settlement of the liability for at least twelve months after the balance sheet date.

4.11 Borrowing costs

General and specific borrowing costs directly attributable to the acquisition, construction or production of qualifying assets, which are assets that necessarily take a substantial period of time to get ready for their intended use or sale, are added to the cost of those assets, until such time as the assets are substantially ready for their intended use or sale.

Investment income earned on the temporary investment of specific borrowings pending their expenditure on qualifying assets is deducted from the borrowing costs eligible for capitalisation.

All other borrowing costs are recognised in profit or loss in the period in which they are incurred.

4.12 Trade debts and other receivables

Trade debts and other receivables are recognised initially at invoice value, which approximates fair value, and subsequently measured at amortised cost using the effective interest method, less provision for impairment. A provision for impairment of trade debts and other receivables is established when there is objective evidence that the company will not be able to collect all the amount due according to the original terms of the receivable. Significant financial difficulties of the debtor, probability that the debtor will enter bankruptcy or financial reorganisation, and default or delinquency in payments are considered indicators that the trade debt is impaired. The provision is recognised in the profit and loss account. When a trade debt is uncollectible, it is written off against the provision. Subsequent recoveries of amounts previously written off are credited to the profit and loss account.

4.13 Trade and other payables

Trade and other payables are recognised initially at fair value and subsequently measured at amortised cost using the effective interest method. Exchange gains and losses arising on translation in respect of liabilities in foreign currency are added to the carrying amount of the respective liabilities.

4.14 Provisions

Provisions are recognised when; the company has a present legal or constructive obligation as a result of past events; it is probable that an outflow of resources shall be required to settle the obligation; and the amount has been reliably estimated. Provisions are not recognised for future operating losses.

Where there are a number of similar obligations, the likelihood that an outflow shall be required in settlement is determined by considering the class of obligations as a whole. A provision is recognised even if the likelihood of an outflow with respect to any one item included in the same class of obligations may be small.

Provisions are measured at the present value of the expenditures expected to be required to settle the obligation using a pre-tax rate that reflects current market assessments of the time value of money and the risks specific to the obligation. The increase in the provision due to passage of time is recognised as interest expense.

4.15 Foreign currency transactions and translation

a) Functional and presentation currency

Items included in the financial statements of the company are measured using the currency of the primary economic environment in which the company operates (the functional currency). The financial statements are presented in Pak Rupees, which is the company's functional and presentation currency.

b) Transactions and balances

Foreign currency transactions are translated into Pak Rupees using the exchange rates prevailing at the dates of the transactions. Foreign exchange gains and losses resulting from the settlement of such transactions and from the translation at year-end exchange rates of monetary assets and liabilities denominated in foreign currencies are recognised in the profit and loss account except for exchange differences related to foreign currency loans obtained for the acquisition, development and construction of qualifying assets which are capitalised over the period of the Implementation Agreement in accordance with SRO 24(I)/2012 dated January 16, 2012 of the SECP.

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4.16 Contingent liabilities

Contingent liability is disclosed when:

- there is a possible obligation that arises from past events and whose existence will be confirmed only by the occurrence or non occurrence of one or more uncertain future events not wholly within the control of the company; or

- there is present obligation that arises from past events but it is not probable that an outflow of resources embodying economic benefits will be required to settle the obligation or the amount of the obligation cannot be measured with sufficient reliability.

4.17 Revenue recognition

Revenue is recognised when it is probable that the economic benefits will flow to the company and the revenue can be measured reliably. Revenue is measured at the fair value of the consideration received or receivable on the following basis:

Revenue on account of energy is recognised on transmission of electricity to NTDC on a monthly basis, whereas on account of Non Project Missed Volume is recognised when these are due and invoiced when underlying data is available on monthly basis. Moreover interest on delayed payments by Central Power Purchasing Agency Guarantee Limited(CPPAG) against invoices is recognized as revenue when the invoice becomes due as per the EPA.

Income on bank deposits is accrued on a time proportion basis by reference to the principal outstanding and the applicable rate of return.

4.18 Share capital

Ordinary shares are classified as equity and recognised at their face value. Incremental costs directly attributable to the issue of new shares are shown in equity as a deduction, net of tax.

4.19 Leases

The company is the lessee:

4.19.1 Operating leases

Leases where a significant portion of the risks and rewards of ownership are retained by the lessor are classified as operating leases. Payments made under operating leases (net of any incentives received from the lessor) are charged to profit and loss account on a straight line basis over the lease term.

4.20 Stores and spares

Stores and spares are valued principally at weighted average cost except for items in transit which are stated at invoice value plus other charges paid thereon till the balance sheet date while items considered obsolete are carried at nil value.

5. Issued, subscribed and paid up share capital

This represents 3,373,650 (2016: 3,373,650) ordinary shares of Rs 1,000 each fully paid in cash.

		2017 Rupees	2016 Rupees
6. Long term finances - secured			
Long term loans from financial institutions - local	- note 6.1	5,456,000,001	2,550,000,001
Long term loans from financial institution - foreign	- note 6.2	5,171,600,000	4,963,000,000
Total receipt		10,627,600,001	7,513,000,001
Initial loan transaction cost		(320,940,867)	(320,940,867)
		10,306,659,134	7,192,059,134
Amortisation of initial loan transaction cost		57,209,133	28,406,748
		10,363,868,267	7,220,465,882
Exchange loss		36,054,898	20,720,000
		10,399,923,165	7,241,185,882
Repaid during the year		(222,468,514)	-
		10,177,454,651	7,241,185,882
Current portion shown under current liabilities		(855,338,112)	(157,409,546)
		9,322,116,539	7,083,776,336

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6.1 This represents debt financing amounting to Rs 5,456 million obtained from Consortium of banks comprising Meezan Bank Limited, Bank Al-Habib Limited, The Bank of Punjab and Habib Metropolitan Bank Limited in pursuance of the Musharika Agreement dated February 20, 2015. The complete facility of Rs 5,456 million has been availed by the company as at June 30,2017. The overall financing is secured against a first charge by way of hypothecation over all present and future assets of the company. It carries mark-up, payable quarterly, at the rate of three months Karachi Inter-Bank Offer Rate (KIBOR) plus 3% per annum. The effective rate charged during the year on the outstanding balance is 9.44% per annum (2016 : 5.1% per annum). As of June 30, 2017, the principal amount is repayable in nineteen unequal semi annual installments ending on August 15, 2026 in accordance with the amortization schedule. During the current year an amount of Rs 113.99 million was repaid in the month of February 2017.

6.2 This represents long term finance facility of USD 49.6 million obtained from OPIC for the construction of the wind power plant at Jhimpir in accordance with the Finance Agreement dated March 09, 2015. The complete facility of USD 49.6 million (equivalent to Rs 5,063 million) [2016 : USD 47.6 million (equivalent to Rs 4,963 million)] has been availed by the company as of June 30, 2017. The overall financing is secured against a first charge by way of hypothecation over all present and future assets of the company. It carries mark-up, payable quarterly, at the rate of three months London Inter-Bank Offered Rate (LIBOR) plus 3.7% OPIC guarantee fee per annum and 0.3% alternate basis maintenance fee per annum.The effective rate charged during the year on the outstanding balance is 4.82% per annum (2016: 3.17% per annum) . As of June 30, 2017, the principal amount is repayable in nineteen unequal semi annual installments ending on August 15, 2026 in accordance with the amortization schedule provided by OPIC.During the current year an amount of Rs 108.47 million was repaid in the month of February 2017.

		2017 Rupees	2016 Rupees
7. Trade and other payables			
Creditors		1,464,444,408	560,548,189
Accrued liabilities		1,451,450	700,000
Lender fees and charges payable		2,851,771	2,949,924
Payable to Provident Fund	- note 7.1	58,332	4,445,345
Payable to employees		-	11,000
Sales tax payable		107,380,410	6,194
Sindh sales tax payable		800	3,047
Workers' profit participation fund	- note 7.2	30,514,521	-
		1,606,701,692	568,663,699

7.1 A separate fund has been created in the month of May 2017, during the current year. Major amount has been transferred to the fund and balance was transferred subsequentl to year end. Markup at the rate of 4.5% (2016: 4.5% to 5%) per annum has been charged on the funds utilized by the company. Disclosures required by the Fifth Schedule to the Companies Ordinance, 1984 are detailed in note 27.

		2017 Rupees	2016 Rupees
7.2 Workers' profit participation fund			
Opening balance		-	-
Provision for the year	- note 13.2	30,514,521	-
Closing balance		30,514,521	-

7.3 Provision for Workers' Welfare Fund has not been made since all the available taxable profits were adjusted against tax depreciation and the company has no taxable income.

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8. **Contingencies and commitments**

8.1 **Contingencies**

(i) Irrevocable letter of credit of USD 1.733 million equivalent to Rs 181.566 million (2016: USD 1.733 million equivalent to Rs 181.046 million) in favour of NTDC under section 2.7(b) of the EPA;

(ii) For tax years 2015 and 2016, the tax authorities raised an aggregate demand of Rs 3.799 million whereby the "Unabsorbed Depreciation" and "Depreciation Allowance" were disallowed for the reason that commencement of business had not happened. The company has paid an amount of Rs 1.910 million against the orders to avoid any coercive measures.

The company is contesting the above orders before CIRA and has not made any provision against the above demands as the management is confident that the ultimate outcome of the appeals would be in favor of the company, inter alia on the basis of the advice of the tax consultant and the relevant law and the facts;

(iii) During the current year proceedings under Section 176(1) of the Income Tax Ordinance, 2001 for tax year 2015 were initiated by the Deputy Commissioner Inland Revenue (DCIR) . Later, the DCIR issued show cause notice under section 161(1A) of the Income Tax Ordinance, 2001 wherein he contended that the company has not deducted tax amounting to Rs 26.517 milllion on payments of Rs 132.585 million. No further correspondence has been received from the tax department in this regard till date. The company has paid an amount of Rs 9.34 million out of the total amount so as to avoid any coercive measures.

Based on advice of the company's tax advisor the management believes that there are meritorious grounds to support the company's stance in respect of this matter. Consequently, no provision for this amount has been made in these financial statements.

8.2 **Commitments**

(i) The company has an agreement with Zhejiang Huadong Engineering Science & Technology Development Co. Limited ('Zheijang') for the Operations and Maintenance ('O & M') of the wind power plant for a period of two years from the Taking-Over Date ('TOD') as per terms of the O & M Agreement. Furthermore, the company has also signed an O & M Agreement for a term of eight years starting from the end of the above mentioned Zheijang's O & M Agreement, with a consortium between GE Wind Energy GMBH and General Electric International Inc (hereinafter referred to as the 'Consortium'). Under the terms of both above mentioned O & M Agreements, the company is required to pay a monthly fixed O & M fee which shall be adjusted annually to account for the effect of inflation on the basis of indexation mechanism mentioned in the O & M Agreements.

(ii) The amount of future payments under operating leases and the period in which these payments will become due are as follows:

	2017 Rupees	2016 Rupees
Within one year	2,527,034	-
Later than one year but not later than five years	11,264,000	10,975,034
Later than five years	77,015,671	79,831,671
	90,806,705	90,806,705

9. **Property, plant and equipment**

		2017	2016
Operating fixed assets	- note 9.1	11,454,553,178	40,539,974
Capital work-in-progress	- note 9.2	2,772,500	10,491,104,030
Major spare parts and stand-by equipment	- note 9.3	96,530,486	-
		11,553,856,164	10,531,644,004

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9.1 Operating fixed assets

	Building on leasehold land	Plant and machinery	Furniture and fixtures	Computer equipment	Office equipment	Vehicles	Total
							Rupees
COST							
Balance as at July 01, 2015	435,000	5,726,589	1,171,289	2,417,682	86,923	3,840,987	13,678,470
Additions during the year	-	-	3,984,905	2,947,116	1,030,100	29,719,565	37,681,686
Balance as at June 30, 2016	435,000	5,726,589	5,156,194	5,364,798	1,117,023	33,560,552	51,360,156
Balance as at July 01, 2016	435,000	5,726,589	5,156,194	5,364,798	1,117,023	33,560,552	51,360,156
Additions during the year:							
- Transfers from capital work-in-progress (note 9.2.1)	54,601,583	11,791,364,979	-	-	-	-	11,845,966,562
- Direct additions	-	-	2,014,082	635,186	3,332,271	30,000	6,011,539
- Exchange loss capitalised (note 9.1.1)	70,683	15,264,215	-	-	-	-	15,334,898
Balance as at June 30, 2017	55,107,266	11,812,355,783	7,170,276	5,999,984	4,449,294	33,590,552	11,918,673,155
DEPRECIATION							
Balance as at July 01, 2015	29,000	2,145,971	133,655	528,221	11,330	498,726	3,346,903
Charge for the year (note 9.1.2)	40,600	537,093	582,373	1,061,980	143,098	5,108,135	7,473,279
Balance as at June 30, 2016	69,600	2,683,064	716,028	1,590,201	154,428	5,606,861	10,820,182
Balance as at July 01, 2016	69,600	2,683,064	716,028	1,590,201	154,428	5,606,861	10,820,182
Charge for the year (note 9.1.2)	1,893,540	443,173,253	970,281	1,339,923	329,059	5,593,739	453,299,795
Balance as at June 30, 2017	1,963,140	445,856,317	1,686,309	2,930,124	483,487	11,200,600	464,119,977
Book value as at June 30, 2016	365,400	3,043,525	4,440,166	3,774,597	962,595	27,953,691	40,539,974
Book value as at June 30, 2017	53,144,126	11,366,499,466	5,483,967	3,069,860	3,965,807	22,389,952	11,454,553,178
Annual depreciation rate %	5	5	15	30	15	20	

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9.1.1 This represents the exchange difference on the foreign currency loan, as referred to in note 6 to these financial statements, capitalised in accordance with SRO 24(I)/2012 dated January 16, 2012 of the SECP (as fully explained in note 4.15 to these financial statements). Had the company followed IAS 21 "The Effects of Changes in Foreign Exchange Rates", the effect on the financial statements would be as follows:

	2017 Rupees	2016 Rupees
Decrease in the book value of property, plant and equipment	(15,271,003)	-
Decrease in cost of sales	63,895	-
Increase in other expenses	(15,334,898)	-
Decrease in profit for the year and un-appropriated profit	(15,271,003)	-

9.1.2 The depreciation charge for the year has been allocated as follows:

Cost of sales	- note 16	448,821,318	-
Unallocated expenditure- Capital work -in- progress	- note 9.2.2	1,520,949	5,024,074
Administrative expenses	- note 17	2,957,528	2,449,205
		453,299,795	7,473,279

9.1.3 There was no disposal of operating fixed assets during the current and previous years.

9.2 **Capital work-in-progress ('CWIP')**

Advances to supplier		2,772,500	433,335,912
Plant and machinery and civil works		-	9,229,941,637
Unallocated expenditure	- note 9.2.2	-	827,826,481
		2,772,500	10,491,104,030

9.2.1 The reconciliation of the carrying amount is as follows:

Opening balance		10,491,104,030	3,029,586,998
Additions during the year		1,500,734,910	7,461,517,032
Transfers during the year	- note 9.1	(11,989,066,440)	-
Closing balance		2,772,500	10,491,104,030

9.2.2 **Unallocated expenditure**

Unallocated expenditure incurred upto COD:			
Salaries, wages and other benefits		113,235,959	101,732,522
Travelling and conveyance		52,849,996	48,835,099
Telephone and communication		2,704,641	2,559,507
Consultancy charges		180,443,294	170,781,330
Legal and professional charges		26,304,183	26,174,183
Fee and subscription		16,662,020	15,832,862
Rent		4,992,112	4,405,976
Vehicle running expenses		2,136,890	1,920,930
Depreciation on operating fixed assets	- note 9.1.2	9,218,721	7,697,772
Printing and stationery		271,409	171,409
Security expenses		10,223,797	10,065,397
Repairs and maintenance		1,373,504	1,019,173
Carried forward		420,416,526	391,196,160

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		2017 Rupees	2016 Rupees
Brought forward		420,416,526	391,196,160
Insurance		77,716,877	77,716,877
Entertainment		-	150,575
Net mark-up on long term finances	- note 9.2.3	485,694,818	304,064,332
Exchange loss		20,720,000	20,720,000
Utilities		838,818	-
Lender's fees and charges		37,683,612	32,417,089
Others		1,797,073	1,561,448
		1,044,867,724	827,826,481
Sale of trial production		(67,448,092)	-
		977,419,632	827,826,481
Transferred to operating fixed assets during the year as part of the overall transfer from CWIP		(977,419,632)	-
		-	827,826,481

9.2.3 **Net mark-up on long term finances**

This is composed of:

Mark-up on long term finance	491,966,154	304,319,173
Interest income on temporary investments of borrowings	(6,271,336)	(254,841)
	485,694,818	304,064,332

9.3 **Major spare parts and stand-by equipment**

Opening balance	-	-
Additions during the year	96,530,486	-
Closing balance	96,530,486	-

9.3.1 These major spare parts and stand-by equipment are in the possession and control of the company's O & M contractor, Zhejiang Huadong Engineering Science & Technology Development Co. Limited (the Operator), for smooth and uninterrupted operation and maintenance of the company's plant as per the terms of the O & M Agreement dated February 1, 2015 for a period of two years from the Taking Over Date. Furthermore, the company has also signed an O & M Agreement dated February 4, 2015 for a term of eight years starting from the end of the above mentioned the Operator's O & M Agreement, with the General Electric International Inc. (GE) and these items will be handed over to the GE on expiry of the Operator's O & M Agreement. As per the terms of the above mentioned O & M Agreements, the Operator's and, subsequently, the GE will replenish and hand over these items to the company on the expiry of their respective O & M Agreements.

		2017 Rupees	2016 Rupees

10. **Long term prepayments**

Prepaid rent	- note 10.1	-	3,749,224
		-	3,749,224

10.1 This represents prepaid portion of rentals to AEDB for a period upto January 31, 2018 for a 20 year lease of 1,408 acres of land, situated in Jhimpir, District Thatta. The aforementioned land has been allocated to the company by AEDB out of the total land leased for a period of thirty years from Government of Pakistan ('GoP') for Wind Power Generation Projects under the Master Lease Deed dated February 11, 2008. The company, in order to gain access to the land for conducting feasibility/other associated studies has signed an Agreement to Lease with AEDB dated October 28, 2008. The formal sub-lease agreement was signed dated January 23, 2015. The term of the site sub-lease has commenced from this date and will end with the term of the EPA. During the current year the prepaid portion of rent was transferred to current assets.

11. **Stores and spares**

Most of the items of stores and spares are of interchangeable nature and can be used as machine spares or consumed as stores. Accordingly, it is not practicable to distinguish stores from spares until their actual usage. Moreover, stores and spares include items which may result in fixed capital expenditure but are not distinguishable.

These stores and spares are in the possession and control of the company's O & M contractor, Zhejiang Huadong Engineering Science & Technology Development Co. Limited (the Operator), for smooth and uninterrupted operation and maintenance of the company's plant as per the terms of the O & M Agreement dated February 1, 2015 for a period of two years from the Taking Over Date. Furthermore, the company has also signed an O & M Agreement dated February 4, 2015 for a term of eight years starting from the end of the above mentioned the Operator's O & M Agreement, with the GE and these items will be handed over to the GE on expiry of the Operator's O & M Agreement. As per the terms of the above mentioned O & M Agreements, the Operator and, subsequently, the GE will replenish and hand over these items to the company on the expiry of their respective O & M Agreements.

		2017 Rupees	2016 Rupees
12. **Trade debts**			
Trade debts - considered good	- note 12.1	970,662,720	-

12.1 These represent trade receivables from NTDC and are considered good. These are secured by way of guarantee issued by Government of Pakistan under the Implementation Agreement dated January 12, 2015 and are in the normal course of business and interest free. Furthermore, these are subject to markup on delay payments under the Energy Purchase Agreement dated January 16, 2015 at the rate of three months KIBOR plus 4.5% per annum.

		2017 Rupees	2016 Rupees
13. **Advances, deposits, prepayments and other receivables**			
Advances to employees-considered good	- note 13.1	799,991	350,472
Advances to others- considered good		12,000	36,500
Insurance claim receivable - considered good		-	7,594,760
Claims recoverable from NTDC for pass through items:			
- Workers' profit participation fund	- note 13.2	30,514,521	-
- Sindh infrastructure development cess	- note 13.3	91,048,398	91,048,398
Prepayments			-
- Prepaid insurnace		15,589,824	-
- Land lease rental-current portion	- note 10.1	1,423,795	-
Profit receivable on bank deposits		15,663,408	-
Balances with statutory authority:			
- Sales tax receivable -net		-	172,900,183
		155,051,937	271,930,313

13.1 This includes advance given to director of the company amounting to Rs 600,000 (2016 : Nil).

		2017 Rupees	2016 Rupees
13.2 **Workers' Profit Participation Fund**			
Opening balance		-	-
Accrued for the year	- note 7.2	30,514,521	-
Closing balance		30,514,521	-

Under section 9.2(a) of the EPA with NTDC, payments to Workers' Profit Participation Fund are recoverable from NTDC as a pass through item.

13.3 This amount represents Sindh Infrastructure Development Cess levied on the import of plant and machinery. As per approved upfront tariff by NEPRA, it is allowed to be recovered from NTDC as a pass through item in twelve equal monthly installments following the COD. During the current year no imports were made and no infrastructure cess was being paid.

		2017 Rupees	2016 Rupees
14. Cash and bank balances			
Cash in hand		62,255	581,285
Cash at bank :			
- On current account		-	17,641
- On saving accounts			
Local currency	- note 14.1	1,095,927,541	335,528,852
Foreign currency	- note 14.2	1,994,951,243	79,042,252
		3,090,878,784	414,571,104
		3,090,941,039	415,170,030

14.1 Profit on balances in saving accounts ranges from 3.75% to 4% (2016: 4.5% to 5%) per annum.

14.2 Profit on balances in saving accounts ranges from 0.2% to 0.85% (2016: 0.2% to 0.85%) per annum.

15. These are exclusive of sales tax of Rs 291.694 million.

		2017 Rupees	2016 Rupees
16. Cost of sales			
Salaries, wages and other benefits	- note 16.1	9,019,550	-
Travelling and conveyance		1,035,286	-
Telephone and communication		151,555	-
Electricity consumed in-house		4,572,736	-
Consultancy fee		23,030,433	-
Fees and subscription		45,117	-
Land lease rentals		1,739,293	-
Vehicle running expenses		612,016	-
Depreciation on operating fixed assets	- note 9.1.2	448,821,318	-
Security expenses		330,000	-
Office expenses		194,308	-
Stationery, printing and postage		21,164	-
Entertainment		213,520	-
Insurance		33,441,750	-
		523,228,046	-

16.1 Salaries, wages and other benefits include Rs 336,715 (2016 ; Nil) in respect of provident fund.

		2017 Rupees	2016 Rupees
17. Administrative expenses			
Salaries, wages and other benefits	- note 17.1	43,708,707	19,381,096
Legal and professional charges		1,215,912	1,331,247
Consultancy charges		4,078,514	-
Utilities		1,020,000	2,400,000
Security expense		-	400,422
Stationery, printing and postage		820,644	373,201
Repairs and maintenance		140,691	538,380
Office expenses		7,711,745	4,008,161
Travelling and conveyance		11,487,778	4,585,747
Vehicle running and maintenance		863,805	432,464
Fees and subscription		110,214	151,570
Communication expenses		1,494,484	316,561
Entertainment		313,378	101,229
Exchange loss	- note 17.2	242,337	46,203
Insurance		945,234	695,761
Depreciation on operating fixed assets	- note 9.1.2	2,957,528	2,449,205
		77,110,971	37,211,247

17.1 Salaries, wages and other benefits include Rs 2,203,573 (2016 : Rs 661,096) in respect of provident fund.

17.2 This represents exchange loss on foreign currency transactions and translation of foreign currency balances other than foreign currency loan.

		2017 Rupees	2016 Rupees
18.	**Other income**		
Income from financial asset:			
Income on bank deposits		44,009,570	41,657,061
19.	**Finance cost**		
Mark-up on long term finances-secured		519,569,640	-
Bank charges		4,258	8,160
Markup on Provident Fund		228,689	193,705
Amortization of loan transaction cost	- note 6	20,437,857	-
Lender's fees and charges		16,962,875	-
		557,203,319	201,865
20.	**Taxation**		
Current tax			
-For the year		7,481,623	10,681,109
-Prior year		64,959	(1,220,465)
		7,546,582	9,460,644
20.1	**Relationship between tax expense and accounting profit**		
Profit before taxation		610,290,427	4,243,949
Tax at the applicable rate of 31% (2016: 32%)		189,190,032	1,358,064
Tax effect of amounts that are:			
Exempt as referred to in note 4.1		(175,547,066)	9,323,045
Effect of change in prior year's tax		64,959	(1,220,465)
Charged at different tax rate		(6,161,343)	-
		7,546,582	9,460,644
21.	**Cash generated from operations**		
Profit before tax		610,290,427	4,243,949
Adjustment for non-cash charges and other items:			
- Depreciation on operating fixed assets		451,778,846	2,449,205
- Finance cost		557,203,319	201,865
- Profit on bank deposits		(44,009,570)	-
- Exchange loss		242,337	46,203
- Land lease rentals		1,739,293	-
Profit before working capital changes		1,577,244,652	6,941,222
Effect on cash flow due to working capital changes:			
- Decrease / (increase) in advances, deposits, prepayments and other receivables		133,965,579	(271,545,313)
- Increase in trade debts		(970,662,720)	-
- Increase in stores and spares		(46,569,392)	-
- Increase in trade and other payables		1,038,037,993	437,275,665
- Increase in accrued markup on long term finances		29,540,202	60,211,926
		184,311,662	225,942,278
		1,761,556,314	232,883,500

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22. **Transactions with related parties**

The related parties comprise the associated undertakings, other related group companies and key management personnel. The company in the normal course of business carries out transactions with various related parties. Amounts due from and to related parties are shown under receivables and payables and remuneration of key management personnel is disclosed in note 25. Significant related party transactions have been disclosed in respective notes in the financial statements except for the following :

Relationship with the company	Nature of transactions	2017 Rupees	2016 Rupees
i. Associated undertakings	Purchase of fixed assets	1,510,206	4,043,805
	Common costs charged to company	2,230,552	4,800,000

There are no other significant transactions with related parties during the year, other than those disclosed elsewhere in these financial statements.

23. **Capacity and production**	2017 MWh
Installed capacity	101,743
Actual energy delivered	76,913

24. **Financial risk management**

24.1 **Financial risk factors**

The company's activities expose it to a variety of financial risks: market risk (including currency risk, other price risk and interest rate risk), credit risk and liquidity risk. The company's overall risk management programme focuses on the unpredictability of financial markets and seeks to minimize potential adverse effects on the financial performance.

Risk management is carried out by the Board of Directors (the 'Board'). The Board provides principles for overall risk management, as well as policies covering specific areas such as foreign exchange risk, interest rate risk, credit risk and investment of excess liquidity. All treasury related transactions are carried out within the parameters of these policies.

(a) **Market risk**

(i) **Currency risk**

Currency risk is the risk that the fair value or future cash flows of a financial instrument will fluctuate because of changes in foreign exchange rates. Currency risk arises mainly from future commercial transactions or receivables and payables that exist due to transactions in foreign currencies.

The company is exposed to currency risk arising primarily with respect to the United States Dollar (USD). Currently, the company's foreign exchange risk exposure is restricted to bank balances and amounts receivable from/payable to the foreign entities.

At June 30, 2017 if the Rupee had weakened / strengthened by 5% against the USD with all other variables held constant, the impact on profit or loss for the year would have been Rs 32.849 million (2016: Nil) higher mainly as a result of exchange gain on translation of USD denominated financial instrument.

At June 30, 2017 if the Rupee had weakened / strengthened by 5% against the USD with all other variables held constant, the impact on property, plant and equipment for the year would have been Rs 254.959 million (2016: Rs 249.186 million) higher mainly as a result of exchange loss / gain on translation of USD denominated financial instrument.

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(ii) **Other price risk**

Other price risk represents the risk that the fair value or future cash flows of a financial instrument will fluctuate because of changes in market prices (other than those arising from interest rate risk or currency risk), whether those changes are caused by factors specific to the individual financial instrument or its issuer, or factors affecting all similar financial instruments traded in the market. The company is not exposed to equity price risk since there are no investments in equity instruments traded in the market either classified as available-for-sale or at fair value through profit or loss at the reporting date. The company is also not exposed to commodity price risk since it does not hold any financial instrument based on commodity prices.

(iii) **Interest rate risk**

Interest rate risk represents the risk that the fair value or future cash flows of a financial instrument will fluctuate because of changes in market interest rates.

The company has no significant long-term interest-bearing assets. The company's interest rate risk mainly arises from borrowings. Borrowings obtained at variable rates expose the company to cash flow interest rate risk.

At the balance sheet date, the interest rate profile of the company's interest bearing financial instruments was:

	2017 Rupees	2016 Rupees
Fixed rate instruments:		
Financial assets		
Bank balances - saving accounts	3,090,878,784	414,571,104
Financial liabilities	-	-
Net exposure	3,090,878,784	414,571,104
Floating rate instruments:		
Financial assets	-	-
Financial liabilities		
Long term finances-secured	(10,663,654,899)	(7,533,720,001)
Net exposure	(10,663,654,899)	(7,533,720,001)

Fair value sensitivity analysis for fixed rate instruments

The company does not account for any fixed rate financial assets and liabilities at fair value through profit or loss. Therefore, a change in interest rate at the balance sheet date would not affect profit or loss of the company.

Cash flow sensitivity analysis for variable rate instruments

If interest rates on variable rate financial instruments, at the year end date, fluctuates by 1% higher/lower with all other variables held constant, post tax profit for the year would have been Rs 111.470 million (2016: Nil) lower/higher mainly as a result of higher/lower interest expense on floating rate instruments.

If interest rates on variable rate financial instruments, at the year end date, fluctuates by 1% higher/lower with all other variables held constant, capital work-in-progress would have been Nil (2016: Rs 77.39 million) higher/lower mainly as a result of higher/lower interest expense on floating rate instruments.

(b) **Credit risk**

Credit risk represents the risk that one party to a financial instrument will cause a financial loss for the other party by failing to discharge an obligation. The company's credit risk is primarily attributable to its trade and other receivables and its balances with banks and government. The credit risk is limited because the counter parties are banks with reasonably high credit ratings and government authorities.

(i) **Exposure to credit risk**

The carrying amount of financial assets represents the maximum credit exposure. The maximum exposure to credit risk at the reporting date was as follows:

	2017 Rupees	2016 Rupees
Trade debts	970,662,720	-
Advances and other receivables	138,038,318	99,030,130
Bank balances	3,090,878,784	414,588,745
	4,199,579,822	513,618,875
As of June 30, age analysis of trade debts was as follows:		
Neither past due nor impaired	816,070,727	-
Past due but not impaired:		
- 1 to 30 days	152,081,832	-
- 31 to 90 days	1,283,742	-
- 91 to 180 days	1,226,419	-
	154,591,993	-
	970,662,720	-

(ii) **Credit quality of financial assets**

The credit quality of financial assets that are neither past due nor impaired can be assessed by reference to external credit ratings (if available) or to historical information about counterparty default rate:

	Rating		Rating Agency	2017 Rupees	2016 Rupees
	Short term	Long term			
NTDC	Not available			970,662,720	-
Bank Al-Habib Limited	A1+	AA+	PACRA	584,085	10,371,989
CitiBank, N.A.	P-1	A1	MOODY'S	3,090,294,699	404,216,756
				4,061,541,504	414,588,745

(c) **Liquidity risk**

Liquidity risk is the risk that an entity will encounter difficulty in meeting obligations associated with financial liabilities.

Prudent liquidity risk management implies maintaining sufficient cash and the availability of funding through an adequate amount of committed credit facilities. The company's approach to managing liquidity is to ensure that, as far as possible, it always has sufficient liquidity to meet its liabilities when due, under both normal and stressed conditions, without incurring unacceptable loss or risking damage to the company's reputation.

The table below analyses the company's financial liabilities into relevant maturity groupings based on the remaining period at the balance sheet date to the contractual maturity date.

	Carrying amount	Less than one year	One to five years	More than five years
	Rupees			
At June 30, 2017				
Long term finances - secured	10,441,186,385	855,338,112	3,861,967,600	5,723,880,673
Trade and other payables	1,606,701,692	1,606,701,692	-	-
Accrued markup on long term finances	89,752,128	89,752,128	-	-
	12,137,640,205	2,551,791,932	3,861,967,600	5,723,880,673

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	Carrying amount	Less than one year	One to five years	More than five years
		Rupees		
At June 30, 2016				
Long term finances - secured	7,533,720,001	157,409,546	2,581,805,844	4,794,504,611
Trade and other payables	568,663,699	568,663,699	-	-
Accrued markup on long term finances	60,211,926	60,211,926	-	-
	8,162,595,626	786,285,171	2,581,805,844	4,794,504,611

24.2 **Financial instruments by categories**

	Loans and receivables	
	2017	2016
Assets as per balance sheet	Rupees	Rupees
Trade debts	970,662,720	-
Advances and other receivables	138,038,318	99,030,130
Balances with banks	3,090,878,784	414,588,745
	4,199,579,822	513,618,875

	Financial liabilities at amortised cost	
	2017	2016
	Rupees	Rupees
Liabilities as per balance sheet		
Long term finances - secured	10,441,186,385	7,533,720,001
Trade and other payables	1,499,320,482	568,654,458
Accrued markup on long term finances	89,752,128	60,211,926
	12,030,258,995	8,162,586,385

24.3 **Fair value estimation**

Fair value is the amount for which an asset could be exchanged, or a liability can be settled between knowledgeable willing parties in an arms length transaction and is determined on the basis of objective evidence at each reporting date. The company has not disclosed the fair values for financial assets and liabilities, as they are either short term in nature or reprice periodically. Therefore, their carrying amounts are reasonable approximation of fair value.

24.4 **Offsetting financial assets and financial liabilities**

There are no significant financial assets and financial liabilities that are subject to offsetting, enforceable master netting arrangements and similar agreements.

24.5 **Capital management**

The company's objectives when managing capital are to safeguard the company's ability to continue as a going concern in order to provide returns for shareholders and benefits for other stakeholders and to maintain an optimal capital structure to reduce the cost of capital. In order to maintain or adjust the capital structure, the company may adjust the amount of dividends paid to shareholders, return capital to shareholders through repurchase of shares, issue new shares or sell assets to reduce debt.

Consistent with others in the industry, the company monitors capital on the basis of the gearing ratio. This ratio is calculated as net debt divided by total capital. Net debt is calculated as total borrowings (including 'current and non-current borrowings' as shown in the balance sheet) less cash and cash equivalents. Total capital is calculated as 'equity' as shown in the balance sheet plus net debt. The gearing ratio as at June 30, 2017 is as follows:

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		2017 Rupees	2016 Rupees
Borrowings			
- Long term finances - secured	- note 6	10,177,454,651	7,241,185,882
- Cash and cash equivalents	- note 14	(3,090,941,039)	(415,170,030)
Net debt		7,086,513,612	6,826,015,852
Total equity		3,949,710,879	3,346,967,034
Total capital		11,036,224,491	10,172,982,886
Gearing ratio	Percentage	64%	67%

In accordance with the terms of agreement with the lenders of long term finance (as disclosed in note 6 to these financial statements), the company is required to comply with the following financial covenants:

- the debt to equity ratio must be not more than 75%. Equity for the purpose of computing debt to equity ratio, as per the terms of the above mentioned agreement, will include equity contributions and/or shareholder loan whereas, debt will only include loan taken from the lender.

The company has complied with this covenant throughout the reporting period. As at June 30, 2017, the above mentioned ratio was 64% (2016: 67%).

25. Remuneration of Chief Executive and Directors

25.1 The aggregate amount charged in the financial statements for the year for remuneration, including certain benefits, to the Chief Executive, Directors and Executives of the company is as follows:

	Chief Executive		Director	
	2017 Rupees	2016 Rupees	2017 Rupees	2016 Rupees
Short term employee benefits				
Managerial remuneration	-	-	20,400,000	18,539,136
Bonus	-	-	1,700,000	-
	-	-	22,100,000	18,539,136
Number of persons	-	-	1	1

25.2 No remuneration has been given to the Chief Executive and other directors of the company.

25.3 The company also provides the directors and some of its executives with company maintained cars in accordance with company's policy.

26. Number of employees

	2017	2016
Total number of employees as at June 30	16	32
Average number of employees during the year	24	25

27.	Disclosures relating to Provident Fund	2017 Rupees	2016 Rupees

The company operates a recognised provident fund for its permanent employees.

		2017 Rupees	2016 Rupees
(i)	Size of the Fund- total assets	6,978,101	-
(ii)	Cost of investments made	6,874,765	-
(iii)	Percentage of investments made	98.52%	-
(iv)	Fair value of investments	6,874,765	-
	Break up of investments		
	Special account in a scheduled bank	6,874,765	-
	Break up of investments	**% age of size of the Fund**	
	Special account in a scheduled bank	98.52%	-

The figures for 2017 are based on the un-audited financial statements of the Provident Fund. Investments out of Provident Fund have been made in accordance with the provisions of section 227 of the Ordinance and the rules formulated for this purpose.

28. **Date of authorisation for issue** 25 AUG 2017

These financial statements were authorised for issue on 25 AUG 2017, 2017 by the Board of Directors of the company.

29. **Event after the balance sheet date**

The Board of Directors have proposed a final dividend for the year ended June 30, 2017 of Rs 165 per share (2016: Nil), amounting to Rs 556,652,250 (2016: Nil) at their meeting held on 25 AUG 2017 for approval of the members at the Annual General Meeting to be held on 28 SEP 2017.

30. **Corresponding figures**

Corresponding figures have been re-arranged and re-classified, wherever necessary, for the purposes of comparison and better presentation. However, no significant re-arrangements have been made.

Chief Executive | Director

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27.	Disclosures relating to Provident Fund	2017 Rupees	2016 Rupees

The company operates a recognised provident fund for its permanent employees.

		2017 Rupees	2016 Rupees
(i)	Size of the Fund- total assets	6,978,101	-
(ii)	Cost of investments made	6,874,765	-
(iii)	Percentage of investments made	98.52%	-
(iv)	Fair value of investments	6,874,765	-
	Break up of investments		
	Special account in a scheduled bank	6,874,765	-
		% age of size of the Fund	
	Break up of investments		
	Special account in a scheduled bank	98.52%	-

The figures for 2017 are based on the un-audited financial statements of the Provident Fund. Investments out of Provident Fund have been made in accordance with the provisions of section 227 of the Ordinance and the rules formulated for this purpose.

28. Date of authorisation for issue

These financial statements were authorised for issue on 2 5 AUG 2017, 2017 by the Board of Directors of the company.

29. Event after the balance sheet date

The Board of Directors have proposed a final dividend for the year ended June 30, 2017 of Rs 165 per share (2016: Nil), amounting to Rs 556,652,250 (2016: Nil) at their meeting held on 2 5 AUG 2017 for approval of the members at the Annual General Meeting to be held on 18 SEP 2017.

30. Corresponding figures

Corresponding figures have been re-arranged and re-classified, wherever necessary, for the purposes of comparison and better presentation. However, no significant re-arrangements have been made.

Chief Executive **Director**

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4.3.5 Latest financial statements of the Applicant

Master Hydro (Private) Limited was incorporated on August 9, 2017. Audited Financial Statements of the Project Company will be available after one operational year.

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4.3.6 Employment records of technical and engineering staff

MASTER

August 09, 2017

Syed Shahzad Ali
House # B-152 Block 3 Saadi Town
Scheme 33 Karachi
CNIC# 41304-2323997-7

<u>Letter of Appointment</u>

Dear Mr. Syed Shahzad Ali

Master Hydro Private Limited ("the company"), based on your representation, assurances, expertise and qualifications is pleased to offer you the position of Senior Project Manager Your appointment will be subject to your antecedents being verified and found to be satisfactory by the company in you and are continuing to be qualified, competent and medically fit to the satisfaction of the company.

You will be governed by the following terms and conditions:

Gross Salary	**:**
Benefits	**: As per Company Policy**
Department	**: Site Operations**
Job Location	**:**

1. The negotiated salary, allowances, benefits etc. shall remain confidential and you will not divulge any related information to anybody in any case unless compelled to do so by a Court of Law.
2. You will be entitled to such allowances and benefits as may be prescribed by the Company from time to time applicable to your level. Annual Leaves (15), sick leave (08), and casual leave (10) will be governed by the Company rules and regulations as applicable from time to time.
3. Payment against any entitlement shall be subject to provisions as stipulated in the relevant Policies and amended from time to time, included in the HR Policy Manual.
4. During your service, you will be governed by the terms of this Letter of Appointment and the relevant Company Rules and Regulations contained in the HR Policy Manual, as may be applicable from time to time.
5. You may be transferred or assigned tasks anywhere in Pakistan at the sole discretion of the Management in the interest of the Company.

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6. You will have authority necessary to perform your duties. This authority will be subject to any rules, regulations, stipulation and conditions as may be laid from time to time by the Directors or Management of the Company.

7. You will discharge all such duties, responsibilities and authorities as assigned to you, efficiently and diligently to the satisfaction of the Management and you will not act in any manner contrary to the interest of the Company.

8. As an employee you will not divulge directly or indirectly to any person or organization any knowledge or information which you may acquire concerning the affairs, property, enterprise, clients, and undertaking of the company including but not limited to its business, trade matters and secrets. You are required to protect intellectual property rights and interests of the company. In this respect at the time of joining the company, you shall be required to sign Non-Disclosure Agreement (NDA).

9. You will be bound to make good any loss or damage to Company property caused by negligence, inadvertence, fraud, carelessness or act of omission, on your part. The termination of your services may not exonerate you from liability to make good this loss or damage.

10. You shall not accept any other employment, whether part time or otherwise with any other person nor engage in any business activity directly or indirectly during your service with the Company.

11. Your services will be subject to termination by 30 days written notice on either side or pay in lieu thereof.

12. In case of resignation or termination, you will not leave the Company until formal acceptance of resignation and / or clearance is issued by the Company. The clearance will be processed within 40 days from the date of resignation.

13. In case of breach of any of the terms of this Letter of Appointment and Company rules and regulations, or any fraudulent activity which may constitute a misconduct on your part, your services are liable to immediate termination and you will not be entitled to any compensation as a result thereof. In such a case, suitable necessary action may further be initiated against you as per Law and Company rules and regulations.

14. Under the Rules, you are eligible to become member of Provident Trust Fund (whenever the company decides to have a fund).

Please join us at the earliest but not later than August 09, 2017 You are advised to report to HR Department at Master Hydro (Private) Limited.

Please sign and date a copy of the letter as your unequivocal acceptance of the aforesaid terms and conditions and their after hand it over to HR Department.

We look forward to welcome you as a member of Master Hydro (Private) Limited

With Best Regards,

Human Resources / Administration Division
Master Hydro (Private) Limited

ACCEPTANCE

I, Syed Shahzad Ali, hereby declare that I have carefully read/understood the terms and conditions of employment as set out in letter of which this is a true copy. I confirm that I fully accept the conditions of the letter of appointment. I shall report for duty on August 09, 2017.

Syed Shahzad Ali

Date: August 09, 2017

Certified True Copy

MASTER

August 23, 2017

Faheem Ali
House # G-69, Fauji Fertilizer
Company Township, Mirpur,
Mathelo, Sindh
CNIC# 45104-0127236-7

Letter of Appointment

Dear Mr. Faheem Ali

Master Hydro (Private) Limited ("the company"), based on your representation, assurances, expertise and qualifications is pleased to offer you the position of Mechanical Engineer. Your appointment will be subject to your antecedents being verified and found to be satisfactory by the company in you and are continuing to be qualified, competent and medically fit to the satisfaction of the company.

You will be governed by the following terms and conditions:

Gross Salary	:
Benefits	**: As per Company Policy**
Department	**: Site Operations**
Job Location	:

1. The negotiated salary, allowances, benefits etc. shall remain confidential and you will not divulge any related information to anybody in any case unless compelled to do so by a Court of Law.
2. You will be entitled to such allowances and benefits as may be prescribed by the Company from time to time applicable to your level. Annual Leaves (15), sick leave (08), and casual leave (10) will be governed by the Company rules and regulations as applicable from time to time.
3. Payment against any entitlement shall be subject to provisions as stipulated in the relevant Policies and amended from time to time, included in the HR Policy Manual.
4. During your service, you will be governed by the terms of this Letter of Appointment and the relevant Company Rules and Regulations contained in the HR Policy Manual, as may be applicable from time to time.

Certified True Copy

5. You may be transferred or assigned tasks anywhere in Pakistan at the sole discretion of the Management in the interest of the Company.

6. You will have authority necessary to perform your duties. This authority will be subject to any rules, regulations, stipulation and conditions as may be laid from time to time by the Directors or Management of the Company.

7. You will discharge all such duties, responsibilities and authorities as assigned to you, efficiently and diligently to the satisfaction of the Management and you will not act in any manner contrary to the interest of the Company.

8. As an employee you will not divulge directly or indirectly to any person or organization any knowledge or information which you may acquire concerning the affairs, property, enterprise, clients, and undertaking of the company including but not limited to its business, trade matters and secrets. You are required to protect intellectual property rights and interests of the company. In this respect at the time of joining the company, you shall be required to sign Non-Disclosure Agreement (NDA).

9. You will be bound to make good any loss or damage to Company property caused by negligence, inadvertence, fraud, carelessness or act of omission, on your part. The termination of your services may not exonerate you from liability to make good this loss or damage.

10. You shall not accept any other employment, whether part time or otherwise with any other person nor engage in any business activity directly or indirectly during your service with the Company.

11. Your services will be subject to termination by 30 days written notice on either side or pay in lieu thereof.

12. In case of resignation or termination, you will not leave the Company until formal acceptance of resignation and / or clearance is issued by the Company. The clearance will be processed within 40 days from the date of resignation.

13. In case of breach of any of the terms of this Letter of Appointment and Company rules and regulations, or any fraudulent activity which may constitute a misconduct on your part, your services are liable to immediate termination and you will not be entitled to any compensation as a result thereof. In such a case, suitable necessary action may further be initiated against you as per Law and Company rules and regulations.

14. Under the Rules, you are eligible to become member of Provident Trust Fund (whenever the company decides to have a fund).

MASTER

Please join us at the earliest but not later than August 23, 2017 You are advised to report to HR Department at Master Hydro (Private) Limited.

Please sign and date a copy of the letter as your unequivocal acceptance of the aforesaid terms and conditions and their after hand it over to HR Department.

We look forward to welcome you as a member of Master Hydro (Private) Limited

With Best Regards,

Human Resources / Administration Division
Master Hydro (Private) Limited

ACCEPTANCE

I, Faheem Ali, hereby declare that I have carefully read/understood the terms and conditions of employment as set out in letter of which this is a true copy. I confirm that I fully accept the conditions of the letter of appointment. I shall report for duty on August 23, 2017.

Faheem Ali

Date: August 23, 2017

Certified True Copy

MASTER

September 04, 2017

Abdul Jabbar House
72-A Street # 24A,
F-10/1,
Islamabad

Letter of Appointment

Dear Mr. Abdul Jabbar

Master Hydro (Private) Limited ("the company"), based on your representation, assurances, expertise and qualifications is pleased to offer you the position of Electrical Engineer. Your appointment will be subject to your antecedents being verified and found to be satisfactory by the company in you and are continuing to be qualified, competent and medically fit to the satisfaction of the company.

You will be governed by the following terms and conditions:

Gross Salary	:
Benefits	**: As per Company Policy**
Department	**: Site Operations**
Job Location	:

1. The negotiated salary, allowances, benefits etc. shall remain confidential and you will not divulge any related information to anybody in any case unless compelled to do so by a Court of Law.
2. You will be entitled to such allowances and benefits as may be prescribed by the Company from time to time applicable to your level. Annual Leaves (15), sick leave (08), and casual leave (10) will be governed by the Company rules and regulations as applicable from time to time.
3. Payment against any entitlement shall be subject to provisions as stipulated in the relevant Policies and amended from time to time, included in the HR Policy Manual.
4. During your service, you will be governed by the terms of this Letter of Appointment and the relevant Company Rules and Regulations contained in the HR Policy Manual, as may be applicable from time to time.

5. You may be transferred or assigned tasks anywhere in Pakistan at the sole discretion of the Management in the interest of the Company.

6. You will have authority necessary to perform your duties. This authority will be subject to any rules, regulations, stipulation and conditions as may be laid from time to time by the Directors or Management of the Company.

7. You will discharge all such duties, responsibilities and authorities as assigned to you, efficiently and diligently to the satisfaction of the Management and you will not act in any manner contrary to the interest of the Company.

8. As an employee you will not divulge directly or indirectly to any person or organization any knowledge or information which you may acquire concerning the affairs, property, enterprise, clients, and undertaking of the company including but not limited to its business, trade matters and secrets. You are required to protect intellectual property rights and interests of the company. In this respect at the time of joining the company, you shall be required to sign Non-Disclosure Agreement (NDA).

9. You will be bound to make good any loss or damage to Company property caused by negligence, inadvertence, fraud, carelessness or act of omission, on your part. The termination of your services may not exonerate you from liability to make good this loss or damage.

10. You shall not accept any other employment, whether part time or otherwise with any other person nor engage in any business activity directly or indirectly during your service with the Company.

11. Your services will be subject to termination by 30 days written notice on either side or pay in lieu thereof.

12. In case of resignation or termination, you will not leave the Company until formal acceptance of resignation and / or clearance is issued by the Company. The clearance will be processed within 40 days from the date of resignation.

13. In case of breach of any of the terms of this Letter of Appointment and Company rules and regulations, or any fraudulent activity which may constitute a misconduct on your part, your services are liable to immediate termination and you will not be entitled to any compensation as a result thereof. In such a case, suitable necessary action may further be initiated against you as per Law and Company rules and regulations.

14. Under the Rules, you are eligible to become member of Provident Trust Fund (whenever the company decides to have a fund).

Please join us at the earliest but not later than September 04, 2017 You are advised to report to HR Department at Master Hydro (Private) Limited.

Please sign and date a copy of the letter as your unequivocal acceptance of the aforesaid terms and conditions and their after hand it over to HR Department.

We look forward to welcome you as a member of Master Hydro (Private) Limited

With Best Regards,

Human Resources / Administration Division
Master Hydro (Private) Limited

ACCEPTANCE

I, Abdul Jabbar, hereby declare that I have carefully read/understood the terms and conditions of employment as set out in letter of which this is a true copy. I confirm that I fully accept the conditions of the letter of appointment. I shall report for duty on September 04, 2017.

Abdul Jabbar

Date: September 04, 2017

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4.3.7 Profile of sub contractors, if any, along with expressions of interest of such sub-contractors

The Project will be developed under a standard, lump-sum, fixed schedule, turn-key EPC contract, in line with market norms and standards for such projects. Sinohydro Corporation Limited (**SHCL**) and Hydrochina International (**HDC**) have been selected as the preferred EPC contractor for the project.

Sinohydro Corporation Limited

Sinohydro Corporation Limited is well known as China's leading contractors in hydropower construction, responsible for 65% of large and medium scale hydropower stations in China. With over 60 years of development and expertise, SHCL is the key international brand of Powerchina Corporation, a Fortune Global 500 company. In 2016, Powerchina was ranked no. 6 on the engineering design enterprises (ENR) lists of Top 250 Global Contractors and no. 11 in Top 250 International Contractors. With diversified operations in over 100 countries, SHCL's businesses cover almost all areas of the construction sector, including energy, transport, water works, civil engineering and building.

Over the past decade, SHCL has constructed more than 78 hydropower plants globally with a total capacity of 27,780 MW. In addition, it has built 16 thermal and renewable power plants overseas, with a total capacity of approximately 2,776 MW. SHCL multi-purpose hydropower projects not only generate electricity, they also provide flood protection, river regulation and diversion, agricultural irrigation, tourism development and improved shipping transport. SHCL has been awarded ISO 9001, ISO 14001 and OHSAS 18001 for their high performance standards. Currently, SHCL has 65 water projects under construction in more than 24 countries, with a total contract value of nearly US $ 3.45

A brochure of SHCL is attached below for reference.

Projects undertaken by Sinohydro in Pakistan

Sinohydro has significant experience in the global hydel power sector, and has also completed a number of projects in Pakistan. A list of projects completed by Sinohydro Corporation Limited in Pakistan is provided below as reference[2].

Project Name	Capacity (MW)	Status
Tarbela 4th Extension - Civil Works	1410	Completed
Ghazi Barotha Hydropower Project	1450	Completed
Gomal Zam Multipurpose Dam Project	17.4	Completed

Hydrochina Corporation International

Hydrochina Corporation International is a large consultation enterprise for development of water resource and renewable energy, and serves as an important institution for undertaking and implementation of oversea business in the Powerchina group. HDC is focused on development of hydro, wind and solar power through provision of resource survey, planning, investigation, design, consultation, financing, procurement, EPC contracting, construction supervision, and operation maintenance for renewable energy projects.

Hydrochina has expanded its business scope to the sectors of transmission and transformation, thermal power, power grid construction, environment protection, municipal construction, port and navigation and oil underground structure as well. Over the years, HDC has developed three core business sectors, design and consultation, EPC contract and investment, and setting up of overseas representative offices or branches for providing high quality services abroad. HDC is ranked No.1 in the 60 China's ENR, 15th in the Global top 150 engineering design companies and 59th of 225 international engineering design companies.

A brochure of HDC is attached below for reference.

[2]Sinohydro has also undertaken irrigation projects in Pakistan,recently Darawat Dam was completed by the company

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中国电建
POWERCHINA

中国水电
SINOHYDRO

SINOHYDRO

BUILDING A SUSTAINABLE FUTURE

SINOHYDRO

Address: No. 22 Chegongzhuang West Road
Haidian District, Beijing, 100048, P. R. China
Website: www.sinohydro.com
E-mail: intl@sinohydro.com

RAD
Certified True Co

Our Values

Integrity, Excellence, Innovation, Responsiveness, Responsibility

Our Mission

Taking it further is our approach to doing business, serving our clients, and achieving company objectives. It means demonstrating our expertise and commitment to our customers wherever they are, to deliver safe and successful energy and infrastructure projects.

Strategic Priorities

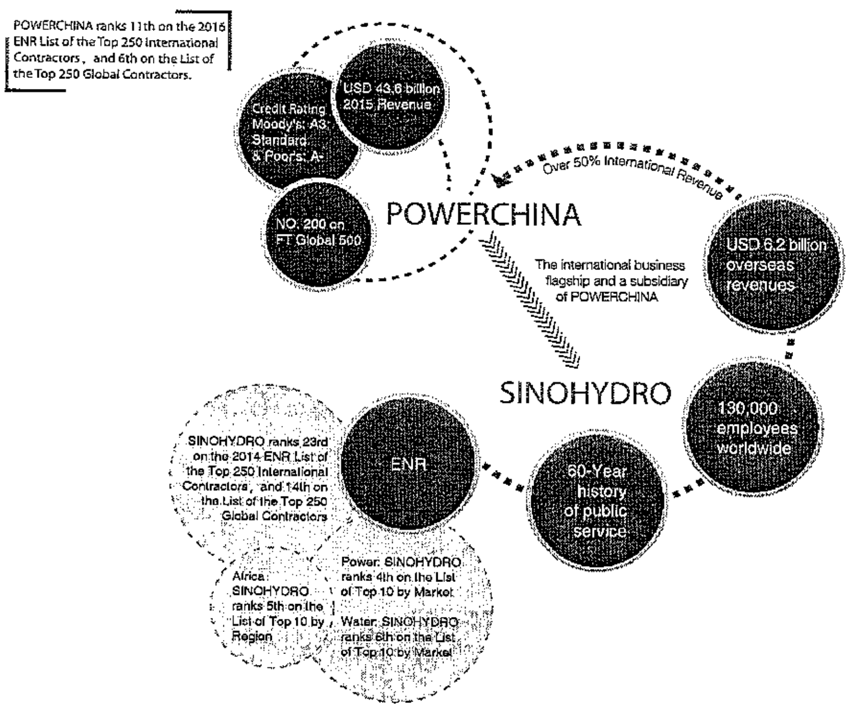
Prioritize occupational health & safety in our business.
Contribute to the economic & social life of the local communities where we operate.
Ensure our business respects the environment.
Build relationships with our clients based on quality service, transparency and innovation.
Develop local capacity and our employees' skills.

SINOHYDRO PROFILE

A leading player in global construction, SINOHYDRO designs and builds major infrastructure works and buildings around the world.

SINOHYDRO is well known as China's first brand in hydropower construction, responsible for 65% of large- and medium-scale hydropower stations in China. Today, with over 60 years of development and expertise, SINOHYDRO is the key international brand of POWERCHINA Corporation, which is a Fortune Global 500 company. In 2016, POWERCHINA was ranked No. 6 and No. 11 on the ENR lists of Top 250 Global Contractors and Top 250 International Contractors respectively.

As the international business flagship and a subsidiary of POWERCHINA Corporation, SINOHYDRO Corporation Limited is the bearer of the SINOHYDRO brand and has continuously updated its value. With diversified operations in over 100 countries, SINOHYDRO Corporation Limited is an internationally renowned and management-oriented contractor. Its businesses cover almost all areas of the construction sector, including energy, transport, water works, civil engineering and building.



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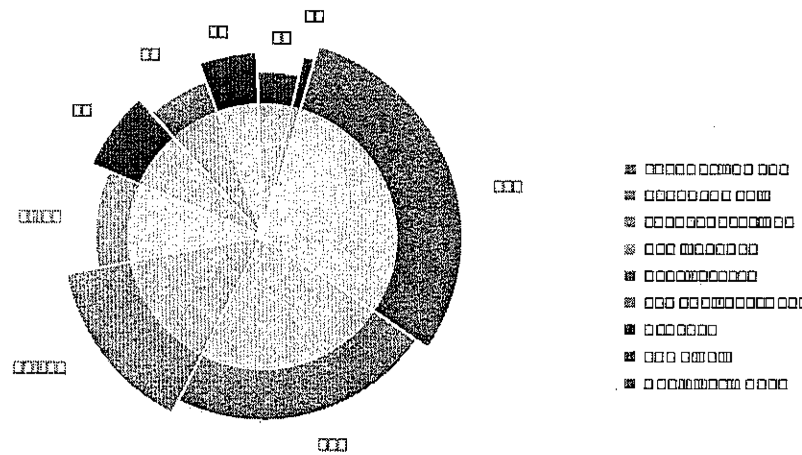
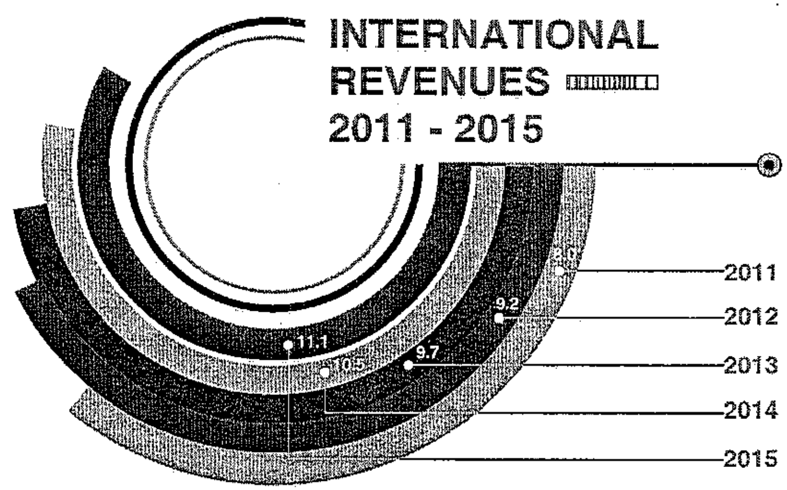
POWERCHINA INTERNATIONAL BUSINESS

Breakdown by activities





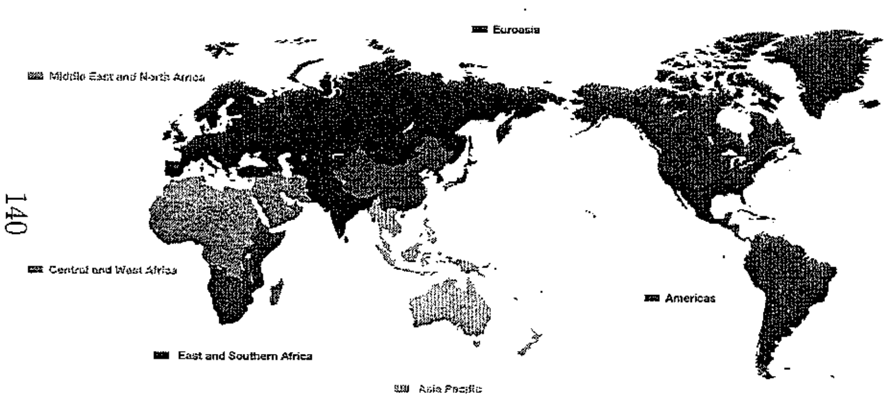
MARKETS

Operations in Over 90 Countries

SINOHYDRO Corporation Limited has 6 regional offices in East and Southern Africa, Middle East and North Africa, Central and West Africa, Eurasia, Asia Pacific, Americas, supervising 126 overseas offices in 92 countries.

Currently, SINOHYDRO has over 500 international projects under construction in more than 70 countries, with a total contract value of approximately USD 50 billion.

One Belt One Road
SINOHYDRO is playing an active role in One Belt One Road (OBOR) projects. Among the approximately 64 countries along the OBOR route, SINOHYDRO has 171 projects under construction in about 29 countries, with a total contract value reaching USD 12.9 billion.



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International Cooperation

To further optimize SINOHYDRO's position and to build an increasingly international brand, SINOHYDRO Corporation Limited has established strategic partnerships with leading global enterprises and maintains close cooperation with global financial institutions.

As of December 2015, SINOHYDRO has set up strategic partnerships with 46 enterprises & institutions around the world.

SIEMENS Bolloré HYUNDAI ALSTOM GAUFF GDF SUEZ CAT AECOM ABEINSA Infrastructures for a sustainable world

RAD
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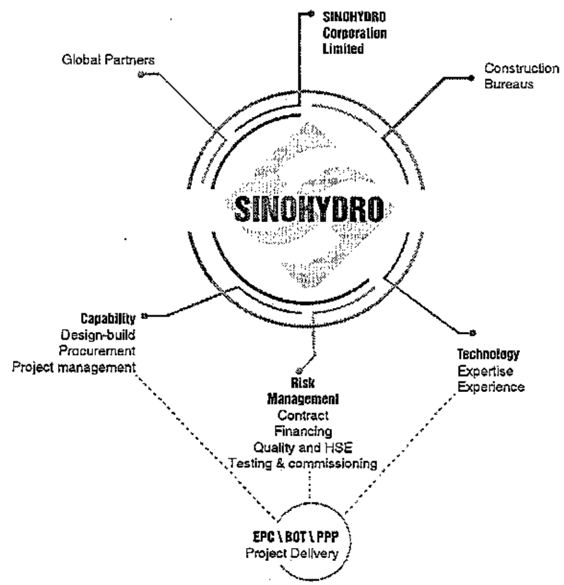
PROVIDING ONE-STOP SERVICE

Our expertise in design, procurement, financing, construction, operations and maintenance makes SINOHYDRO a reliable partner.

SINOHYDRO Corporation Limited is dedicated to providing our clients with best quality one-stop service:
- We assist our clients with project financing.
- We identify clients' needs in order to optimize projects successfully.
- We combine the strengths of large companies, institutional networks and banks with a focus on strong relationships.
- We provide all services from conceptual design to construction through value engineering and innovation.

Project Financing

Multilateral Financial Institutions	Funded by Client	From Chinese Financial Institutions, China Exim Bank, Bank Of China, China Development Bank	Other
11%	42%	44%	3%



Our extensive international business network and strong organizational and managerial abilities enable us to successfully employ complex project models. By operating successful EPC, EPC+Financing, BOT, BOO, BT, and PPP projects, we have demonstrated our diverse abilities in the global construction sector.

China, The Yangtze Three Gorges Project (22400 MW).

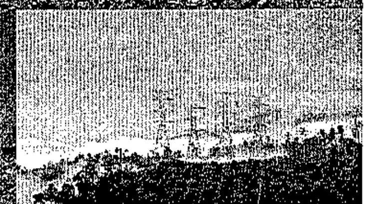
Iran, Taleghan Dam (18 MW), received the First "Lu Ban" Award (2009) for an international project.

Zambia, Kariba Hydropower Plant, North Bank Extension (360 MW).

Ecuador, Coca Codo Sinclair Hydroelectric Project (1500 MW).

Equatorial Guinea, Djiploho Hydropower Plant (120 MW).

Pakistan, Gomal Zam Dam Multipurpose Project (17.4 MW), termed by locals as "the Project of a Century".



Malaysia, Power Transmission Project for Bakun.

ENERGY

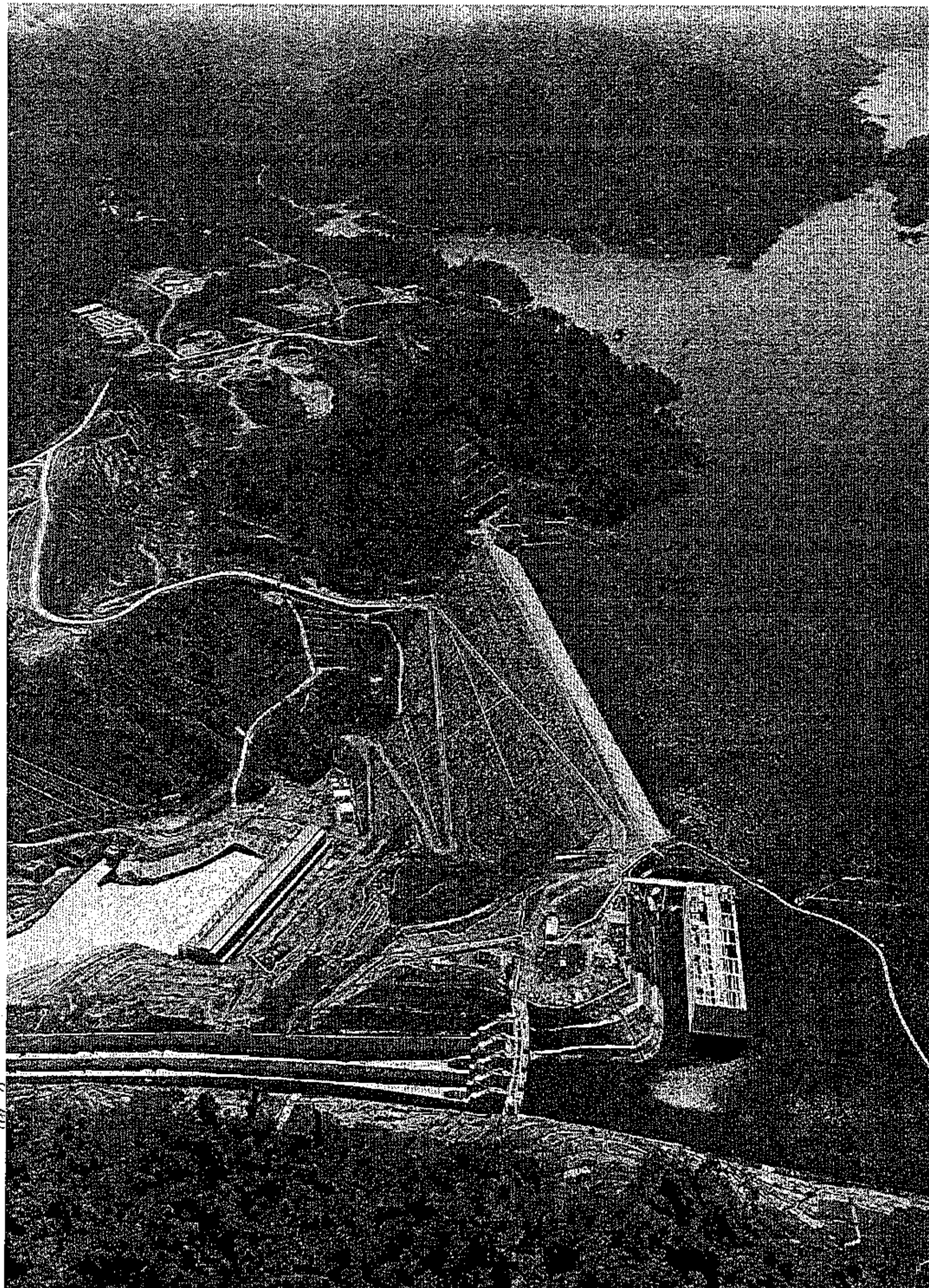
[Hydropower, Thermal Power, Solar Power, Wind Power, Power Transmission]

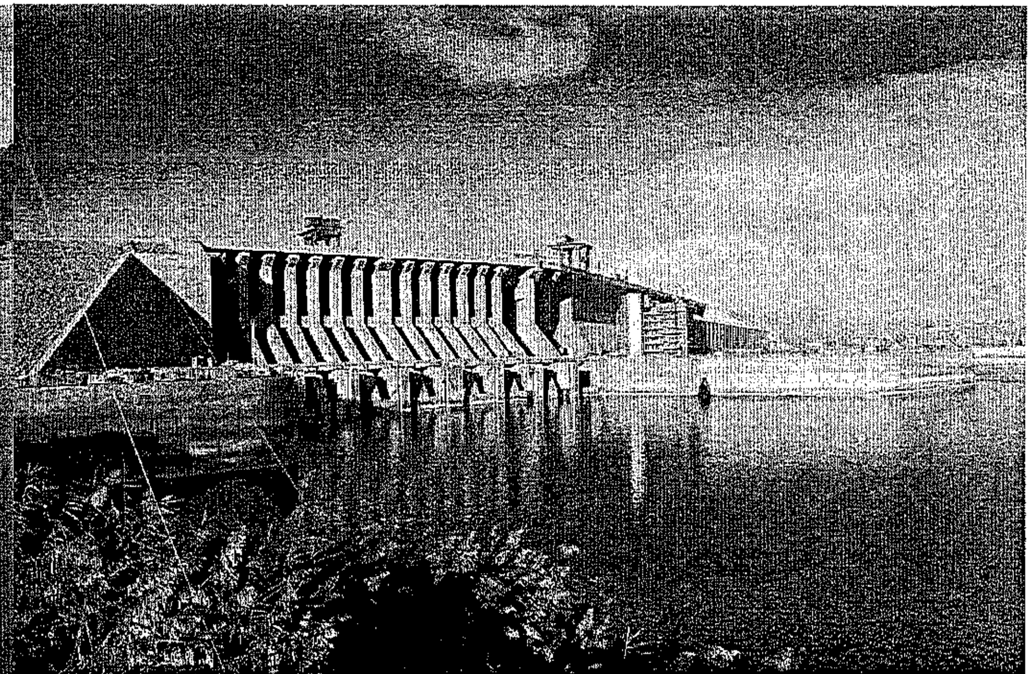
Providing Our Clients with Integrated Solutions

Our vast experience allows us to provide the optimal plan for each energy project by choosing the best engineering design and most efficient construction method.

Over the past decade, SINOHYDRO has constructed more than 78 hydropower plants overseas with a total capacity of 27,780 MW. In addition, it has built 16 thermal and renewable power plants overseas, with a total capacity of approximately 2,776 MW.

SINOHYDRO multi-purpose hydropower projects not only generate electricity, they also provide flood protection, river regulation and diversion, agricultural irrigation, tourism development and improved shipping transport.

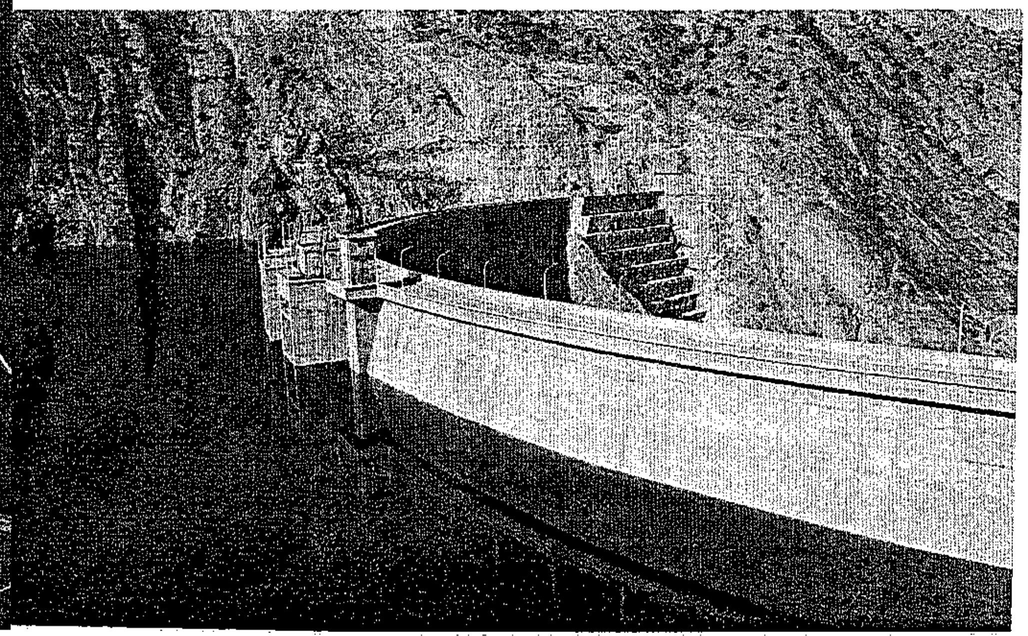




◄ Malaysia,
Bakun Hydropower Plant
(2400 MW),
the largest hydropower plant in South Asia.

▲ Sudan,
Merowe Hydropower Plant
(1250 MW),
one of the longest dams in the world (9800 m).

▼ Ethiopia,
Tekeze Hydropower Project
(300 MW),
highest double-curvature arch dam in Africa (185 m).



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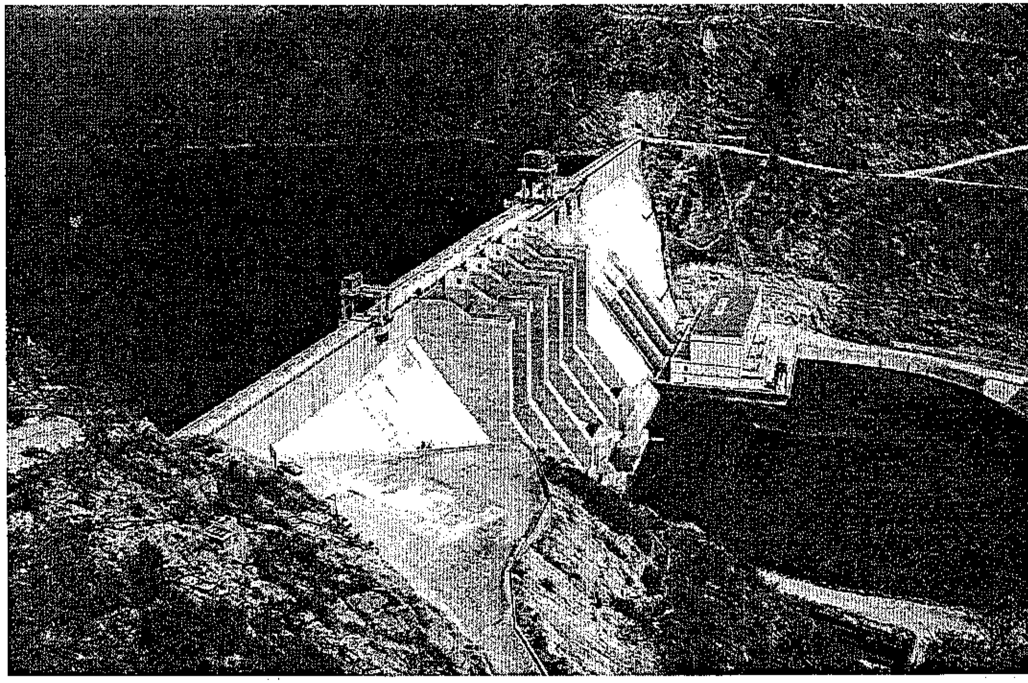
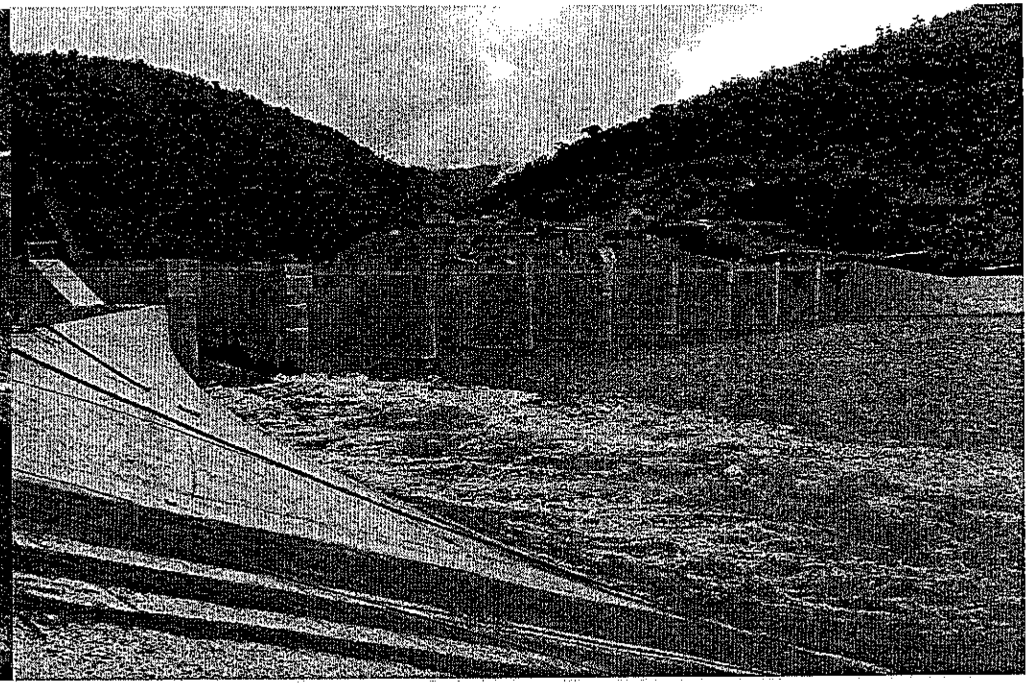


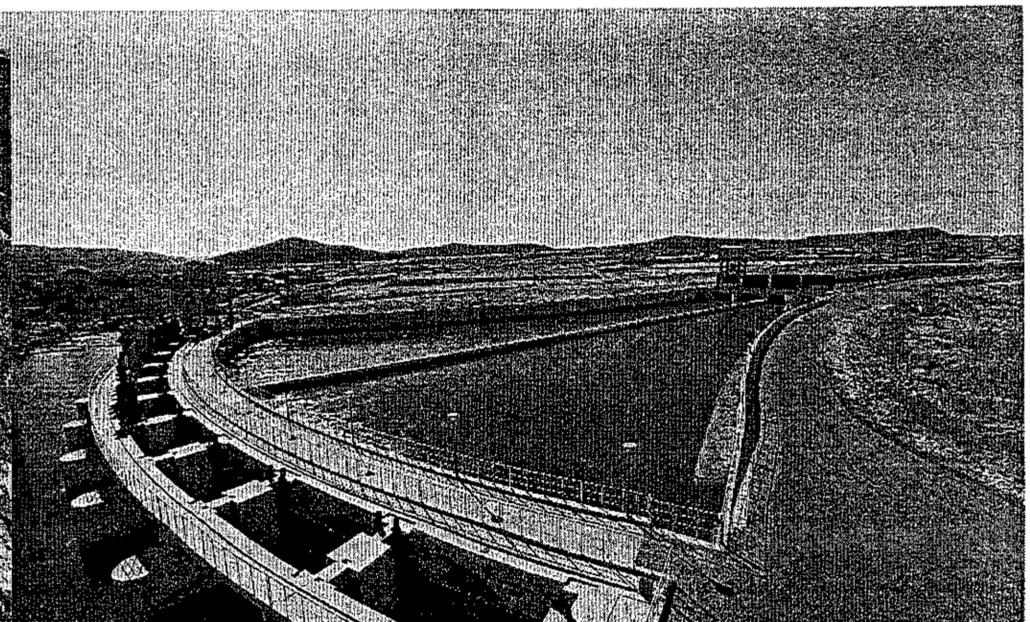


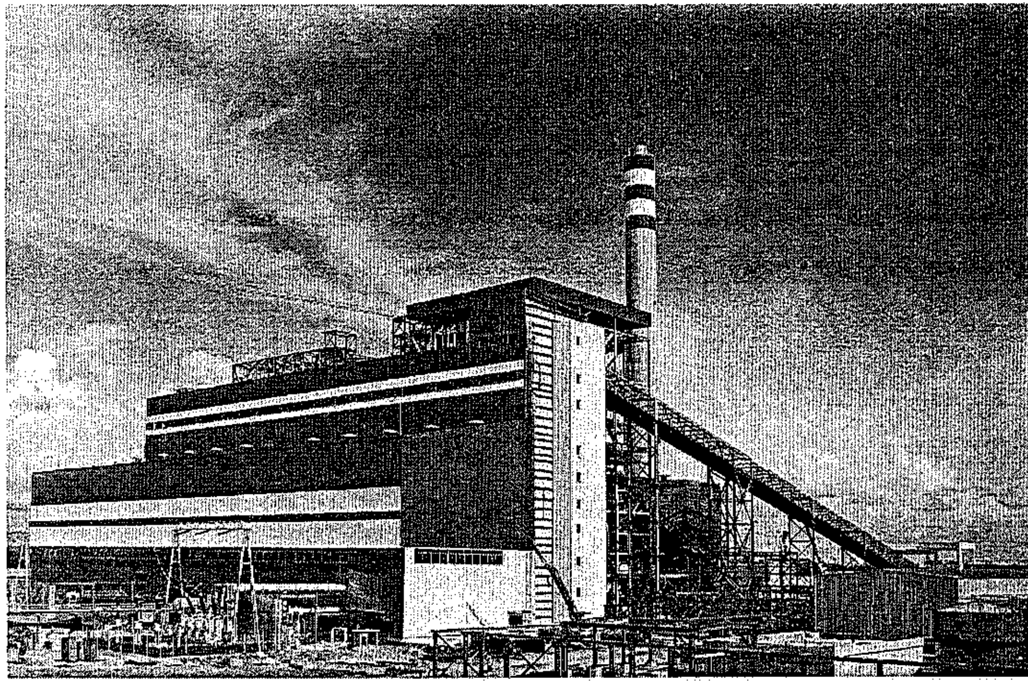
▲ Ghana,
Bui Hydropower Station (400 MW),
received 1st Engineering Excellence Award (2014) by Ghana Institution of Engineers,
Power Project of the Year (2013) by TO&GY.

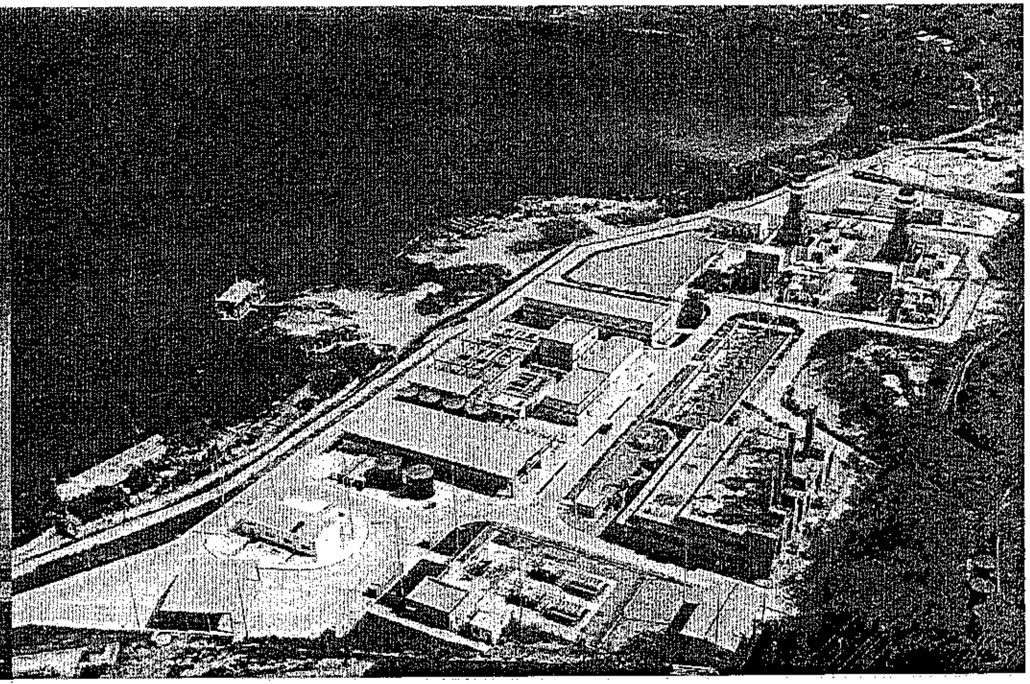
▼ Indonesia,
Jatigede Dam (110 MW),
presently the largest hydropower plant in Indonesia.

▲ Ecuador,
Coca Codo Sinclair Hydroelectric Project (1500 MW),
presently the largest hydropower plant in Ecuador.

▼ Mali,
Felou Hydropower Project (63 MW).





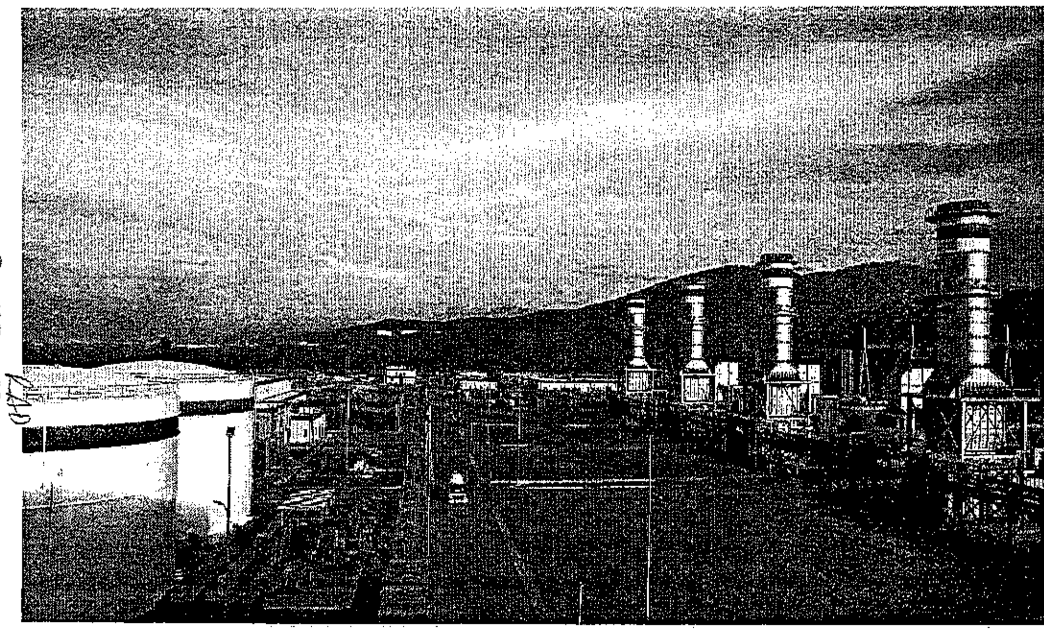


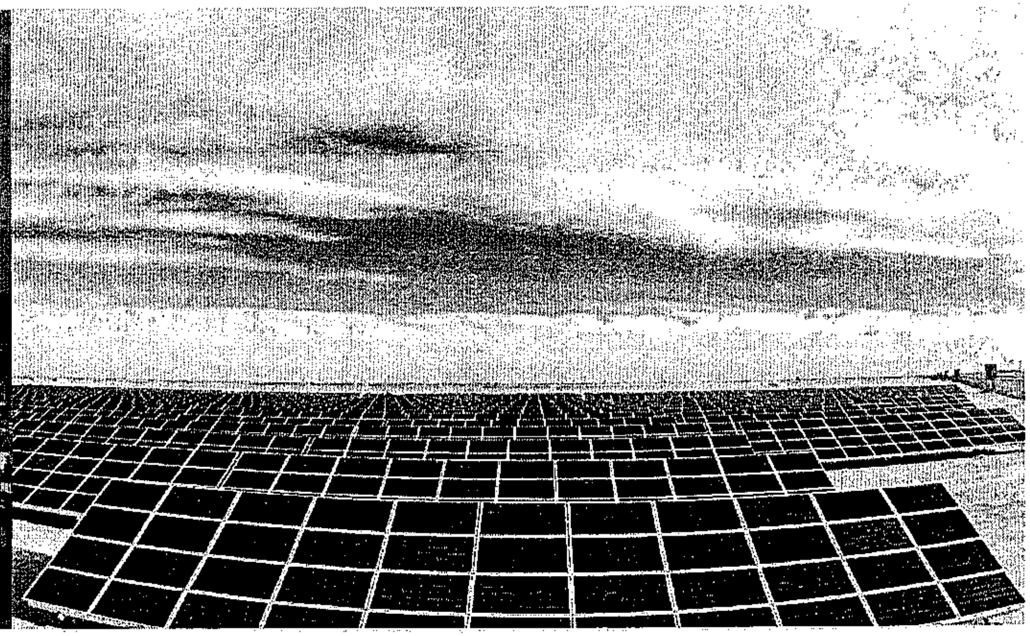
▲ Indonesia,
PLTU Nangroe Aceh Darussalam Thermal Power Plant (220 MW).

▼ Venezuela,
Carabobo II Thermal Power Project (772 MW).

▲ Venezuela,
Jose Felix Ribas Thermal Power Project (382 MW).

▼ Algeria,
Photovoltaic Power Station (233 MW).





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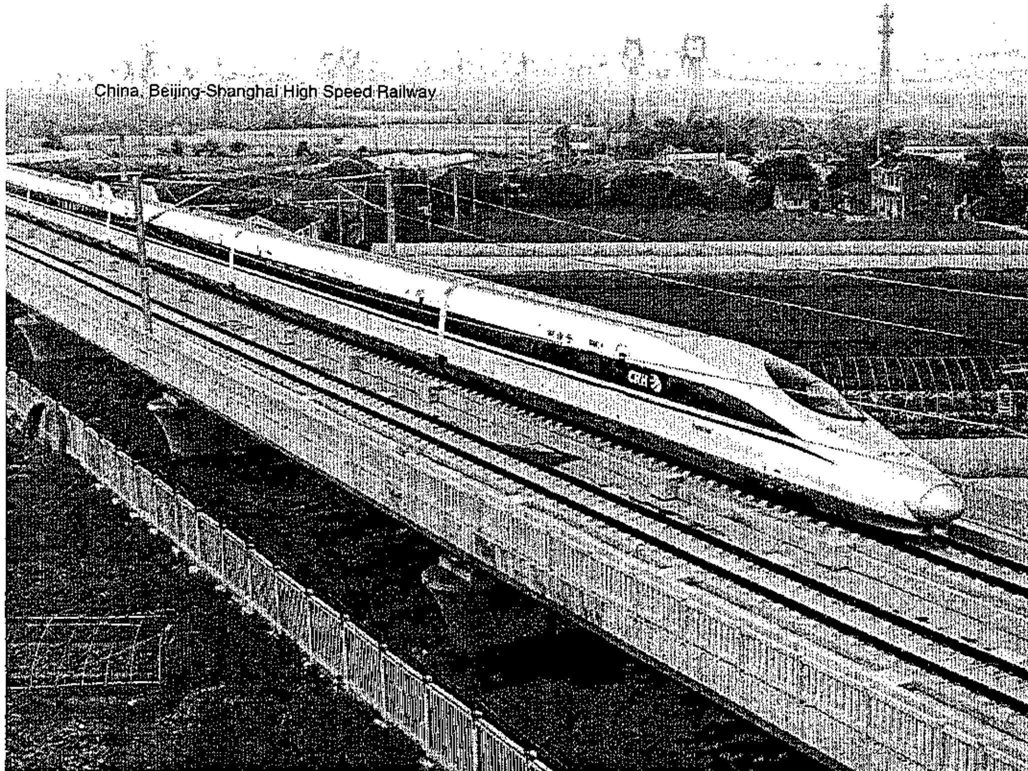
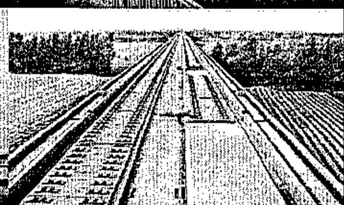


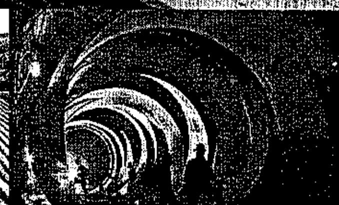
China, Beijing-Shanghai High Speed Railway

Qatar, New Doha International Airport

Bridge Erection, Beijing-Shanghai HSR.



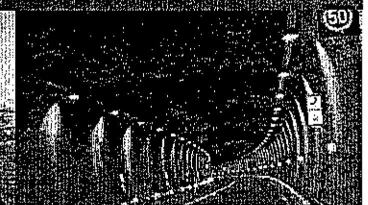
Track Laying, Beijing-Shanghai HSR.



Tunnel Construction, Beijing-Shanghai HSR.

Zambia, Road Project.

Mauritania, Nouadhibou Mineral Port.



Georgia, Rikoti Tunnel on the E-60 Highway.

TRANSPORTATION

[Railways, Airports, Bridges, Roads, Tunnels, Piers, Dredging, Marine Facilities]

Multi-disciplinary teams with professional technical skills

With landmark projects in Asia, Eurasia and Africa, SINOHYDRO possesses outstanding capabilities in the design and development of large-scale transportation infrastructure.

Over the past decade, SINOHYDRO has undertaken a variety of overseas transportation projects in Asia, Africa, the Middle East, the Americas and Eastern Europe. All around the world, SINOHYDRO has constructed over 10,000 km of road and bridge projects and 1,100 km of railway and high-speed railway projects. SINOHYDRO was the main contractor of the Beijing-Shanghai High Speed Railway. In addition, SINOHYDRO has been a leading player in world airport and harbor construction.

By building high quality transportation projects, we demonstrate our competences in this sector while contributing to urban development worldwide.

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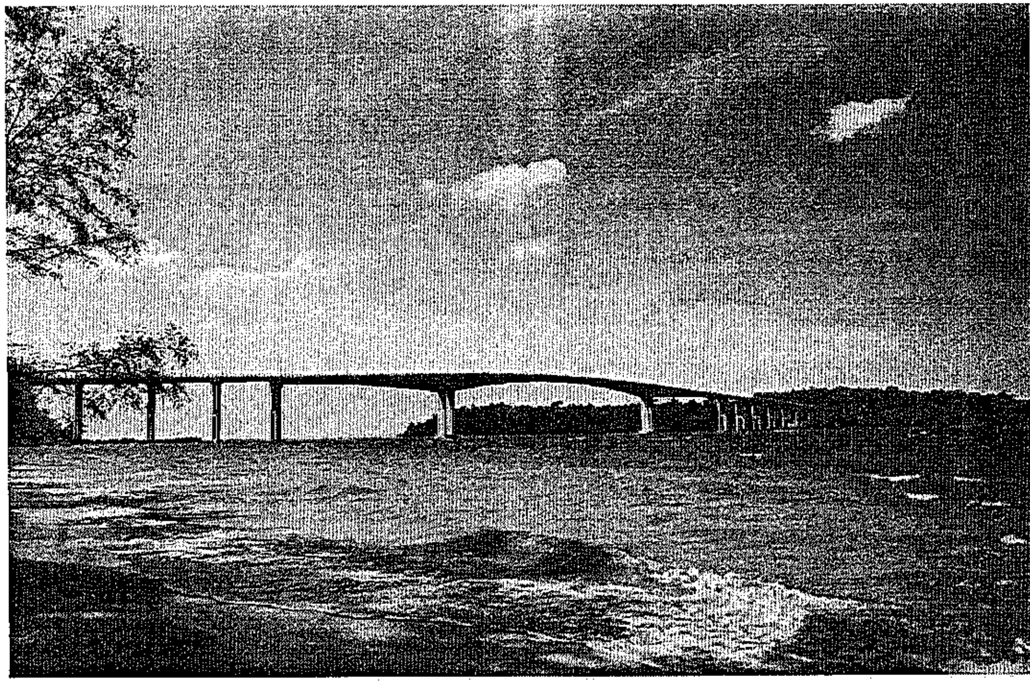
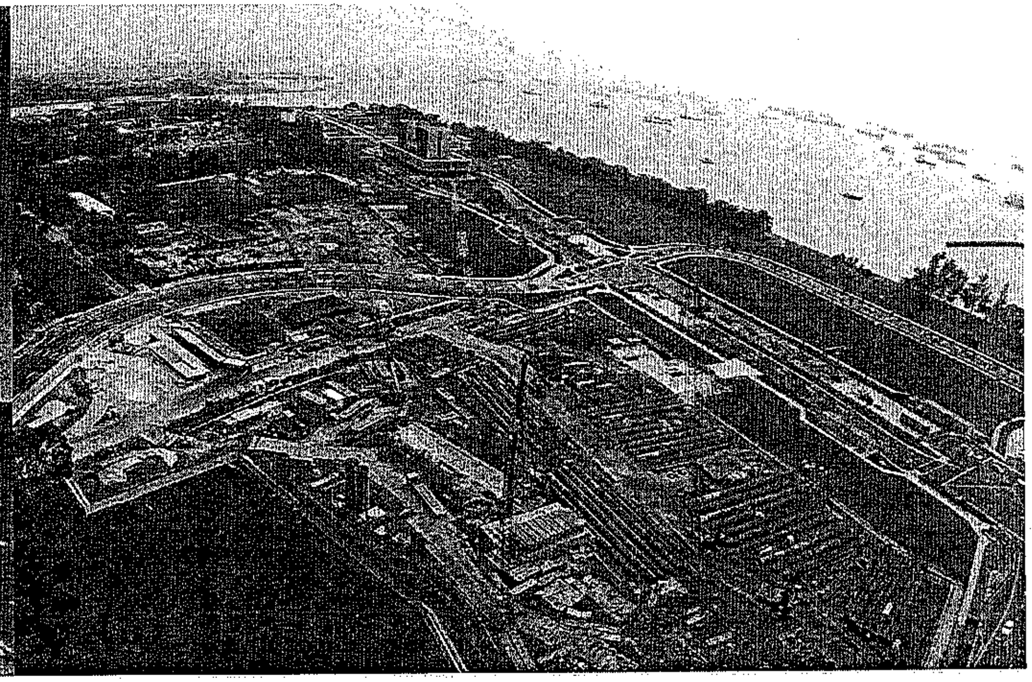


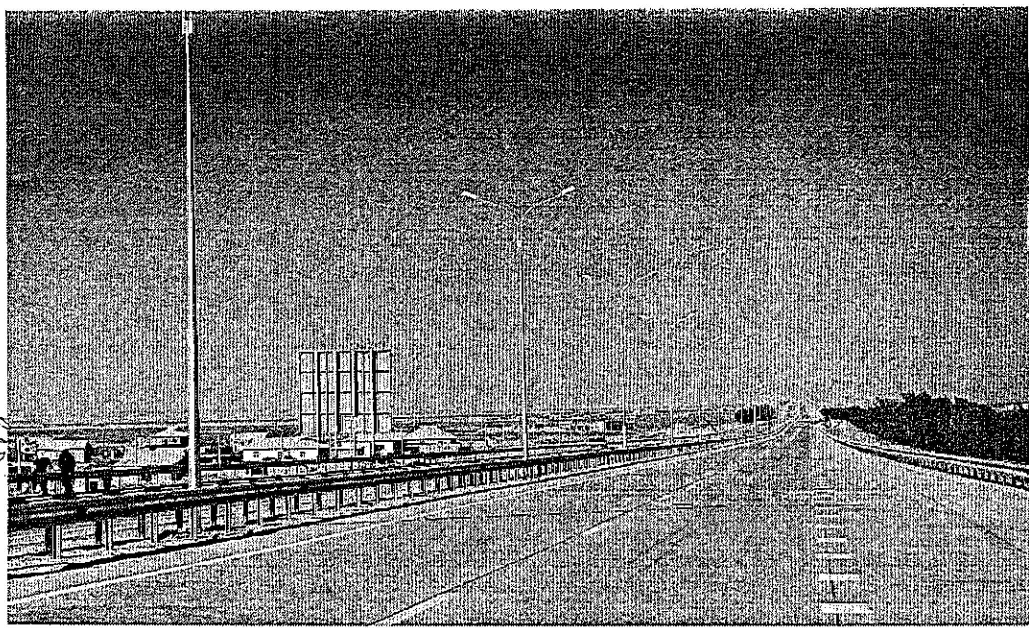


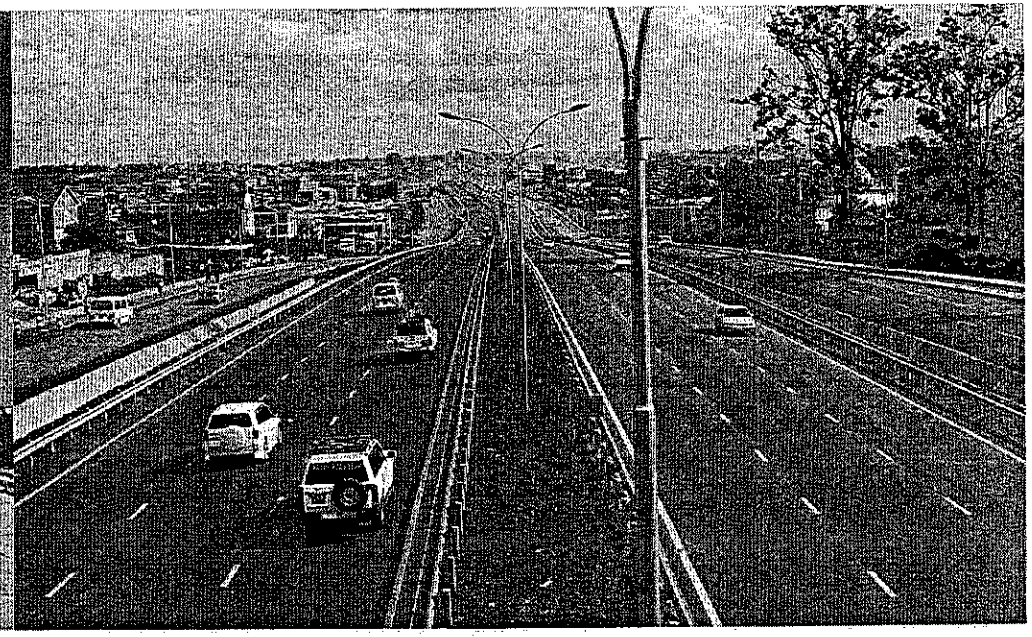
▲ Cambodia,
Koh Puos Bridge.

▼ Kazakhstan,
Western Europe – Western China International Transit Corridor.

▲ Singapore,
MRT Marina South Station and Tunnels TSL (T227).

▼ Kenya,
Upgrading of Nairobi-Thika Road.





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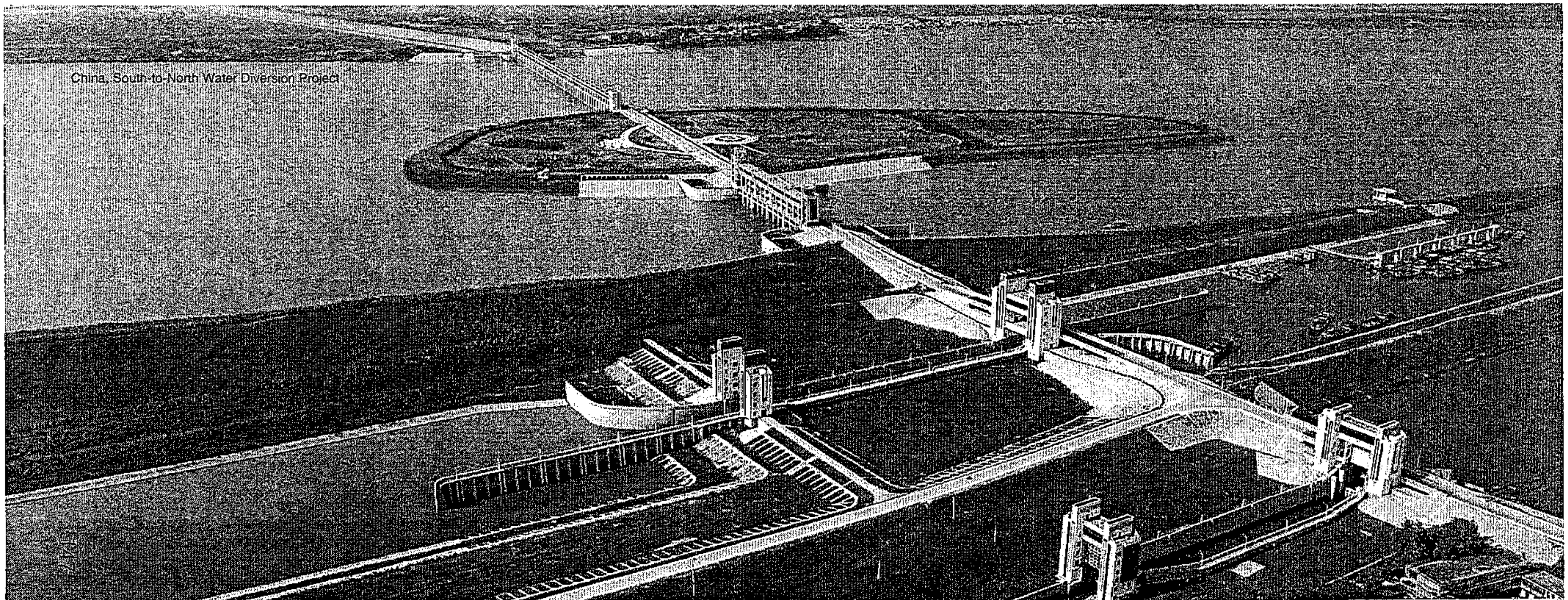
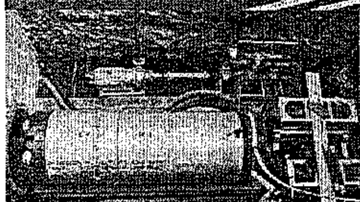
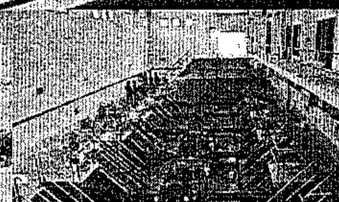


China, South-to-North Water Diversion Project



Oman, Muscat Wastewater Scheme Project-Network

Algeria, Souf Water Supply



Qatar, GTC182 Water Project

Nepal, Sikta Irrigation Project

Poland, Wroclaw Floodway System

Angola, Kuito Water Supply Project

WATER WORKS

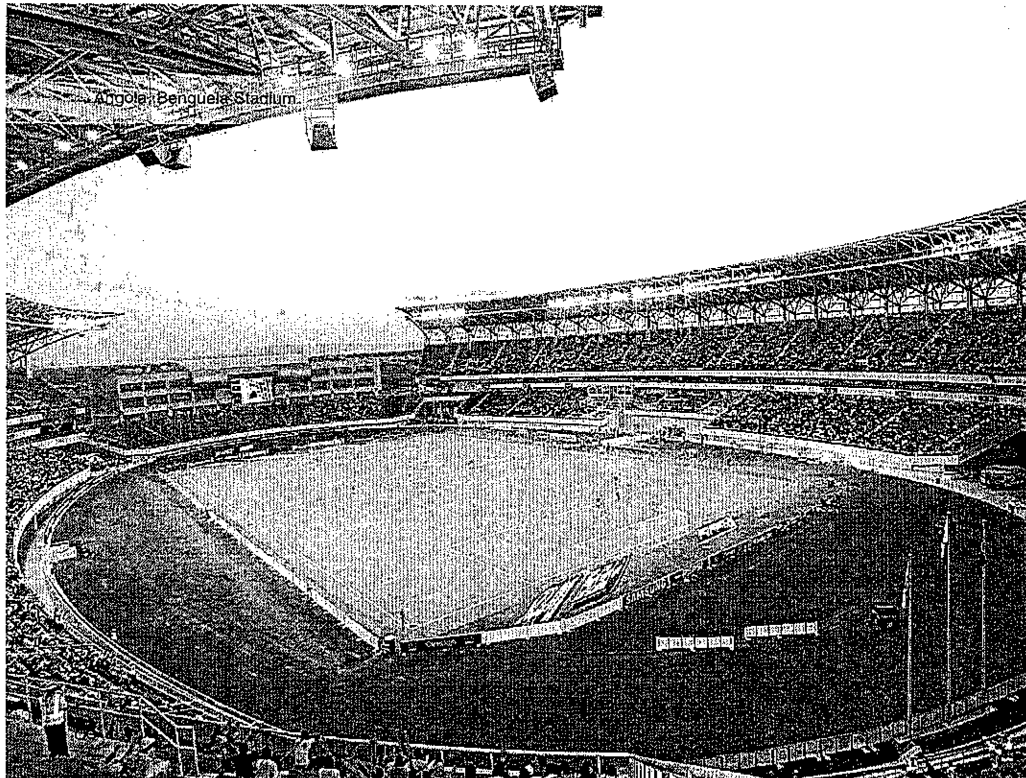
[River Control, Irrigation, Water Supply & Treatment]

Providing our customers with total control over the water cycle.

SINOHYDRO possesses wide-ranging expertise in water resource management, including water catchment, storage and supply, water treatment, sea water desalinization and irrigation.

Currently, SINOHYDRO has 65 water projects under construction in more than 24 countries, with a total contract value of nearly 3.45 billion USD.

SINOHYDRO has a fundamental stake in the preservation of water. We apply our expertise to various water distribution projects, and by optimizing canals, drinking water systems and water treatment facilities, we bring benefits to local communities.



Angola, Benguela Stadium

UAE, Novotel and Ibis Hotel, Abu Dhabi

Ecuador, Panama Primary School. Qatar, CP1 Project.

Indonesia, China-Indonesia Friendship Village.

Libya, Housing Project.

DR of Congo, Kinshasa, Central Hospital.

Algeria, Reinforced Concrete Silos for Cereal Storage.

GENERAL BUILDING

[Commercial Buildings, Offices, Educational Facilities, Stadiums, Hospitals, Hotels, Apartments]

SINOHYDRO contributes in major urban development projects including residential houses, hospitals, schools, stadiums and other public facilities. Providing responsiveness and efficiency to meet even the most complex requirements, SINOHYDRO delivers improved livelihood for local communities.

SUSTAINABILITY FIRST

Our proven experience in China and around the world is paired with our ongoing commitment to meet contractual deadlines, safeguard the environment, and strive for technological innovation.

To be seen as a true leader in our field, we build and protect our reputation for leadership in values and behavior.

We are dedicated to building an increasingly international SINOHYDRO, advancing greener business practices and living in harmony with society.

Safety As A Priority

Zero accident objectives;
Principles and procedures applied to all our companies;
Training employees in safety and first aid;
Insure that all employees are actively involved in making their worksite safer.

Management Approach

Decentralized structure;
Networked collaborative work;
Empowerment of local managers;
Development of local employees;
Responsive organization.

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Around the world, SINOHYDRO has launched numerous initiatives aimed at fostering responsible development, benefiting customers, employees, neighboring residents and society as a whole.

Integrating Local Development with Our Projects

SINOHYDRO participates in local community life wherever it operates by building schools and local hospitals, providing clean water, and promoting local employment.

- Sasumu Dam Project in Kenya supported education programs in four local primary and high schools.

Our Green Action

For each project, we provide an Environment Management Plan (EMP) for issues associated with air pollution control, water/natural resource and habitat protection, site remediation, waste management and biodiversity.

- During the construction of the Merowe Dam in Sudan, SINOHYDRO built an original phyto-filtration system to recover and treat used water in order to avoid the leakage of oil-polluted water into the natural ecosystem.

Dedication To Post-Disaster Reconstruction

SINOHYDRO has dedicated itself to post-disaster reconstruction work, primarily in Africa and Asia.

For each reconstruction project, we provide houses, clinics and sanitary facilities, water and power supplies, and entertainment.

SINOHYDRO's business compliance guidelines define our basic principles with regard to business ethics.

Our Certifications

- ISO 9001
- ISO 14001
- OHSAS 18001

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ENERGY

Cameroon, Memve' Ele Hydropower Station
Dr Congo, Hpp Zongo II
Equatorial Guinea, Djiploho Hydropower Plant
Equatorial Guinea, Extension Of The Electric Network Of Bata City
Ethiopia, Tekeze Hydropower Station
Gabon, Grand Poubara Hydropower Station
Ghana, Bui Hydropower Station
Ivory Coast, Soubre Hydropower Project
Mali, Felou Hydropower Project
Mali, Goulna Hydroelectric Project
Angola,Chiumbe-Dala Hydropower Project
Nigeria, Zungeru Hydropower Plant
Sudan, Merowe Hydropower Project
Sudan, Roseires Dam Heightening Project
Uganda, Karuma Hydropower Project
Zambia,Kafue Gorge Lower Hydropower Project
Zambia, Kariba Hydropower Plant, North Bank Extension
Zimbabwe, Kariba Hydropower Plant, South Bank Extension
Zambia, Itezhi Hydropower Project
Zambia, Kariba North Bank-Kafue West(330Kv)Transmission Line Project
Lesotho, Metolong Dam & Raw Water Pump

Bangladesh, Shikalbaha Peaking Power Plant
Iran, Taleghan Dam
Nepal, Upper Tama Koshi Project
Pakistan, Darawat Dam
Pakistan, Duber Khwar Hydropower Project
Pakistan, Ghazi-Barotha Hydropower Project
Pakistan, Gomal Zam Multipurpose Dam Project
Pakistan, Tarbela Dam 4th Extension
Kazakhstan, Golovnaya Hydropower Project

Mexico,Chicoasen-II Hydropower Project
Bolivia, San José Hydroelectric Project
Costa Rica, Chucas Hydroelectric Project
Ecuador, Coca Codo Sinclair (CCS) Hydropower Station
Honduras, Patuca-3 Hydroelectric Project
Venezuela, ThermoCarabobo II Thermoelectric Plant
Venezuela, Barinas Power Plant and 115/34.5 KV Electrical Substation
Indonesia, Jatigede Hydropower Plant
Indonesia, Pangkalan Susu Unit 3 & 4 Coal Fired Power Plant
Indonesia, PLTU Kaltim Teluk Balik Papan Thermal Power Plant
Indonesia, PLTU Nangroe Aceh Darussalam Thermal Power Plant
Lao PDR: Nam Khan2 Hydropower Project
Lao PDR: Nam Khan3 Hydropower Project
Lao PDR: Nam Ngum 3 Hydroelectric Project
Lao PDR:Don Sahong Hydropower Project
Lao pdr, Hinheup – Luangprabang transmission Line
Malaysia, Murum RCC Dam
Malaysia, Bakun Hydropower Plant
Malaysia, Hulu Terengganu HEP Lot CW2&CW3
Myanmar, Yeywa Hydropower Station
Malaysia, Mukah 132/275KV Power Transmission and Distribution Project
Malaysia, 500KV Backbone Transmission Line Project
Malaysia, Connaught Bridge 384.6MW Combined Cycle Generating Plant Project
Thailand, Chao Phraya Hydropower Station
Thailand, Khlong Tha Dan Dam Project
Vietnam, Song Bung 4 Hydropower Project

Main Project List

TRANSPORTATION

Angola, Luena & Saurino Airports Airfields Rehabilitation
Botswana, Rehabilitation of Kang-Hukuntsi Road
Botswana, Reconstruction of Francistown-Ramokgwebana Road
Botswana, Sir Seretse Khama International Airport
DR of Congo, Rehabilitation of RN1 & RN4
DR Congo, Kinshasa International Airport
Ethiopia, Nazareth-Assela & Nekempt-Mekenajo Road Upgrading
Ethiopia, The Asosa-Kulmok Road
Mauritius, M1 Road
Mali, Modernization and Extension of Bamako-Senou Airport
Mauritania, Mineral Port of Nouadhibou
Morocco, Rabat Highway Bypass Motorway
Morocco, North-south High-speed Rail Line
Kenya, Emali-Oloitokitok Road
Kenya, Upgrading of Nairobi – Thika Road (lot 2)
Tanzania, Puge-Tabora Road
Tanzania, Buzirayombo - Geita – Usagara Road
Tanzania, Singida-Katesh Road upgrading
Tanzania, Tanga-Horohoro Road upgrading

Qatar, New Doha International Airport
Qatar, Doha Expressway (Package 6) East Industrial Road

Bangladesh, Dhaka-Chittagong Highway
Georgia, Construction of Kobuleti Bypass Road
Georgia, Rikoti Tunnel at the E-60 Highway
Kazakhstan, Europe – China International Transit (lot 5)
Kazakhstan, Western Europe -Western China International Transit Corridor
Kyrgyzstan, Renovation of Bishkek – Naryn – Torugart Road
Macedonia, Road Kicevo-Ohrid
Macedonia, Road Miladinovci-Sv.Nikole-Stip
Sri Lanka, the C11 A &B Road
Sri Lanka, Hambantota Port
Tajikistan, Dushanbe-Kyrgyz Border Road Rehabilitation
Tajikistan, Road Construction of Voshy-Hovalin
Uzbekistan, Tashkent International Airport

Bolivia, Ichilo-Ivirgarzama Road
Bolivia, Construction of the Padilla-El Salto Road Project
Ecuador, 10 Roads Updating and Construction Project
Ecuador, Extension of Simon Bolivar Avenue
Venezuela, Highway System of Valles del Tuy

Indonesia, Jakarta - Bandung High Speed Railway Project
Laos-China Railway Project (Boten-Vientiane)Section IV
Cambodia, Sihanoukville, Koh Puos Bridge
Malaysia, Rawang Highway Bypass
Malaysia, Lembah Kelang MRT Project
Singapore, Thomson Line Package T217 & T227
Thailand, Bangkok MRT Blue Line Extension

China, Beijing-Shanghai High Speed Railway
China, Guangzhou Subway
China, Guiyang-Guangzhou Railway
China, Nanning-Guangzhou Railway
China, Ning-Hang High Speed Railway
China, Tianjin Subway
China, Xi'an Subway
China, Shenzhen Subway
China, Wuxi Subway
China, Chengdu Subway

WATER WORKS

Algeria, Bougous Dam
Algeria, Souf Water Supply
Algeria, Mina Irrigation Expansion Project
Angola, Kuito Water Supply Works
Angola, Irrigation Projects
Botswana, Dikgatlhong Dam Irrigation Scheme
Botswana, Lotsane Dam
Mali, Irrigation Scheme (Ala-B03)
Mauritania, Dhar North City Water Supply Project
Kenya, Nzoia Water Supply System

Oman, Muscat Wastewater Scheme Project-Network
Qatar, GTC606 Transmission Pipeline Associated with QEZ Desalination Plant
Qatar, Head Work Construction At West Bay Area, Um Slal and Al Khor Water Station GTC182/2007
Tunisia, Sousse Sewage Treatment Project
Tunisia,Sahline Sewage Treatment Project

Bangladesh, River Training Works, Padma Multipurpose Bridge Project
Nepal, Bagmati Irrigation Project
Nepal, Sikta Irrigation Project
Poland, Wroclaw Floodway System
Sri Lanka, Construction of The Headworks for The Kalu Ganga Reservoir
Sri Lanka, Moragahakanda Reservoir Headworks Project
Uzbekistan,Drainage,Irrigation and Wetlands Improvement Phase-1 Project

Trinidad and Tobago, Malabar Wastewater Treatment Plant and Collection System-Phase 1

Brunei, Ulu Tudong Dam
Indonesia, Jatigede Dam Project
Malaysia, Construction of Pantai 2 Sewage Treatment
Venezuela, Overflow Dam on the Santo Domingo River, Barinas
Vietnam, Phuoc Hoa Irrigation Project

GENERAL BUILDING

Algeria, Silos for Cereal Storage
Algeria, Touggourt Hospital
Algeria, Wilaya d' El Oued Social Housing Program
Angola, Benguela Stadium
Angola, Construction Of Two Agriculture Institutes Huambo And Bie
Angola, Hospital Projects
Dr Of Congo, Kinshasa Place De L' Independence
Dr Of Congo, Kinshasa, Central Hospital
Republic of Congo (Brazzaville), Olympic Village

Kuwait, Sabah Al-Salem University City
Qatar, Lusail Development Project Primary Infrastructure
Qatar, Sidra Village Staff Housing for Sidra Medical & Research Center
Qatar, Kahramaa Awareness Park - GTC 400
Qatar, NPP/0057 – Port Buildings and Infrastructure
Saudia Arabia, Shaybah Support Facilities To Crude Increment (IK)

Tajikistan, Construction of Diar Dushanbe Project-Phase 1

Malaysia, Sarawak Ferroalloy Smelter Plant Project
Malaysia, OM Ferroalloy Project
Malaysia, Xiamen University, Malaysia Campus
Myanmar, Copper Mine Projects

SINOHYDRO
BUILDING A SUSTAINABLE FUTURE

Main Project List

HYDROCHINA CORPORATION

中国电建
POWERCHINA

中国水电工程顾问集团公司
HYDROCHINA CORPORATION

HYDROCHINA CORPORATION
Address: No.2 Beixiaojie Street Liupukang Dewai Beijing 100011 China
Website: www.hydrochina.com.cn

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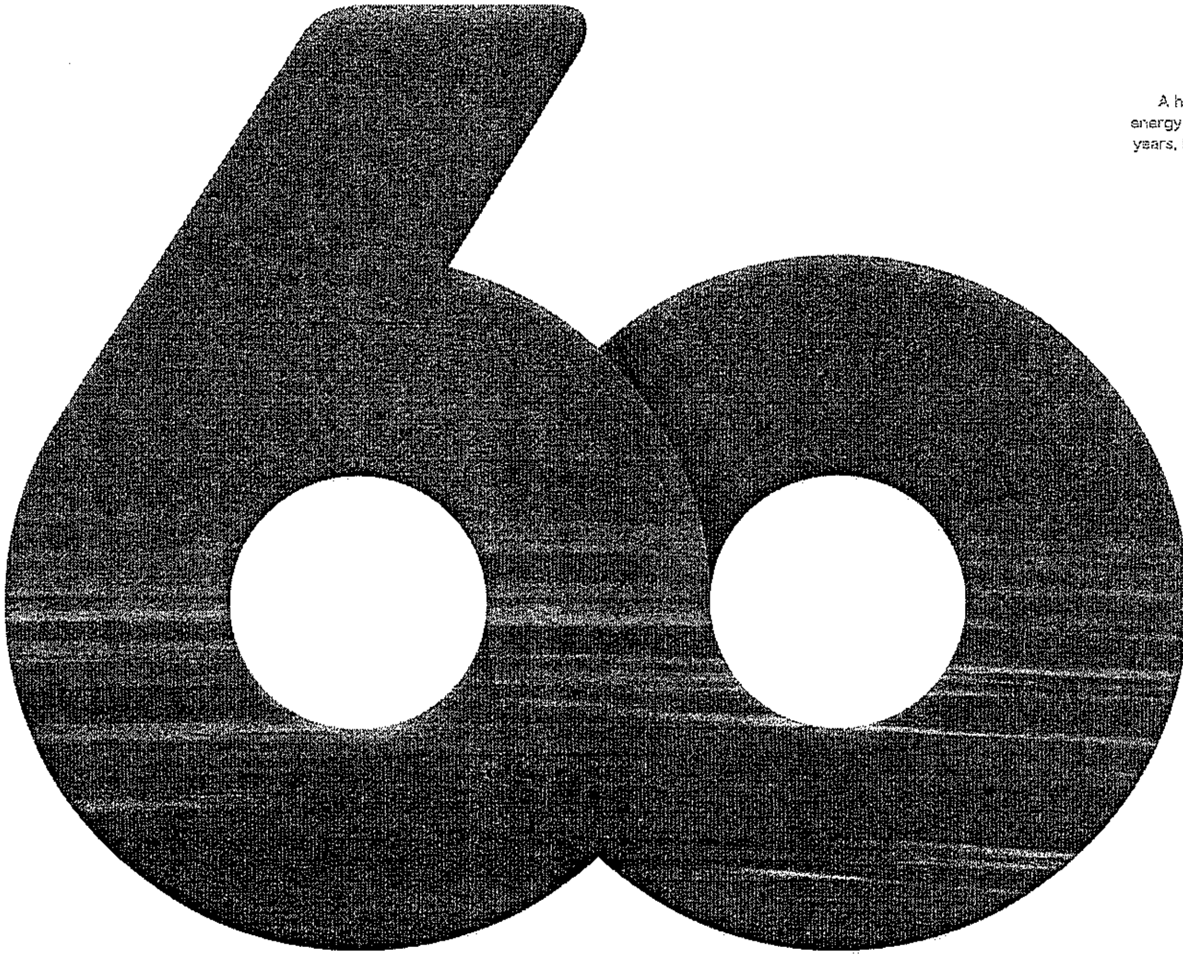
HYDROCHINA CORPORATION



A history of human civilization is accompanied by energy development and utilization. Over the past 60 years, HYDROCHINA focus on providing services for development of clean energy at all times.

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ABOUT US

01 INTRODUCTION

HYDROCHINA CORPORATION, affiliated to POWERCHINA which is one of the world's top 500 enterprises and a comprehensive construction group with diversified industrial structures, is a large consultation enterprise for development of water resource and renewable energy, and serves as an important institution for undertaking and implementation of oversea business in the POWERCHINA group. As an sub-brand of POWERCHINA, HYDROCHINA is focused on providing services in development of hydropower, wind power and solar power, involving resources survey, planning, investigation, design, consultation, financing, procurement, EPC contracting, safety appraisal, construction supervision, construction inspection and final acceptance, and operation maintenance for renewable energy projects, and offers its clients valuable solutions by taking full advantage in advanced technology. Otherwise, on behalf of POWERCHINA, HYDROCHINA expands its business scope to the sectors of transmission and transformation, thermal power, power grid construction, environment protection, municipal construction, port and navigation and oil underground structure.

Over the years, HYDROCHINA has developed three core business sectors, design and consultation, EPC contract and investment, and set up overseas representative offices or branches for providing high quality services abroad. Moreover, it has been always looking on environment protection as important as the corporation' s development, and voluntarily takes developing clean energy and benefiting the whole society as its duty. Sticking to the philosophy "to have our heart with clients, to pursue excellence" , HYDROCHINA, with a positive and aggressive attitude, keeps reaching for a higher level of technology, does its best endeavors to assure the quality of each project and has completed numerous world-famous projects.

Now, HYDROCHINA has ranked No.1 in the 60 China engineering design enterprises ENR, 15th in the Global top 150 engineering design companies and 59th of 225 international engineering design companies.

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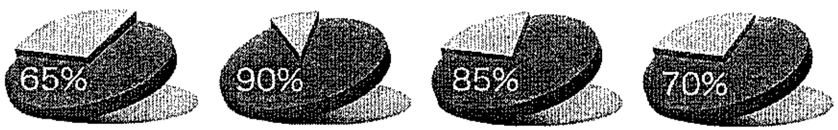
02 MARKET SHARES



HYDROCHINA has completed the investigation and design of hydropower projects with a total installed capacity of 95.24GW, accounting for approximately 65% of that of all hydropower projects completed in China.

HYDROCHINA is implementing the preliminary works for proposed hydropower projects with a total installed capacity of 143.7GW, accounting for approximately 90% of that of all proposed hydropower projects in China

HYDROCHINA has undertaken the investigation and design of hydropower projects under construction with a total installed capacity of 77.345GW, accounting for approximately 85% of that of hydropower projects under construction in China.

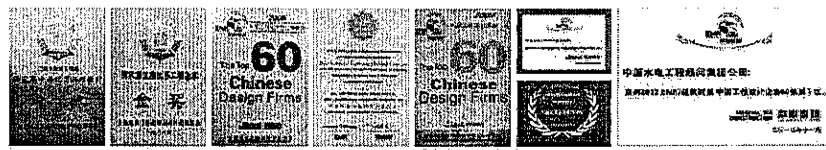
HYDROCHINA has taken as much as 70% of the hydropower project safety appraisal in China.

03 TECHNOLOGICAL INNOVATION

In recent years, HYDROCHINA has undertaken and completed 9 national key science and technology research projects, more than 30 national science and technology research items and 30 power industry key science research and technology items. Moreover, it conducted a series of significant scientific and technical researches, including those key techniques for 300m-class high earth and rock fill dams, offshore wind farms, digitalized power stations and digitalized river basins network, 3D collaborated design for hydropower and wind power projects, new-type construction materials, new-type structures and advanced technique for hydropower construction projects.

04 HONORS

By the end of 2012, HYDROCHINA has been awarded 70 National Science and Technology Progress Prize, including 6 first prizes, 35 second prizes, 29 third prizes; 94 prizes for excellent investigation and design at national level, including 31 gold medals and 35 silver medals; 355 prizes for remarkable science and technology achievement at provincial or ministerial level. At present, it possesses over 500 patents for technology, in which 73 patents are of invention.



05 MAJOR FINANCIAL INDICATORS

HYDROCHINA' s operating income and total assets have grown by 1.98 times and 2.46 times respectively over five years.

MAJOR FINANCIAL INDICATORS OF HYDROCHINA FOR FIVE YEARS

Indicator	2008	2009	2010	2011	2012
Operating Income (100 million USD)	12.61	14.67	17.30	21.05	24.92
Total assets (100 million USD)	21.23	24.34	31.58	37.59	52.22

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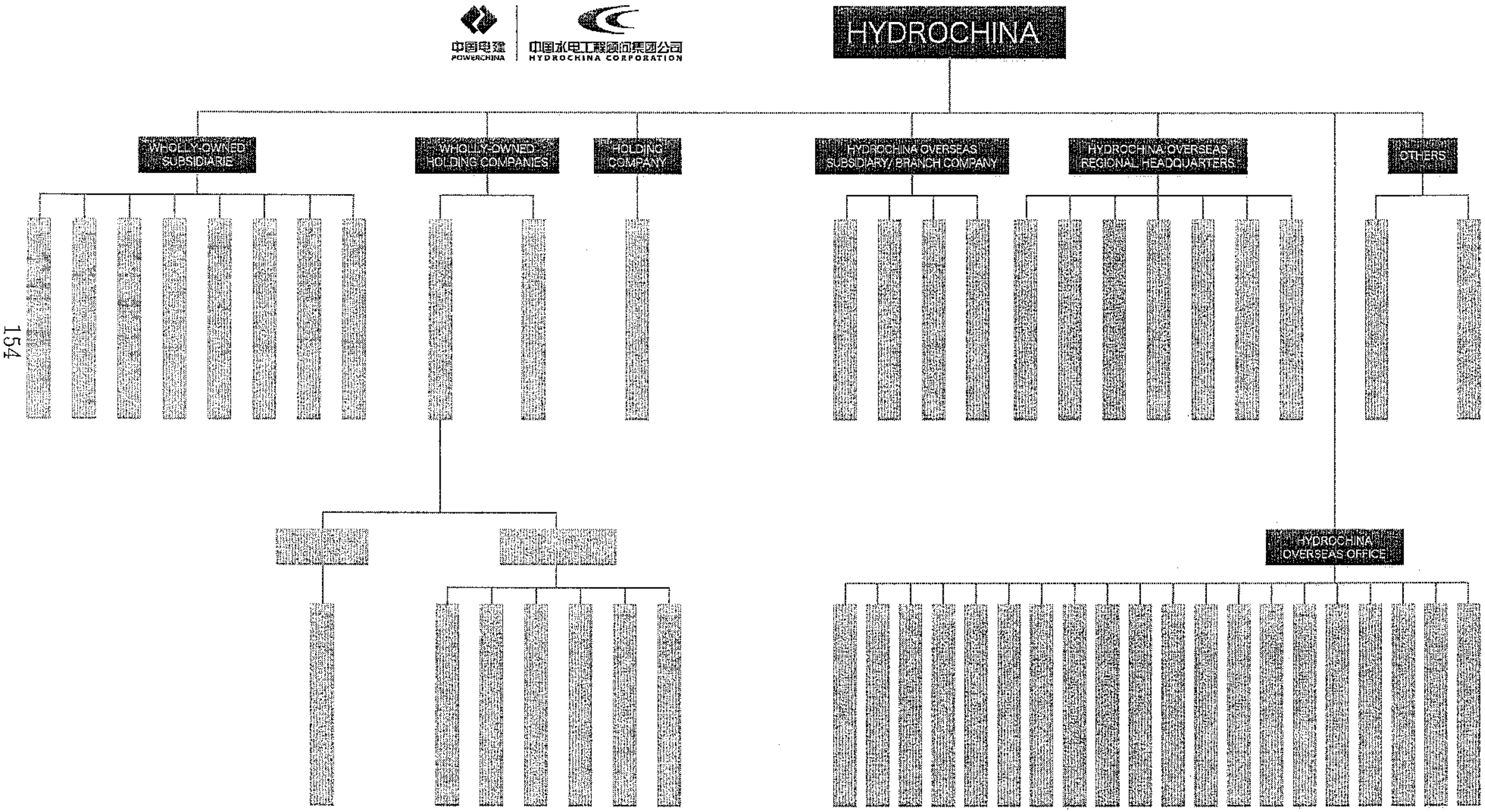
ORGANIZATION



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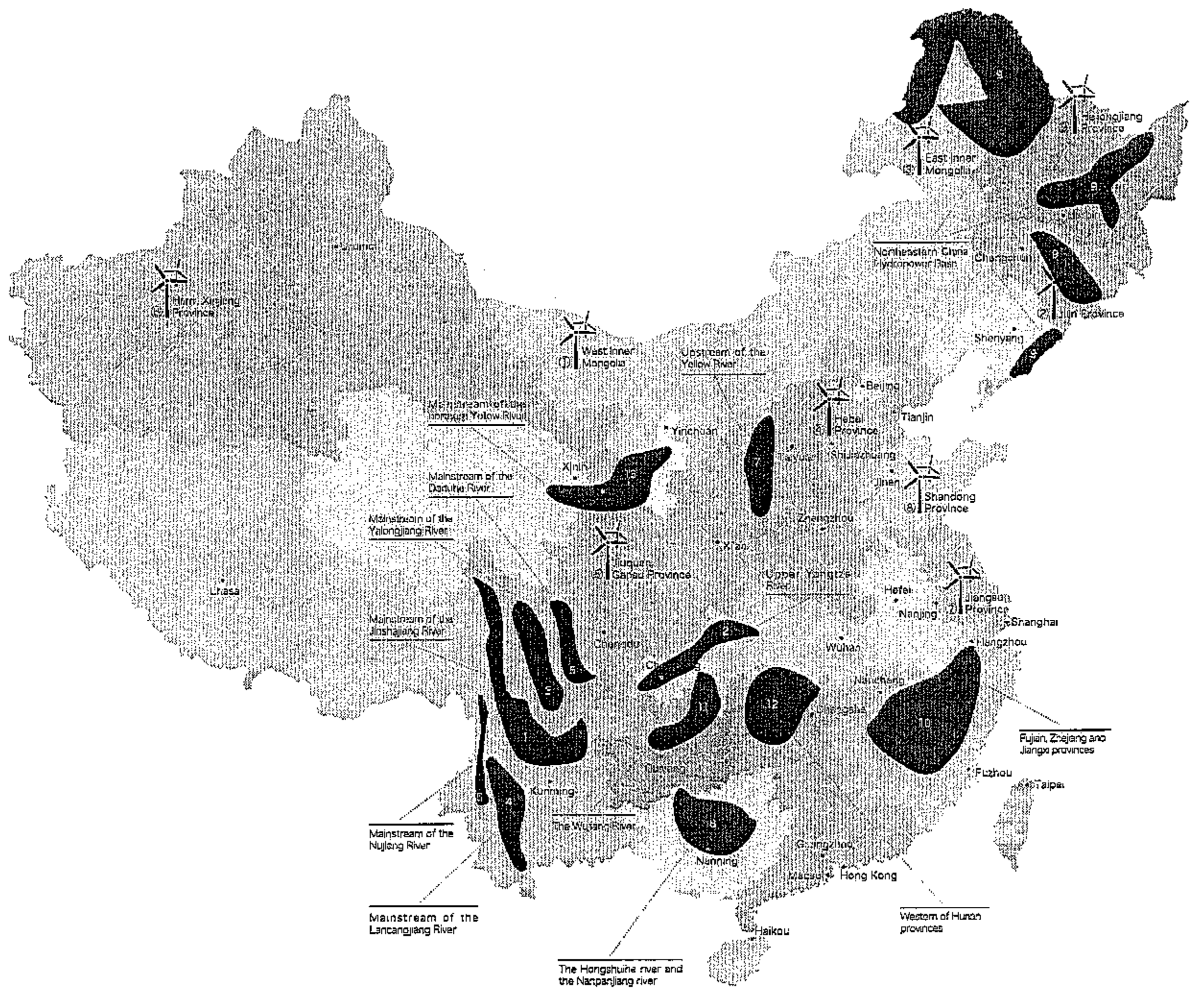
01 HYDROPOWER BASES AND WIND POWER BASES
13 HYDROPOWER BASES

No.	Name	Location / River Section	Installed capacity (MW)	Annual energy output (TW · h)
1	Mainstream of the Jinshajiang River	Shigu to Yibin city	62,560	292
2	Upper Yangtze River	From Yibin city to Yichang city, mainstream of the Qingjiang River	23,840	128
3	Mainstream of the Yalongjiang River	From Lianghekou to Jiangkou	25,700	125
4	Mainstream of the Lancangjiang River	Within Yunnan Province	25,110	140
5	Mainstream of the Daduhe River	From Xia'erge to Tongjiezi	24,920	113.6
6	Mainstream of the Nujiang River	In mainstream of Songta river to the border	21,990	103.7
7	Upstream of the Yellow River	From mainstream of Cina to Qingtongxia	20,930	75
8	The Hongshuihe river and the Nanpanjiang river	From Huangnihe river, Tianshengqiao to Changzhou	14,300	65.5
9	Northeastern China Hydropower Base	in Heilongjiang, Jilin and Liaoning provinces	13,250	35.5
10	The hydropower base of Fujian, Zhejiang and Jiangxi provinces	Rivers in Zhejiang, Jiangxi and Fujian provinces	12,200	31.6
11	The Wujiang River	mainstream + Hongjiadu	11,220	39.6
12	Western Hunan	Xiang river, Zi river, Yuan river, Lishui river and their tributaries	10,810	37.8
13	Mainstream of the northern Yellow River	From Tuoke county to Tongguan	6,430	17.8
	Total		277,960	1203

02 WIND POWER BASES WITH INSTALLED CAPACITY OVER 10GW EACH

No	LOCATION	INSTALLED CAPACITY (MW)	TO BE COMPLETED YEAR
1	West Inner Mongolia	38300	2020
2	Jilin	27290	2020
3	East Inner Mongolia	20000	2020
4	Hebei	14130	2020
5	Jiuquan, Gansu	12710	2020
6	Hami, Xinjiang	10800	2020
7	Jiangsu	10000	2020
8	Shandong	12750	2030
9	Heilongjiang	34180	2030



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03 COMPREHENSIVE PLANNING FOR FLOOD CONTROL AND DROUGHT RELIEF, THAILAND

This is the first large planning and consultation project between both governments, Thailand and China, and is also an important part of reconstruction plan of Thailand government after the severe flood disaster across the country. Since commencing the project in November 2011, it has been paid much attention and the achievement has been fully recognized by the both governments. A project proposal in three phases with fund amounting to US 95 billion dollar has been raised for flood prevention and drought relief.

04 COMPREHENSIVE PLANNING OF MAGDA LENA RIVER, COLUMBIA

This is the first large river planning aided by Chinese government and the project commenced in April, 2011. Meanwhile, HYDROCHINA carried out lots of works including organization, coordination, investigation and technical research for the planning. Over 20 key projects were proposed in four fields including harbor, navigation, environment protection and hydropower development, and a cooperative developing plan was preliminarily determined by both parties. This project became a successful cooperative model in technology between the both governments, Columbia and China, and the recommendation was given for developing Magdalena River

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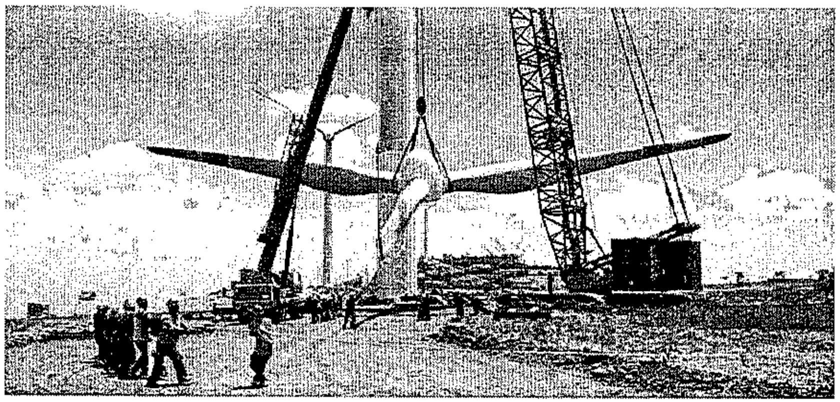
05 WIND POWER AND SOLAR POWER PLANNING IN ETHIOPIA

This is the first new energy planning aided by the Chinese government. Since commenced, the project has drawn much attention between the both governments, Ethiopia and China. 51 wind farm sites (with a total capacity of 6820MW) and 5 solar power sites (with a total capacity of 135MW) were recommended in the planning, the planning will guide the future development of wind power and solar power in Ethiopia.



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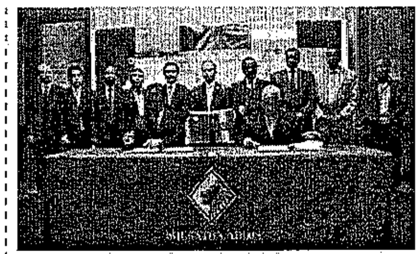
06 HYDROPOWER PLANNING IN GUINEA

This is the first hydropower planning carried out by HYDROCHINA, a Chinese enterprise, for aiding African countries Since November, 2008, the project has been highly valued by the both governments, Guinea and China, and the achievement has been recognized as well. 58 hydropower sites with a total capacity of 3695MW and a total output of 14.37 billion kWh has been recommended in the planning. Presently, the Guinea government has started the construction of hydropower projects based on the planning.

07 HYDROPOWER PLANNING IN SIERRA LEONE

This is other hydropower planning carried out by HYDROCHINA for aiding African countries. Since July, 2009, the project has been highly valued by the both governments, Sierra Leone and China, and the achievement has been recognized. 51 sites of hydropower stations with a total capacity of 1798MW and a total output of 8.454 billion kWh have been recommended in the planning. Presently, the government of Sierra Leone is implementing the projects based on the planning.



08 WATER RESOURCE SURVEY IN ETHIOPIA

This is the first water resource survey project aided by the Chinese government for African countries. Since August, 2012, the project has been highly valued by the governments of both countries. Presently, the information collection, analysis and study are being carried out as planned.

TECHNICAL INNOVATION AND PREPARATION OF INDUSTRIAL TECHNICAL CODES

Based on its rich experiences HYDROCHINA has prepared numbers of industry codes which represents the Chinese construction level and industry authority. it has become an industry leading in China.

HYDROCHINA is backing up and leading the development sectors of water energy and wind energy by proposing relevant policies improving technologies, innovating techniques and enhancing communication with related internal commissions.

01 PREPARATION OF CODES FOR HYDROPOWER INVESTIGATION AND DESIGN

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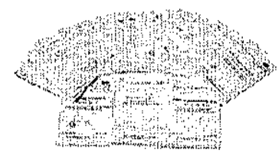
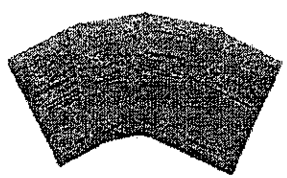
HYDROCHINA has taken the responsibility for preparation of national and industrial codes, and has drafted or revised over 160 codes, covering investigation and design construction, inspection and final acceptance. Meanwhile, it provides technologic support to the development planning of China' s hydropower industry and has made outstanding contribution to China' s hydropower development



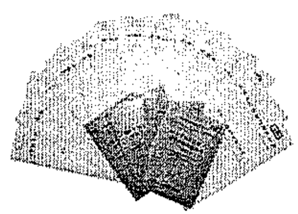


02 PREPARATION OF WIND POWER DESIGN CODES

HYDROCHINA has undertaken technical management of China' s wind power development. It has prepared over 20 technical specifications, standards and provisions regarding wind power. Moreover, it has provided technologic support to the planning of China' s wind power industry and has made outstanding contribution to China' s wind power development.

03 PREPARATION OF SOLAR POWER DESIGN CODES

HYDROCHINA is responsible for technical management, supervision and inspection/ acceptance of China' s solar power projects. In addition, it has instructed to prepare or prepared industrial technical codes for solar power generation, such as Methods of preparing a planning report for a solar power project, and Methods of preparing a feasibility study report for a solar power project, etc.



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01 NATIONAL WIND POWER RESEARCH CENTER

HYDROCHINA has established the national wind power research center to undertake such tasks as planning, policy study, technology improving, personnel training and international exchanges in hydropower and wind power fields and provides services of policy and technology supporting for hydropower and wind power management.

02 NATIONAL ENERGY AND HYDROPOWER ENGINEERING TECHNOLOGY RESEARCH CENTER

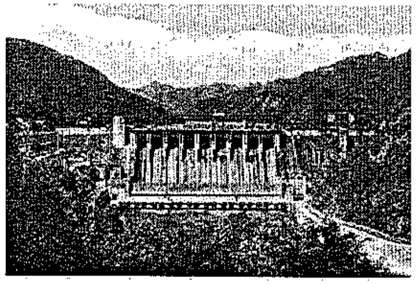
The national energy and hydropower engineering technology research center takes the major responsibility to participate in preparing the development planning of science and technology strategy in hydropower industry, and it also undertakes the research on key technology and significant subjects for national and industrial hydropower projects, in order to promote the conversion of research findings into productive forces and international communication/ cooperation in terms of hydropower development technology.

03 CHINESE ENGINEERING DIGITALIZING INNOVATION CENTER

The Chinese engineering digitalizing innovation center devotes itself to develop world-advanced-level digitalized solutions. Based on HYDROCHINA' s technologic advantages, the center aims to technologic progress in new energy industry by aid of advanced three-dimension experience technology of Dassault system and industrial strategy.

04 TECHNICAL TRAINING AND CIVIL ENGINEERING TESTING CENTER IN LAOS

The Laos technical training and civil engineering testing center is established to meet the demand of training persons in engineering technology and management in Lao and is a proper platform for HYDROCHINA to develop Lao markets



01 XINANJIANG HYDROPOWER STATION

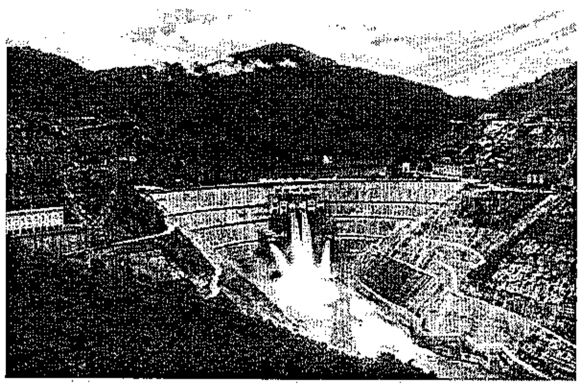
The station, with total installed capacity 662.5MW, total reservoir storage of 17840 million m³ and average annual power generation 1960GWh, is located in Zhejiang province. The reservoir has become a famous national scenic area.

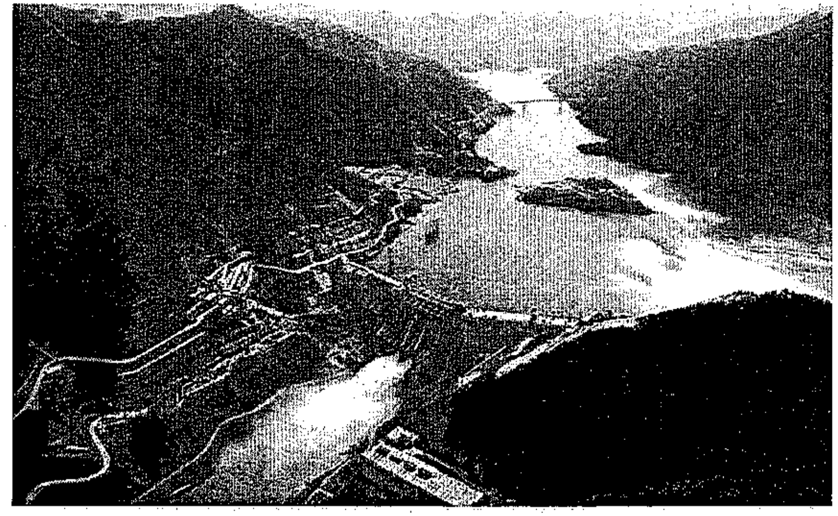
02 JINPING I HYDROPOWER STATION

The station, with total installed capacity 3600MW, total reservoir storage of 7760 million m³ and average annual power generation 16620GWh, is located on the lower reach of Yalongjiang river in Sichuan province. Its double curvature arch dam with a maximum height of 305m ranks No.1 among the similar projects under construction in the world.

03 XIAOWAN HYDROPOWER STATION

The station, with total installed capacity 4200MW, total reservoir storage of 15040 million m³ and average annual power generation 19000GWh, is located on middle reach of Lancangjiang river, Dali, Yunnan province. Its double curvature arch dam with a maximum height of 295m ranks No.1 among the similar projects completed in the world.





04 LONGTAN HYDROPOWER STATION

The station, with total installed capacity 6300MW, total reservoir storage of 27300 million m³ and average annual power generation 18710GWh, is located on upper reach of Hongshuihe river, Guangxi Autonomous Region. Its RCC gravity dam with a maximum height of 216.5m ranks No.1 in the world among the similar projects completed.

05 ERTAN HYDROPOWER STATION

The station, with total installed capacity 3300MW, total reservoir storage of 5800 million m³ and average annual power generation 17000GWh, is located on lower reach of Yalongjiang river, Sichuan province. Its double curvature arch dam with a maximum height of 240m ranks No.1 in the world among the similar projects completed, which can withstand the total load of 9.8 million tons.

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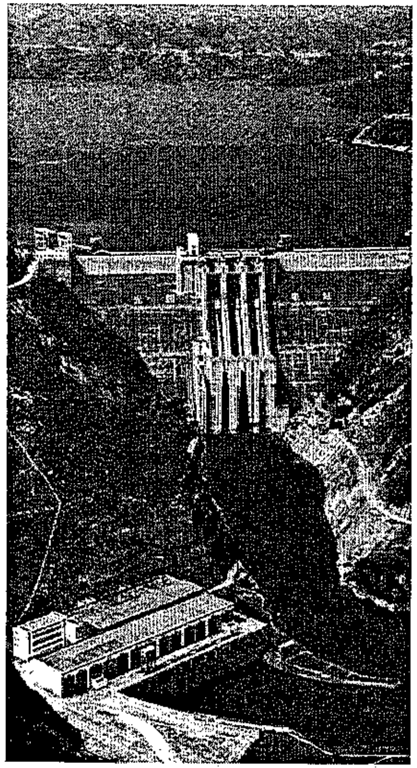


06 GUANZHAO HYDROPOWER STATION

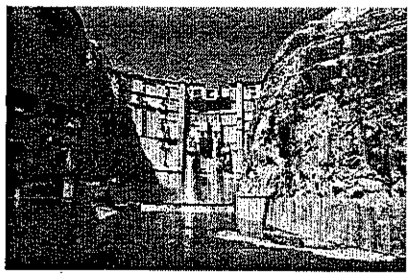
The station with total installed capacity 1040MW, total reservoir storage of 3245 million m³ and average annual power generation 2754GWh, is located on middle reach of Beipanjiang river, Guizhou province. Its RCC gravity dam with a maximum height of 200.5m ranks No.2 in the world among the similar projects completed

07 NUOZHADU HYDROPOWER STATION

The station, with total installed capacity 5850MW, total reservoir storage of 23703 million m³ and average annual power generation 23912GWh, is located on middle-lower reach of Lancangjiang river Simao, Yunnan province. Its rockfill dam with a maximum height of 261.5m ranks No.3 in the world and No.1 in China among the similar projects completed.

08 LAXIWA HYDROPOWER STATION

The station, with total installed capacity 4200MW, total reservoir storage of 1079 million m³ and average annual power generation 10223GWh, is located on the main stream of Yellow river, Qinghai province. Its double curvature arch dam with a maximum height of 250m ranks No.2 in the world among the similar projects completed.

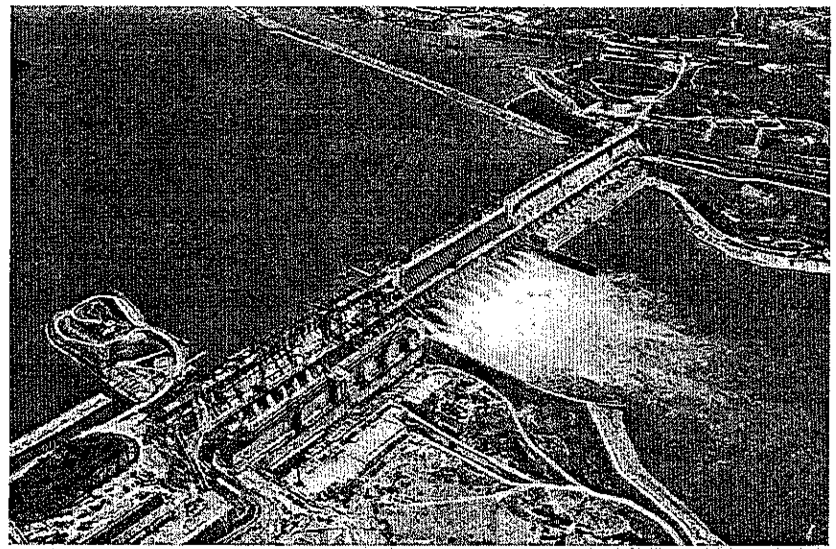


09 TIANHUANGPING PUMPED STORAGE POWER STATION

The station, with total installed capacity 1800MW, annual power generation 3.014 billion kWh and annual power consumption for pumping 4.104 billion kWh, is located in Anji county, Zhejiang province. The station is the largest in Asia and the second largest in the world, with the highest water head of 607 m in the world.

10 SHISANLING PUMPED STORAGE POWER STATION

The station, with total installed capacity 800MW, annual power generation 1.2 billion kWh and annual power consumption for pumping 1.669 billion kWh, is located in the scenic area of the Ming tombs in Beijing and serves the functions of peaking and emergency for the power grid to improve the quality of supply power in the Capital.



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No. 11 BUI HYDROPOWER STATION, GHANA

This station is located in west Ghana, mainly for power generation and subordinately for irrigation. The project has a total installed capacity of 400MW and an annual output of 1000 GWh, the first unit put into operation in May, 2012. This is the second largest power station in Ghana and has become one of the main sources for Ghana' s power supply.

No. 12 PUNGLUNG HYDROPOWER STATION, MYANMAR

Punglung hydropower station is located on Punglung river, in Pyinmana, Myanmar. The station is a dam type development and its features are as follows: total reservoir storage capacity of 850 million m^3, total installed capacity of 280 MW with unit capacity of 70MW each, annual energy output 911 GWh and rockfill dam with core of 130m height.

No. 13 BAKUN HYDROPOWER STATION, MALAYSIA

The station with total installed capacity 2400MW, annual output 17000GWh and the total reservoir storage capacity 44 billion m^3, is located in the center part of Sarawak, Malaysia. The dam is a concrete facing rockfill one with the maximum height of 205m, ranking No.2 among the same type in the world. This is the largest hydropower station completed in Southeast Asia.

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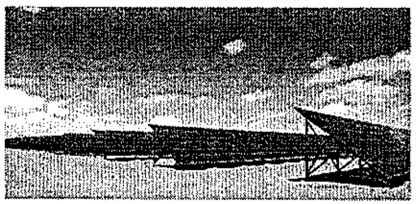


No. 14 10MWP DUNHUANG ON-GRID PV POWER STATION

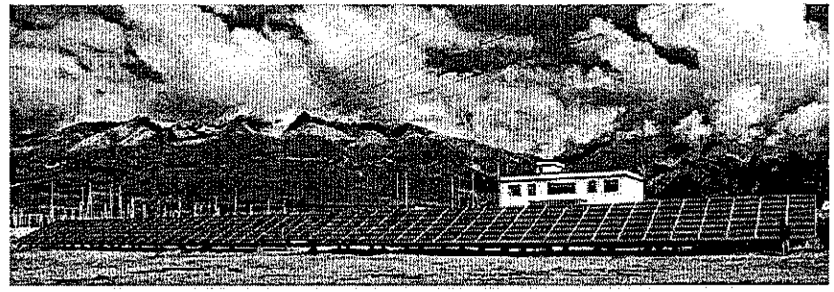
The station is located in the southwest of Dunhuang, Gansu Province. It is the first project connected to grid with a concession and also a demonstration one. The 1MWp solar cell array was connected to the grid in December, 2009, and the whole project was completed and put into operation in December, 2010.

No. 15 SHWELI I HYDROPOWER STATION, MYANMAR

Shweli I hydropower station is a diversion conduit type development, with daily regulation capacity. The features of station are as follows: total reservoir storage capacity of 24.11 million m^3, regulation storage capacity of 4.46 million m^3, installed capacity of 600mW and annual energy output of 4033GWh.

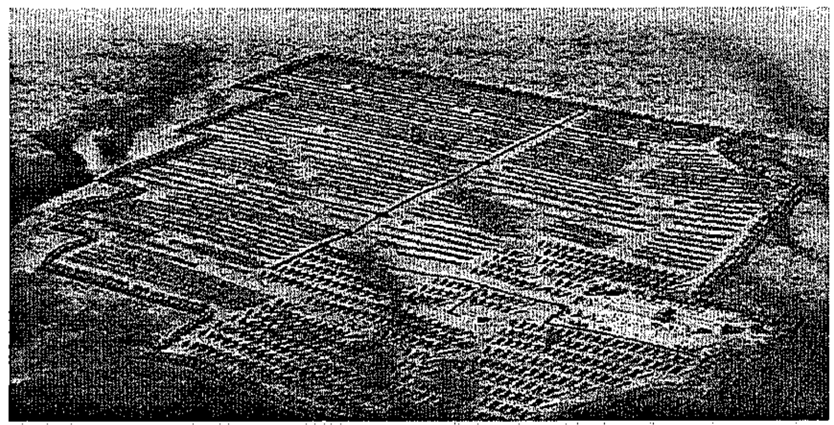
No. 16 100KWP YANGBAJING ON-GRID PV POWER STATION

The station, located in Yangbajin, Tibet, is the first PV power station connected to a HV-grid in China, with total installed capacity 100kWp. The project put into operation at the end of August, 2005.



No. 17 10MWP QINGTANGXIA ON-GRID PV POWER STATION

The on grid station with a capacity of 10MWp is located in Qingtangxia, Ningxia autonomous region. The project was completed and put into operation in 2010



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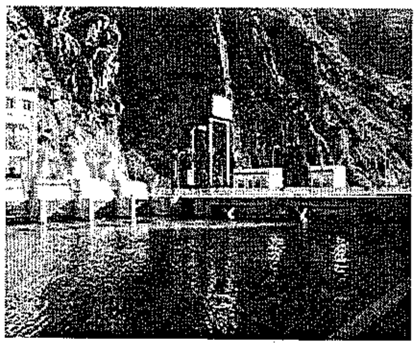
INVESTMENT + OPERATION MAINTENANCE

HYDROCHINA seeks to push forward EPC contracting business with advanced technologies. By 2013, HYDROCHINA holds equity of hydropower projects at different development stages with a total capacity of 5941 MW and shares of water treatment projects with a capacity of 0.50 million ton/day. In 2012, the business revenue of RMB 1160 million yuan is achieved in the investment sector

01 JIUZHAIGOU CASCADE HYDROPOWER STATIONS

The project is located on Baishui river, in Aba, Sichuan province, and composed of 7 hydropower stations, with the total installed capacity of 566.8 MW.



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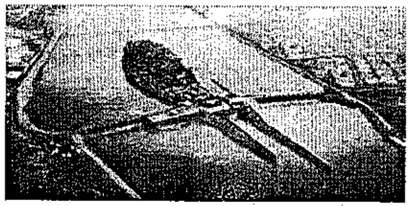
02 LIUHONG HYDROPOWER STATION

The station, with total installed capacity 180MW and average annual power generation 911 GWh is located on Meigu river Meigu County, Sichuan Province. The project commenced in 2004 and put into operation in 2007.

03 PINGTOU HYDROPOWER STATION

The station is located on Meigu river Liangshan, Sichuan Province, which is a diversion type hydropower station. The station has a total installed capacity of 180MW with 3 Francis turbine units

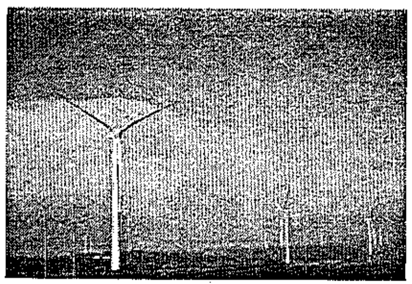


04 TAOYUAN HYDROPOWER STATION

The station, with total installed capacity 180MW and average annual capacity 793 GWh, is located in the mainstream of Yuan river in Changde city, Hunan province The project commenced in 2010, and the first unit was put into operation in March 2013.

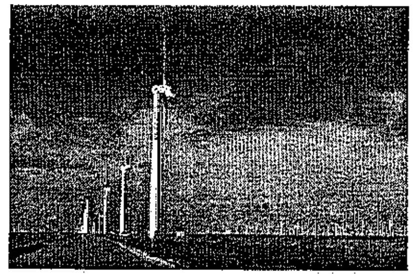
05 BATOU I WIND FARM

The project is located in Zhangbei County Habei province, which is the first wholly owned wind farm for HYDROCHINA. 67 WTGS are installed there and the installed capacity is 99.5 MW with unit capacity of 1.5MW each, and the total construction duration is 20 monthes.



06 BEIDAQIAO WIND FARM

The wind farm is located 18km northwest of Guazhou town, Gansu province. The 134 WTGS with unit capacity of 1.5MW each, are installed there, with total installed capacity 201MW. The project commenced in October 2009, WTGS erection started in May, 2010, and the whole project was put into operation at the end of 2010. This project is a demonstration one for 10 GW wind power bases in China.



07 DAWOOD WIND FARM, IN PAKISTAN

The wind farm to be constructed, with a total installed capacity of 49.5MW, is located at a wind power base near Karachi, Sindh province, Pakistan

08 HUAXIYUNDING WIND FARM

The wind farm is located in Guiyang city, Guizhou province. The project was constructed in two stages, and the first stage with the installed capacity of 49.5MW was put into operation at the end of 2012.

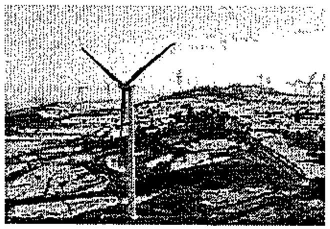
09 LONGTANGSHAN WIND FARM

The wind farm is located in Huishui county, Guizhou province. The project was constructed in two stages, and the first stage with the installed capacity of 49.5MW was put into operation at the end of 2012. 33WTGS installed there.

10 LIZIJING WIND FARM

The wind farm, with total installed capacity of 16.8MW and unit capacity of 1500 kW each, is located in Luxi County, Yunnan province. The wind farm is constructed in four stages, with 33 WTGS 27 WTGS, 21 WTGS and 33 WTGS installed, respectively. The four projects have put into operation in November 2011, December 2011, March 2012 and November 2012.

01 ADAMA I WIND FARM IN ETHIOPIA



The wind farm, with total installed capacity is 51MW, is located at Adama, 95km south of Addis Ababa, the capital of Ethiopia. The financing agreement for the project came into effect in May, 2011, commenced in June, 2011 and the first unit put into operation in March, 2012. The project has handover smoothly and the operation maintenance has been implemented. This wind farm is the first EPC project undertaken by HYDROCHINA abroad, which is constructed with Chinese codes, technology and financing. As the leading party of the EPC contractor, HYDROCHINA has undertaken such work as design, construction, procurement and 5-year operation maintenance. The project is a demonstration of new energy development in international contracting market.

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02 ADAMA II WIND FARM IN ETHIOPIA

The project with a total installed capacity 153MW is financed by a Chinese bank and constructed by HYDROCHINA. The project commenced in June 2013 and all works are undergoing based on the construction schedule.

03 SAPPHIRE WIND FARM, PAKISTAN

The project is located in Sindh province, Pakistan, with total installed capacity of 49.5 MW and 33 WTGS of GE82/1500.

04 SAPPHIRE WIND FARM, PAKISTAN

The project is located in Karachi, Pakistan, and has a total installed capacity of 30 MW and 12 WTGS with unit capacity of 2.5MW each.

05 SACHAL WIND FARM, PAKISTAN

The project is located in Sindh province, Pakistan, and has a total installed capacity of 50 MW and 33 WTGS with unit capacity of 1.5MW each.

06 FLOOD CONTROL PROJECT, THAILAND

The project for design and construction of infrastructure for sustainable water resources management and flood prevention for the Kingdom of Thailand is a competitive international bidding project owned by the Thai Government. The China-Thailand joint venture (HYDROCHINA is a main party) has obtained 5 lots with contract amount USD 3.6 billion yuan.

07 MOINAK HYDROPOWER STATION, KAZAKHSTAN

The station is located in Kazakhstan, with installed capacity of 353 MW, annual energy output of 1027 GWh and 94 m earth-rock fill dm. The project commenced in 2008 and completed at the end of December, 2011.

08 SAN PABLO HYDROPOWER PROJECT, COSTA RICA

The project is located in Alajuela, Costa Rica, with installed capacity of 50 MW, two Francis turbines with unit capacity of 25 MW each are adopted.

09 NAMARESTAGH HYDROPOWER STATION, IRAN

The project is located in Mazandaran, Iran, with installed capacity of 12.6 MW and annual energy output of 70GWh.

10 DELSI-TANISAGUA HYDROPOWER STATION, ECUADOR

This station is located on the bordering area between Loja and ZAMORA provinces, Ecuador. This is a diversion type hydropower station with a total installed capacity of 115.532MW (two sets of impulse turbine generation units). The maximum water head is 524m, and the average annual output 887 GWh. The main structures comprise of a concrete gravity dam, a diversion channel (7.63km) and a ground powerhouse. The concrete gravity dam is 24m high with dam axis 95m long. The project commenced on November 28, 2011, and complementary exploration finished, and the diversion system is under construction.

11 SHIYAZI HYDROPOWER STATION

Shiyazi hydropower station, with total installed capacity 140MW, reservoir regulating storage capacity 156.4 million m³ and average annual power generation 453 GWh, is located in Wuchuan County, Guizhou province. The project commenced in June, 2007 and the reservoir storage reached the normal level by June, 2011. The retaining dam is a RCC gravity one.

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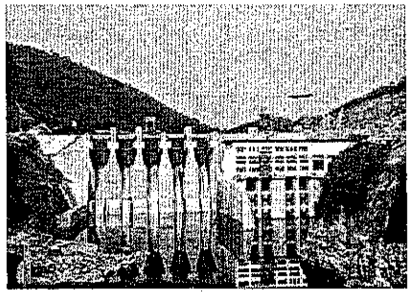
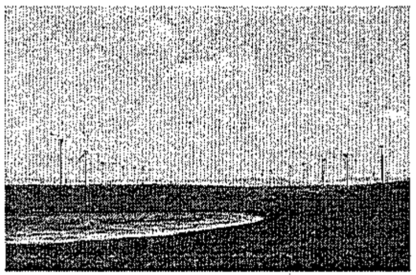
12 YOUCHOU HYDROPOWER STATION

The station is located in Youyang County, Chongqing, with total installed capacity 120MW, total reservoir storage capacity 152 million m³ and annual power generation 392 GWh. The main structures of project commenced in 2006 and the first unit was put into operation in 2008.



13 HUITENGLIANG WIND FARM

The wind farm is located in Xilin Gol League, Inner Mongolia. The total installed capacity is 300MW, contributed by 200 WTGS with a capacity of 1500 kW each. The project commenced in May, 2007 and put into operation at the end of 2008.



14 DUNHUANG II PV POWER STATION

This project, with a total construction area of about 0.5 km² is located in Tun Huang photoelectric industrial park. The master plan is being prepared for the project. Tun-Huang Energy Authority has entrusted HYDROCHINA to undertake design, construction, operation and management of the project. The project was put into operation in 2013.

15 MAONIUPING WIND FARM

The wind farm is located in Lijiang city, Yunnan province. The first stage project has an installed capacity of 49.5MW, contributed by 33 WTGS with unit capacity of 1500kW each, and annual design power generation is 118GWh.

16 DALONGKOU WIND FARM

The wind farm is located in Yao-an County, Yunnan province. The total installed capacity is 139.5 MW and annual power generation is about 308 GWh.

17 HAIXI BUILDING INTEGRATED PV

This project, solar energy photovoltaic array (3087m²) with annual power output of 249MWh, is located in Delingha City, Qinghai Province. The project was put into operation in October 2009. It serves as the reduction of 30% of center building's energy consumption, and has greatly promoted energy saving and gas emission reduction.

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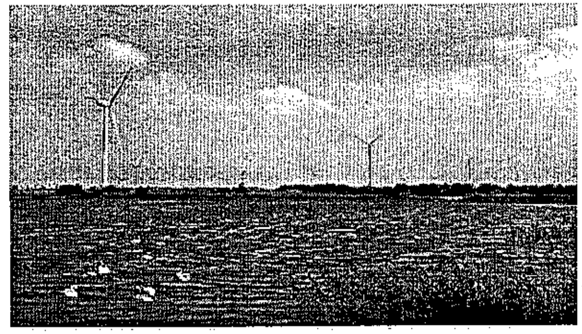
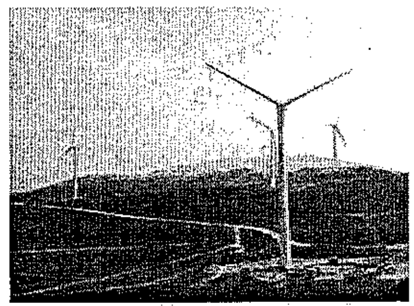
18 DONGLING I WIND FARM

The wind farm is located in Rudong County, Jiangsu province. The total installed capacity is 70.5MW, contributed by 47 WTGS with unit capacity of 1500kW each. The project commenced in July, 2008 and put into operation at the end of 2009.



19 SHENCHI WIND FARM

The wind farm is located in Shenchi County, Shanxi province. The total installed capacity is 48MW, contributed by 24 WTGS with unit capacity of 2MW each. The project commenced in 2007 and put into operation in 2008.



20 LUHEJIN I WIND FARM

The wind farm is located in Chenzhou, Hunan province. The total installed capacity is 48MW, contributed by 24 WTGS with unit capacity of 2MW each.

21 HAMI PV POWER STATION

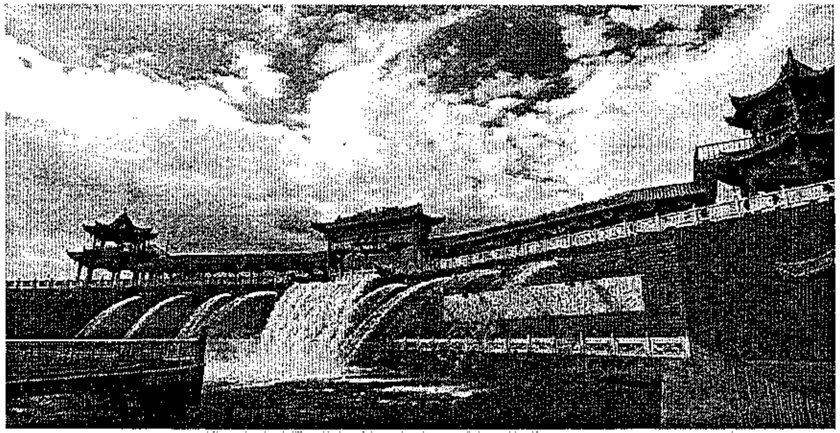
This station is located in Hami City, Xinjiang autonomous region, with a capacity of 20MW. The project consists of 86480 pieces of polycrystalline silicon cell modules (235W/pcs.), cell array consists of 20 sub-arrays (1MW/pcs) a total of 40 inverts (500kW/set) are used, annual average on-grid energy during operation period is 31.26GWh. The project was put into operation in 2013.

22 WULAN PV POWER STATION

The project is located 10km from Wulan, Qinghai Province, the first EPC PV project undertaken by HYDROCHINA. A total of 22 arrays (0.94MWp) are applied, each solar cell array consists of two 500kW inverters and one 1000kVA/35kV prefabricated substation' a total of 5(or 6) 35kV prefabricated substations are connected parallel at HV side into one united incoming unit, a total of 4 united incoming units are connected to 35kV single busbar, one circuit of 35kV outgoing line is connected to 110kV Baizhuang substation at 35kV side. The project was put into operation in November 2011

DIVERSIFICATION

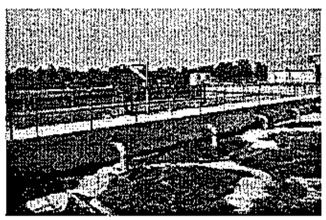
HYDROCHINA takes full advantages of polices and date on application of water resources and seizes the opportunities in infrastructures construction industry, such as architectural, municipal and road projects so as to form a pattern of diversification and differentiation.



01 KARAMAY DIVERSION PROJECT , XINJIANG AUTONOMOUS REGION

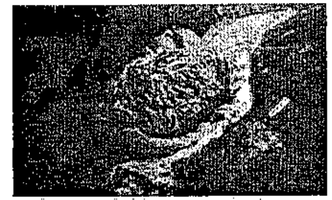
This project begins at the upper reach of the mainstream of Ergis River and stops in Karamay Reservoir 463m long in total. This project goes across Karamay City and forms an 8.5km artificial channel. The main works completed in September, 2000 and the project can add water supply of 400 million m³ per year to Karamay.

02 WENJIANG SEWAGE TREATMENT PLANT, SICHUAN PROVINCE



The plant, with daily sewage treatment capacity 40 thousand tons, is located in Wenjiang, Chengdu, Sichuan province. It is a BOT project combining construction, operation and management for water treatment. The project commenced in 2006, and was completed and put into operation in December, 2007.

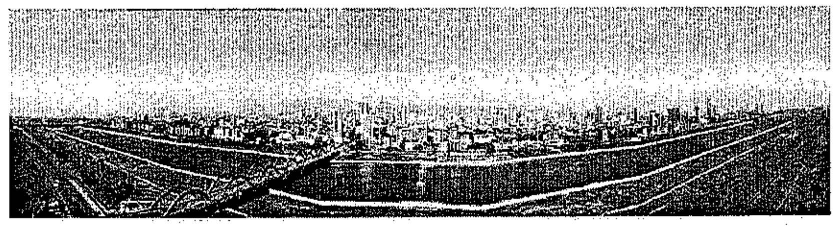
03 TREATMENT OF TANGJIASHAN DAMMED LAKE



The dammed lake, formed after the violent earthquake in May 12, 2008, is located at Tongkou River, Beichuan County, Sichuan Province. The lake has the storage of 246.6 million m³. After discharging the lake water, 2008, the threat to people living downstream was successfully eliminated. Meanwhile, reconstruction commenced in November, 2008, and completed in May, 2009.

04 ENVIRONMENTAL IMPROVEMENT AND TRAINING OF CHANNEL FOR FENHE RIVER

The project is situated in urban of Taiyuan city with a length of 6750m. The purpose of this project is to train the river channel along urban section of Fenhe river as well as improvement of eco-environment there. The project has won UN "Dubai Prize" and "Prize for Model Residential Environments of China" by the Ministry of Construction of China in 2001.



05 JIANGXIA BIDIRECTIONAL TIDAL POWER STATION

The station, with total installed capacity of 3MW and total reservoir storage capacity 4.9 million m³, is located at the Port Jiangxia, Wenling, Zhejiang province. The maximum tidal head is 8.39m and the average tidal head is 5.08m. The first unit was put into operation in May, 1980. This is the first bidirectional tidal power station in China, and can operate 14-15hours one day with output 30-40% more than that of unidirectional tidal stations.

06 LIUHENG ISLAND DESALINATION PROJECT WITH CAPACITY OF 100 THOUSAND TONS

The project is located on Liuheng Island, Zhoushan, Zhejiang province and the reverse osmosis process is applied there. The phase I of project was completed and put into operation in 2010. The capacity of sea water desalination will reach 100 thousand tons per day after completion of the whole project. As the largest desalination project in China, it is also taken as a national demonstration project.

PROJECTS UNDERTAKEN BY HYDROCHINA

No	Name	Country/Location	Installed capacity (MW)	Development status	Execution mode
1	Planning for 13 hydropower bases	China	277960	completed	Planning
2	Planning for 9 wind power bases	China	79000	completed	Planning
3	Comprehensive planning for flood control and drought relief	Thailand		completed	Planning
4	Comprehensive planning of Magdalena River	Columbia		completed	Planning
5	Water resources surveying	Ethiopia		completed	Surveying
6	Hydropower resources surveying	Guinea	6000	completed	Planning
7	Hydropower planning	Sierra Leone	1626	completed	Planning
8	Hydropower planning on Nan Pradesh and Nan Dan Patrick	Myanmar	765	completed	Planning
9	Planning for hydropower and wind power	Ethiopia	6965	completed	Planning
10	Xinanjiang hydropower station	Zhejiang, China	662.5	completed	Investigation & design
11	Jinping I hydropower station	Sichuan, China	3600	Under construction	Investigation & design
12	Xiaowan hydropower station	Yunnan, China	4200	Under construction	Investigation & design
13	Longtan hydropower station	Guangxi, China	6300	completed	Investigation & design
14	Guangzhao hydropower station	Guizhou, China	1040	completed	Investigation & design
15	Ertan hydropower station	Sichuan, China	3300	completed	Investigation & design
16	Nuozhadu hydropower station	Yunnan, China	5850	Under construction	Investigation & design
17	Laxiwa hydropower station	Qinghai, China	4200	Under construction	Investigation & design
18	Tianhuangping pumped storage power station	Zhejiang, China	1800	completed	Investigation & design
19	Shisanling pumped storage power station	Beijing, China	800	completed	Investigation & design
20	Bui hydropower station	Ghana	400	completed	Investigation & design
21	Bakun hydropower station	Malaysia	2400	completed	Investigation & design
22	Lungbung hydropower station	Myanmar	280	completed	Investigation & design
23	Shweli I hydropower station	Myanmar	1000	completed	Investigation & design
24	Pubugou hydropower station	Sichuan, China	3600	Under construction	Investigation & design
25	Maerdang hydropower station	Qinghai, China	1500	Under construction	Investigation & design
26	Tianwan hydropower station	Sichuan, China	760	completed	Investigation & design
27	Yangcajing on-grid PV power station	Tibet, China	100	completed	Investigation & design
28	Dunhuang on-grid PV power station	Gansu, China	10	completed	Investigation & design
29	Qingtongxia on-grid PV power station	Ningxia, China	10	completed	Investigation & design
30	Delingha PV power station	Qinghai, China	10	completed	Investigation & design
31	Ge-ermu I PV power station	Qinghai, China	50	completed	Investigation & design
32	Jiuzhaigou cascade hydropower stations	Sichuan, China	556.8	completed	Investment + EPC+ O&M
33	Liuhong hydropower station	Sichuan, China	180	completed	Investment + EPC+ O&M
34	Pingtou hydropower station	Sichuan, China	180	completed	Investment+ EPC+ O&M
35	Taoyuan hydropower station	Hunan, China	180	completed	Investment+ EPC+ O&M
36	Zhangbei I wind farm	Hebei, China	99	completed	Investment+ EPC+ O&M
37	Zhangbei II wind farm	Hebei, China	100.5	completed	Investment+ EPC+ O&M
38	Beidaqiao wind farm	Gansu, China	201	completed	Investment+ EPC+ O&M
39	Laijing wind farm	Yunnan, China	171	completed	Investment+ EPC+ O&M
40	Dawood wind farm	Pakistan	49.5	preparing	Investment+ EPC+ O&M
41	Huaxi Yunding wind farm	Guizhou, China	79.5	Under construction	Investment+ EPC+ O&M
42	Longtangshan wind farm	Guizhou, China	99	Under construction	Investment+ EPC+ O&M
43	Anninghe I wind farm	Sichuan, China	16	completed	Investment+ EPC+ O&M
44	Heihetang Hydropower Station	Sichuan, China	88	completed	Investment+ EPC+ O&M
45	WANAO Hydropower Station	Sichuan, China	33	completed	Investment+ EPC+ O&M
46	DUONUO Hydropower Station	Sichuan, China	100	completed	Investment+ EPC+ O&M
47	QINGLONG Hydropower Station	Sichuan, China	102	completed	Investment+ EPC+ O&M
48	SHUANGHE Hydropower Station	Sichuan, China	81	completed	Investment+ EPC+ O&M
49	Adama I Wind Power Project	Ethiopia	51	completed	FEPC+ O&M
50	Adama II Wind Power Project	Ethiopia	153	Under construction	FEPC+O&M
51	Sapphire Wind Power Project	Pakistan	50	preparing	EPC+ O&M
52	Tapal Wind power Project	Pakistan	30	preparing	EPC+ O&M
53	Sachal wind farm	Pakistan	50	preparing	EPC+ O&M
54	Flood prevention project	Thailand		preparing	EPC
55	Namaresmgh hydropower station	Iran	12.6	preparing	EPC
56	Moinak hydropower station	Kazakhstan	553	completed	EPC
57	Dalsi Hydropower Plant Project	Ecuador	115.4	Under construction	EPC
58	Youchou Hydropower Plant Project	Chongqing, China	120	completed	EPC
59	Malutang II hydropower station	Yunnan, China	240	completed	EPC
60	Tiechuanqiao Hydropower station	Yunnan, China	42	completed	EPC
61	Shenxigou hydropower station	Sichuan, China	733.2	completed	EPC
62	Shitang Hydropower station	Zhejiang, China	78	completed	EPC
63	San Pablo hydropower project	Costa Rica	50	preparing	EPC
64	Shuyazi hydropower station	Guizhou, China	140	completed	EPC
65	Maoniuping wind farm	Yunnan, China	49.5	completed	EPC
66	Langmushan wind farm	Yunnan, China	49.5	Under construction	EPC
67	Dalongkou wind farm	Yunnan, China	139.5	Under construction	EPC
68	Huitengliang wind farm	Inner Mongolia, China	300	completed	EPC
69	Tangling I wind farm	Jiangsu, China	70.5	completed	EPC
70	Shenchi wind farm	Shanxi, China	48	completed	EPC
71	Luhejin wind farm	Hunan, China	48	completed	EPC
72	Haixi Building Integrated PV	Qinghai, China	0.18	completed	EPC
73	Dunhuang I on-grid PV power station	Gansu, China	10	completed	EPC
74	Dunhuang II on-grid PV power station	Gansu, China	30	Under construction	EPC
75	Hami PV power station	Xijiang, China	20	Under construction	EPC
76	Wulan PV power station	Qinghai, China	0.84	completed	EPC

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4.4 Charges or Encumbrances

Pursuant to the Regulation 3(5)(e), there is no charge or encumbrances on the Project Company assets.

4.5 Technical & Financial Proposal

Pursuant to the Regulation 3(5)(f), please refer to section ??

4.6 Technical details of proposed facility

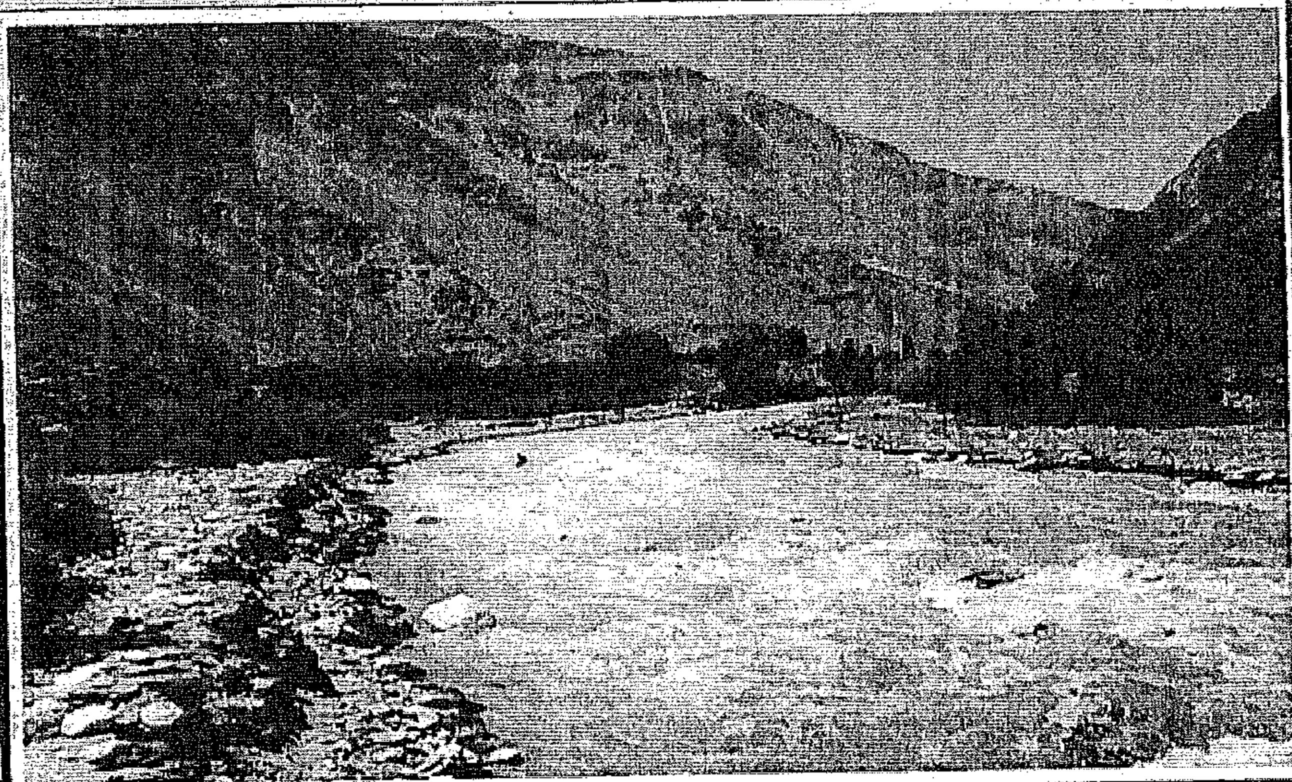
Please refer to section **??** of this document for complete technical details of proposed facility as required under Regulation 3(5)(g) and Schedule III of the Licensing Regulations.

4.7 Project Feasibility Study

Please see attached Project Feasibility Study as required pursuant to Regulation 3(5)(h) of the Licensing Regulations.

PAKHTUNKHWA HYDEL DEVELOPMENT ORGANIZATION (PHYDO)

GOVERNMENT OF KHYBER PAKHTUNKHWA



FEASIBILITY STUDY

ARKARI GOL HYDROPOWER PROJECT

DISTRICT CHITRAL (LOWER), KHYBER PAKHTUNKHWA

MARCH 2014

VOLUME 1: Main Report - Part I

A JOINT VENTURE OF
CIV-TECH ASSOCIATES & EPAC CONSULTANTS (PESHAWAR)
INTERNATIONAL EXPERT GROUP FOR HYDROPOWER DEVELOPMENT (GERMANY)
DESIGNMEN CONSULTING ENGINEERS (ISLAMABAD)
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PAKHTUNKHWA HYDEL DEVELOPMENT ORGANIZATION (PHYDO)

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REPORT STRUCTURE (4 VOLUMES)

VOLUME 1: Main Report – Part I	
Chapter 0	Executive Summary
Chapter 1	Introduction & Summary
Chapter 2	Power Market
Chapter 3	Topography
Chapter 4	Hydrology and Sediments
Chapter 5	Geology, Geotechnical Engineering & Construction Materials
Chapter 6	Seismic Hazard
Chapter 7	Alternative Study & Selection of Plant Layout & Optimization
Chapter 8	Hydropower Design, Civil Design, Construction
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Section 2	Appendix 5: Geology, Geotechnical Engineering & Construction Materials

VOLUME 4: Appendices – Part II	
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Section 2	Appendix 8: Hydropower Design, Civil Design, Construction
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VOLUME 1: Main Report (Part I)

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1. INTRODUCTION AND SUMMARY

1.1 Introduction

The Government of the Khyber Pakhtunkwa Province (KPK) represented by the Pakhtunkhwa Hydel Development Organization (PHYDO) is engaged in the development of the hydropower resources in the mountainous areas of KPK.

When the available hydropower potential is systematically developed, the power demand of the province may be met with sufficient surplus for export to other provinces, thus significantly contributing to satisfy the future power demand of Pakistan.

Within the inventory of hydropower potential of the Chitral District within the KPK Province, a project site at the Arkari River, a left side tributary of Lutkho River approximately 37 km from Chitral Town was identified by SHYDO/GTZ and selected by GoKPK and PHYDO for conducting a Feasibility Study.

The summary describes the Uchhatur-Andakht hydropower project which was found the most favourable solution for the hydropower development of the lower reaches of the Arkari River.

Extensive field reconnaissance, topographical survey, hydrological and geological investigations as well as environmental and social impact and mitigation studies and engineering studies were carried out for preparation of the Feasibility Study. This study establishes a project that will be relevant to supply power to the National grid system.

The chapters dealing with the engineering structures are preceded by a description of the results of the above mentioned field investigations as well as those of the study of alternative layouts and a discussion of design criteria such as optimization of maximum storage level, determination of turbine discharge and regarding storage operation of the plant. As a result of field investigations and engineering studies, it is concluded that the project is technically viable, economically feasible and environmentally safe.

1.2 Power Market

Introduction

Electricity is the basic requirement of life and economy and most vital instrument of socioeconomic development of a country. Electricity has pivotal role in running machinery in factories and industrial units, for lighting our cities and powering our vehicles. Provision of electricity to all sectors of economy is a challenge for the government.

There has been an enormous increase in the demand of electricity as a result of industrial development and population growth, in comparison to enhancement in electricity production. Supply of electricity is, therefore, far less than the demand, resultantly crisis has emerged and load shedding has become a routine of the day.

Electricity Demand

The electricity demand is a function of GDP growth, population growth, unmet demands etc. at present the available capacity is not capable of meeting demand due to various reasons including capacity and capability as sufficient fuel is not available for power plants. However in order to asses' future power requirement it is essential that a realistic demand is made so that adequate planning could be made for capacity addition.

Demand Forecasting

Demand forecasting or Load forecasting is an important element of the power planning process involving prediction of future level of demand. The forecast serves as the basis for supply-side and demand-side planning. Load forecasts are typically prepared by utilities for different time frames and levels of detail and used for generation, transmission as well as distribution planning. It further helps investment planning for these sectors and for their associated industries like manufacturing, fuel and resource exploration etc.. Demand forecast by customer category class is presented as follow:

Electricity Demand forecast Based on Normal GDP Growth (GWh)									
Fiscal Year	Domestic (GWh)	Commercial (GWh)	Industrial (GWh)	Agriculture (GWh)	Bulk (GWh)	Total (GWh)	Self Generation (GWh)	Energy Sentout (GWh)	%-tage Growth Rate
2010-11	44901	7304	26967	11419	5337	95928	11284	107212	
2011-12	46648	8054	28365	11635	5635	100337	11869	112206	4.66%
2012-13	47916	8922	29596	12288	5908	104630	12384	117014	4.28%
2013-14	51104	9912	30820	11987	6310	110133	12896	123029	5.14%
2014-15	54286	10705	32161	12344	6688	116184	13457	129641	5.37%
2015-16	57670	11883	33648	12950	7139	123290	14079	137369	5.96%
2016-17	61266	13221	35303	13066	7639	130495	14772	145267	5.75%
2017-18	65093	14735	37151	13554	8189	138722	15545	154267	6.20%
2018-19	69160	16249	39216	14200	8767	147592	16409	164001	6.31%
2019-20	72692	18123	41526	14599	9384	156324	17375	173699	5.91%
2020-21	75885	20243	44128	15338	10038	165632	18458	184090	5.98%
2021-22	81358	22638	47058	16204	10877	178135	19676	197811	7.45%
2022-23	86984	25253	50355	16969	11780	191341	21047	212388	7.37%
2023-24	93007	28314	54063	17975	12799	206158	22589	228747	7.70%
2024-25	99456	31781	58237	19107	13930	222511	24324	246835	7.91%

Source: Electricity Demand forecast based on multiple Regression Analysis by Planning Power NTDC, May 2012

1.3 Topographic Survey

Topographic survey of the project area was conducted by professional surveyors under the guidance and supervision of consultants as per the following scope of work:

i) To select the most suitable Project Layout to minimize geological and climatological hazards so that stable infrastructure could be built for the Project.

ii) To highlight the topographic features of the areas covering the short-listed layouts.

iii) To minimize disturbance to the local population and to the extent possible, avoid their relocation as a result of the project.

iv) To prepare computerized topographic maps of the locations of project components such as weir, intake structure, de-sanders, headrace / power tunnel, surge shaft, pressure shaft, powerhouse and tailrace canal.

v) To establish longitudinal profiles of Arkari Gol River from the proposed locations of weir site to the powerhouse

vi) To prepare valley cross-sections upstream and downstream of the weir axis.

vii) To prepare valley cross-sections upstream and downstream of the powerhouse axis.

viii) To prepare a Project Map on a scale of 1:10,000.

The main areas of field surveys included the weir site near Uchhatur village, the head race tunnel along the right bank of Arkari River and the powerhouse site near Andakht village. The survey covered both accessible (weir / intake, reservoir, de-sander, pressure shaft, powerhouse and tail race) and inaccessible (tunnel alignment, surge shaft and part of pressure shaft) areas of the project site. Topographic maps were developed with the help of digitized maps of 1:10,000 scale, Survey of Pakistan (SOP) sheets of 1:50,000 scale and a satellite map of 0.5 m resolution.

The Topographic Survey entailed recording of Arkari River's longitudinal sections starting 4 km upstream of the weir axis up to the anticipated backwater effect and terminating 6.7 km downstream of the weir axis. For the powerhouse site, longitudinal sections were recorded from 600 m upstream of the powerhouse to a distance of 5 km downstream of the powerhouse. Longitudinal sections have been recorded for approximately 16 km length of the river. This includes the reservoir area.

The Topographic survey also entailed preparation valley cross-sections at the weir and powerhouse locations. At the weir location, 100 m interval valley cross-sections were recorded up to the anticipated backwater effect (approximately 4 km) on the upstream side of the weir location and up to 6.7 km on the downstream side of the weir location. At the powerhouse site, cross-sections have been taken at 25 m intervals. Originating from the confluence of Arkari and Lutkho rivers, cross-sections have been taken upstream along the Arkari River up to a distance of 500 m. Likewise, cross-sections along Lutkho River have been taken at 25 m intervals up to a distance of 2421 m downstream of the Ruji Bridge.

The project's Reference Grid has been established by connecting the project area survey with Survey of Pakistan (SOP) Grid permanent benchmarks. Control Points have accordingly been established at the project site.

1.4 Hydrology and Sediments

The Hydrology and Sedimentation studies of the Arkari Gol Hydropower Project covers the aspects of data availability, data collection, data evaluation, climatology of the area, delineation and characteristics of the dam site watershed, flow study for the dam site and flood study for the dam and powerhouse sites. Moreover, the report also contains the observed suspended sediment discharges at the Arkari Gol gauging site and bed material gradation characteristics in the river bed of the reservoir area, which were collected by the present Consultants.

Climatological data of Chitral gauging station was collected from Pakistan Meteorological Department and flow data of Chitral Gauging Station from 1964 to 2011 were collected from SWHP, WAPDA. Flow data of seven more stream gauging stations were also collected from SHWP and PHYDO.

Collected data were evaluated by plotting double mass curves for checking their quality. All double mass curves showed that the collected data are consistent and do not require any corrections.

Climatology study was carried out by using the data of Chitral gauging station from 1992 to 2009. Temperature data recorded at the Chitral Gauging Station shows that July is the hottest month and January, the coldest month with highest and lowest mean monthly temperatures of 36.42 and -0.76 ^{o}C respectively. At the Chitral climatological station, mean annual values of precipitation and relative humidity are estimated as 471.9 mm and 36.15 % respectively.

The watershed area of Arkari River at the weir site is 1036 km^2 whereas watershed area of Arkari Powerhouse site is 1060 km^2. On the basis of the

100 m DEM, the elevation in the watershed varies from 2172 m to 6732 masl. The mean elevation of the watershed is 4156.5 masl with a standard deviation of 721.6 m.

Considering the quality of the available flow data record at the Arkari stream gauging station, the flow study for the project was carried out in two phases, initially by regional analysis approach to establish the mean annual flow at the site and then by utilizing the Arkari gauge data to have its temporal distribution. To carry out the flow study using regional analysis approach, flow data of 8 stream gauging stations were collected and used.

Mean annual flows estimated for the Arkari stream gauging station, Arkari weir site and Arkari powerhouse site are 16.66, 17.02 and 17.41 m^3/s, respectively.

As Statistical Approach looks best for the Arkari HPP site, hence flood magnitudes are recommended by this method, the recommended flood magnitudes corresponding to various return periods for Arkari weir and powerhouse sites, and the recommended flood magnitudes corresponding to 1000 year return period are 562 and 571 m^3/s, respectively

A stream gauging station was installed by the Consultants along river Arkari to measure flows for the Arkari weir site at Uchhatur Bridge which is situated at 200m upstream of the proposed weir site. Water and sediment discharge measurements were commenced at this station on 25th September 2012 and will remain continued up to completion of Feasibility Study Period.

Mean annual specific suspended sediment yield at Arkari weir site is about 241 Tons/km^2/year. Mean annual suspended sediment load at the weir site is about 0.259 MCM. The recommended density of deposited sediments is taken as 982.4 kg/m^3 (61.3 Pcf).Mean annual bed load at the weir site is about 0.039 MCM. Mean annual total sediment inflow to the Arkari reservoir is about 0.297 MCM.Trap efficiency of reservoir computed on the basis of Churchill curve is 35 %. The recommended trap efficiency is 62.5 % based on total sands and coarser material. Mean annual trapped sediment load in the proposed reservoir would be 0.015 MCM.

The life of the Arkari reservoir without considering any flushing would be only 09 years. Flushing discharge required to carry out flushing of the reservoir would be 20 to 40 m^3/s, whereas flushing duration required would be around 3-10 days depending on the amount of deposited sediments to be flushed and the flow rate available for this purpose. The life of the Arkari reservoir can be enhanced to about 110 years with appropriate flushing operations at the rate of one flushing per year in the month of August or whenever flushing discharges are available.

1.5 Geological and Geotechnical Investigations

The project area lies in the eastern Hindu Kush and western Karakorum mountain ranges, separated by the Tirichmir Boundary Zone (TBZ). The eastern Hindu Kush in Chitral consists of Paleazoic Wakhan slate and upper Paleozoic to Oligocene granitoid intrusions, many of which demonstrate a NE – SW trend. The Tirichmir Boundary Zone (TBZ) separates the eastern Hindu Kush to the north-west from the western Karakorum (Gaetaui at el, 1996). The eastern Karakorum in the project area consists of quaternary deposits, slates, phyllites, gneiss, quartzite granitic intrusions and amphibolites

Regional tectonic setting of the Chitral district is characterized by the continental collision between the Eurasian Plate, the Indian Plate and the intervening Kohistan Island arc. The Chitral district has three main mountain ranges, namely Hindu Kush, Karakoram and Kohistan.

The Hindu Kush and Karakoram ranges are part of the Eurasian Plate while the Kohistan range is part of the Indian Plate. The Indian Plate is under-thrusted and the Eurasian Plate is upper-thrusted. Both the plates are separated by a Main Karakoram Thrust (MKT) which trends in NE-SW direction through Shishi Valley, Rizhun Gol and passes through Harchin from Chitral district. The crushing zone between the MKT and Kohistan is known as Northern Suture Mélange zone (NSM).

On the basis of structural evolution, the Chitral district has been divided into the following three units:

1) The North Western Unit: This unit starts from Reshun fault, continues towards north- western and central Afghanistan and Tirich Mir Boundary Zone (TBZ).

2) The Central Unit: This unit is bounded by the Reshun Fault in the north-west and the Main Karakoram Thrust (MKT) in the south-east.

3) The South-Eastern Unit: This unit comprises of the Karakoram - Kohistan Suture Zone and the Kohistan Arc block.

Tectonically, the project area is part of the Eurasian plate and structurally, it falls in the north-western unit of the Chitral structural unit.

The powerhouse site is located on metamorphic rocks i.e. Phyllites and Gneiss. The bed rock is covered with quaternary deposits. The general strike of bed rock is in NE-SW direction and dipping is towards NW with 40^0 to 60^0 angle of dip.

From the weir site to the powerhouse, the tunnel passes through various metamorphic and igneous rocks i.e. phyllites, schist, quartzite, gneiss and granite.

The weir site is located in a granitic outcrop which is part of the Tirichmir Boundary Zone (TBZ) in Chitral region. The TBZ separates the Hindu Kush and Karakorum ranges in the project area. The granitic outcrop has an inclusion along the strike of the Wakhan Formation which consists of slate, gneiss and quartzite. This granitic outcrop has contact with amphibolites and slates.

For geotechnical investigations, drilling and coring of the lithological units has been carried out through boreholes at specified intervals. The activity was aimed at assessing the physical properties of the lithological units under imposed loading conditions.

Drilling of boreholes was carried out as per the following schedule:

Project Component	Boreholes	Depth (m)	Remarks
Powerhouse Site	PH-BH#01	35.0	Drilled in bed rock.
	PH-BH#02	35.0	
	PH-BH#03	45.0	Drilled in overburden, no bed rock encountered up to 45.0 m depth.
	PH-BH#04	60.0	Drilled in overburden, bedrock encountered at 48.0 m.
Weir Site	WS-BH#01	35.0	Drilled in bed rock.
	WS-BH#02	60.0	Drilling in progress. No bed rock encountered up to 150 m depth through VES.
	WS-BH#03	35.0	Drilled at left abutment and bed rock encountered at 25.0 m depth.
	WS-BH#04	40.0	Drilled at right abutment and bed rock encountered at 18.0 m depth.

For further confirmation of bed rock, Vertical Electrical Sounding (VES) was conducted in the project area. Bedrock was not encountered up to 150 m depth in VES carried out at the centre of valley along weir axis. Two dimensional imaging systems were also applied to investigate properties of sub-surface lithological units. During drilling, the following in-situ tests were also performed in boreholes:

- Constant Head Permeability Test
- Water Pressure Permeability Test
- Standard Penetration Test (SPT)

The above tests for determination of rock/soil conditions were performed at 5 m intervals. Details of these tests have documented in the project's geotechnical investigation report.

Physical and chemical properties of lithological units are assessed through laboratory analysis carried out mainly in Central Material Testing Laboratory (CMTL), WAPDA.

Foundations recommendations for the feasibility study of the Arkari Gol Hydropower project, which is anticipated to be Concrete Faced Rock Fill Dam (CFRD) with a height of 30 m and a maximum crest length of 168 m between abutments. The recommendations are based on interpretation of data obtained from field investigations.

Different foundation options have been considered for the weir and powerhouse sites.

The structures can be founded on shallow foundations/structural rafts and a combination of structural rafts and piles. For the powerhouse site, a bearing capacity of 3.8 ton/ft^2 has been calculated at 10.0 m depth for shallow foundations/structural rafts. For the weir site, a bearing capacity of 2.2 ton/ft^2 has been calculated at 12.0 m depth for shallow foundations/structural rafts. A more detailed analysis of the subject matter has been presented in project's geology report submitted by this consultant.

The strength and stability of rock masses largely depends on the density, nature and extent of fractures. Stability of the tunnel for the Arkari Gol project has been evaluated on the basis of Rock Mass Rating (RMR) system (Bieniawski's et al. 1976) and Norwegian Geotechnical Institute's Q-Values. RMR and Q-values calculated for the tunnel through three lithological units, namely schist, granite and phyllites are presented below.

Schist: The RMR values range from 35 to 45 and Q values ranges from 0.5 to 3 categorized as a rock class III – IV (Fair – Poor).

Granite: The RMR values range from 40 to 60 and Q values ranges from 0.5 to 3 categorized as a rock class III (Fair).

Phyllites: The RMR values range from 35 to 60 and Q values ranges from 0.5 to 3 categorized as a rock class III – IV (Fair – Poor).

Rocks classified as "Fair" require permanent tunnel supports which are provided by pattern bolts. In such cases, temporary supports are provided for span width of less than 5m within a period of 1 week while safe-cut slopes are kept below 55°.

Rocks classified as "Poor" require bolts & shot-crete for permanent tunnel support. For such rocks, temporary supports are provided for span width of less than 2m within a period of 1 week while safe-cut slopes are kept below 45°.

1.6 Seismic Hazard

Seismo tectonic studies are performed for the project area Arkari Gol HPP situated in District Chitral of KPK province. Geographically, project area is NW corner of Pakistan with meeting point of three great mountain ranges i.e. the Hindu Kush Range, along with the Himalayan Range to its south and the Karakoram Range to its east, form the southern part of the Pamir Knot, which is amongst the few regions in the world with average altitude in excess of 3000 m.

Seismicity of the area is studied with help of recorded historical data and instrumental data. Potential earthquake sources are:-

1. Reshun Fault (RF)
2. Tirich Mir Fault (TMF)
3. Main Karakorum Fault (MKF)
4. Chitral Fault (CF)
5. Bomb Barat Fault (BBF)
6. Panjal Thrust (PT)
7. Ayun Fault (AF)
8. Naz Bar Fault (NBF)
9. Shishi Fault (SF)

Seismic design parameters PGA and Design earthquake have been evaluated. Attenuation equations of Boore et al 1993, 1997 & 2007, Campbell 1997 and Idriss 1985 are used for calculations of PGA values. Design earthquake for the project are carefully decided by the experts.

The Reshun Fault source is the one which could generate an event of magnitude 6.5 to 7.8 during the life span of the project, for powerhouse site and Tirich Mir Fault could generate an event of almost same magnitude for weir site, and then the projected Maximum Credible Earthquake values for these would be from 0.60 to 0.61 respectively. It is, therefore, suggested that a mean value of 0.305 g may be adopted conservatively for power house as the Design Basis Earthquake, while the Maximum Conceivable Earthquake can be 0.61 g. Similarly the OBE for weir should be 0.305, also MCE is 0.61g. Final recommendation for OBE of 0.34g is considered to comply with the Seismic Zoning Map of Building Code of Pakistan (2007 SP)

The DBE is OBE, and factor of 2 with respect to MCE is as per different codes (USNRC, Indian Code), otherwise OBE is mostly based on probability analysis, which again depends on availability of large strong motion earthquake data of the area.

So OBE can be taken as ½ of MCE for a fair assessment and is recommended international codes as well as other relevant codes for such projects.

1.7 Alternative Study and Selection of Plant Layout & Optimization

1.7.1 Project Layout Studies

Alternative project layouts have been considered in this study to plan a scheme for optimum utilization of potential resources to be connected with National grid. The average gradient of River in the project area is about 4.5%. At inception stage, based on previous studies and the Consultant field visits, two weir and two powerhouse sites were identified to frame three alternative project layouts.

Alternative-I: W1-P1, Project Layout identified as "Uchhatur Andakht" in 2001 study.

Alternative-II: W2-P1, Modified Project Layout identified as scheme no. 8 in 1988 study.

Alternative-III: W2-P2, Project Layout identified as scheme no. 7 in 1988 study.

- W1: Weir site identified near Uchhatur village as identified in the study of 2001.
- W2: Weir site identified 1.5 km upstream of W1 as in the study of 1988.
- P1: Powerhouse site identified near Andakht village in the study of 2001.
- P2: Powerhouse site identified near Shoghore Gram in the study of 1988.

Alternative project layouts are indicated in Drawing No. ARKF-01.

The comparison of alternative layout has been made by estimating benefits and costs for a design discharge of 32 m^3/s. Structure dimensions of various project components are taken from on topographic maps. For the three alternative layouts, cost estimates have been prepared with the help of computer program. Net head has been estimated for Pelton turbines to estimate power and annual energy for average year flows.

COMPARISON OF ALTERNATIVES			
Project Components	Alternative-I W1-P1	Alternative-II W2-P1	Alternative-III W2-P2
Project Base Cost	134.8	149.3	141.2
Power	92	100	81
Energy	367.7	358.6	312.5
Energy Cost1_/ (USc/kWh)	6.37	7.58	8.23

1_/ Capital Recovery Factor = 0.14 (12% discount rate, 30 years and O&M 2% of capital cost), IDC is approx 30%.

Alternative-III with less power output and high energy cost is not selected for further studies. Alternative-I and II have economic benefits in the same range, therefore both layouts are considered as preferred layouts to be studied for optimization of project layout studies.

1.7.2 Optimization of Installed Capacity

Capacity optimization has been carried out for two preferred alternative layouts. From the available monthly flows at weir sites, a design discharge range from 24 to 46 m^3/s with interval of 2 m^3/s has been selected. Compensation flows of 0.80 m^3/s and 2.0 m^3/s have been used in winter and summer months respectively. Head losses in water ways and efficiencies of turbine, generator and transformer have been used to estimate power and energy. For each selected design discharge, the benefits and cost have been estimated to compute incremental benefits and incremental cost and NPV. The design discharge and corresponding capacity with maximum NPV is selected.

S.No.	Design Discharge	Alternative-1 Installed Capacity	Alternative-1 Total Energy	Alternative-1 Total Cost	Alternative-2 Installed Capacity	Alternative-2 Total Energy	Alternative-2 Total Cost
	m^3/s	MW	GWh/a	M US$	MW	GWh/a	M US$
1	24	67	320.03	135	71	324.11	147
2	26	73	332.87	141	80	337.00	154
3	28	78	344.96	146	82	345.59	160
4	30	84	353.48	152	88	354.17	167
5	32	89	361.63	159	93	362.75	175
6	34	94	369.77	165	99	371.33	182
7	36	99	377.92	172	105	373.14	190
8	38	105	382.66	180	110	373.14	198
9	40	110	382.66	187	116	373.14	207
10	42	116	382.66	195	122	373.14	216
11	44	121	382.66	204	128	373.14	226
12	46	127	382.66	213	134	373.14	236

The project power benefits have been quantified on basis of Long Run Marginal Cost (LRMC). The capacity LRMC of the generation level is estimated to be about 80% of the capital cost of the OCGT. The peak and off-peak energy costs of thermal equivalents are used as proxies for LRMC energy peak and off-peak. The estimated LRMC at 132 kV are:

- Capacity 623 US $/kW
- Peak Energy 16.78 US cent/kWh
- Off Peak Energy 10.37 US cent/kWh

The economic evaluation of two alternatives layouts has been carried out by using 10% discount rate, the results are graphically presented in Figure below.

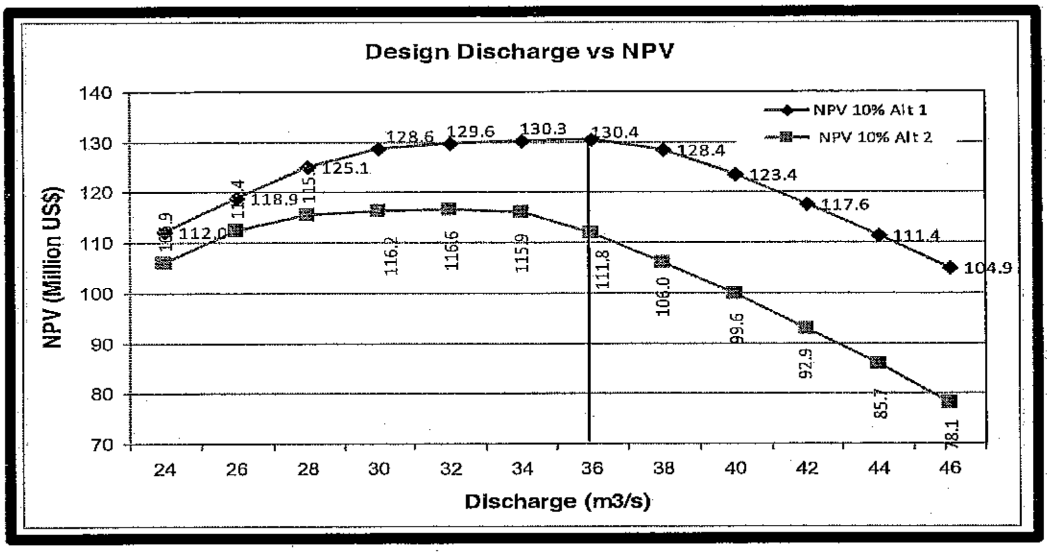
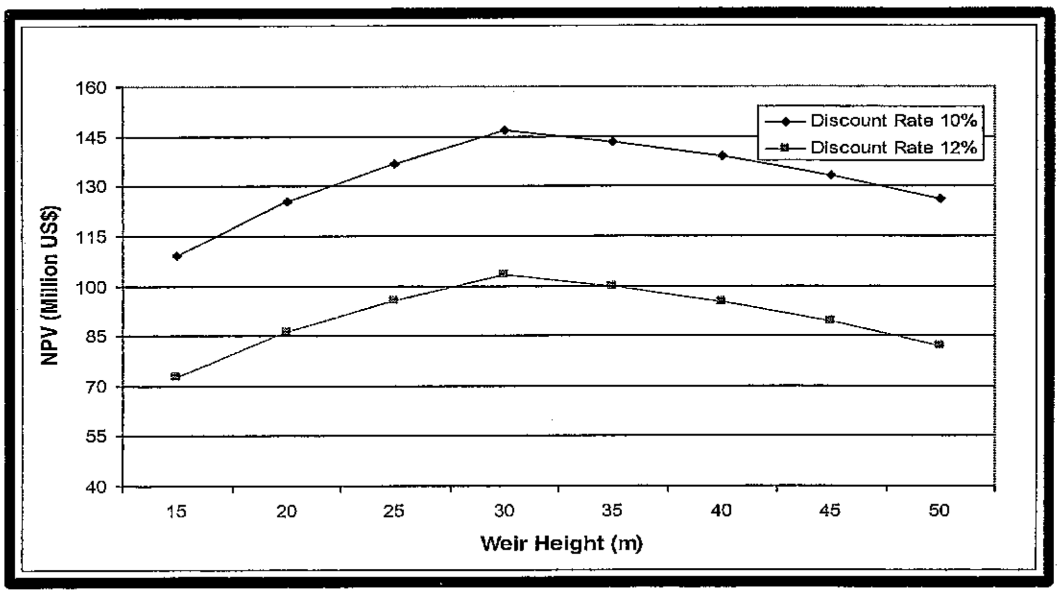


Figure : Comparison of NPVs Alternatives 1 and 2

Alternative 1 has a higher NPV values as compared with that of Alternative-2 and therefore it is is selected. The selected design discharge for Alternative-I at the highest NPV (130.4 Million US$) is 36 m^3/s for which corresponding capacity is 99 MW.

1.7.3 Optimization of Reservoir Level

Reservoir level has been optimized considering a live storage for 4 hours peaking during low flow in winter months. The range of reservoir level operation from minimum to maximum improves the net benefits of the project in terms of increased power in peaking hours. The availability of maximum power in peaking hours justifies the higher reservoir level upstream of the weir intake. The increased weir cost, area inundated and realignment of road restrict the net benefits. Up to a certain water level, the net benefits increase and then decrease. The reservoir length would vary from 1300 m to 1500 m for reservoir elevation from 2186 m to 2190 m respectively.



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The above graph indicates that NPV is maximum at a reservoir level of 2190 m. It is therefore recommended that 2190 m elevation may be taken as the maximum reservoir level. The minimum operating level would be 2186 m. A 4 m reservoir variation would provide a live storage of 673,794 m^3. With this live storage, the design discharge of 36 m^3/s would be available during 4 hours of daily peaking even in winter months.

1.8 Hydropower Design, Civil Design and construction

Principal components of the project include construction of a concrete face rock fill dam with 20m height above river bed. The dam body shall be 150m long at the river bed level and 200 long at the crest level. Construction of dam would create a reservoir of 1.06 hm^3 capacity with live storage of 0.489 hm^3 for normal and four hours of peaking operation. The spillway with four regulation gates of 6 x 6 m each and bottom out lets of the same size for periodic flushing of sediment deposits in front of the intake structure have been provided. This will also serve to pass floods of 1000 return period. Stilling basin of 90m length have been proposed for dissipation of energy of the water flowing through the spillway. A horse shoe diversion tunnel is proposed for diversion of water during construction of dam body, spillway and power canal intake structure designed to convey 36 m^3/s water to the power house.

Water drawn through the intake structure shall be conveyed to the desanders through a concrete lined open channel for removal of suspended sediments.

Gated arrangements for flushing of sediments from desanders will be provided. Water from the desanders is planned to be conveyed through 5.6 km long, 4.15m* 2.68m horse shoe profile tunnel with multi-chamber surge shaft of 4.5 m internal diameter and 71.2m height. The steel lined pressure shaft of 296 m length and pressure tunnel of 3.0 m diameter and 494 m length would convey water to the turbines installed in the power house.

The external type power house building shall be 46.7 m long, 24.2 meter wide and 13.5 m high and will be equipped with 3 vertical axis turbines coupled with synchronized generators designed to operate with 12m^3/sec inflow at 375 rpm to produce 33 MW each. Collectively 99 MW energy will be produced by the three units.

Principal Project Features

Details of principal project features are summarized as follows:

River:	Arkari Gol, left side tributary to Lutkho River		
	Catchment Area at dam site	1,036	km^2
	Mean Annual Discharge	17.00	m^3/s
	Total annual flow	536	hm^3

Reservoir:	Total Storage Capacity	1.06 Mm^3
	Live Storage Capacity	0.489 Mm^3
	Dead Storage Capacity	0.656 Mm^3
	Surface Area	0.121 km^2
	Length of Reservoir	1.3 km
Dam Structure	Rock-Fill Dam with Concrete Face	
	Height above Riverbed	20 m
	Crest Length	200 m
	Width at Riverbed (extended)	150 m
Stilling Basin:	Length	90 m
Flood Control:	Design Flood (Return Period 1000a)	562 m^3/s
	4 Vertical Gates	6 m x 6 m each
	4 Bottom Outlets	6 m x 6 m each
River Diversion:	Diversion Flood (Construction Phase-	
	Return Period = 10 a)	162 m^3/s
	1 Diversion Tunnel (Horse Shoe)	
	(Protected by upstream & downstream cofferdams)	
	Cross Sectional Area	50 m^2
Intake Components:	2 Stoplogs	3 m x 4 m each
	2 Trashracks	5.89 x 7.63 m each
	Rack Cleaning Machine	
	Velocity of lifting	0.3 m/s
	2 Intake gates	3 m x 4m each
Headrace Tunnel:	Pressure Tunnel	
	Length	6265 m
	Excavation Diameter (TBM)	4.4 m
	Internal Dimensions (horse shoe)	3.8 m
	Adit	1
Surge Tank:		
Surge Shaft	Internal Diameter	4.5 m
	Height	71.2 m

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Lower Chambers:	Units	2
	Length	96 m each
	Cross Section	21.9 m² each
Upper Chamber:	Length	74.5 m
	Cross Section	33.5 m²
Pressure Shaft:	Vertical Shaft, Steel Lined	
	Internal Diameter	3.0 to 3.2 m
	Difference in Height	296 m
Pressure Tunnel:	Horizontal Tunnel, Steel Lined	
	Length from Pressure Shaft to Power House	494 m
	Internal Diameter	3.0 m
Powerhouse:	External powerhouse	
	Turbine Shaft depth below machine hall floor	15 m
Machine Hall:	Length	46.7 m
	Width	24.2 m
	Height	13.5 m
Tail Race:	Covered Channel, length	100 m

1.9 Design of Hydraulic Steelwork and Hydro-mechanical Equipment

1.9.1 Hydraulic Steelwork

Hydraulic steel structures are provided to regulate the flow through different civil structures which includes 4 vertical roller gates of spillway with stoplog arrangements.

A gantry crane of 10 ton capacity is proposed for stoplogs' operation and for maintenance of spillway gates and intake gates.

Hydraulic steel works at intake includes 2 trash racks, inclined at 80° with 30 mm bar spacing and two hydraulically operated vertical lift gates are proposed for regulation of flow through intake structure.

Each sand trap chamber will be equipped with one steel gate at outlets. 4 flushing gates will be provided for flushing of sediments from sand trap chamber.

Steel works also include steel lined pressure shaft and pressure tunnel.

1.9.2 Hydro-Mechanical Equipment

1.9.2.1 Turbines

The design discharge of 36 m^3/s will find an arrangement of 3 vertical-shaft Pelton turbines as optimum from the technical and economical point of view.

Each unit will be designed for a rated flow of 12 m^3/s, producing at net head of 318 m a rated mechanical turbine power of 33 MW and a turbine speed of 375 rpm.

The gross head will be 335.30 m. and net head 318.0 m. with maximum reservoir level 2190.0 m.a.s.l. and 1854.70 m.a.s.l. tail water level.

The distribution of rated turbine flow was selected for all the three units with 12 m^3/s. Considering the advantages in maintenance, plant space and construction cost, the installation of Pelton turbines is proposed:

The powerhouse will be equipped with the following:

Vertical Pelton Turbines	3	Nos.
Speed	375	rpm
Discharge per Unit	12	m^3/s
Total Discharge	36	m^3/s
Capacity per Unit	33	MW
Total Capacity	99	MW

Equipped with an PID type electronic **Speed Governor** to operate the turbine inlet valve under all conditions including emergency stops, interacting with the control system of the plant and the monitoring equipment, allowing proper operation of the unit under all conditions of load and speed, steadily. A protective spherical inlet valve is located immediately upstream each turbine inlet.

1.9.2.2 Auxiliary Powerhouse Equipment.

Adequate auxiliary equipment in including a 95 t bridge-type powerhouse crane with 20 t auxiliary hoist, additional cranes in workshops etc., work shop equipment for maintenance and repair works, oil handling equipment and fire fighting equipment.

1.10 Design of Electrical Equipment and Grid Interconnection

1.10.1 Electrical Equipment

This chapter summarizes the feasibility design considerations for the electrical installations of the powerhouse indoor and the adjoining 11/132 kV switchyard outdoor.

The layouts are the basis for the cost estimates and will also serve as basis for future final design.

1.10.1.1 Equipment at the Powerhouse Building

Coupled with and mounted on top of the 3 vertical shaft Pelton turbines to be installed in the power house will be 3 vertical shaft synchronous generators of 38.82 MVA, at a power factor of 0.85 corresponding to a nominal turbine power of about 33.0 MW. The voltage was chosen in accordance with WAPDA Standards to be 11 kV.

The generators are equipped with a Thyristor-controlled rotating excitation system and a multi-functional comprehensive voltage regulation system.

The generators' output is connected to the 11/132 outdoor switchyard by cables, laid out in a trench.

Further on within the power powerhouse building are accommodated:

- Medium voltage (11kV) switchgear panels
- Low voltage (0.4 kV) switch boards
- DC supply systems
- Control and alarm systems
- Plant and unit control systems
- Protection equipment.

1.10.1.2 Equipment in the 132 kV Outdoor Switchyard

Cable racks for installation of cable glands for connection of 11 kV cables to the 3 Block Transformers,

3 Block transformer each 40 MVA,11kV/ 132 kV

1 Station Service transformer 6.3 MVA. 11kV/0.4kV

3 Auxilliary Service transformers

Single bus bar switchgear installation with 6 feeders equipped with SF6 gas breakers, isolators, CTs/PTs etc.

1.10.1.3 General Equipment Data:

Generators	
Speed	375 rpm

Voltage	11 kV
Capacity	38.82 MVA
Block Transformers	
Voltage	11/132 kV
Capacity	40 MVA
Grid Station Transformer	
Voltage	132/11 kV
Capacity	6.3 MVA

1.10.2 Grid Interconnection

Existing and ongoing efforts suggest that the local demand of Chitral District is almost covered, this implies that the proposed power plants, to be developed or under development, in the District will feed the output for consumption outside the District. The outflow from the District to the NTDC system is estimates as follows:

Power Flow Chitral District						
	Jul		Feb.		Total	
	Capacity	Energy	Capacity	Energy	Capacity	Energy
Year	MW	GWh/a	MW	GWh/a	MW	GWh/a
2016	106	71	106	12	106	436
2017	106	71	106	12	106	436
2018	185	150	185	91	185	515
2020	264	206	264	100	264	857
2021	264	206	264	100	264	857
2022	397	293	397	115	397	1395
2024	455	335	455	121	455	1649
2025	455	335	455	121	455	1649
2026	507	369	507	127	507	1862
2028	642	463	638	143	651	2440
2029	642	463	638	143	651	2440
2031	787	571	775	158	796	3052
2032	817	592	805	162	826	3183
2034	857	620	845	166	866	3350
2035	857	620	845	166	866	3350
2037	908	657	896	172	917	3581
2038	988	710	976	181	997	3902

Two power plants, Golen Gol and Lawi are under implementation. There are ten others that are being planned for addition over time. There is need to develop a consolidated, long term plan for the transmission interconnection between Chitral District and The System. It is suggested that NTDC, Office of General Manager Planning (Power) may be requested to undertake load flow studies and develop a long term interconnection for transmission interconnection of Chitral District with the System. Line design will need special considerations related to: spans; ice loading; and conductor types, for portions identified to be prone to heavy winter snow falls. Load flow and stability studies to interconnect the Arkari HPP will be carried out under separate arrangements. The analysis is based on the fact that the output from the proposed power plant will be delivered to the NTDC system, since the local demand is already met or is being met with existing and ongoing projects

1.11 Environmental & Social Impact Assessment and Resettlement

This Chapter describes Environmental and Social Impact Assessment referred to as Environmental Impact Assessment (EIA) of the Arkari Gol Hydro Power Project (Arkari Gol HPP). The study was carried out as part of the draft Feasibility Study at the planning stage of the aforesaid project required under the Pakistan Environmental Protection Act, 1997, Schedule II of IEE / EIA Regulations 2000 adopted under section 33 of the aforesaid Act; and donor agencies requirement. EIA of the project has been conducted in compliance with the guidelines of Pak - EPA's and safeguard / operational policies of Asian Development Bank / World Bank and other legislations and regulations applicable to natural resources, involuntary resettlement and environment, health and safety in the country. Outcome of the chapter shall be transformed into a standalone report that will be submitted to the Provincial Environmental Protection Agency, Government of Khyber Pakhtunkhwa to obtain Environmental Approval for the project.

The study was operationalized by a team comprising of experienced experts from the diverse fields of environment, forestry and sericulture, sociology and resettlement. The team collected relevant data by employing different tools and methods including Questionnaires, Household Profile Surveys, Interviews, Field Observations and Focus Group Discussions (FGDs). Meaningful and result oriented interactions were held with important stakeholders / officials of Forest, Wildlife and Fisheries Departments, local populations, project affected persons and local NGOs. The study covered Andakht, Momin, Momi, Uchhatur and Pechuch villages of the Arkari Gol valley to gather primary and secondary data for impacts analysis of the project.

The study compiled in the EIA report provides information on the project activities, country's legal and institutional framework responsible for taking decisions on IEE / EIA studies and matters relating to protection and management of environment; the baseline information that serves as a benchmark for assessing the project's impacts on the physical and ecological components of the natural and human-use values and quality of life values of the human environment. Qualitative and quantitative data collected in the baseline study constituted basis for the study of the subsequent positive and adverse impacts of the project on the physical, ecological and human environment in the study area. The following sections provides analysis of impacts along with proper mitigation measures; Environmental

Management Plan (EMP) environmental and resettlement cost of the project, and, the process of consultation and scoping sessions with the stakeholders.

Analysis of data from 1992 to 2008 reveals that the hottest month in Chitral is July with a temperature of 36.4°C, followed by August with 34.9°C. Rainfall mainly occurs in spring and winter. Precipitation graphs show that summer and autumn are largely dry. Since high altitude locations receive snowfall instead of rains, the Arkari Valley, like other parts of Upper Chitral, receives relatively less rainfall. Existing data reveals that maximum monthly rainfall of (93.8 mm) occurs in March followed by 71.8 mm rainfall in April. Likewise, minimum rainfall (2.7 mm) occurs in August, followed by 3.4 mm rainfall in July. Per historical records, highest relative humidity (44%) occurs in December, followed by 43.4% in January. Lowest relative humidity (24%) occurs in June.

Owing to low population density and lack of commercial and industrial activities, noise levels in the project area are rather low and well within environmentally acceptable parameters. It can be inferred from personal observations that in general, ambient air in Arkari valley is undisturbed and unpolluted and of environmentally acceptable standards. Data on hydrology acquired for the Arkari Gol at the Weir Site (1964-2011) shows the highest mean monthly flow in the month of July with a value of 39.48 m^3/s and minimum in the month of March with a value of 5.68 m^3/s. The mean monthly flow at dam site comes as 17.02 m^3/s. The project area is part of the continental collision zones between Eurasian and Indian plates and the intervening Kohistan, Ladakh Arc.

The Arkari Gol supports a variety of fish species and scattered trees of Juniper, Prunus and Olea species, rich variety of medicinal and fruit plants and a good variety of wildlife species are found in the area.

Main castes / ethnic groups of the area include the *Katur, Zondray, Katur, Dashmaner, Raees, Gorgakha, Khujakhel and Raees. Khowar* (Chatrali) is the main language spoken in the Project Area. Besides, Urdu is also spoken and understood in the Project Area. The project area is undeveloped and devoid of amenities that constitute comfortable living for the locals.

Analyses of the impacts show that except a few adverse impacts, no significant resources in the area will get impaired to cause concerns for the decision makers. Adverse impacts are largely related to preconstruction and construction phase of the project. Significant adverse impacts include land acquisition (a total of 116.56 acres) and displacement of 14 families which however, shall be adequately compensated under the Land Acquisition Act, 1894 and safeguard / operational policies of ADB/World Bank.

Adverse impacts on biological resources including fisheries, irrigation channels, water mills and mini hydel generation plant down the weir site shall be compensated with the release of 0.8 m^3/s to 2.0 m^3/s flows during the respective winter and summer months.

Other adverse impacts of slight significance on air quality, impacts due to municipal solid waste, spoil materials and blasting and quarrying activities shall be offset adequately with adopting proper mitigation measures and initiating environment friendly initiatives in the project. The overall analyses of the impacts show that the project is largely beneficial both at the national and local level.

Besides, creating job opportunities and improvement of the local infrastructure and transportation system, establishment of health and education facilities, encouraging ecotourism and small businesses in the project area; the project constitutes significant source of electric energy that is environmentally safe and economically cheapest enough to help trigger economic activities in the country.

Based on above, it is evident that the project is largely beneficial and due to a comprehensive EMP and environment friendly initiatives in the project, no adverse or harmful impacts of any significance are expected to arise in the project area. Therefore, it is recommended that the client may request Environmental Approval for Arkari Gol HPP as required under the law of the land.

1.12 Documentary Basis for Project Evaluation

1.12.1 Final Energy Calculations

Energy harvest to be expected during dry, wet and average years have been assessed methodologically as follows.

The power and energy have been estimated on the basis of 10-daily flows. The **design capacity** is computed with the following formula;

$$P = \eta * g * Q * h / 1000$$

where:

a) **P** is capacity (MW) estimated from 10 days discharge and corresponding head.
b) **Q** is the 10 days discharge with maximum value of design discharge Q_d (m^3/s).
c) **h** is net head (m), which is estimated from gross head with deduction of head losses in the power waterway.
d) η is combined efficiencies of turbine, generator, transformer
e) **g** is acceleration due to gravity = 9.81 m/s^2

The **mean annual energy** is estimated on the basis of 10-daily flows using the following formula.

$$\mathbf{E = \eta * g * Q * H * t / 10^6}$$

where:

a) **E** is mean annual energy in GWh/annum.
b) **Q** is average design discharge (m^3/s).
c) **t** is time in hours over 10 days.

The **plant factor** which provides the basis for the installed capacity of the project is calculated as follows:

$$\mathbf{pf} = [E/(P*8.760)]*100$$

where:

a) **pf** = Plant factor (%)
b) **E** is mean annual energy (GWh/annum)
c) **P** is Installed capacity (MW)

Net head has been defined with **h = 318** m

Efficiency η of turbine, generator and transformer will be 0.92*0.97*0.99 = **0.892**

Available flows at weir site of Arkari River have been elaborated from measurements carried out over a period of 48 years at Chitral River gauging station operated by WAPDA near Chitral Town and for different periods between 3 and 49 years at 13 more gauging station within the region, through a correlation model. The results have been supplemented by observations on a gauging station installed within this feasibility for more than one compete year in 2012/13

Considering requirements for residual water 0.8 m^3/s during winter and 2.0m^3/s in summer months design discharge has been optimized as **Q = 36 m^3/s**

For the design discharge of 36 m^3/s and net head of 319 m, the optimum installed capacity would be **99 MW** with average mean annual energy of **377.92 GWh.** The plant factor has been taken as 43.6%.

1.12.2 Cost Estimates

Estimate cost, for preparation of site and arrangement if infrastructure, design, acquisition and erection of equipment, construction, commissioning of plant and environmental mitigation, is estimated us under:

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PROJECT COST ESTIMATE		
S.No	Description	Total Cost in 1000 US$
A	Preliminary Works	18066.014
B	Civil Works	86156.645
C	Hydraulic Steel Works	393.257
D	Hydro-Mechanical & Electrical Equipment	41848.376
E	Transmission Line	1557.308
F	Engineering Design, Engineering Supervision And Administration Charges	15667.659
G	Miscellaneous Charges (Erection, Commissioning, Testing, Duties, Taxes, Transportation, Shipment & Contingencies Etc.)	14018.012
H	Financial Charges	641.477
	Total Project Cost Price Level 2013 (105 Rupees/ US$)	178348.748

1.12.3 Construction Methodology and Planning

1.12.3 Construction Methodology and Planning

Detailed construction and implementation schedule for the project has been prepared on the basis of implementation of construction methods envisaged.

The planning is carried out in a way that the net construction time is neutralized from all preparatory activities, necessary before start actual construction work, so that this will be limited to **48 month only.**

Arrangement of project financing from national and international resources must have highest priority in this. At the same time less costly activities like definition of procurement- and contracting modes and arrangements for construction supervision will be taken in hand.

Preparation of physical infrastructure, however, should only be started when date of availability of comprehensive project financing will be conceivable.

Where construction of works for power plant as such are concerned, 24 d/h must be endeavored, applying 3 to 4 shifts per day. This however needs to consider remoteness of the project area, harsh climate in winter season, national and local holidays and limitations in effective working in the time of Ramadan as well as long and difficult access to the area and project site.

These aspects also need special consideration where accommodation of the labor force is concerned and office building are concerned.

Construction planning will carefully consider availability of

- construction material from local quarries and river deposits,
- locally manufactured materials

- construction equipment
- delivery periods to site of equipment and construction machinery from international market.

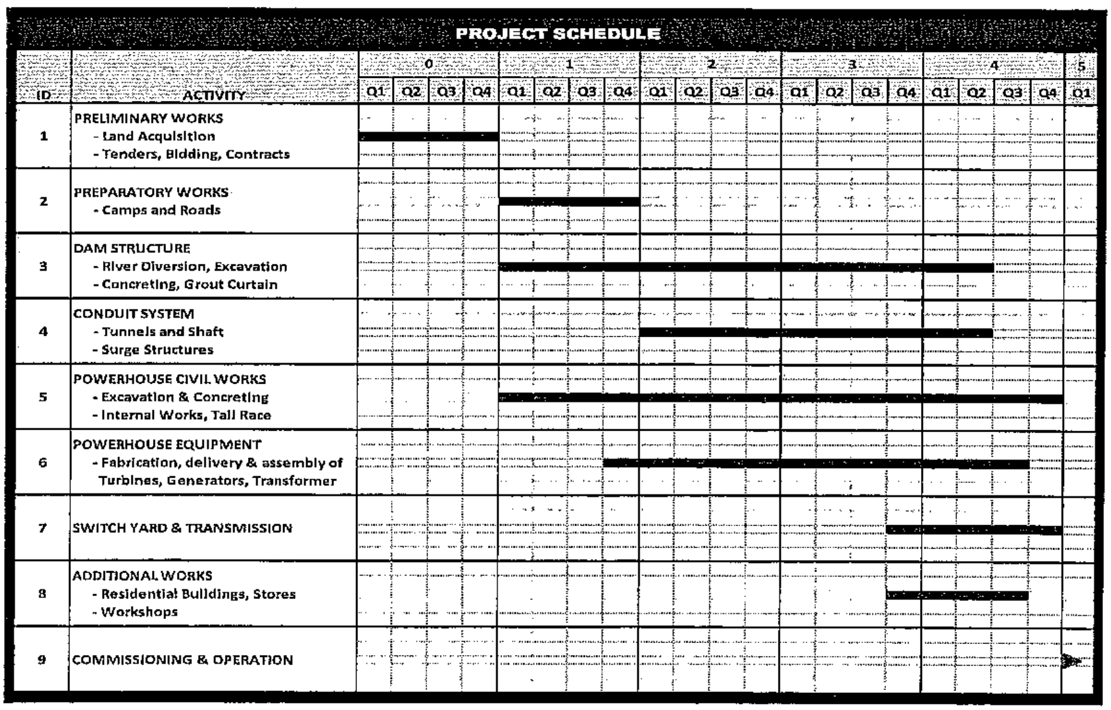
The construction is sequenced as follows:

- Mobilization;
- Pre-construction works;
- Diversion tunnel;
- Dam;
- Spillway;
- Power canal from Intake structure;
- Headrace tunnel;
- Surge chambers
- Pressure shaft and pressure tunnel
- Tailrace canal

In parallel:

- Construction of power house
- Switchyard preparation
- Erection of equipment.

Testing and Commissioning



1.12.4 Transport and Accessibility

The Arkari Gol hydropower project will entail procurement, transportation and installation of heavy and large sized construction and powerhouse equipment such as cranes, turbines, generators, transformers etc. Most of the equipment will be imported from foreign countries and will first land at the Karachi Port before being subsequently transported to the project site. This will require specialized handling of the equipment during loading, transit and off-loading. This will also need a review of the alternative transport modes and routes and their comparative suitability for the project's transportation needs.

In terms of modes of transport, the following two options were considered:

- Railway
- Road

Both road and railway are suitable for the transport of project equipment. The railway option, however, is limited to transportation of equipment up to Nowshera, beyond which it will be transported by road. Furthermore, beyond Chakdara, the road infrastructure will need rehabilitation / upgradation at certain sections. This will entail upgradation / maintenance of roads, bridges, culverts, tunnels etc. and improvements in their existing design parameters such as widths, clear heights, profiles, cross-sections, curves, slopes, loading class etc.

A final decision with regard to the route and mode of transport will however be taken after sufficient data is available for making a comparative analysis of the competing options.

It is recommended that the proposed transport infrastructure up-gradation / rehabilitation works should be pursued in due coordination with the Communication & Works (C&W) Department of the Government of Khyber Pakhtunkhwa and the National Highway Authority (NHA) and accomplished before the work on the project is commenced.

1.13 Economic and Financial Analysis

Arkari Gol Hydropower Project comprises of a Diversion Weir near Uchhatur village. With an installed power generation capacity of 99 MW, the project is expected to generate 378 GWh of electricity annually.

Methodology - Economic Viability

The economic viability of the proposed project has been analyzed according to the following methodology: firstly, establishing the need for the project, secondly, establishing that the project represents the least-cost means of achieving the desired objectives, and finally, establishing that the project has a positive economic return – i.e. that its economic internal rate of return (EIRR) exceeds the economic opportunity cost of capital. The financial viability of the proposed power plant has been determined on the basis of it being a stand-alone privately owned power plant. The NEPRA and PPIB stipulations towards determination of reference tariff have been followed.

Rationale for Investment

Pakistan is suffering from an acute energy crisis, which is caused by (i) insufficient energy supply (ii) increasing demand (iii) inefficient use of energy (iv) improper pricing .The system is at present stretched on a number of counts. This sub-optimality is expected to continue in the near future. The near future may see further deterioration in system performance.

Project Outputs

The project size (installed capacity and design discharge) has been optimized. This optimization has been made on the basis of a marginal analysis. The optimized installed capacity is 99 MW, 377.92 GWh/a average energy at 43.49% plant factor. Peak energy is estimated to be 138.51 GWh/a.

Estimation of Benefit

Incremental Consumption Valued at Willingness-to-Pay

Willingness-to-pay (WTP) for incremental consumption was estimated by comparing the current price of electricity with the price of alternative sources of energy..Due to the fact that the primary and secondary transmission grids are peak-constrained, it has been assumed that the bulk of incremental consumption will be in the residential sector .The estimates are presented as follows:

Willingness-to-Pay Estimates	
SECTOR	**WTP (Rs/kWh)**
Residential	37.54
Agricultural	33.73
Commercial	34.41
Industrial	33.26
Weighted average	35.47

Source: Consultants Estimates

The proposed investment is feasible, when benefits are valued on consumer surplus basis, as the NPV, at a discount rate of 12%, is 407 M. US$ and the IRR is. 7.93%

The uncertainty in costs and benefits is reflected in the sensitivity analysis, which is presented in as follows:

Sensitivity Analysis		
Consumer Surplus Basis	NPV	IRR
	M.US$	%
Base Case	407	27.93
Sensitivity		
Costs +10%	394	26.43
Costs +20%	381	25.10
Benefits -10%	354	26.34
Benefits -20%	300	24.56
Cost +20%, Benefit -20%	273	21.87
Switching Value		
Consumer Surplus	c/kWh	5.88
Consumer Surplus	Rs./kWh	5.95

The project seems to be feasible on certain assumptions, The project also seems to be based on robust parameters as it is feasible on 10% and 20% reduction of benefits and on 10% and 20% increase of costs, and the project is feasible even if costs increase by 20% and benefits reduce by 20% .The switching value at which the project is marginally feasible is when the gross consumer surplus at generation level is 5.88 c/kWh. The average bulk tariff in FY 2012 was about 10.82 c/kWh (2013 bulk tariff was about 12 c/kWh).The project seems robust as it is feasible even with significant changes in benefits or costs.

Economic Feasibility on LRMC Basis

The project seems to be feasible when benefits are quantified on the basis of LRMC of capacity, peak energy and off peak energy at 132 kV level. The NPV at 12% discount rate is about 110 M.US$ whereas the IRR is about 17%. The uncertainty in costs and benefits is reflected in the sensitivity analysis, which is presented as follows:

Sensitivity Analysis		
	LRMC	Basis
Analysis Parameter	NPV	IRR
	M.US$	%
Base Case	110	16.88
Sensitivity	NPV	IRR
Costs +10%	96	15.63
Costs +20%	82	14.53
Benefits -10%	85	15.50
Benefits -20%	60	14.03
Costs +20%, Benefits -20%	32	11.88
Switching Value		
Capacity	$/kW	352
Peak Energy	c/kWh	9.48
Off Peak Energy	c/kWh	5.86

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The proposed investment seems to be robust as it is economically viable even when benefits and costs are changed by 20%, even a combined sensitivity with benefits decreased by 20% and costs increased by 20% still results in a feasible project. The switching values (estimates of LRMC which are used as benefit parameters) at which the project is only marginally feasible are: firm capacity 352 $/kW; peak energy 9.48 c/kWh; and off peak energy 5.86 c/

The project seems to be economically feasible both when benefits are valued on willingness to pay (consumer surplus) basis and upon LRMC basis

Financial Tariff and Feasibility

Financial Assumptions

The financial analysis of the project is based on the assumption that the project will be developed as a standalone, privately financed project. Interest rates, discount rates and other assumptions used all reflect the point of view or perspective of a private investor and conform to PPIB/NEPRA guidelines on the subject. The tariff calculations are presented as follow:

Table 13.33: Summary of Tariff Calculations

		Years			Lev.
Average		1-10	11-20	21-30	at 12 %
CPP	Rs./kW/m	3511	1514	1514	
EPP	Rs./kWh	0.16	0.16	0.16	
Total	Rs./kWh	11.20	4.92	4.92	
Lev.	Rs./kWh			at 12%	9.33

Financial Feasibility

The financial analysis of the proposed hydropower plant has been carried out in accordance with the Asian Development Bank's (ADB) *Financial Management and Analysis of Projects*. All financial costs and benefits have been expressed at early 2013 constant prices. Cost streams used for the purposes of financial internal rate of return (FIRR) determination (i.e., capital investment, operations and maintenance, insurance costs and taxes) reflect costs of delivering the estimated benefits. The NEPRA approved tariff for Suki Kinari, a high head hydroelectric project was used to estimate the financial benefits.

To estimate the weighted average cost of capital (WACC), it has been calculated that the foreign exchange loan component of the project is US $ 73.28 million (without IDC) whereas the local loan component is US$ 59.86 million (without IDC). Equity is estimated to be US $ 33.31 million. Local capital cost has been calculated as 14.5%, whereas foreign capital cost has been calculated as 3.00% while the owner expects 15% return on equity. Domestic inflation is to be 10.0% per annum, whereas foreign inflation is taken to be 1.5%. The WACC for the investment program is 6.322%.The project seems to be financially feasible as the FIRR is above the WACC of 6.322%; risks are quantified by the sensitivity analysis presented, in **Table 13.36**, below:

Table 13.36: Sensitivity Analysis		
		FIRR %
Base Case		7.94
Cost +10%		7.20
O&M +10%		7.81
Cost +10% O&M +10%		7.08
Switching Value		
Tariff	Rs./kWh	5.75
WACC	%	6.32

The project is financially feasible on central assumptions. The project is based on robust parameters and will be able to stand reasonable uncertainties.

1.13 Conclusion and Recommendation

1.14.1 Conclusions

On the basis of detailed analysis of power potential and plant operation options, it has been concluded that at rated discharge of 36 m^3/s and net head of 319 m, the optimum installed capacity will be **99 MW** with average mean annual energy of **377.92 GWh**. The plant factor has been taken as 43.6%.

The financial model was developed and analysis carried out to determine feasibility of the project. The project seems to be financially feasible. The project is, however, sensitive to cost overruns of reduction in tariffs. The variations induced in the key parameters however do not affect the overall financial viability of the project.

1.14.2 Recommendations

A power plant with installed capacity of (3 x 33) 99.0 MW is recommended for implementation.

Observations and recordings of flow and sediment data should be continued to build up a data bank to make available as much data as possible for detailed design stage.

Model studies of the spillway, intake structure and desanders should be carried out to confirm the following:

- Functioning of low level outlets at the dam/spillway
- Sediment flushing
- Efficiency of desanders

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- Integrated planning of dispatch and transmission of power produced by the Chitral Valley projects to the National Transmission and Dispatch Company.

- In view of the power shortage in the country, the project is recommended to be implemented on fast track.

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2 Power Market

2.1 Introduction

Electricity is the basic requirement of life and economy and most vital instrument of socioeconomic development of a country. Electricity has pivotal role in running machinery in factories and industrial units, for lighting our cities and powering our vehicles. Provision of electricity to all sectors of economy is a challenge for the government.

There has been an enormous increase in the demand of electricity as a result of industrial development and population growth, in comparison to enhancement in electricity production. Supply of electricity is, therefore, far less than the demand, resultantly crisis has emerged and load shedding has become a routine of the day.

This situation is expected to persist for at least a decade, as capacity addition in the system will take its own time. However the government is pursuing a multi-dimensional approach for capacity addition in the system that includes import of power from neighboring countries, encouraging national and international investment in Pakistan besides mobilizing own resources. In addition Provincial Governments are also being encouraged for investment in the sector. All these efforts are not expected to bring revolutionary results as the government resources are limited and private sector including national and international are hesitant in bringing investment in Pakistan. This is basically due to prevailing governance and law and order situation in the country.

In this situation the efforts being made by KP government will be helpful in reducing gap in supply and demand.

2.2 History of Power Development in Pakistan

At the time of independence in 1947, Pakistan inherited about 60 MW of power generation capability for a population of 31.5 million, yielding 4.5 units per capita consumption. These were private sector owned power plants. However, the Government of Pakistan in 1952 by acquiring majority shareholding took control of the Karachi Electric Supply Company (KESC) engaged in generation, transmission and distribution of electric energy to the industrial, commercial, agricultural and residential consumers of the metropolitan city of Karachi and its suburbs.

In 1958, Water and Power Development Authority (WAPDA) was created as a semi-autonomous body for the purpose of coordinating and giving a unified direction to the development of in water and power sectors, which were previously being dealt with by the respective electricity and irrigation department of the provinces. In 1959, the generation capacity had increased to 119 MW and by that time the country had entered the phase of development, which required a dependable infrastructure, electricity being its most significant part. The task of power development was undertaken by WAPDA by executing a number of hydel and thermal generation projects, a transmission network and a distribution system, which could sustain the load of the rapid economic development.

After the first five years of its operation by 1964-65, the electricity generation capability rose to 636 MW. The task of accelerating the pace of power development picked up speed and by the year 1970, the generating capability rose from 636 MW to 1331 MW with installation of a number of thermal and hydropower units. In the year 1980 the system capacity touched 3,000 MW which rapidly rose to over 7,000 MW in 1990-91.

The rapid progress witnessed a new life to the social, technical and economic structures of the country. Mechanized agriculture started, industrialization picked up and general living standards improved. Due to fast economic development, the government could not keep momentum of development of power sector due to resource constraint. The government resources were limited and were not able to invest the required amount to power sector as it had responsibility for social sector as well more investment was needed. This resulted in heavy load shedding in 1990s.

2.3 Induction of Private Sector in Power Generation

In order to give enough impetus to the power sector, the government in 1985 declared the power sector as an industry and consequently power sector also became eligible for getting all the incentives that was available to industrial sector.

This did not prove successful and no private sector came forward for investment. In 1994 the government issued an investor friendly power policy that was very well received by national and International investors and more than the required amount of additional power generation capacity was committed by the government that caused power surplus situation.

The over commitment of additional power generation capacity was based on the presumption that economic growth will keep its momentum. But actually it did not happened and economic growth slowed down that proved detrimental to the economy as the government had to pay capacity charges to the investors as per power policy and the agreement signed with the investors.

2.4 Power Policy

In order to eliminate power shortage/load shedding in the minimum possible time, the Government constituted an Energy Task Force in 1993 to devise a consolidated and comprehensive policy for revamping the energy sector. On the recommendations of the Energy Task Force, the Government announced a "Policy Framework and Package of Incentives for Private Sector Power Generation Projects" in March 1994 for a large scale induction of private sector in power development and the terms for Independent Power Producer (IPPs) were standardized.

Under this policy, the government offered a fix levelized tariff of USD 0.0557/kWh to the prospective investors (USD 0.06.1/kWh average for 1-10 years) and a number of other incentives to attract foreign investment in the power sector.

The Power Policy 1994 helped in overcoming load shedding in the country. Rather, it resulted in surplus power as the actual load growth was much less than that projected and the projects were contracted beyond requirement. Moreover the Policy attracted only thermal projects resulting in reversal of the hydro/thermal generation mix.

In order to provide one window facility to new investors in the power sector the GoP created a new organization, the Private Power and Infrastructure Board (PPIB), to negotiate agreements with sponsors and provide assistance in obtaining necessary government consents through a 'single window'. This power policy resulted in an enthusiastic response from the international investor community. The bulk supply tariff offered to the IPPs became a controversial issue as consumer tariffs had to be increased to meet the substantial financial commitments made for the IPP construction projects.

The 1994 power policy was only for a limited period and in 2002, the government issued a new policy (the 2002 Power Policy), which basically has the same structure and set of incentives as the 1994 policy but is broader in terms of its applicability.

The government's new power policy (2002) encourages solicited and unsolicited proposals for the establishment of new power plants. Unsolicited proposals allow investors to install a power plant at a location of their choice while solicited proposals give the government the opportunity to locate proposed power plants as it desires, generally, close to a load center. However the 2002 power policy could not bring same result due to one reason or the other.

2.5 Restructuring/ Unbundling of Power Wing of WAPDA

In the past there were two vertically integrated power supply companies operating in Pakistan, i.e., the Water and Power Development Authority (WAPDA) and Karachi Electric Supply Corporation (KESC). WAPDA was responsible for supplying electricity to various sectors of the economy across the country apart from the greater metropolis of Karachi which is supplied by the KESC. However, with the passage time and unprecedented expansion of WAPDA was witnessed thereby loosing control of the government which resulted in en-efficiencies and governance issues. Therefore the government decided to restructure the power wing of WAPDA. Under the restructuring plan all the power generation, transmission and distribution formations was made separate corporate entities leading to privatization. Accordingly the power wing of WAPDA has been un-bundled into ten Distribution and four Generation companies and one Transmission and Dispatch Company known as the National Transmission and Dispatch Company (NTDC).

These fourteen (14) corporate entities are:

1. **Ten (10) Distribution Companies (DISCOs) as under:**

   - Lahore Electric Supply Company (LESCO)
   - Gujranwala Electric Power Company (GEPCO)
   - Faisalabad Electric Supply Company (FESCO)
   - Islamabad Electric Supply Company (IESCO)
   - Multan Electric Power Company (MEPCO)
   - Peshawar Electric Power Company (PESCO)
   - Hyderabad Electric Supply Company (HESCO)
   - Quetta Electric Supply Company (QESCO)
   - Tribal Electric Supply Company (TESCO)
   - Sukkar Electric Power Company (SEPCO)

2. **Four (4) Thermal Power Generation Companies (GENCOs)**

   - Southern Generation Power Company Limited (GENCO-1) head quarter at Jamshoro district Dadu near Hyderabad Sindh.
   - Central Power Generation Company Limited (GENCO-2) head quarter at Guddu district Jacobabad Sindh.
   - Northern Power Generation Company Limited (GENCO-3) head quarters at TPS Muzaffargarh district Muzaffargarh Punjab.
   - Lakhra Power Generation Company Limited (GENCO-4) Headquarter at WAPDA House Lahore.
   - One (1) National Transmission & Power Dispatch Company (NTDC)

These un-bundled companies are being controlled by another newly created company called Pakistan Electric Power Company (PEPCO) working under the Ministry of Water & Power. The water wing of WAPDA was not touched and it remained responsible for controlling dams and hydro generation installed in the country in public and private sector.

The function of NTDC is to control national transmission & grid network and economical dispatch of hydro & thermal power generation by various companies connected through the national grid system. It is also responsible for development, operation and maintenance of National Grid system of the country (i.e. primary grid system).

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2.6 Power Supply

The main electric power producers in Pakistan are Water and Power Development Authority (WAPDA), Karachi Electricity Supply Company (KESC) and Pakistan Atomic Energy Commission (PAEC, the operator of the two nuclear power plants). Besides these three main power producers, a number of independent power producers (IPPs) established since 1994 are also contributing significantly to the electricity sector of the country.

2.7 Installed Capacity

The total installed capacity in the country (both PEPCO and KESC system) is about 23,302 MW (20,774 MW in PEPCO and 2,803 MW in KESC system), which constitutes 15,888 MW in thermal power (13,930 MW in PEPCO and 2,666 MW in KESC system), 6,844 MW in hydropower (6,733 MW operated by WAPDA and 111 MW operated by IPPs), and 787 MW in nuclear. Of this total thermal capacity in the PEPCO system, 4,900 MW is operated and maintained by various corporate entities of PEPCO known as Generation Companies (GENCOs) and other isolated system, while 8,380 MW is operated and maintained by the private sector. In the KESC system, only 285 MW is run by the private sector whereas rests of the plants are owned by the KESC. Almost all the thermal power generation units operated and maintained by GENCOs and KESC are capable of using multiple fuels, i.e., oil and gas simultaneously.

2.8 De-Rated Capacity

The power plants operating under the PEPCO and KESC system are old and have depreciated through natural wear and tear. As a result, the system's actual capability is much lower than its installed capacity.

The total installed hydropower generation capability varies due to the water outflows from the Tarbela and Mangla reservoirs that mainly depend upon irrigation indents.

These water indents are controlled by Indus River System Authority (IRSA), since these reservoirs are built only for the purpose of irrigation in the country and power being produced as a by-product.

The installed and de-rated power generating capacity of the country is given in the **Tables 2-1, 2-2, 2-3, 2-4 & 2-5**

Table 2-1: PEPCO Existing Installed Hydropower Generation Capacity (Public & Private)						
No.	Name of Power Station	Type of Power Station	Date of Commissioning	Capability		
				Total	Summer	Winter
Major Hydropower Stations (Public)						
1	Tarbela	Reservoir	1977- 1993	3,702	3,702	1,874
2	Mangla	Reservoir	1967-1994	1,000	1,120	450
3	Warsak	Reservoir	1960-1981	243	190	20
4	Chashma	Low Head	2001	184	184	184
5	Ghazi Barotha	Power Chanel	2003-2004	1,450	1,450	1160
6	Khan Khwar	Canal	2011	72	68	68
	Sub Total			**6,427**	**6,714**	**3,756**
7	Small Hydro Stations				56	41
8	Malakand – III	Canal	November 2008	81	81	81
9	Jagran – I (AJK)	Nullah	October 2000	30	30	30
	Sub total hydropower (Private)			111	111	111
	Grand Total of Hydropower			**6,627**	**6,881**	**3,908**

Source: NPSEP 2011~2030 final report by SNC-LAVALIN prepared for NTDC & Electricity Marketing Data (37^{th} issue) by Planning Power NTDC.

Table 2-2: PEPCO Existing Installed Thermal Power Generation Capacity (Public)					
No	Name of Power Station	Type of Power Station	Date of Commissioning	Company Total (MW)	De-Rated Capability (MW)
	GENCO-1			1,024	840
1	Jamshoro	Steam	1990~1991	850	700
2	Kotri	Gas Turb.	1970~1994	174	140
	GENCO-II			1,690	1,180
3	Guddu	Steam/ gas turbine/ CC	1974~1994	1655	1155
4	Quetta		November 1984	35	25
	GENCO-III			1,941	1,550
5	Muzaffargarh	Steam	1993~1997	1,350	1,130
6	Faislabad	Steam	1967	132	100
7	Faislabad	Gas Turb/ CC	1975	244	210
8	Multan	Steam	1963	195	90
9	Shahdara		June 1969	20	20
	GENCO-IV				
10	Lakhra Coal 1~3	Steam	1995-1996	150	30
	Total (GENCO-IV)			150	30
			Sub Total GENCOs	4,805	3,600
	Isolated Generation (Panjgoor and Pasni			56	35
	& Total GENCOs Isolated Generation			4,861	3,635
	Nuclear Power Stations				
1	CHASHNUP - I	Nuclear	October 2000	325	300
2	CHASHNUP - II	Nuclear	March 2011	325	315
	Total Nuclear			650	615
	Total Thermal Public Entities			**5,511**	**4,250**

Table 2-3: PEPCO Existing Installed Thermal Power Generation Capacity (Private)					
No	Name of Power Station	Type of Power Station	Date of Commissioning	Company Total (MW)	De-Rated Capability (MW)
Private / Independent Power Producers (IPPs)					
1	KAPCO	CCGTs	1987~1997	1,639	1,342
2	HUBCO	Steam Turb.	1996~1997	1,292	1,200
3	Kohinoor Energy Limited	Diesel Engines	June 1997	131	124
4	AES LALPIR Ltd.	Steam Turb.	November 1997	362	350
5	AES PAKGEN Ltd.	Steam Turb.	February 1998	365	349
6	SEPCOL	Diesel Engines	March 1999	135	110
7	HCPC	CCGTs	September 1999	140	129
8	ROUSCH	CCGTs	December 1999	450	395
9	Saba Power	Steam Turb.	December 1999	134	126
10	FKPCL	CCGTs	April 2000	157	151
11	JPGL	Diesel Engines	March 2000	135	107
12	UCH-I Power	CCGTs	October 2000	586	551
13	AEL	Gas Engine	June 2001	31	27
14	TNB Liberty Power	CCGT	September 2001	235	212
15	Attock Gen Limited	Diesel Engines	March 2009	165	156
16	Atlas Power Ltd.	Diesel Engines	December 2009	219	214
17	Engro Energy	CCGTs	March 2010	233	214
18	Saif Power	CCGTs	April 2010	229	205
19	Orient Power Ltd.	CCGTs	May 2010	229	213
20	Nishat Power Ltd.	Diesel Engines	June 2010	202	195
21	NCPL	Diesel Engines	July 2010	202	196
22	Sapphire Electric	CCGTs	October 2010	229	212
23	Liberty Power Tech	Diesel Engines	January 2011	202	196
24	Hub Norwal	Diesel Engines	April 2011	219	214
25	Foundation power	CCGTs	May 2011	230	178
26	Halmore Power	CCGTs	June 2011	229	207
	Total Thermal IPPs under PEPCO			**8,381**	**7,573**
	Total PEPCO Thermal			**13,892**	**11,808**
	Total PEPCO System in Summer			**20,519**	**18,604**
	Total PEPCO System in Winter			**20,519**	**15,716**

Table 2-4: KESC Existing Installed Thermal Power Generation Capacity (Public & Private)						
No	Name of Power Station	Type of Power Station	Nos. of Units	Capacity of each Unit (MW)	Company Total (MW)	De-Rated Capability (MW)
Thermal Own by KESC					1656	1463
1	Bin Qasim	Steam Turbine	6	210	1260	1120
2	SGTPS	Reciprocating Gas Engines	32	2.7	88	88
3	KGTPS	Reciprocating Gas Engines	32	2.7	88	88
4	KCCPP	CCGTs	4	55	220	167
IPPs Thermal in KESC System					366.5	354
1	Gul Ahmed Energy	Reciprocating Diesel Engines	9	14.3	128.5	128
2	Tepal Energy Limited	Reciprocating Diesel Engines	12	10.6	127	124
3	DHA Cogen	CCGTs	1	80	80	71
4	IIL	Reciprocating Diesel Engines	6	3.2	19	19
5	Anoud Power	Reciprocating Diesel &Gas Engines	12	4	12	12
Nuclear Power Stations in KESC System						
1	KANUPP	Nuclear	1	137	137	80
	Total Thermal in KESC System				**2,159.5**	**1,897**

Source: NPSEP 2011~2030 final report by SNC-LAVALIN prepared for NTDC & Electricity Marketing Data (37th issue) by Planning Power NTDC

Table 2-5: Installed Generation Capacity of PEPCO, IPPs and KESC				
No.	Power Station	Total Installed Capacity (MW)	De-Rated Capability (MW)	
			Max	Min
1.	WAPDA Hydropower	6516	6770	3797
2.	Public Thermal Plants	4900	3615	3615
3	IPPs Thermal	8,380	7,575	7,575
	IPPs Hydropower	111	111	111
4.	Nuclear (PAEC)	787	695	695
6.	KESC (Own)	1656	1463	1463
7.	KESC (Private)	367	354	354
	Total	**22,679**	**20,501**	**17,613**
	Total Country			
	Total Country System in Summer	**22,678**	**20,501**	
	Total Country System in Winter	**22,678**		**17,613**

Source: Electricity Marketing Data (37th issue) by Planning Power NTDC

2.9 Load Shedding

The existing total de-rated capability of hydro and thermal power stations of the country is 20501 MW, in which the hydel and thermal portions are 6781 MW (33%) and 13720 MW (67%) respectively. Presently there is substantial gap in power demand and supply. Less than the required power generation capability it is not only the reason but there are many other system constraints i.e. schedule or forced outages of generating units, shortage of oil , nonpayment of energy bill to the IPPs etc. Therefore, the power demand and supply gap is more prominent and to cope with this gap, NPCC and DISCOs carry out load shedding/load management round the clock to secure and stabilize the power system parameters. The actual system generation, load shedding /load management carried out by the system operator and computed demand during the year 2012 are given in **Table 2-6** and **Figure 2-1**.

Table 2-6: System Generation, Load Management and Computed System Demand during the year 2012

Month	Actual Load Supplied (MW)	Load Shedding (MW)	Computed Demand (MW)	%-age Load Shedding w.r.t. Load Supplied
January 12	8415	2923	11339	34.74%
February 12	8221	3133	11354	38.11%
March 12	8670	4036	12705	46.55%
April 12	9214	3846	13060	41.75%
May 12	10350	4777	15128	46.15%
June 12	10877	5265	16142	48.40%
July 12	12746	3952	16697	31.00%
August 12	12830	2836	15666	22.10%
September 12	11254	2655	13909	23.59%
October 12	10671	2360	13031	22.12%
November 12	9265	2048	11313	22.11%
December 12	8597	2881	11479	33.51%

Source: Power Data Reference Book, Planning Power NTDC

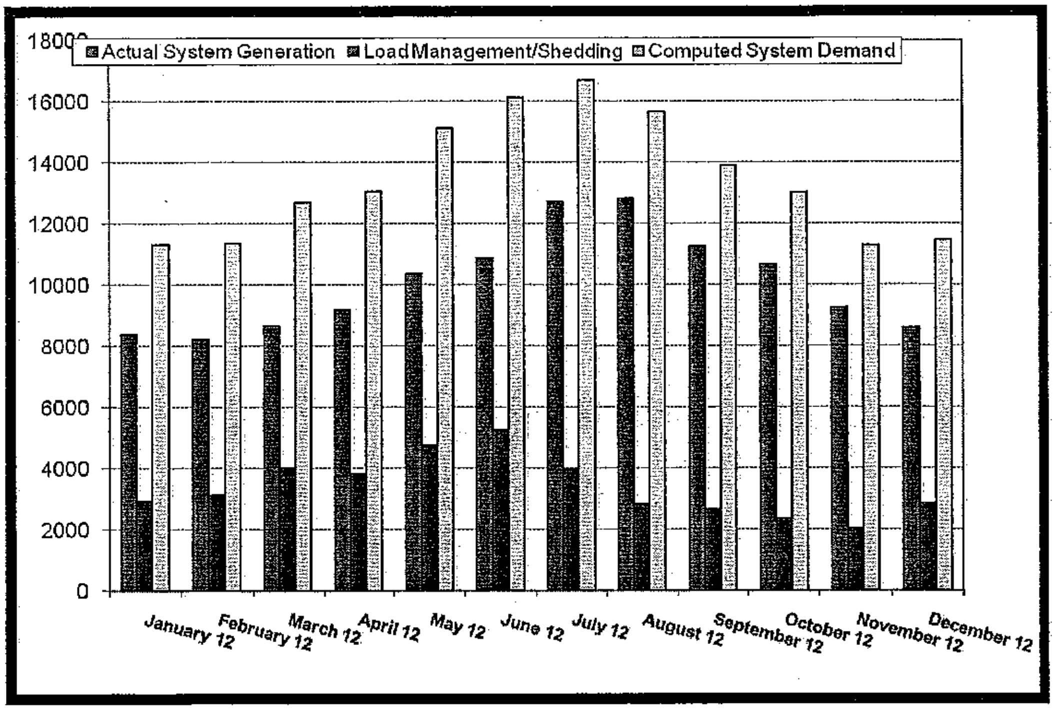


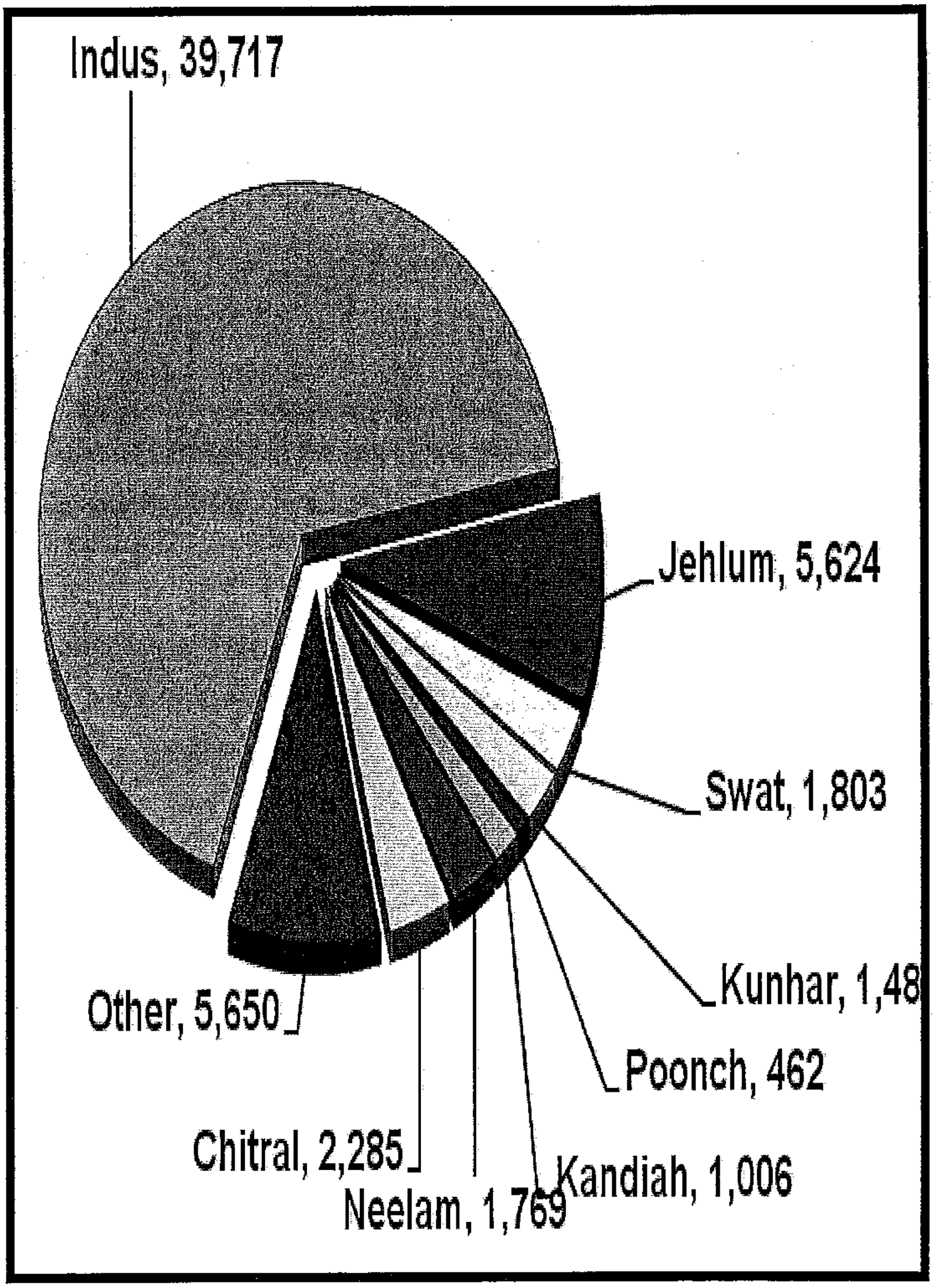
Figure 2-1: Actual Generation, Load Management & System Computed Demand 2012

2.10 Hydropower Potential in Pakistan

At independence hydro generation capacity was only 10.7 MW (9.6 MW - Malakand Power Station & 1.1 MW - Renala Power Station). With the passage of time, new hydropower projects of small and medium capacities were commissioned including the first water storage dam and power house at Warsak due to which country's hydel capability rose to about 267 MW up till 1963.In the year 1967 & 1977, Mangla Dam on Jhelum River and Tarbela Dam on Indus River having the provision of power generation of 1000 MW and 3702 MW were commissioned respectively.

Pakistan has been blessed with ample water resources but could store only 13% of the annual flow of its rivers. The statistics warrant construction of a number of reservoirs to enhance availability of water which stands at 1,070 cubic meters per capita. The Country is endowed with hydropower resources of about 60,000 MW, almost all of which lie in the Khyber Pakhtunkhwa, Gilgit- Baltistan Area, Azad Jammu & Kashmir, and Punjab, whereas abundant hydropower potential i.e. about 89% is still untapped and yet to be harnessed. **Figure 2-2** shows identified sites of hydropower resources on major rivers of the Country.

Figure 2-2: Identified Hydropower Potential on Major Rivers of The Country



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2.10.1 Existing Hydropower Generation Capacity

The total capacity of existing 16 hydropower stations connected with National Grid System as of 2013 is 6,881 MW including 30 MW Jagran hydropower project of AJ&K HEB. During the year 2012-13, aggregate energy sharing of the hydropower plants was 34.4%.

The Country existing hydropower resources can be divided into six regions in order to their geographical position, i.e. Khyber Pakhtunkhwa, Punjab, Sindh, Balochistan State Azad Jammu & Kashmir and Gilgit Baltistan. **Figure 2-3** shows region wise share of existing installed hydropower generation projects under operation, whereas **Table 2-7** shows its detail.

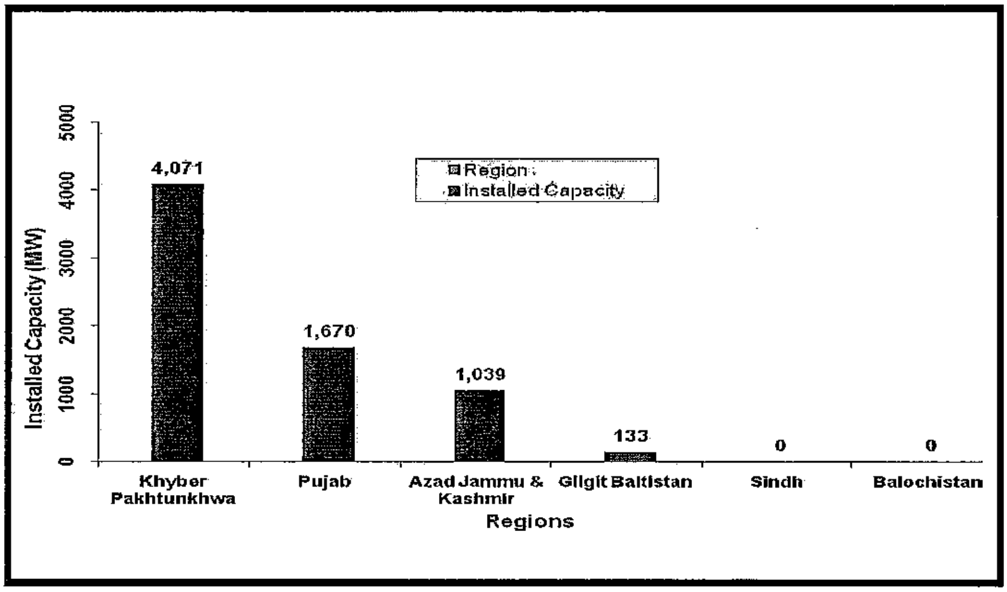

Figure 2-3: Region Wise Share Of Existing Installed Hydropower Projects

A. WAPDA

Table 2-7: Pakistan Existing Installed Hydro Power Generation a. Khber Pakhtunkhwa			
Sr.No.	**Name of Station**	**Location**	**Capability (MW)**
1	Tarbela	Indus River, Tarbela	3702
2	Warsak	Kabul River, Peshawar	190
3	Khan Khwar	Indus River	72
4	03 Small Hydropower Projects less than 50MW	Various Locations	20

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b. Punjab			
Sr.No.	Name of Station	Location	Capability (MW)
1.	Ghazi Barotha	Indus River, Attack	1450
2.	Chashma	Indus River, Chashma	184
3.	05 Small Hydropower Projects less than 50MW	Various Locations	36

c. Azad Jammu & Kashmir			
Sr.No.	Name of Station	Location	Capability (MW)
1.	Mangla	Jehlum River, Mirpur	1000

d. Gilgit Baltistan			
Sr.No.	Name of Station	Location	Capability (MW)
1.	Satpara	Satpara River, Sakardu	16
2.	Kar Gah	Phase VI Gilgit	4

B. PHYDO

a. Khber Pakhtunkhwa			
Sr.No.	Name of Station	Location	Capability (MW)
1	Malakand-III	River Swat, Malakand	81
2	13 Small Hydropower Projects less than 10 MW	Various location	6

e. HEB-AJ&K			
Sr.No.	Name of Station	Location	Capability (MW)
1	Jagran	Jagran River/Neelum	30.4
2	7 Small Hydel Projects less than 5 MW	Various Location	8.3

D. Water & Power Department– Gilgit-Baltistan			
Sr.No.	Name of Station	Location	Capability (MW)
1	96 Small Hydel Project less than 20 MW	Various Locations	113
	Isolated with National Grid System		

Source: Hydropower Resources of Pakistan by PPIB

2.10.2 Seasonal Variations of Hydropower Generation

The seasonal variations of reservoir levels and consequent reduction in Power outputs of storage type hydel projects in Pakistan are very pronounced. Tarbela with maximum head of 450 feet experiences variation of 230 feet while Mangla has 162 feet variation against the maximum head of 360 feet. The lean flow period of Tarbela reservoir is from November to June when the Capability reduces to as low as about 1,350 MW against the maximum of 3,692 MW during high head period i.e. August to September (15% permissible overloading on Units 1~10).Lean flow period of Mangla reservoir is observed from October to March when the minimum generating capability is 500 MW. The capability rises to as high as 1,150 MW during 'high head' period (15% permissible overloading).

In all, WAPDA's hydropower generating capability varies between the two extremities of 2,279 MW and 6,937 MW over the cycle of a year.

2.10.3 Hydropower Potential in Khyber Pakhtunkhwa

Khyber Pakhtunkhwa is bounded by Afghanistan in the west, Gilgit Baltistan in the north, the State of Azad Jammu & Kashmir in the northern east, Punjab in the southeast and Baluchistan in the south. It is separated from Punjab by the River Indus. The main rivers of Khyber Pakhtunkhwa are the Indus, Kabul, Swat, Kunhar, Kohat, Kurram, Tochi, Chitral, Panjkoora, Ushu and Gabral. About 142 project sites with a total capacity of 24736 MW were identified having high, medium and small head. Out of these, 19 projects are in operation with a total capacity of 3849 MW, 27 sites are under implementation in the public sector with a total capacity of 9559 MW, whereas 11 sites are under implementation in the private sector with a total capacity of 2398 MW. Mostly, these are run-of river sites, with small poundage for daily peaking.

Table 2-8 & 2-9 shows the details of the projects, their location and capacities under implementation in public sector, private sector and identified hydropower resources (raw sites) in Khyber Pakhtunkhwa respectively, whereas Figure 2-4 shows the location of operational hydropower projects and identified hydropower potential (Raw sites) in Khyber Pakhtunkhwa.

Table 2-8: Projects in Public Sector in Khyber Pakhtunkhwa			
A. WAPDA			
Sr.No.	Name of Station	Location	Capability (MW)
1	Dassu	Kohistan/Indus River	4320
2	Chor Nullah System	Kohistan/ Chor Nullah/Indus River	1176
3	Munda Multipurpose Dam	Mohmand Agency, FATA/Swat River	660
4	Spat Gah (lower)	Kohistan/ Spat Gah/Indus River	567
5	Spat Gah (middle)	Kohistan/ Spat Gah/Indus River	501
6	Spat Gah (upper)	Kohistan/ Spat Gah/Indus River	273
7	Duber Khwar	Kohistan/DuberKhwar/Indus River	130
8	Kayal Khwar	Kohistan/Kayal Khwar/ Indus River	125
9	Allai Khwar	Mansehra/Allai Khwar/Indus River	121
10	Golen Gol	Chitral/Golen Gol/Mastuj River	106
11	Kurram Tangi Dam	North Wazirstan Agency/Kurram River	83
12	Khan Khwar	Kohistan/ Khan Khwar/Indus River	72
13	Gomal Zam Dam	Waziristan Agency/ Gomal Zam	18
14	Tarbela 4th Extension	Haripur /Indus River	960
		Sub Total	**9112**

B. PHYDO			
Sr.No.	Name of Station	Location	Capability (MW)
1	Sharmai	Dir/Panjkora River	115
2	Matiltan	Swat/ Ushu Khwar	84
3	Koto	Dir/Panjkora River	52
4	10 Small Hydel Project less than 50 MW	Various Locations	119
		Sub Total	**370**
		Grand Total	**9482**

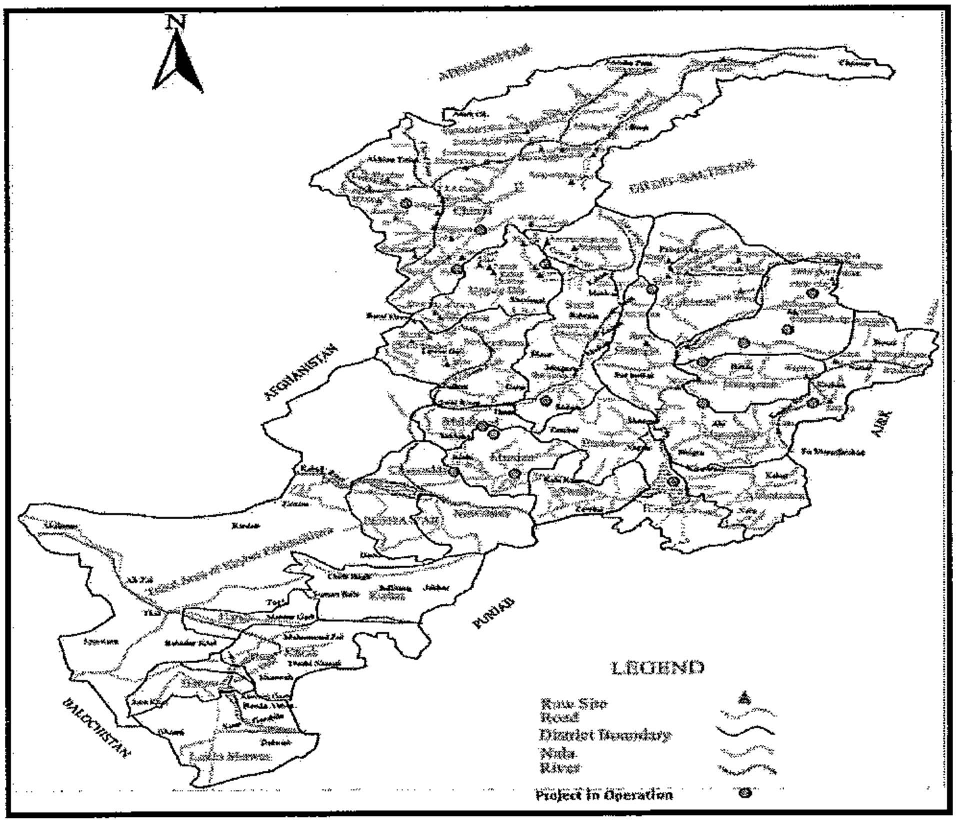
Source: Hydro Power Resources of Pakistan by PPIB

Table 2-9: Projects under Implementation in Private Sector in Khyber Pakhtunkhwa			
A. PHYDO			
Sr.No.	Name of Station	Location	Capability (MW)
1	Mahandri	Mansehra/Manur Nullah	13.20
2	Tangar	Mansehra/Barniali Katha	12.54
3	Machai	Machai Canal RD 52+775	2.50
		Total	**28.24**

B. PPIB			
Sr.No.	Name of Station	Location	Capability (MW)
1	Suki Kinari	Mansehra/Kunhar River	840
2	Kaigah	Kohistan/Kandiah River/Indus River	548
3	Asrit-Kedam	Swat/Swat River	215
4	Kalam-Asrit	Swat/Swat River	197
5	Madian	Swat/Swat River	157
6*	Shushghai-Zhendoli	Chitral/Tirich Gol	144
7	Gabral Kalam	Swat/Gabral Khwar/Swat River	137
8*	Shogo-Sin	Chitral/Lutkho River	132
		Total	**2370**

*Feasibility Study conducted by PPIB under ADB Technical Assistance Loan.
Source: Hydro Power Resources of Pakistan by PPIB

Figure 2-4: Hydropower Potential in Khyber Pakhtunkhwa



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2.11 Electricity Demand

The electricity demand is a function of GDP growth, population growth, unmet demands etc. at present the available capacity is not capable of meeting demand due to various reasons including capacity and capability as sufficient fuel is not available for power plants.

However in order to asses' future power requirement it is essential that a realistic demand is made so that adequate planning could be made for capacity addition.

2.11.1 Demand Forecasting

Demand forecasting or Load forecasting is an important element of the power planning process involving prediction of future level of demand. The forecast serves as the basis for supply-side and demand-side planning. Load forecasts are typically prepared by utilities for different time frames and levels of detail and used for generation, transmission as well as distribution planning. It further helps investment planning for these sectors and for their associated industries like manufacturing, fuel and resource exploration etc.

Load forecast or power demand is not independent of the Country's economic situation, its estimation depends on many diverse parameters related to development of domestic, commercial, agricultural and industrial sectors. Small variations in parameter estimations can produce huge swings in the investment volumes required and can make or break the decisions of country's economic development.

Long range planning requires a system level forecast of total generation requirement and peak demand. Planning Power NTDC is responsible for developing medium and long term forecast for the whole country as ordained in its transmission license granted by NEPRA. Accordingly the demand forecast has been carried out by Planning Power NTDC with the consultation of other stakeholders.

The Demand forecast is based on **Multiple Regression Technique** using historical data, variables like electricity consumption for different categories, electricity tariff, GDP of different sectors, CPI, population of the country, number of customer for different electricity tariff categories etc. On the other hand transmission and distribution planning require for more load level and geographic detail to assess location, timing and loading of individual lines, substation and transformation facilities. There are three types of load forecasts; long-term, medium-term and short-term. In PEPCO system, Planning Power NTDC carried out medium term and long term forecasts.

2.11.2 Regression Methodology

The regression methodology using in **Multiple Regression Technique** by Planning Power NTDC is summarize herein.

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The long-term forecast is carried out by regression analysis of consumption trends, relationships with price, GDP, population and number of customers.
A detailed regression analysis involves the review of fundamental quantitative relationships in the electricity demand and the independent variables of the equation like electricity price, sector's GDP, and population of Pakistan etc.

For this model the impact of historical load management (load shedding) is included in the data base, so the resulting equations estimate the actual energy demand.

2.11.3 Parameters of Regression

Dependent Variables (Y)

Electricity consumption (GWh) for various consumer categories including domestic, commercial, industrial and agricultural are our selected dependent variables.

Independent Variables (X)

The potential independent variables (demographic and economic) for regression analysis include;

- Total GDP
- GDP by major sector (agriculture, manufacturing, trade, services, etc.)
- Electricity revenue per kWh sold by customer class (real price)
- Number of customers by consumption category
- Population

Lag variables

In many cases, dependence of variable Y (Dependent Variable) on another Variable X (Independent variable) is not instantaneous. Generally, Y responds to X with a lapse of time. Such a lapse of time is called Lag.

Dummy Variable

Dependence of variable Y (Dependent Variable) is not only influenced by variables which can be quantified on some well defined scale (e.g., income, price, costs, etc.) but also by variables which are essentially qualitative in nature (e.g., sex, race, color, change in government policy, etc.). Such qualitative variables usually indicate presence or absence of a "quality" by assuming value (0 or 1) called the "dummy variables".

Regression Equations

Electricity consumption forecast through regression analysis is very common and popular in the world. Take electricity consumption as a dependent variable while electricity price, GDP, population and electricity consumers etc are different independent variables. These relationships form a combination of different independent and dependent variables. This is called a regression equation as shown below:

S= β1X1+β2X2+................+βnXn+.........+C

Where: S = sales in a specific category

C = a constant

X_1, X_2, X_3 are independent variables

β_1, β_2, β_3, are coefficients derived from least squares regression analysis

The analysis is done with log values as well as without log values in this equation

2.11.4 Projection of Electricity Demand and GDP Growth of the Country

The economy of the country has undergone unexpected changes during the last ten years. The GDP growth rate in 2000-01 was 2.0% per annum that increased to 9.0% per annum in 2004-05. International high oil prices along with low production of food crops in the country has decreased economic growth to 6.8% per annum in the financial year 2006-07 and further to 5% in the year 2007-08. The global financial crisis and law and order situation in the country has further decreased the economic growth to 0.4% in 2008-09. During 2009-10, the economy of the country recovered slightly to 2.6%. Economic analysts foresee that the economy of the country will gradually recover to 6% by 2014-15. Details of percentage GDP growth, percentage of Domestic and total Electricity Consumption and percentage Core Inflation with respect to each fiscal year are given in the **Table 2-10**, while **Figure 2-5** shows the graphical analysis of these variables.

Table 2-10: Comparison between GDP, Electricity Consumption and Inflation Rates with respect to Fiscal Years

Fiscal Year ending 30th June	% Growth Electricity Consumption Domestic	% Growth Electricity Consumption Total	GDP growth w.r.t.Categories				% Core Inflation
			Commercial	Industrial	Agriculture	Total	
1996	10.0%	5.4%	5.0%	3.7%	11.7%	6.6%	10.9%
1997	5.4%	4.3%	3.6%	-0.1%	0.1%	1.7%	11.4%
1998	5.0%	2.3%	1.6%	6.9%	4.5%	3.5%	7.5%

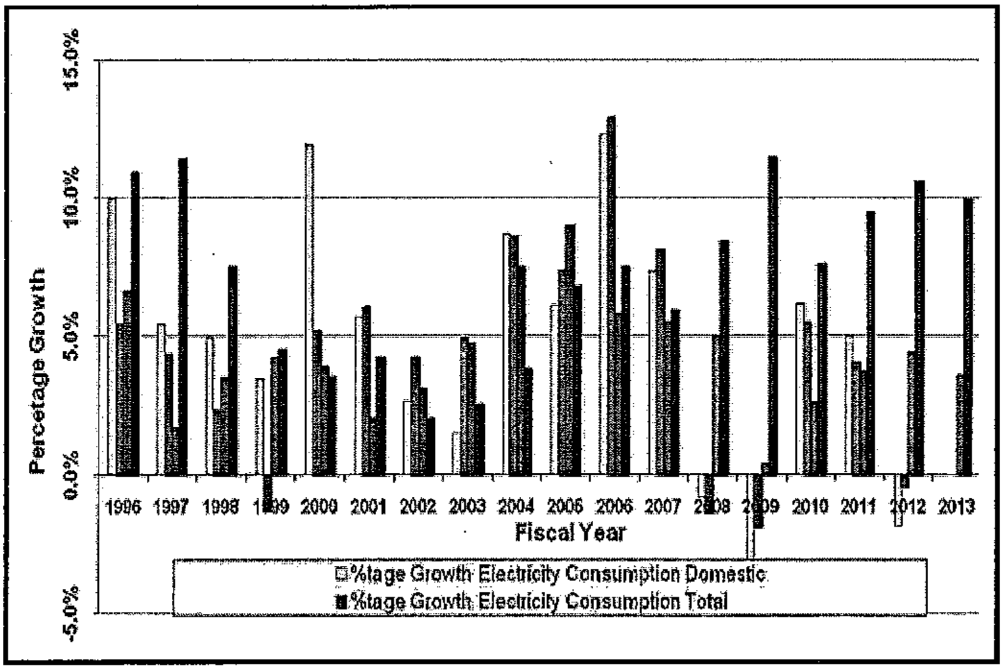
Table 2-11: Comparison between GDP, Electricity Consumption and Inflation Rates with respect to Fiscal Years

Fiscal Year ending 30th June	% Growth Electricity Consumption Domestic	% Growth Electricity Consumption Total	GDP growth w.r.t.Categories	% Core Inflation	GDP growth w.r.t.Categories		% Core Inflation
2000	11.9%	5.2%	4.8%	1.5%	6.1%	3.9%	3.5%
2001	5.7%	6.0%	3.1%	9.3%	-2.2%	2.0%	4.2%

2002	2.6%	4.2%	4.8%	4.5%	0.1%	3.1%	2.0%
2003	1.5%	4.9%	5.2%	6.9%	4.1%	4.7%	2.5%
2004	8.7%	8.6%	5.9%	14.0%	2.4%	7.5%	3.8%
2005	6.1%	7.4%	8.5%	15.5%	6.5%	9.0%	6.8%
2006	12.3%	12.9%	6.5%	8.7%	6.3%	5.8%	7.5%
2007	7.3%	8.1%	5.6%	9.0%	3.4%	5.5%	5.9%
2008	-0.8%	-1.4%	4.9%	6.1%	1.8%	5.0%	8.4%
2009	-3.4%	-1.9%	1.3%	-4.2%	3.5%	0.4%	11.4%
2010	6.2%	5.5%	3.2%	1.4%	0.2%	2.6%	7.6%
2011	5.0%	4.1%	3.9%	2.5%	2.0%	3.7%	9.4%
2012	-1.9%	-0.4%	5.3%	2.1%	3.5%	4.4%	10.6%
2013			3.7%	3.5%	3.3%	3.6%	9.9%

Source: Economic Survey of Pakistan 2012~13 & Power System Statistics 37th Edition by Planning Power NTDC

Figure 2-5: GDP growth Electricity Consumption and Core Inflation



It can be noted that periods of high growth rate of energy consumption was by high growth rate of GDP, conversely period of lower growth in energy consumption caused lower growth in GDP.

The Planning Power NTDC has developed electricity demand forecast of country for three scenarios Low, Normal and High at average annual GDP growth rates of 3.5%, 5.0% and 6.5% respectively. Based on the economy's performance over the last five years (2008-12), peak demand of electricity is expected to grow at annual rates of 5.89%, 7.42% and 8.99% by the year 2034-

35 in Low, Normal and High scenarios respectively[1] (reference year is 2011 with peak demand as 18,270 MW).

The low, normal and high GDP growth rates that are used for demand projection by Planning Power NTDC, summary and details are given in **Table 2-12 to 14** below:

Table 2-12: GDP Growth Rates

Year	Low	Normal	High
2011~2012	2.4	2.4	2.4
2012~2013	2.7	3.1	3.4
2013~2014	3.0	3.7	4.5
2014~2015	3.2	4.4	5.5
2015~2016	3.5	5.0	6.5
2017~2020	3.5	5.0	6.5
2021~2025	3.5	5.0	6.5

Source: Electricity Demand forecast based on multiple Regression Analysis by Planning Power NTDC, May 2012

Table 2-13: Country's Sector wise projected GDP Growth for Low Scenario

Year	Gross Domestic product (%)			
	Total	Commercial	Industrial	Agriculture
2010-11	2.4	4.8	3.2	0.9
2011-12	2.7	4.9	3.5	1.2
2012-13	3	5.2	3.8	1.5
2013-14	3.2	5.4	4	1.7
2014-15	3.5	5.7	4.3	2
2015-16	3.5	5.7	4.3	2
2016-17	3.5	5.7	4.3	2
2017-18	3.5	5.7	4.3	2

Table 2-14: Country's Sector wise projected GDP Growth for Low Scenario

Year	Gross Domestic product (%)			
	Total	Commercial	Industrial	Agriculture
2018-19	3.5	5.7	4.3	2
2019-20	3.5	5.7	4.3	2
2020-21	3.5	5.7	4.3	2
2021-22	3.5	5.7	4.3	2
2022-23	3.5	5.7	4.3	2

[1] Electricity Demand forecast based on multiple Regression Analysis by Planning Power NTDC, May 2012.

2023-24	3.5	5.7	4.3	2
2024-25	3.5	5.7	4.3	2

Source: Electricity Demand forecast based on multiple Regression Analysis by Planning Power NTDC, May 2012

Table 2-154: Country's Sector wise projected GDP Growth for Normal Scenario

Year	Gross Domestic Product (%)			
	Total	Commercial	Industrial	Agriculture
2010-11	2.4	4.8	3.2	0.9
2011-12	3.1	5.3	3.9	1.6
2012-13	3.7	5.9	4.5	2.2
2013-14	4.4	6.6	5.2	2.9
2014-15	5	7.2	5.8	3.5
2015-16	5	7.2	5.8	3.5
2016-17	5	7.2	5.8	3.5
2017-18	5	7.2	5.8	3.5
2018-19	5	7.2	5.8	3.5
2019-20	5	7.2	5.8	3.5
2020-21	5	7.2	5.8	3.5
2021-22	5	7.2	5.8	3.5
2022-23	5	7.2	5.8	3.5
2023-24	5	7.2	5.8	3.5
2024-25	5	7.2	5.8	3.5

Source: Electricity Demand forecast based on multiple Regression Analysis by Planning Power NTDC, May 2012

Table 2-165: Country's Sector wise projected GDP Growth for High Scenario

Year	Gross Domestic Product (%)			
	Total	Commercial	Industrial	Agriculture
2010-11	2.4	4.8	3.2	0.9
2011-12	3.4	5.6	4.2	1.9
2012-13	4.5	6.7	5.3	3
2013-14	5.5	7.7	6.3	4
2014-15	6.5	8.7	7.3	5
2015-16	6.5	8.7	7.3	5
2016-17	6.5	8.7	7.3	5
2017-18	6.5	8.7	7.3	5

Table 2-165: Country's Sector wise projected GDP Growth for High Scenario				
Year	Gross Domestic Product (%)			
	Total	Commercial	Industrial	Agriculture
2018-19	6.5	8.7	7.3	5
2019-20	6.5	8.7	7.3	5
2020-21	6.5	8.7	7.3	5
2021-22	6.5	8.7	7.3	5
2022-23	6.5	8.7	7.3	5
2023-24	6.5	8.7	7.3	5
2024-25	6.5	8.7	7.3	5

Source: Electricity Demand forecast based on multiple Regression Analysis by Planning Power NTDC, May 2012

In order to achieve high economic growth, the Government has gradually started increasing investment for infrastructure development and desires to invest mostly in the construction of major water reservoir for production of hydro electricity and to meet the water need for the agriculture sector which is the backbone of economic growth. Therefore, most of the investment in thermal power generation is expected to come from national and international private sector entrepreneurs.

Electricity supply is a service industry catering to various economic and service sectors. Demand is thus driven by the growth in these sectors. In order to project a realistic growth rate for power demand, electricity consumption in various economic sectors (domestic, industrial, agricultural, etc.) and corresponding economic parameters such as GDP, services value-added, industrial value-added, and agricultural value-added also need to be taken into account. Various GDP growth rate scenarios, i.e., high, medium, and low, have been analyzed to see which would best-fit them.

Current economic trends show that the economy may grow at an average rate of around 5% over the next twenty years. Therefore, projections of the demand for power have been developed accordingly. Electricity demand projections based on Low, normal and high GDP growth are presented in **Table 2-15 to 17** respectively, whereas corresponding elasticity are given in **Table 2-18.**

Table 2-176: Electricity Demand forecast Based on Low GDP Growth (GWh)									
Fiscal Year	Domestic (GWh)	Commercial (GWh)	Industrial (GWh)	Agriculture (GWh)	Bulk (GWh)	Total (GWh)	Self Generation (GWh)	Gross Total (GWh)	% Growth Rate
2010-11	44901	7304	26967	11419	5337	95926	11284	107210	
2011-12	46563	8025	28334	11590	5625	100137	11856	111993	4.5%
2012-13	47652	8834	29474	12159	5874	103993	12333	116326	3.9%
2013-14	50542	9708	30520	11722	6231	108722	12770	121492	4.4%
2014-15	53296	10343	31566	11870	6542	113618	13209	126826	4.4%
2015-16	56203	11308	32655	12225	6910	119301	13663	132965	4.8%
2016-17	59271	12378	33813	12074	7307	124842	14147	138990	4.5%
2017-18	62508	13545	35062	12226	7734	131075	14671	145747	4.9%
2018-19	65925	14647	36423	12490	8170	137653	15240	152894	4.9%
2019-20	68689	16010	37911	12499	8614	143725	15863	159588	4.4%
2020-21	70989	17515	39558	12761	9068	149890	16545	166435	4.3%
2021-22	75251	19168	41377	13090	9658	158542	17300	175843	5.7%
2022-23	79442	20911	43383	13295	10271	167303	18133	185436	5.5%
2023-24	83873	22920	45594	13645	10948	176980	19050	196030	5.7%
2024-25	88555	25142	48030	14042	11687	187455	20061	207516	5.9%

Fiscal Year	Domestic (GWh)	Commercial (GWh)	Industrial (GWh)	Agriculture (GWh)	Bulk (GWh)	Total (GWh)	Self Generation (GWh)	Energy Sent out (GWh)	% Growth Rate
2010-11	44901	7304	26967	11419	5337	95928	11284	107212	
2011-12	46648	8054	28365	11635	5635	100337	11869	112206	4.66%
2012-13	47916	8922	29596	12288	5908	104630	12384	117014	4.28%
2013-14	51104	9912	30820	11987	6310	110133	12896	123029	5.14%
2014-15	54286	10705	32161	12344	6688	116184	13457	129641	5.37%
2015-16	57670	11883	33648	12950	7139	123290	14079	137369	5.96%
2016-17	61266	13221	35303	13066	7639	130495	14772	145267	5.75%
2017-18	65093	14735	37151	13554	8189	138722	15545	154267	6.20%
2018-19	69160	16249	39216	14200	8767	147592	16409	164001	6.31%
2019-20	72692	18123	41526	14599	9384	156324	17375	173699	5.91%
2020-21	75885	20243	44128	15338	10038	165632	18458	184090	5.98%
2021-22	81358	22638	47058	16204	10877	178135	19676	197811	7.45%
2022-23	86984	25253	50355	16969	11780	191341	21047	212388	7.37%
2023-24	93007	28314	54063	17975	12799	206158	22589	228747	7.70%
2024-25	99456	31781	58237	19107	13930	222511	24324	246835	7.91%

Source: Electricity Demand forecast based on multiple Regression Analysis by Planning Power NTDC, May 2012

Table 2-187: Electricity Demand forecast Based on High GDP Growth (GWh)

Table 2-198: Modified Elasticity Coefficients by Customer Class

Fiscal Year	(GWh)	(GWh)	(GWh)	(GWh)	(GWh)	(GWh)	Generation (GWh)	Total (GWh)	Growth Rate
2010-11	44901	7002	26967	11419	5337	95926	11284	107210	
2011-12	46729	7738	28393	11668	5645	100511	11881	112392	4.8%
2012-13	48186	8634	29718	12418	5944	105277	12435	117712	4.7%
2013-14	51679	9688	31126	12243	6390	111548	13024	124572	5.8%
2014-15	55296	10604	32772	12813	6836	118783	13713	132496	6.4%
2015-16	59170	11944	34674	13697	7376	127381	14508	141890	7.1%
2016-17	63320	13511	36856	14107	7982	136365	15422	151786	7.0%
2017-18	67765	15326	39351	14982	8665	146757	16466	163223	7.5%
2018-19	72527	17228	42199	16095	9401	158203	17657	175860	7.7%
2019-20	76884	19599	45449	16990	10214	169990	19017	189007	7.5%
2020-21	81074	22349	49176	18357	11107	183039	20569	203609	7.7%
2021-22	87909	25531	53451	19967	12246	200217	22349	222566	9.3%
2022-23	95168	29112	58355	21548	13509	218962	24391	243352	9.3%
2023-24	103039	33375	63984	23548	14958	240361	26734	267095	9.8%
2024-25	111573	38323	70459	25845	16605	264475	29429	293903	10.0%

Demand forecast based on multiple Regression Analysis by Planning Power NTDC, May 2012

Year	GDP Short - term Elasticities (Used)				Lag Elasticities				GDP Long - Term Elasticities			
	Domestic	Commercial	Industrial	Agriculture	Domestic	Commercial	Industrial	Agriculture	Domestic	Commercial	Industrial	Agriculture
2010-11	0.5060	0.9365	0.2731	0.9438	0.7078	0.3963	0.6265	0.4994	1.7315	1.5511	0.7311	1.8853
2011-12	0.5070	0.9444	0.2980	0.9629	0.7078	0.3963	0.6265	0.4994	1.7351	1.5642	0.7979	1.9234
2012-13	0.5081	0.9523	0.3230	0.9820	0.7078	0.3963	0.6265	0.4994	1.7387	1.5773	0.8647	1.9615
2013-14	0.5091	0.9602	0.3479	1.0010	0.7078	0.3963	0.6265	0.4994	1.7423	1.5904	0.9315	1.9996
2014-15	0.5102	0.9681	0.3729	1.0201	0.7078	0.3963	0.6265	0.4994	1.7459	1.6035	0.9982	2.0377
2015-16	0.5112	0.9760	0.3978	1.0392	0.7078	0.3963	0.6265	0.4994	1.7495	1.6166	1.0650	2.0759
2016-17	0.5123	0.9839	0.4228	1.0583	0.7078	0.3963	0.6265	0.4994	1.7531	1.6297	1.1318	2.1140
2017-18	0.5134	0.9918	0.4477	1.0774	0.7078	0.3963	0.6265	0.4994	1.7567	1.6428	1.1986	2.1521
2018-19	0.5144	0.9997	0.4726	1.0964	0.7078	0.3963	0.6265	0.4994	1.7603	1.6559	1.2654	2.1902
2019-20	0.5155	1.0076	0.4976	1.1155	0.7078	0.3963	0.6265	0.4994	1.7639	1.6690	1.3322	2.2283
2020-21	0.5165	1.0155	0.5225	1.1346	0.7078	0.3963	0.6265	0.4994	1.7675	1.6821	1.3989	2.2664
2021-22	0.5176	1.0235	0.5475	1.1537	0.7078	0.3963	0.6265	0.4994	1.7712	1.6952	1.4657	2.3045
2022-23	0.5186	1.0314	0.5724	1.1728	0.7078	0.3963	0.6265	0.4994	1.7748	1.7083	1.5325	2.3426
2023-24	0.5197	1.0393	0.5974	1.1918	0.7078	0.3963	0.6265	0.4994	1.7784	1.7214	1.5993	2.3808
2024-25	0.5207	1.0472	0.6223	1.2109	0.7078	0.3963	0.6265	0.4994	1.7820	1.7345	1.6661	2.4189
2025-06	0.5218	1.0551	0.6473	1.2300	0.7078	0.3963	0.6265	0.4994	1.7856	1.7476	1.7329	2.4570
2026-27	0.5228	1.0630	0.6722	1.2491	0.7078	0.3963	0.6265	0.4994	1.7892	1.7607	1.7996	2.4951
2027-28	0.5239	1.0709	0.6972	1.2682	0.7078	0.3963	0.6265	0.4994	1.7928	1.7738	1.8664	2.5332
2028-29	0.5249	1.0788	0.7221	1.2872	0.7078	0.3963	0.6265	0.4994	1.7964	1.7869	1.9332	2.5713
2029-30	0.5260	1.0867	0.7470	1.3063	0.7078	0.3963	0.6265	0.4994	1.8000	1.8000	2.0000	2.6094
2030-31	0.2922	0.6037	0.3735	1.3254	0.7078	0.3963	0.6265	0.4994	1.0000	1.0000	1.0000	2.6475
2031-32	0.2922	0.6037	0.3735	1.3445	0.7078	0.3963	0.6265	0.4994	1.0000	1.0000	1.0000	2.6857
2032-33	0.2922	0.6037	0.3735	1.3636	0.7078	0.3963	0.6265	0.4994	1.0000	1.0000	1.0000	2.7238
2033-34	0.2922	0.6037	0.3735	1.3827	0.7078	0.3963	0.6265	0.4994	1.0000	1.0000	1.0000	2.7619
2034-35	0.2922	0.6037	0.3735	1.4017	0.7078	0.3963	0.6265	0.4994	1.0000	1.0000	1.0000	2.8000

2.12 Demand and Supply analysis

For years, the matter of balancing Pakistan's supply against the demand for electricity has remained a largely unresolved matter. Pakistan faces a significant challenge in revamping its network responsible for the supply of electricity.

Demand & Supply analysis plays an important role in power planning. In this analysis we do a comparison between future forecasted demands with its corresponding committed or firm power supply position and the result gives an idea about future power position.

The demand & supply balance is based on the current inputs and may change with any change in the input data. The input data includes list of generation projects and the data obtained from different formations including PPIB, WAPDA, PAEC, GENCOs and AEDB etc.

The NTDC forecast in its report has presented three scenarios (low, normal and high) for the period 2011-2035 and a scenario, where the normal forecast is considered for power demand balance analysis as the low GDP growth appeared to be too low and high GDP seems to be too optimistic.

The normal load forecast of the PEPCO system for the financial year 2012~13 to 2024~25 is detailed in following **Table 2-19.**

Table 2-19: Electricity Load Forecast Based on Normal GDP Growth

Fiscal Year	Energy Sentout (GWh)	Peak Demand (MW)	Load Factor (%)
2011-12	112206*	23892*	69.4*
2012-13	117014*	24721*	69.3*
2013-14	123029	25793	69.3
2014-15	129641	26976	69.3
2015-16	137369	28558	68.9
2016-17	145267	29866	69.2
2017-18	154267	31527	69.1
2018-19	164001	33317	69.1
2019-20	173699	35074	69.1
2020-21	184090	37130	69
2021-22	197811	39820	69
2022-23	212388	42711	68.9
2023-24	228747	45955	68.9
2024-25	246835	49533	68.8

*Actual Value

Source: Electricity Demand forecast based on multiple regression analysis by planning power NTDC, May 2012

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The list of existing power plants and their present capabilities are given in earlier pages at **Tables 2-1 to 2-5**, while the detail of power plants committed or expected in future along with their expected operation date are given in the **Table 2-20.**

Table 2-200: Generation Plan 2011~2025

Year	Name of Project	Unit Additions				Annual Total (MW)	Retirement (MW)	Cumulative Net Capacity (MW)
		Type	# of Units	Unit net Capacity (MW)	Total net Capacity (MW)			
2011-12								19,296
2012-13	Jinnah HPP	Hydro	1	96	96	423	985	18,734
	Khan Khwar	Hydro	1	72	72			
	Rental Power Projects	Thermal			-985			
	New Bong Escape, IPP	Hydro	1	84	84			
	Allai Khwar	Hydro	1	121	121			
	FFCEL	Wind			50			
2013-14	Duber Khwar	Hydro	1	130	130	722		19,456
	Gomal Zam HPP	Hydro	1	17	17			
	UCH II CCGT	CC	1	375	375			
	Candidate wind PP	Wind			200			
2014-15	Guddu Rehabilitation Project # I & II	CC	2	329	658	1,797		21,253
	Nandipur Power Project	CC	1	364	364			
	Chichoki Mallian CCGT	CC	1	525	525			
	Candidate wind PP	Wind			250			
2015-16	Neelum Jhelum	Hydro	4	240	959	1,209		22,462
	Candidate wind PP	Wind			250			
2016-17	Imported Coal	Coal	2	500	1,000	3,570		26,032
	CHASHNUPP-III, Punjab	Nuclear	1	320	320			
	Candidate wind PP	Wind			250			
	Iran - Pakistan and CASA T/L	I/C	2	1,000	2,000			
2017-18	Imported Coal	Coal	2	500	1,000	5,024		38,305
	CHASHNUPP-IV, Punjab	Nuclear	1	320	320			
	Tarbela 4th Ext.	Hydro	2	475	950			
	Golen Gol	Hydro	3	35	105			
	Parind HPP, IPP	Hydro	1	147	147			
	Candidate wind PP	Wind			300			
2018-19	Imported Coal	Coal	2	500	1,000	1,458		30,312
	Rajdahani HPP, IPP	Hydro	1	131	131			
	Shogosin HPP, IPP	Hydro	1	126	126			
	Shushgai Zhendoli HPP, IPP	Hydro	1	101	101			
	Candidate wind PP	Wind			100			

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Source: NTDC National Power System Expansion Plan 2011~2030 (Generation Planning)

(continue...)

Table 2-21: Generation Plan

Year	Name of Project	Unit Additions				Annual Total (MW)	Retirement (MW)	Cumulative Net Capacity (MW)
		Type	# of Units	Unit net Capacity (MW)	Total net Capacity (MW)			
2019-20	Imported Coal	Coal	2	500	1,000	1,932	414	31,380
	GTPS Faisalabad	Thermal			-129			
	Guddu CCP	Thermal			-285			
	Suki Kinari HPP, IPP	Hydro	4					
	Candidate Wind IPP	Wind						
2020-21	Imported Coal	Coal	2	500	208	832	700	33,169
	Qadirabad PAEC (Nuclear)	Nuclear	1	940		100		
	Jamshoroo Steam	Thermal	4		-700			
	Gulpur HPP	Hydro	1	99	99			
2021-22	Imported Coal	STM	2	500	1,000	2,579	861	34,887
	Various Units of Power Stations	Thermal	6		-861			
	Lawi	Hydro	3	23	69			
	Keyal Khwar	Hydro	2	61	121			
	Kohala	Hydro	4	272	1,089			
	Candidate wind IPP	Wind			300			
2022-23	Kalam Arsit HPP, IPP	Hydro	1	195	195	2,673		37,560
	Diamer Basha # 1	Hydro	6	371	2,228			
	Candidate wind PP	Wind			250			
2023-24	Imported Coal	Coal	2	500	1,000	5,746	1,275	42,031
	PAEC-Karachi II	Nuclear	1	940	940			
	Chakothi HPP, IPP	Hydro	1	495	495			
	Diamer Basha #2	Hydro	6	371	2,228			
	Munda HPP	Hydro	1	733	733			
	Candidate wind PP	Wind			350			
2024-25	PAEC-Karachi III	Nuclear	1	940	940	5,894		47,925
	Thakot	Hydro	8	347	2,772			
	Bunji #1	Hydro	7	255	1782			
	Candidate wind PP	Wind			400			

Source: NTDC National Power System Expansion Plan 2011~2030 (Generation Planning)

2.12.1 Power Demand Balance:

In order to compute the power–demand balance on a monthly basis a spread sheet model on the following data resources and assumptions was developed.

1. In order to develop a power supply and demand balance, power plan as developed by NTDC has been adopted. However to make the balance realistic, commissioning year of the some of the projects has been altered by looking in to physical progress made till June 2013 and GoP's / WAPDA ability to finance these projects.

2. Using Table 2-19 for Electricity Demand Forecast (based on multiple regression analysis) for the period 2012~2025

3. Using Table 2-20 for firm supply commitment for the period 2012~2025.

4. The available monthly capacity of existing hydropower plants was calculated based on the last 10 years average during various months.

5. The available monthly capacity of new hydropower plants is based on data drawn from feasibility studies carried out by reputable international consultants and used for projection purposes. However, most of the hydropower plants expected to be commissioned during the next ten years are at the planning stages and feasibilities are being conducted by the respective entrepreneur. Accordingly, it was very difficult to access the monthly capabilities of such plants. However for calculation purposes following criterion have been developed:

   i. Most of the new power plants are located in rivers / nullahs on which either a power plant already exists or feasibility has been completed in the public/private sector. Accordingly, same water flow pattern has been taken for those proposed power plants located in such rivers / nullahs.

   ii. There are few power plants (new) on such nullahs where nothing (feasibility or existing power plants) is available. For such situations, water flow pattern of near by nullahs have been taken in to account.

6. The de-rated capacity of the WAPDA system was taken into account for existing thermal power plants.

7. Net capacity, i.e. after accounting for their own consumption, has been taken into account for power plants operating in the private sector.

8. Power plants in the public sector have depreciated heavily over time and are more prone to breakdowns. It is assumed that PEPCO has 15% forced outage thermal power plants being operated and maintained by

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GENCOs, 1% for hydro power plants, 10% for renewable energy plant and about 10% in IPPs thermal power plant. In the projection period, ratio of hydropower plants capacity is more than thermal, therefore, forced outage rate of 9% average has been assumed.

9. A 45-day maintenance outage has been assumed for thermal power plants in the public and private sectors.

10. A 36-day maintenance outage has been assumed for hydropower plants

11. The monthly ratio of peak demand is based on the last 20 years' historical record.

12. There are three hydrological regimes, i.e., wet, normal, and dry. During the wet season, there is more water in the reservoirs and consequently, more energy can be produced by hydropower plants. Under normal conditions, a normal volume of energy is produced. During the dry season, low levels of precipitation in the catchments areas of the major reservoirs reduce the production of hydro energy. Therefore, hydropower plant capability has been assumed on the basis of a normal water regime.

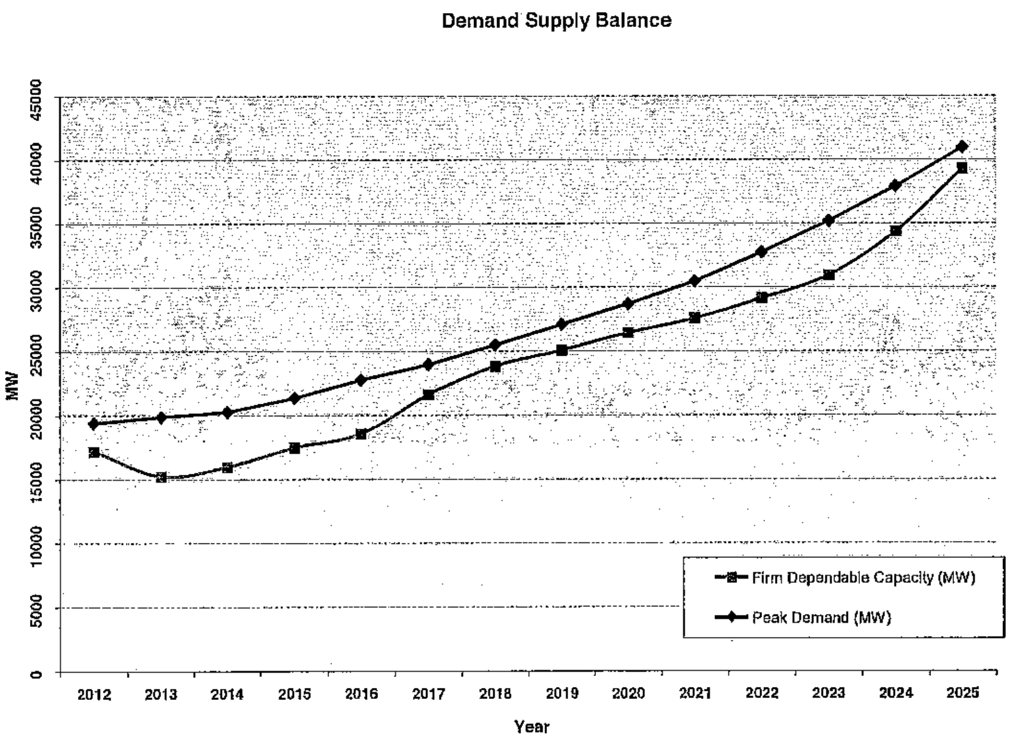
13. Based on these assumptions, the results of the power supply-demand balance model are given in Table 2.21; whereas its graphical presentation is given in Figure 2-6. It may be noted that during the entire planning period, power supply is heavily dominated with thermal and hydro power whereas nuclear power is very small in quantum.

14. The table following shows that there will be some gap in power supply and demand till 2025.

Table 2-211: Load Forecast Based on Normal Growth Scenario (National Grid System, 2010~2025), MW: Net Surplus (+) / Deficit (-)

Year	July	August	September	October	November	December	January	February	March	April	May	June
2011~2012	-71	179	244	-576	645	-1561	-3412	-940	-1482	-2360	-1717	-1542
2012~2013	-4456	-4555	-5226	-6214	-5437	-6272	-6130	-6002	-6178	-5936	-5060	-4644
2013~2014	-4145	-4284	-4988	-5742	-5046	-5567	-5744	-5323	-5433	-5429	-4704	-4293
2014~2015	-4707	-4876	-5313	-5392	-4689	-5153	-5169	-4925	-5003	-4963	-4284	-3871
2015~2016	-4605	-4830	-5598	-6220	-5456	-6161	-6196	-5911	-5990	-5297	-4655	-4196
2016~2017	-2169	-2489	-3416	-4105	-3475	-4095	-3734	-3736	-3622	-3421	-2817	-2335
2017~2018	-1351	-1623	-3069	-4281	-3619	-4169	-3678	-3800	-3618	-2952	-2211	-1656
2018~2019	-1697	-2083	-3679	-4914	-4202	-4728	-4166	-4332	-4075	-3374	-2579	-2008
2019~2020	-2703	-3129	-4732	-5869	-5089	-5609	-5024	-5196	-4931	-4293	-2874	-2246
2020~2021	-2544	-3195	-5156	-6490	-5669	-6179	-5509	-5710	-5271	-4483	-3513	-2896
2021~2022	-3189	-3924	-5977	-7270	-6521	-7003	-6313	-6774	-6266	-5236	-4221	-3588
2022~2023	-3404	-3848	-6005	-7472	-6855	-7980	-7496	-7514	-7004	-6128	-4976	-4253
2023~2024	-2290	-2558	-5054	-6883	-6564	-8288	-8048	-7698	-7091	-6026	-4491	-3539
2024~2025	-6	-427	-3271	-5625	-6114	-8380	-7683	-7085	-5439	-4168	-2710	-1660

Figure 2-6: Illustration of Power



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3. TOPOGRAPHIC SURVEY

3.1. Introduction

This chapter contains a description of the adopted methodology, and extent and results of the Topographic Survey conducted by the Consultant and mapping of the proposed Weir and Power house locations as identified in Id study 2001.

The project area is located in Chitral District of Khyber Pakhtunkhwa. The Chitral District constitutes the northern most part of Pakistan. It borders with Afghanistan in the north and west, Northern Areas in the east and Swat & Dir Districts in the south. The Project area is located in the north-west of Chitral Town at a distance of 37 km.

The whole project layout has been proposed on the right bank of Arkari River with the Powerhouse site proposed near Andakht village in the north-west of Chitral Town at a road distance of about 29 km. The project area is linked by a jeepable road which branches off from main Chitral-Garam Chashma metallic road about 2 km upstream of the confluence of the Arkari River and Lutkho River. The weir location is also accessible through this jeepable road which leads to Arkari Village.

The main areas of investigation are the Weir site near Uchhatur village, the Headrace Tunnel along the right bank of Arkari River and Powerhouse site near Andakht village. Coordinates of the Weir and Powerhouse are given below:

Location	Longitude	Latitude
Weir Site (Uchhatur)	36^0 03′ 57″ N	71^0 41′ 37″ E
Powerhouse Site (Andakht)	36^0 01′ 10″ N	71^0 44′ 11″ E

Topographic Survey of the project layout identified in Id-Study 2001 has been carried out by Gulf Consultants Peshawar. This project layout had been selected at the project's inception stage. The survey covered the weir /intake, reservoir, de-sander, surge shaft, pressure shaft, powerhouse and tailrace canal. Topographic survey work has been completed for accessible areas of the project site. Longitudinal profiles of the potential stretch of the Arkari Gol have also been prepared. Inaccessible portion includes area along the tunnel alignment between the weir and powerhouse sites.

For the inaccessible areas of tunnel alignment, topographic maps were developed with the help of digitized map 1:10,000 scale from 1:50,000 scale Survey of Pakistan (SOP) maps and a satellite map of 0.5 m resolution. The satellite map has been acquired from Geo Solutions, Islamabad.

The whole area is a part of Chitral River catchment which drains from northeast to southwest. The northern part is covered with glaciers and southern part,

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being at lower elevation, has no glaciers but receives heavy snowfall during winter.

Lower Chitral is a mountainous area. Tirich Mir (7690 m.a.s.l), located approximately 50 km north of Chitral Town, is the highest peak of the region. Arandu is the lowest point of the area where Chitral River leaves Pakistan to enter Afghanistan for its subsequent re-entry at a lower elevation.

Main Rivers / Gols in Chitral district are:

- Yarkhun River, Laspur River, Mastuj River
- Tirich Gol, Rich Gol, Turkho River, Golen Gol
- Lutkho River, Ayun River, Shishi River and Chitral River

Lutkho River is comprised of two main streams: Lutkho River (Upper Part) and Arkari Gol. Arkari Gol flows from north to south and upper part of Lutkho River flows from west to east. The lower part of Lutkho River changes its direction to flow from north to south to join Mastuj River near Chitral Town.

3.1.1 Profile of Arkari Gol

The catchment of Arkari Gol borders with Afghanistan in north and west and Turkho River catchment in the east. There are a few glaciers in the upper portion of the catchment. These include Gazikistan, Gham and Dirgol glaciers. The catchment area of Arkari Gol is 1074 km^2. The main stream length of Arkari Gol is 64 km and the average river gradient is 3.4%. Main tributaries of Arkari Gol are tabulated below.

S.NO	TRIBUTARY	CATCHMENT AREA (km^2)	MEAN ELEVATION (m.a.s.l)
1	KUROBAKHO GOL	308	4430
2	AGRAM GOL	225	4220
3	ISHPERU GOL	103	4298
4	BESTI GOL	154	3896

All of the above streams have steep gradients. Arkari Gol runs in a narrow valley.

3.2 Objectives of Topographic Survey

The survey work has been carried out to set the standard on which accurate and meaningful engineering design could be achieved. The survey has been carried out systematically and accurately in one uniform system of co-ordinates and elevations. The survey work has been based on a network of horizontal and vertical control points covering accessible portions of the project area.

Survey was carried out for preparing basic site plan mapping. The mapping has been used for project planning, construction material quantity estimates, feasibility level evaluation estimates, construction cost estimates and preparation of project's concept design documents. River cross-section surveys were carried out for quantification of flow and estimation of maximum flood level under various hydrological conditions.

3.2.1 Scope of Work

a. Select the most suitable Project Layout

b. Minimize geological and climatological hazards for stable project infrastructure

c. Highlight topographic features of areas covering project components

d. Minimize social and environmental costs including relocation of population

e. Prepare computerized topographic maps of project component locations

f. Prepare valley cross-sections up to anticipated backwater effect on the upstream of the weir location and 2.8 km downstream of the powerhouse location.

g. Establish longitudinal profiles of Arkari Gol River from the proposed locations of weir site to the powerhouse

h. To prepare a Project Map on a scale of 1:10,000.

3.3 Methodology

Preparation of a quality Feasibility Report entailed conduct of a detailed topographic survey. Accordingly, a comprehensive topographic survey program was developed and executed in the field by our subcontractor M/s Gulf Consultants Peshawar. The process was carried out under the guidance and supervision of a Senior Survey Engineer.

Initially available topographic information of the project area included SOP topographic sheets at a scale of 1:50,000.

The following sheets were used to mark the layouts of project components.

S.No	Sheet ID	Scale
1	**37- P/12**	**1:50,000**
2	**37- P/8**	**1:50,000**
3	**37- P/16**	**1:50,000**

Detailed maps of the surveyed area have been prepared on Scales 1:500, 1:1000 and 1:5000 with 1 meter contour intervals at the powerhouse and weir sites.

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3.3.1 General Approach

From SOP bench marks, control points were established with double action differential GPS and then verified with total stations using traversing method. Detailed topographic survey was then carried out from the established control points. Survey work was initiated from the Survey of Pakistan Bench Mark (SBM) near the bridge at Garam Chashma. This was followed by establishment of benchmarks, two each at the Powerhouse and Weir sites respectively. These benchmarks were established through Total Stations. Furthermore, two GPS points were also established through Dual Frequency GPS (Sokia) at the Weir Site.

3.2.2 Surveying Site at Designated Locations

Longitudinal Profile of the Arkari Gol upstream and downstream of the weir site covered an area falling within 4 km upstream and 6.7 km downstream of the weir site. Profile cross-sections were taken up to a distance of 100 m on both sides of Arkari Gol. The survey covered the locations for Intake Structure, Sand Trap, Head Race Tunnel and Powerhouse site. Longitudinal Profile survey was extended to a distance of 5 km downstream of the powerhouse axis. Obstacles such as houses, cultivated lands, roads, bridges, electric and telephone lines, etc. were included in the topographic maps.

Detailed Topographic Survey of the Weir reservoir area has been conducted for estimation of water storage. Downstream of the weir site, cross sections have been taken at 100 meter intervals up to a length of 500 m and 3980 m upstream of the weir site. At the Powerhouse site, from the confluence of Arkari and Lutkho River, cross sections in the upstream directions have been taken at 25 m interval up to 500 m length along Arkari River. For the down streams side, cross sections have been taken at 25 m intervals for a distance of 2421 m downstream of Ruji Bridge along Lutkho River. The survey has been carried out during high flow season whereas river bed could be surveyed during minimum flows only. River bed cross sections have now been taken and duly recorded.

The table below represents the area surveyed area at the weir site and powerhouse locations.

Location	Area (km^2)
Weir Site	3.56
Powerhouse Site	5.08

3.3.2 Technical Requirements

The following technical requirements have been considered while carrying out the topographic survey and preparation of maps.

3.3.3.1 Reference Grid and Control Network

In order to prepare large scale topographic maps, reference grid has been established by connecting the area to be surveyed with the Survey of Pakistan (SOP) Grid. Permanent benchmarks and control points at project site have been established to achieve the required detail. To facilitate preparation of 1:5000 scale maps, survey has been carried out for preparation of 1 m contour interval maps at the Powerhouse and Weir sites.

3.3.3.2 Permanent Benchmarks

Four permanent benchmarks were established by G.P.S at the Powerhouse & Weir site locations for the purpose of horizontal & vertical control. The benchmarks were established using Survey of Pakistan benchmark (SBM) on the edge of the bridge at Garam Chashma.

TABLE 1: Bench Mark for Data Weir Site

S.No	Bench Mark	Easting	Northing	Elevation (M)	Reference Location
SBM	SBM (ARKARI)	3064336.67	1307250.29	2263.747	Garam Chashma (SOP Point near Bridge)
1	AR-BM1	3074972.10	1316671.77	2197.800	Steel peg 1 on black stone on left side of the river
2	AR-BM2 (GCP 1)	3074936.86	1316689.67	2198.100	Steel peg 2 on black stone on left side of the river
3	AR-BM3 (GCP 2)	3074991.30	1316675.23	2196.617	Steel peg 3 on black stone on left side of the river
4	AR-BM4	3074938.00	1316689.44	2197.900	Steel peg 4 on black stone on left side of the river
5	AR-BM5	3075923.08	1315618.57	2174.039	Steel peg 5 on black stone on left side of the river
6	AR-BM6	3075990.17	1315530.89	2172.629	Steel peg 6 on black stone on left side of the river

TABLE 2: Bench Mark Data for Powerhouse Site					
S.No	Bench Mark	Easting	Northing	Elevation (M)	Reference / Location
SBM	SBM (ARKARI)	3079972.131	1310816.6	1858.400	Corner of Road in Andakht village
1	AR-PBM1	3084106.582	1309129.9	1730.700	Steel peg 1 on black stone on left side of river
2	AR-PBM2	3084154.48	1309135.4	1733.800	Steel peg 2 on black stone on left side of the river
3	AR-PBM3	3079939.304	1310697.2	1876.200	Steel peg 3 on black stone on left side of the river
4	AR-PBM4	3083144.984	1309803	1787.800	Steel peg 4 on black stone on left side of the river
5	AR-PBM5	3079972.131	1310816.6	1858.400	Steel peg 5 on black stone on left side of the river
6	AR-PBM6	3079981.231	1310859.8	1854.500	Steel peg 6 on black stone on left side of the river

3.3.3.3 Control Points

Two control points have been established at the Weir and Powerhouse sites using Double Action Differential GPS. The control points have been established with reference to SOP Bench marks at Garam Chashma. The Global positioning system (GPS) control points have been plotted on Global Information System (GIS) sheet for accuracy check.

TABLE 3: Control Points Data Weir & Powerhouse Sites				
S.No	Control Points	Easting	Northing	Elevation (Meters)
1	CP1	3074624.643	1317143.805	2227.6
2	CP2	3079956.149	1311151.225	1867.1
3	CP3	3077547.628	1313519.158	2044.9
4	CP4	3077523.832	1313559.618	2045.3
5	CP5	3079972.472	1311011.296	1861.5
6	CP6	3080929.489	1310392.457	1849.9
7	CP7	3079970.615	1310997.124	1860.6
8	CP8	3074594.303	1318517.317	2249.2
9	CP9	3076184.884	1315438.753	2168.8
10	CP10	3079207.313	1310333.752	1855.7
11	CP11	3077838.358	1312787.559	1999.1
12	CP12	3074511.778	1317964.882	2251.8
13	CP13	3075035.906	1316675.24	2196.3
14	CP14	3080929.475	1310392.457	1849.9
15	CP15	3074855.265	1316725.095	2203.8

16	CP16	3077943.599	1312942.358	1978.1
17	CP17	3076634.856	1315041.024	2161.4
18	CP18	3074518.859	1318054.009	2253.1
19	CP19	3075908.631	1315694.571	2174.2
20	CP20	3077235.947	1314073.434	2083.8
21	CP21	3074680.401	1318820.532	2249.1
22	CP22	3077017.291	1314372.118	2105.1
23	CP23	3075624.032	1316277.648	2191.4
24	CP24	3078431.389	1312573.458	1915.5
25	CP25	3076834.795	1314705.166	2140.8
26	CP26	3076601.907	1315011.737	2170.5
27	CP27	3075125.454	1316633.6	2194.6
28	CP28	3077876.078	1313019.329	1987.9
29	CP29	3074431.93	1317607.08	2231.7
30	CP30	3078073.602	1312643.661	1954
31	CP31	3078053.044	1312701.749	1957.8
32	CP32	3075157.595	1316608.343	2202.4
33	CP33	3078405.084	1312607.703	1920.6
34	CP34	3075673.707	1316008.534	2177.6
35	CP35	3074571.519	1317270.48	2234.9
36	CP36	3078013.306	1312926.795	1968.3
37	CP37	3077665.902	1313397.025	2020.4
38	CP38	3076900.046	1314866.988	2167.4
39	CP39	3076663.288	1314976.235	2164
40	CP40	3078763.496	1310298.028	1855.6
41	CP41	3075190.438	1316499.582	2248.1
42	CP42	3077789.298	1313162.474	1997.7
43	CP43	3075071.793	1316639.791	2196.8
44	CP44	3076843.747	1314886.729	2164.2
45	CP45	3077876.072	1313019.501	1987.9
46	CP46	3077151.005	1314685.865	2189.1
47	CP47	3074746.516	1316798.194	2213.7
48	CP48	3077732.552	1313418.05	2001.3
49	CP49	3078450.679	1312499.823	1937.4
50	CP50	3077017.168	1314372.265	2105.1
51	CP51	3077077.773	1314299.484	2095.3
52	CP52	3074750.068	1316776.225	2220.8
53	CP53	3074794.437	1316773.572	2208.7
54	CP54	3076810.531	1314748.338	2137.7
55	CP55	3077946.9	1312904.574	1979.6
56	CP56	3074564.198	1317278.06	2235.6
57	CP57	3075673.492	1315990.827	2178.8
58	CP58	3075657.661	1316254.029	2194
59	CP59	3078066.893	1312692.51	1956.5
60	CP60	3074598.886	1318527.147	2249.1
61	CP61	3076307.848	1315265.306	2165.6
62	CP62	3075163.357	1316635.863	2194.1
63	CP63	3077180.304	1314190.805	2080.5

64	CP64	3077274.099	1313988.489	2069.8
65	CP65	3077161.765	1314610.694	2182.7
66	CP66	3078254.163	1312760.485	1927.6
67	CP67	3076094.674	1315420.942	2189.3
68	CP68	3077441.013	1313715.307	2031.4
69	CP69	3076130.861	1315351.945	2195.4
70	CP70	3076867.227	1314569.537	2128.2
71	CP71	3076843.814	1314886.706	2164.2
72	CP72	3076033.392	1315638.672	2169.4
73	CP73	3075673.703	1316008.538	2177.6
74	CP74	3076157.22	1315522.814	2167.9
75	CP75	3077017.17	1314372.222	2105.1
76	CP76	3077212.559	1314140.448	2082.9
77	CP77	3077805.658	1313060.637	2005.2
78	CP78	3075753.072	1315917.925	2176.1
79	CP79	3077212.688	1314140.544	2082.9
80	CP80	3075726.032	1315874.26	2191.9
81	CP81	3078053.059	1312701.716	1957.8
82	CP82	3077805.683	1313060.593	2005.2
83	CP83	3076052.422	1315477.343	2184.3
84	CP84	3077212.554	1314140.454	2082.9
85	CP85	3078052.976	1312701.767	1957.8
86	CP86	3076834.786	1314705.201	2140.8
87	CP87	3075163.365	1316635.903	2194.1
88	CP88	3075673.44	1315990.917	2178.8
89	CP89	3077789.24	1313162.396	1997.7
90	CP90	3078289.257	1312635.521	1950.2
91	CP91	3077212.695	1314140.522	2082.9
92	CP92	3077077.84	1314299.387	2095.3
93	CP93	3075243.556	1316534.334	2237.9
94	CP94	3075624.137	1316277.616	2191.4
95	CP95	3075071.774	1316639.793	2196.8
96	CP96	3078405.074	1312607.715	1920.6
97	CP97	3076810.526	1314748.346	2137.7
98	CP98	3077828.009	1313213.99	1984.9
99	CP99	3075125.45	1316633.6	2194.6
100	CP100	3075732.973	1316256.173	2204.1
101	CP101	3078431.382	1312573.441	1915.5
102	CP102	3077235.937	1314073.456	2083.8
103	CP103	3077440.983	1313715.286	2031.4
104	CP104	3077463.762	1313731.363	2022.8
105	CP105	3077665.904	1313397.027	2020.4
106	CP106	3076307.81	1315265.324	2165.6
107	CP107	3075908.664	1315694.518	2174.2
108	CP108	3076052.403	1315477.336	2184.3
109	CP109	3075807.712	1315820.023	2176.5
110	CP110	3078175.259	1312669.261	1953.3
111	CP111	3074431.925	1317607.039	2231.7

112	CP112	3075157.621	1316608.314	2202.4
113	CP113	3074564.202	1317278.054	2235.6
114	CP114	3076601.863	1315011.775	2170.5
115	CP115	3077274.056	1313988.56	2069.8
116	CP116	3077943.56	1312942.44	1978.1
117	CP117	3077874.367	1313067.193	1973.4
118	CP118	3078254.16	1312760.488	1927.6
119	CP119	3078437.73	1312588.661	1916
120	CP120	3077706.909	1313293.212	2014.6
121	CP121	3076983.618	1314393.541	2108.4

3.4 Field Survey & Office Work

3.4.1 Headrace Tunnel

The Headrace Tunnel has been reproduced on a digitized map of 1: 50,000 - 10,000 scale of the Survey of Pakistan (SOP).

3.4.3 Weir Site and Intake

Weir site and intake structure locations have been surveyed at a scale of 1:500 with a contour interval of one meter. Longitudinal profile extends 4 km upstream and 6.7 km downstream of the proposed weir location. Maps have been prepared on a scale of 1: 5000.

3.4.4 Power House

This component was surveyed at a scale of 1:500 with a contour interval of one meter. Longitudinal Profile extends 600 meters upstream and 5 km downstream of the proposed Powerhouse location. Maps have been prepared on a scale of 1:5000.

3.4.5 Adit

Harni Gol valley was surveyed for preparing long sections and cross- section to the extent of 1 km on either side of tunnel axis.

3.4.6 Data Processing

Field data collected through Digital Total Stations was transferred to a computer for further processing. 12-D Model Software has been used for transferring of data from the Total Station and also, for further processing on a computer. The software converts topographic data into digital files. The data is subsequently plotted in AutoCAD after which it is transferred to another software i.e. ArcGIS 10. This software is used for preparation of maps to be used for engineering studies.

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Ground control points have been established with reference to GPS control points. The density of ground control points is more than 5 points per km. The points are visible and not affected by trees, steep rocks slopes etc. All reading was regularly transferred from the Total Station to Memory Cards. The following instruments were used during field survey:

- GPS Sokia
- Total Station Sokia

3.4.7 Field Survey

The area has been surveyed with the help of ground control station established at suitable locations. All the topographic features appearing on the ground and spot heights at suitable places have been observed and recorded with proper coding. The observed data has been recorded in ENZ coordinates format by using project code library. During acquisition of data in this field extreme care and all precautionary measures have been taken in order to achieve the desired accuracy. Field data has been processed in camp Headquarters and checked by Surveyor. Name and information picked up by the surveyor during data acquisition have been incorporated in the processed data. As per ToR, 200 acres area was to be surveyed whereas 2134 acres of area has been surveyed which become 8.64 square km. The maps with scale of 1:5000 are attached for review of the survey data.

3.4.8 River Cross Section

Along Lutkho River, cross sections have been taken at 100 m intervals 1000 m upstream and downstream from the confluence of Arkari and Lutkho Rivers. 100 m interval river cross sections were also taken 376 m upstream of the axis of Powerhouse along Arkari River and 449 m downstream of the axis of the powerhouse. At the weir site, 200 m interval cross sections were taken 557 m upstream and 600 m downstream of the weir axis. Drawings of river cross sections are presented in Appendix 3.

3.4.9 Longitudinal Section of Arkari River

Longitudinal section of Arkari Gol River 4 km Up Stream and 6.7 km Down Stream of Weir axis while 600 meter Up Stream and 5 km Down Stream of Power House has been executed. About 16 km length of river including reservoir has been executed. The co-ordinates of river water surface have been mapped at a scale 1:5000. Details of objects touching the river have also been recorded and presented in Appendix 3.

3.4.10 Physical Features

The following prominent features have been shown on maps.

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a. Existing houses / constructed buildings.

b. Existing roads, passages, water courses/irrigation channels, electricity lines, telephone lines and poles.

c. Contact between over burden and exposed rock.

d. Loose scree, large boulders, trees and cultivated areas.

e. Change in abrupt elevation marked differentially.

f. All control points/bench marks, marked and used.

g. Steep slopes, drainage courses/ nullahs

Topographic detailing has been processed in CAD to differentiate different layers.

3.5 Topographic Maps with Satellite Images

For the entire project area, topographical maps with GIS support have been prepared in scale 1:10000 from SOP maps of 1:50,000 scales. These 1:10000 scale maps along with satellite imagery were utilized for inaccessible areas of tunnel alignment. Topographic maps prepared by the consultant have been presented at the end of this chapter.

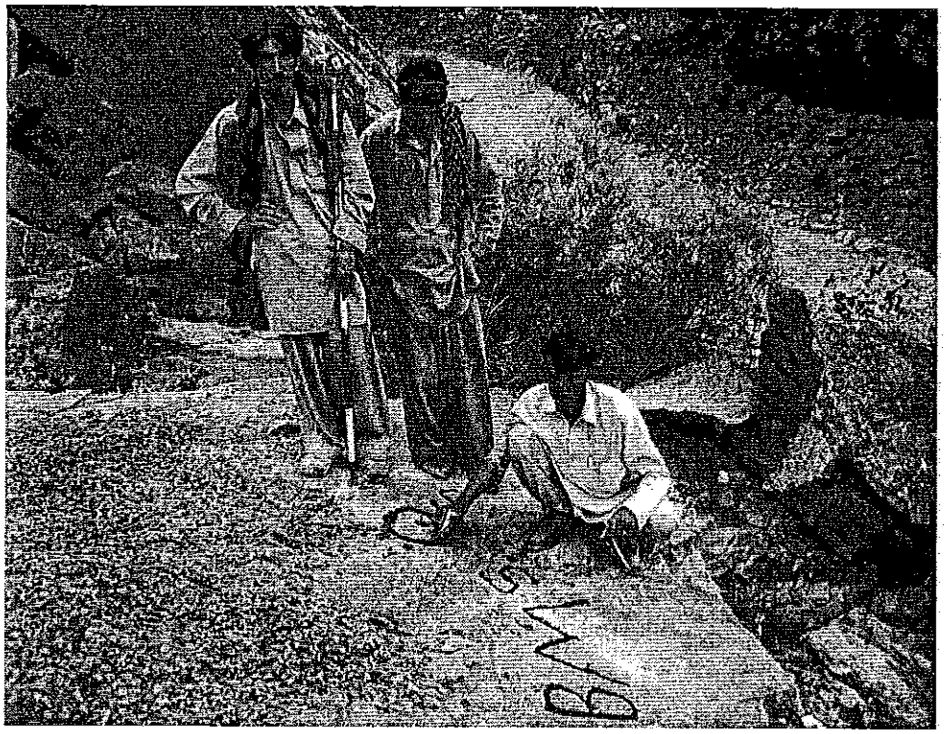
The consultants have obtained satellite imagery from Geo Solutions.

3.6 Digital Model Elevation

The consultant has obtained DEM (Digital Elevation Model) of 5.00 m interval for survey to facilitate planning and design of inaccessible project components such as tunnel, surge tank etc. located in inaccessible areas. Digital Elevation Models of areas housing different project components are presented at the end of this chapter.

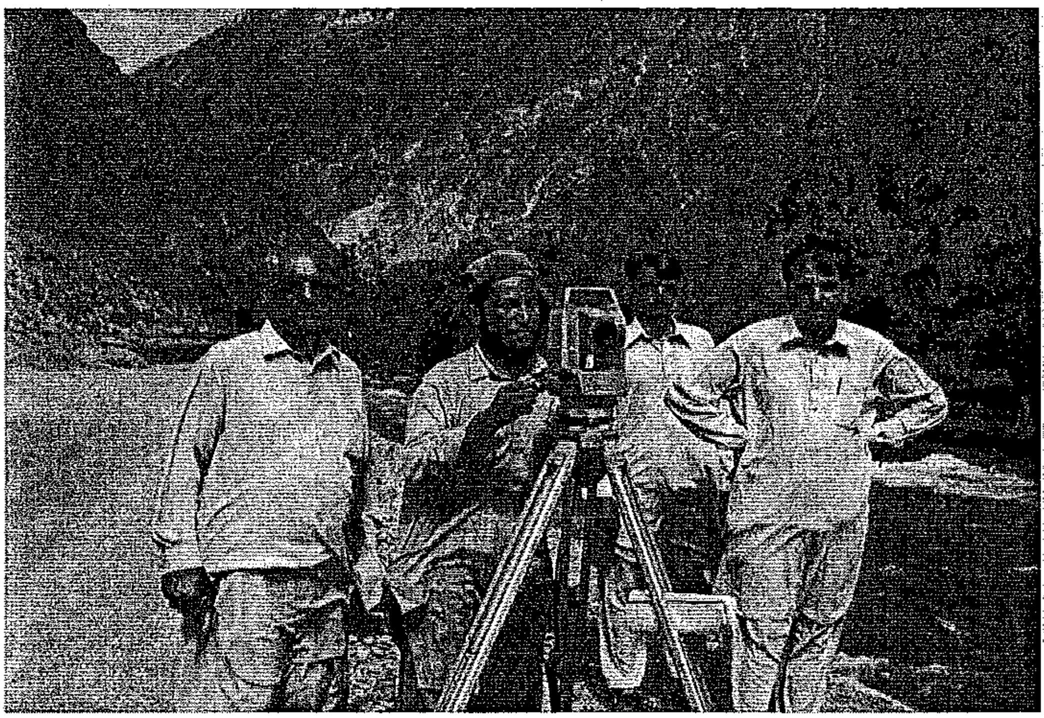
3.7 PICTURES

Pictures of Arkari Gol Topographic Survey



Bench Mark Point No. 5 (AR-BM5) (3075923.08E, 1315618.57N) at Powerhouse Site near Andakht Village.

Bench Mark Point No. 6 (AR-BM6) (3075990.17E, 1315530.89N) at Powerhouse Site.



Control Point (3078763.4960E, 1310298.0280N) near Roji Bridge

Shifting GPS Point

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3.8 Survey Sheets

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VOLUME 4: Appendices – Part II

CHAPTER - 4
HYDROLOGY & SEDIMENTS

4. Hydrology & Sedimentation Studies

4.1 Definition / Introduction

Hydrology describes the main input variable relevant for hydropower plants, namely the occurrence of river flow. The hydrological series that represents variations in river flow throughout the year is utilized to estimate the power and energy production from the available stream flow.

Arkari Gol Hydropower Project has been proposed on the Arkari Gol near Uchhatur village in the Province of Khyber Pakhtunkhwa (KPK). In November 1984, Water and Power Development Authority (WAPDA) with collaboration of Canadian International Development Agency (CIDA) had carried an Inventory and ranking study for Upper Indus Basin, Jhelum Basin and Kabul, Swat and Chitral Basin. Arkari Gol Hydropower Project was also ranked in the GTZ study in 1991 as Sarhad Hydel Development potential in Lower Chitral Region 2 hydropower project.

Arkari Gol project is proposed to be run-of-river HPPs, where the discharges are diverted from its original source and flow through a power channel/tunnel to create the required head. The assessment of long term mean run-off of this river for potential hydropower schemes is of vital importance.

Hydrological and sediment transport studies play a pivotal role in the planning, design and execution of the hydropower projects. The important hydrological parameters to be evaluated are the availability of flows; extreme flow events at the weir site i.e. the minimum flows and the design floods for the coffer and main weir. The spillway design flood is needed for the safe design of the spillway structure. Moreover, the design flows for the hydropower machinery are also decided after thorough understanding of hydrologic characteristics of the watershed and flow availability at the weir site.

This section covers the aspects of data availability, climatology of the area, availability of flows at the Weir site for power generation as well as the estimation of design floods with different return period, observed suspended sediment discharge and bed material gradation curves.

4.1.1 Scope of Services

As per the ToR, these studies include (but are not necessarily limited to) the following.

The work was comprised of installation and operation of a gauging station during the study period and discharge measurements on respective River upstream of the proposed weir site. Analysis of available hydrological data and sediment load was carried out. Detail of activities carried out is as follows.

High flood: estimation, 10 annual, 100 annual, 1000 annual floods and 10,000 annual floods. Definition of flood during construction, Estimation of low discharges

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and development of flow-duration curves with historic data. Collection of water and sediments samples round the year and analysis of the same. Analysis of suspended load and bed materials, estimate on sedimentation.

4.2. Data Collection and Data Evaluation

4.2.1 Data Availability and Collection

The available hydro-meteorological data including Topo sheets from survey of Pakistan (SOP) on 1:50,000 and 1:250,000 have been identified. The details of the hydro-meteorological data available in the vicinity of the project areas of Arkari Gol have received. All 1:50,000 Topo Sheets of the project area have been collected by this consultant.

For the detailed Hydrological study of the watershed, weir site and power house site, large data sets were available and collected from various sources. Most of the Climatological and hydrological data were obtained from Surface Water Hydrology Project (SWHP) of WAPDA, Pakistan. As far as Climatological data is concerned, it was collected from Pakistan Meteorological Department (PMD).

Hydrological aspects in this report are under review. The hydrological and sedimentation studies are under process. The relevant hydro-meteorological data is collected from the concerned agencies. The data includes daily maximum and minimum temperatures; daily monthly and annul precipitation; hourly storm rainfall data, daily discharges and instantaneous maximum flood discharges. The data also includes hourly historical flood discharges; isohyetal maps and daily suspended sediment data.

4.2.1.1 Climatological Data

Precipitation, air temperature, relative humidity and sunshine hours are the important Climatological parameters for understanding the climate of the region. There are number of climatic stations in and around the project area, which are operated by Pakistan Meteorological Department (PMD), Surface Water Hydrology Project (SWHP) of WAPDA and Hydrology and Research Department (H&RD) of WAPDA. Climatic stations operated by PMD and SWHP are located in the valleys while H&RD is operating weather stations at high altitudes. Only two weather stations (Chitral and Shundure) are located in the vicinity of the project area.

Climatological data collected for the detailed study of the watershed area of the hydropower project is given in Table 4.1. Climatological data includes:

- Daily precipitation
- Daily temperatures
- Daily relative humidity
- Daily Sun Shine hours

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Table 4.1: Climatalogical Stations In And Around The Project Catchment						
S. No	Gauging Station	Source	Relative Humidity	Precipitation	Temperature	Sun Shine hours
1	CHITRAL	Pakistan Meteorology Deptt.	1992 - 2009	1992 - 2011	1992-2009	1992-2009
2	YASIN	Snow & ice Hydrology WAPDA Deptt	2006	2006	2006	-
3	KHOT PASS	Snow & Ice Hydrology WAPDA Deptt	1996 - 2008	1997 - 2008	1998-2008	-
4	KALAM	Surface Water Hydrology Deptt	-	1977 - 2007	1964 -2002	-
5	SHENDURE	Snow & ice Hydrology WAPDA Deptt	1996 - 2008	1997 - 2008	1998-2008	-
6	BUNI	SHYDO*	-	1988 -1992	1989-1992	-
7	DHOK MADAK	SHYDO*	1989 - 1992	1988 - 1992	1989- 1992	1989 & 1992

4.2.1.2 Flow Data

Fourteen hydrological stations were available from where flow, instantaneous maximum discharge and sediment discharge data have been collected. These stations had been setup and are being maintained by the SWHP (WAPDA) and PHYDO. The detailed summary for the availability of the flow, flood and sediment data and their record periods are given in Table 4.2.

Among 14 stream gauging stations, locations of seven 07 stream gauging stations closer to the project site are shown in Figure 1 on rivers.

On the stream gauging stations being operated by SWHP, WAPDA, flow and sediment discharges are measured once per week in non-flood-season and twice per week in flood season using current meter and suspended load sediment sampler, respectively. However, stage is observed on hourly basis from 8:00 a.m. to 5:00 p.m.

For stream gauging stations being installed and operated by SHYDO, flow and sediment discharges are usually measured at the rate of once per week, whereas, stage is recorded three times a day, i.e. 9:00 a.m., 12:00 Noon and 4:00 p.m.

Table 4.2: Stream Gauge Stations In And Around The Project Catchment								
S. No	River Name	Gauging Station	Source	Duration of Data	No. of Years	Area (km^2)	Annual Daily Mean (m^3/sec)	Specific Q (m^3/sec/km^2)
1	Buni Gol	Buns	SHYDO	1994	1;	60	1.12	0.02
2	Darkhot Got	Brep	SHYDO	1988-1991 & 1995	5	18	0.21	0.01

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3	Ojhar Gol	Shoghore	SHYDO	1995, 1999	3	180	4.55	0.03
4	Reshun Gol	Reshun	SHYDO	1988-1993	6	102	3.02	0.03
5	Chitral	Chitral	SWHP	1964-2011	48	11400	277	0.02
6	Ptinjkora	Zulam Bridge	SWHP	1999-2006	8		112.88	
7	Swat River	Kalam	SWHP	1961-2010	49	2020	29.7	0.02
8	Swat River	Chakdara	SWHP	1961-2008	47		29.7	0.02
9	Golen Gol	Babuka	SWHP	1993- 2006	14	518	16.76	0.03
10	Shishi	Drosh	SWHP	1987, 1988	0	394	14.82	0.04
11	Lutkho	Shah-Re-sham	SWHP	1987 & 1988	•7	2443	39	0.02
12	Lutkho	Shoghore	SHYDO	2006-2012	7	1990		
13	Arkari Gol	Arkari Gol	SHYDO	2006-2012	7	1015		
14	Mastuj River	Miragram	SHYDO	2006-2012	7	4375		

4.2.1.3 Sediment Data

For Arkari Gol Hydropower project, Sediment data for estimation of long-term average annual sediment load was of Chitral River, Drosh and Golen Gol gauging stations from (1964-2010), (2006-2010) & (1993-2010), respectively.

The data collected for sedimentation study from SWHP (WAPDA) is given in Table 3; the same was used for estimation of sediment load at Arkari Gol. Moreover, the Hydro graphers were engaged to collect water samples on all gauging stations with each flow measurement. The same is being collected and sent to laboratory for analysis of suspended concentration with Pipette method as presented in Table 4.3 on the following page.

Table 4.3: Sediment gauging Stations in and around the Project Catchment

Hydrological data (Sediment Flows) collected for the study

Sr. No.	Gauging Station	River	Latitude	Longitude	Source	Data collected	Data Digitized	Status
1	Chitral	Chitral River at Chitral	35°28'10.00"	72°35'40.00"	Surface Water Hydrology	1964-1980 & 1982-2010	1964-1980 & 1982-2010	Data Digitlized
2	Mastuj Bridge	Golen Gol River	35°56'32.00"	71°58'49.00"	Surface Water Hydrology	1993-2006	1993-2006	Data Digitlized
3	Drosh	Shishi River	35°35'20.00"	71°48'32.00"	Surface Water Hydrology	2006-2010	2006-2010	Data Digitlized
4	Sher Sham	Lutkho River			Surface Water Hydrology	1987 & 1988	1987 & 1988	Data Digitlized

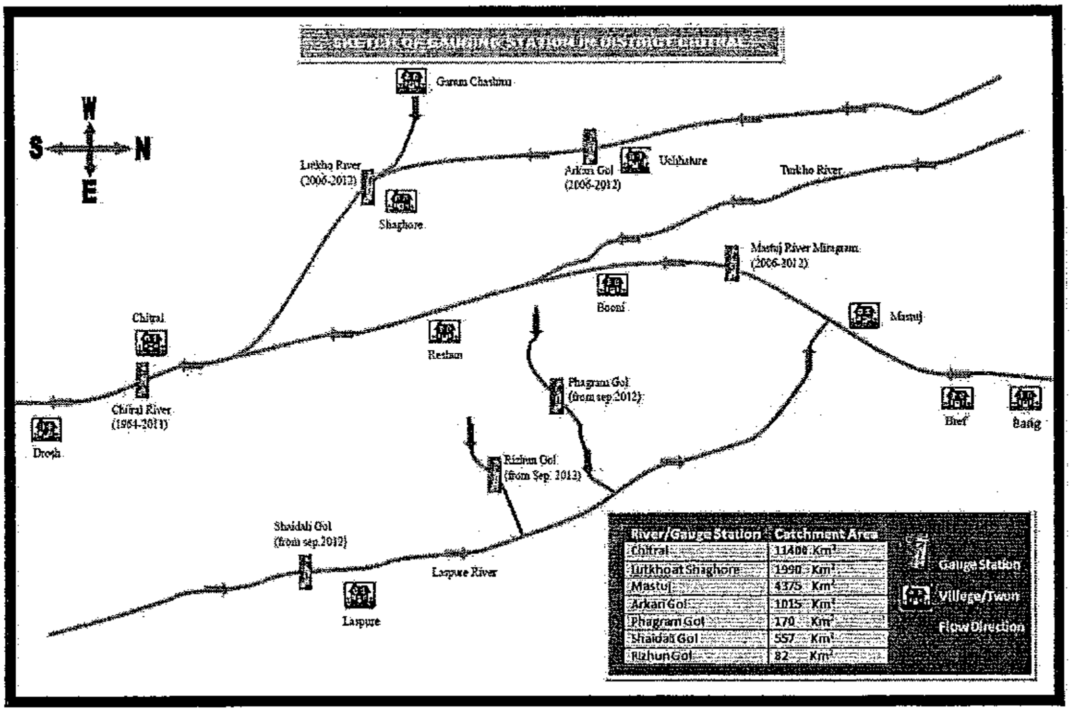

Figure- 4.1 Locations of Stream Gauging Sites closer to Project site

At present, water discharge and suspended sediment concentration data is being collected by the Consultants at the Arkari Gauge installed at the Arkari weir site and analyzed for a period of low flow season (Sep-March).

To develop correlation between the rate of flow and sediment load, it required collecting the site specific suspended sediment concentration data round the year.

The collected Suspended sediment concentration data was used to develop correlation between the rate of flow and sediment load. This relationship is termed as sediment rating curve. The measurement of suspended sediment data will be an ongoing process. The data so collected has been used for developing sediment rating curves as per USBR guidelines procedures.

4.2.2 Data Evaluation

Before using any data, it should be statistically evaluated for its accuracy and authenticity. The goal of the hydrological data analysis is to check the consistency of the rainfall and flow data record. For all data distribution, independence, periodicity and trend were investigated and further tests of data consistency were necessary. The basic statistical investigation and interpretation was done set by set. Only then further processing was conducted. Plotting and analysing the cumulative departures from the mean were the principle methods of verifying the consistency and homogeneity of hydro-meteorological data.

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4.2.2.1 DMC Analysis for Precipitation data

DMCs has been plotted for Chitral precipitation gauging station data using mean annual precipitations of neighboring gauges which includes Khot Pass, Shendure, Dhok Madak, Buni, Kalam and Yasin rainfall stations from 1992 to 2009, as reference stations. This curve is shown on Figure 2 which shows that Chitral Annual Data is almost homogeneous.

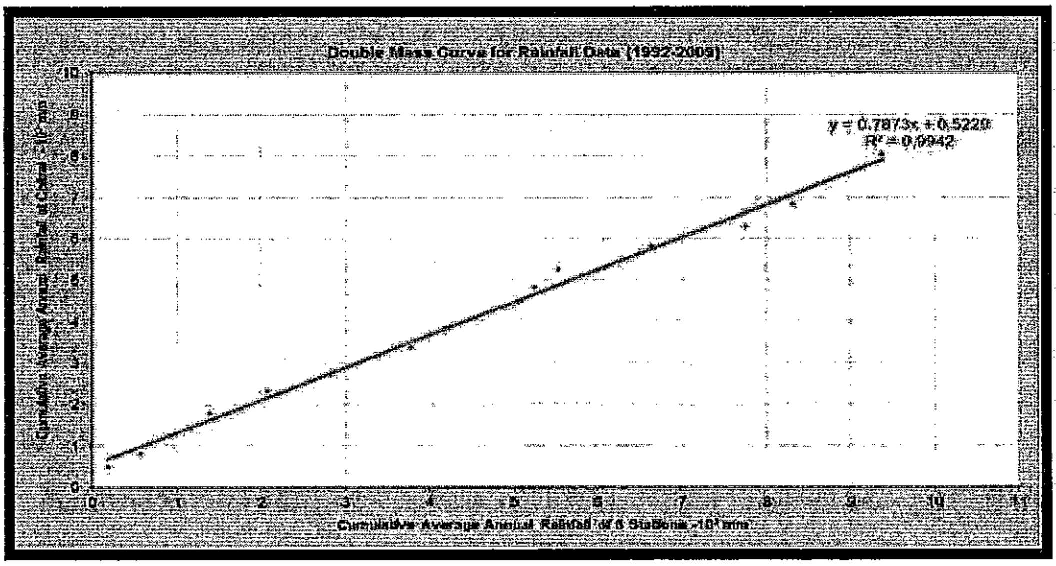

Figure 4.2: Double Mass Curve for Precipitation

4.2.2.2 DMC Analysis for discharge data

DMC has also been used to check the consistency of stream flow data of Chitral River at Chitral Stream gauging station from 1996 to 2010. As a reference time series, the data observed at gauging station of Mastuj River at Golen Gol in the vicinity of the project area were used. The graphical presentations of the DMC are given in Figure 4.3

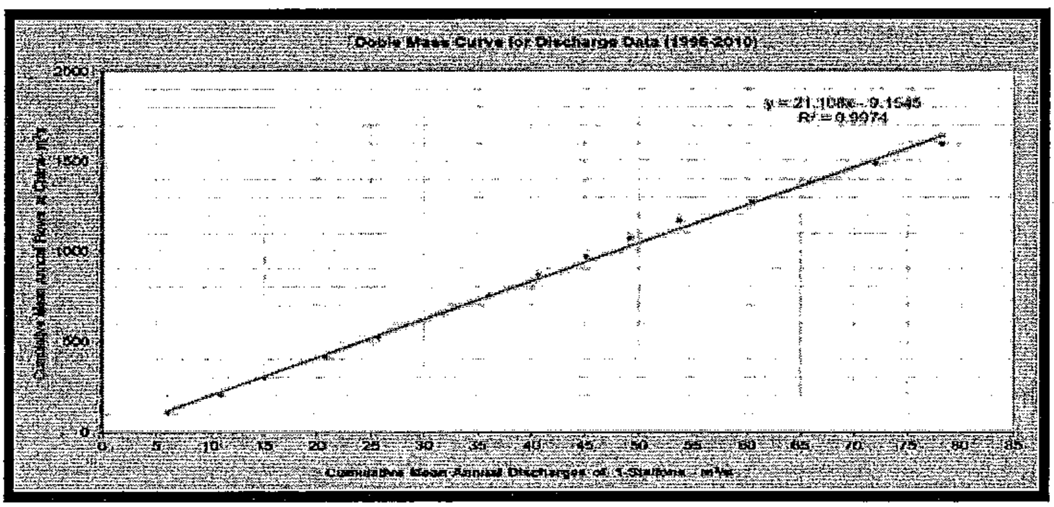

Figure 4.3: Double Mass Curve for Stream Flow Data

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The results of DMC analysis for the Chitral stream gauging station is shown in Figure 3.

Average of 05 neighboring stations mean annual flows were computed and shown in this Figure. It shows that the flow data record at Chitral stream gauging station is consistent with its 05 neighboring stations.

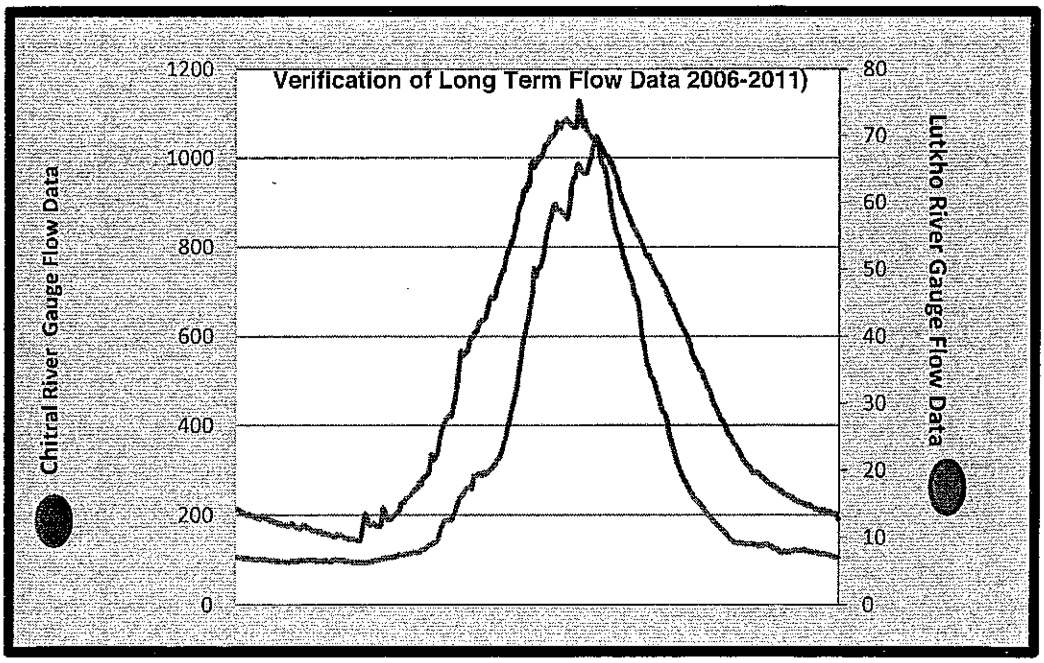
After evaluating the results of double mass curve, the Consultants considered that the collected data are reliable and hence can be used for further analysis of water availability studies.

4.2.2.3. Flow trends between Chitral River and Lutkho River

The Figure 4shows the flow trends between mean daily flows of river Chitral at Chitral and mean daily flows of Lutkho river at Shah-Re-Sham. Shah-Re-Sham temporal distribution trend is almost same except for the peak discharges. In case of Lutkho river peak is relatively higher and develops at a later stage with a time gap of about 20 days. This shows contribution of snowmelt which appears in the hydrograph at a later stage.

4.2.2.4. Flow trends between Chitral River and Arkari Gol

The Figure 5 shows the flow trends between mean daily flows of river Chitral at Chitral and mean daily flows of Arkari River at the gauging site. Arkari Gol flow temporal distribution trend is almost same except for the peak discharges. In case of Arkari Gol peak is relatively higher and develops almost at the same time as at Chiral. However, base flows at Arkari Gol are relatively smaller. This trend shows that using the data of Chitral river at Chitral, long term data of flows at Arkari Gol can be easily generated which is essentially required for the reliable flow study of the HPP.



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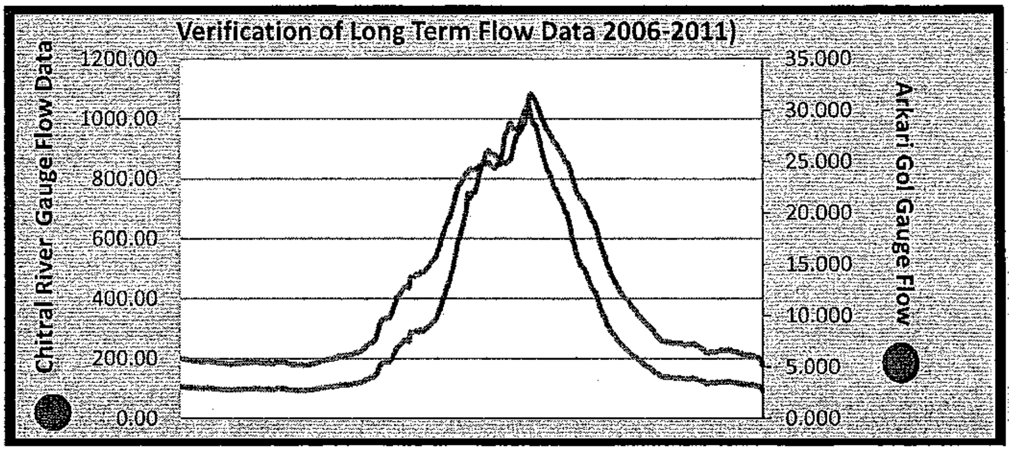

Figure 4.5: Graphical Presentation of Chitral & Arkari Gol Flow Data (Cumecs)

4.3. Climatology

To study the climatology of the proposed Arkari Gol Hydropower Project, analyses have been carried out for several climatological stations in the Chitral valley. Efforts have been made to assess the most representative values for the climatological parameters for the project area. For the reporting purpose, data for Chitral climatological station have been presented.

The weather in the project area is characterized by moderate summers and severe cold winters. The four important parameters that define the climate of a region are precipitation, relative Humidity and air temperature. In general, the climate of the project area is governed by two wind systems. One is the monsoon persisting during the summer months of June to September; the Easterlies and the second system is the Wester lies which dominates in the winter months of November to March. The distribution of rain during the year depends very largely on the topography of the area and season. The intensity of monsoon summer rainfall is very low and only touches the valleys which are on boarder Dir District so it is very important to analyze the climatology of the area.

4.3.1 Precipitation

Daily precipitation data at Chitral rain gauging station is available for 20 years from 1992 - 2011. Rainfall data have been used to compute average rainfall of the locality on daily basis, monthly basis and annual basis for the last 20 years. Based on 20 years of data, the maximum daily precipitation was observed to have occurred on 10th October, 2004 as 109 mm and maximum annual precipitation was recorded as 720 mm in the year 1992.(Note: Rain Data of 2009 is available only for the month of January).

Studies carried out for the Northern Areas of Pakistan, show that precipitation increases with the elevation up to certain elevation. Beyond this elevation the precipitation decreases or remains stable. The physical explanation of these phenomena is that precipitation increases as long as humidity is available to produce increasing amounts of precipitation. However, once a balance between the increasing rate of production of precipitation and availability of humidity is reached, the precipitation decreases or remains stable with the elevation, because the humidity does not provide sufficient water to produce increasing amounts of precipitation. The same precipitation pattern has been observed at many places in the world, where precipitation is mainly of orographic origin. The exact elevation at which precipitation starts decreasing varies from region to region.

Distribution of precipitation with the elevation, in areas with important snow accumulation, may not be suitable to predict run-off, because an important process of mass transfer from higher to lower elevations takes place in the catchment. Large amounts of water in form of snow are transferred from higher to lower elevations through avalanches and mass movements. The run-off is produced at the place where the snow melts, and therefore precipitation does not give a precise indication of run-off origin. However, distribution of precipitation with the elevation accounts for the overall water balance in the catchment.

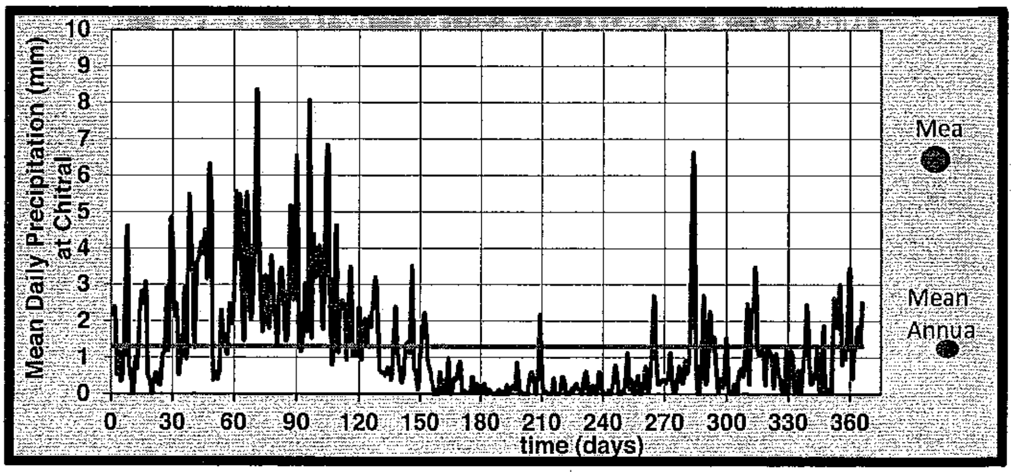

Figure 4.6: Mean Daily Precipitation at Chitral (1992-2011)

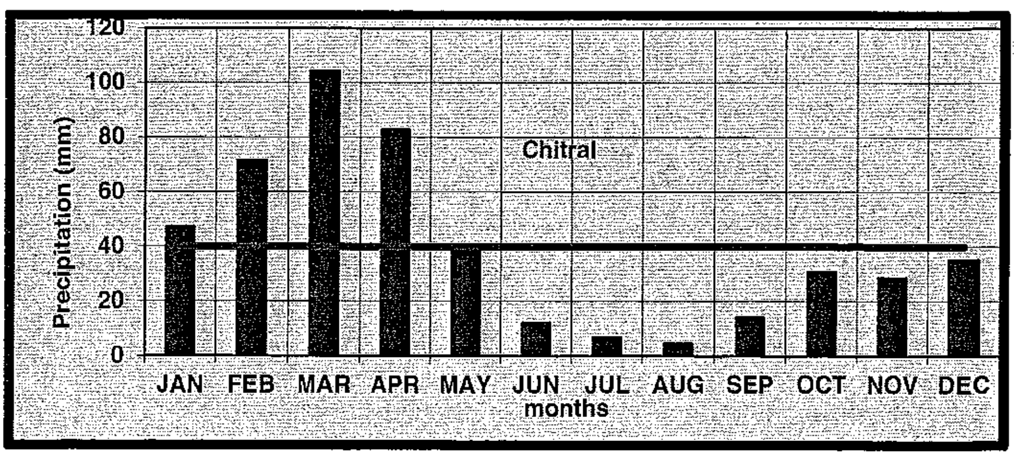

Figure 4.7: Mean Monthly Precipitation at Chitral (1992 - 2011)

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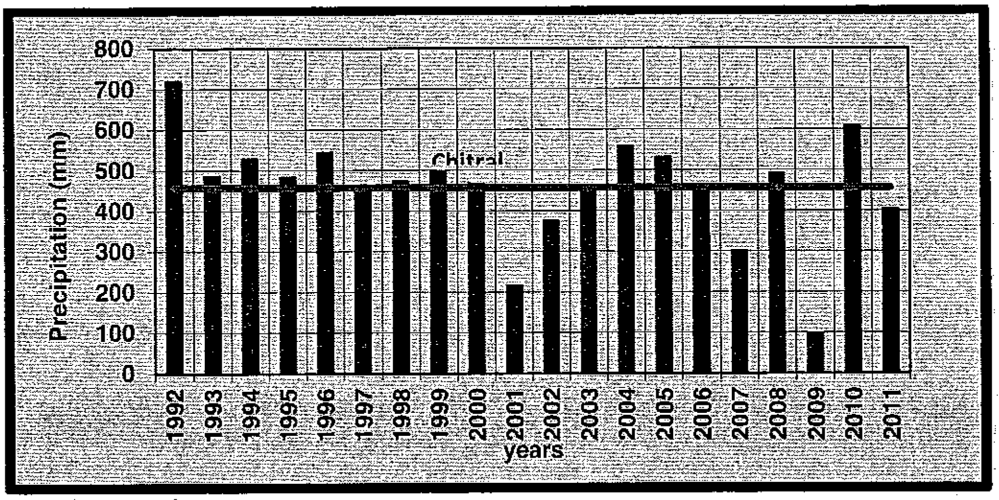

Figure 4.8: Annual Precipitations at Chitral (1992 - 2011)

Mean daily distribution of the precipitation for Chitral climatological station was computed and presented in Figure 4.6. Figures shows that mean maximum daily precipitation occur in the month of March.

Mean monthly precipitations at Chitral meteorological station are shown in Figure 4.7. Mean monthly precipitation is highest in the month of March and lowest in August with values of 110.1 and 3.12 mm, respectively.

Annual precipitations at Chitral meteorological station are shown in Figure 2.8. Highest annual precipitation was observed in 1992 and lowest in 2001 with values of 719.7 and 215.4 mm, respectively.

The mean annual precipitation at the Chitral meteorological station is computed as 471.9 mm.

4.3.2 Relative Humidity

The relative humidity data of Chitral Climatological station has been analyzed which was collected from Pakistan Meteorological Department (PMD) for period of 1992 to 2008. Relative humidity is measured in percentage at 8:00 A.M and 5:00 P.M daily. Mean monthly distribution of relative humidity is shown in **Figure 4.9**. The results show that relative humidity occurs maximum in the month of December with a value of 43.33 % and minimum in the month of June with a value of 24.08 %. Mean annual humidity over Chitral is worked out as 36.15 %.

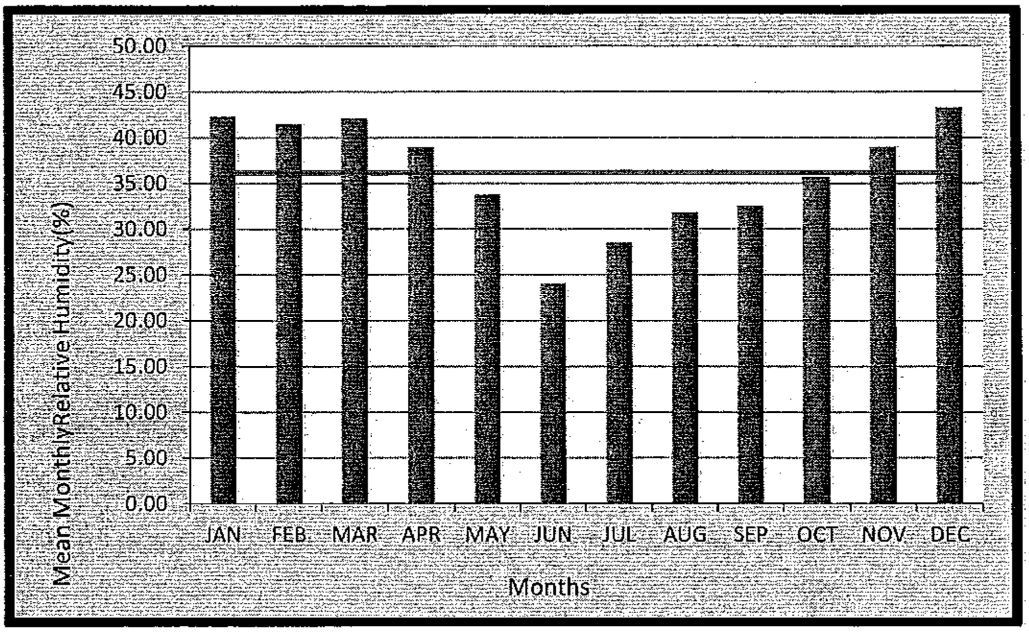

Figure 4.9: Mean Monthly relative humidity (%) for Chitral (1992 to 2008)

The mean annual relative humidity values from (1992 to 2008) are presented in Figure 2.10,which shows that relative humidity of 2005 was the highest with a value of 44.37 % and minimum in 2001 with a value of 31.72 %.Mean annual relative humidity at Chitral climatological station is 36.15 %.

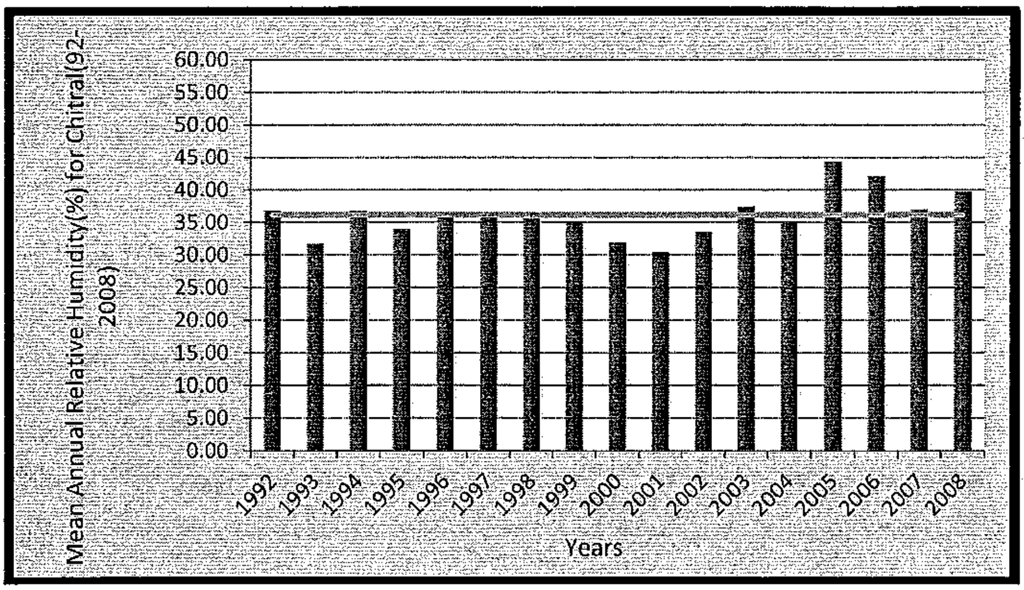

Figure 4.10: Mean Annual relative humidity (%) for Chitral (1992 - 2008)

4.3.3 Air Temperature

The maximum and minimum air temperature data of Chitral Climatological station have been analyzed which were collected from Pakistan Meteorological Department from (1992 to 2008).

4.3.3.1 Maximum Temperatures

The mean monthly maximum air temperatures at Chitral Gauging Station are presented in **Figure 4.11,** which shows that the highest mean monthly temperatures are observed in the month of July, which is 36.42 °C on average basis. The lowest maximum mean monthly temperature is 10.02°C and is found in the month of January.

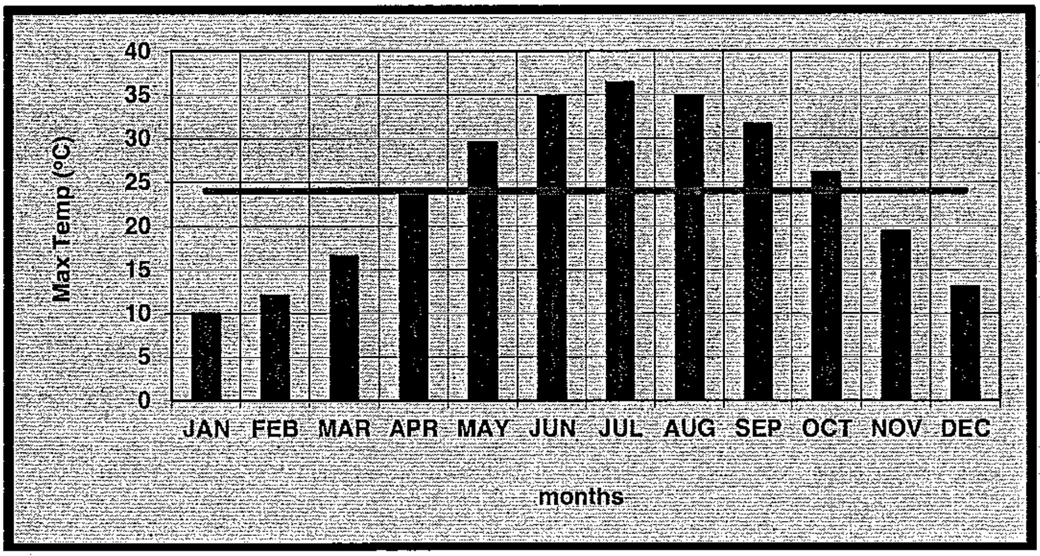

Figure 4.11: Mean monthly Maximum Temperature of Chitral (1992 to 2008).

The mean annual maximum temperatures from 1992 to 2008 are presented in Figure 4.11,which shows that the mean annual maximum temperature of 2001 was highest with a numerical value of 25.8 C° and lowest 22.2 C° in 1992. However mean annual maximum temperature of the study area by long term data record was worked out as 24.02 C°

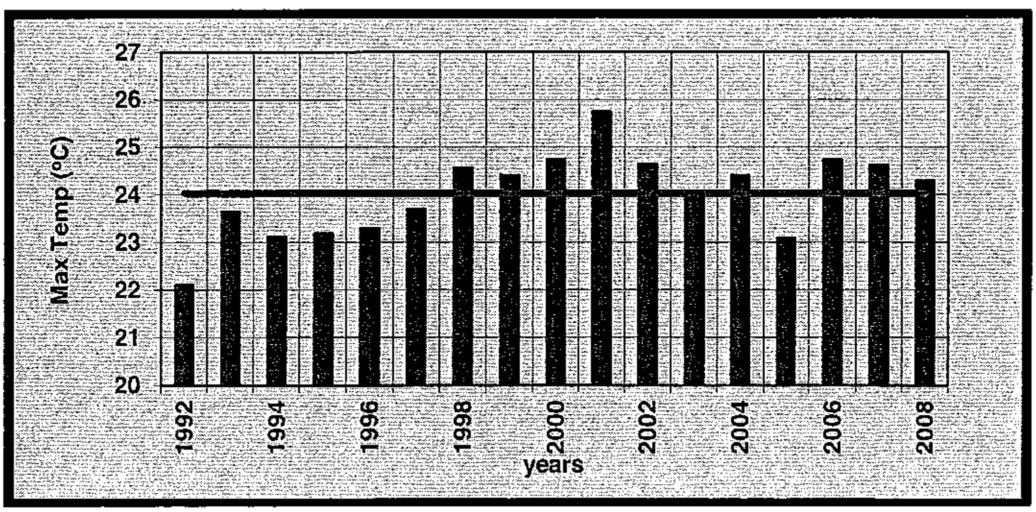

Figure 4.12: Mean Annual Maximum Temperature of Chitral (1992 to 2008).

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4.3.3.2 Minimum Temperatures

The mean monthly minimum air temperatures at Chitral Gauging Station are presented in **Figure 2.13**, which shows that the highest temperatures are observed in the month of July, which is 19.46 °C on average basis. The lowest mean monthly temperature is -0.76°C and is found in the month of January and average temperature is 8.39°C.

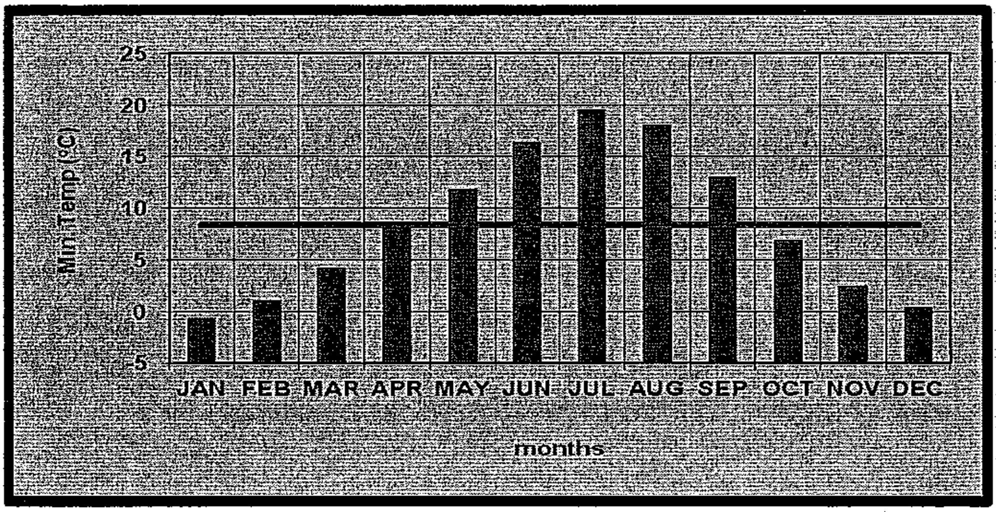

Figure 4.13: Mean monthly Minimum Temperature of Chitral (1992 to 2008).

The mean annual minimum temperatures from 1992 to 2008 are presented in **Figure 4.14,** which shows that the mean annual minimum temperature of 2006was the highest with a numerical value of 9.6 C° and lowest 6.4 C° in 2004. However mean annual minimum temperature of the study area by long term data record was worked out as 8.4.

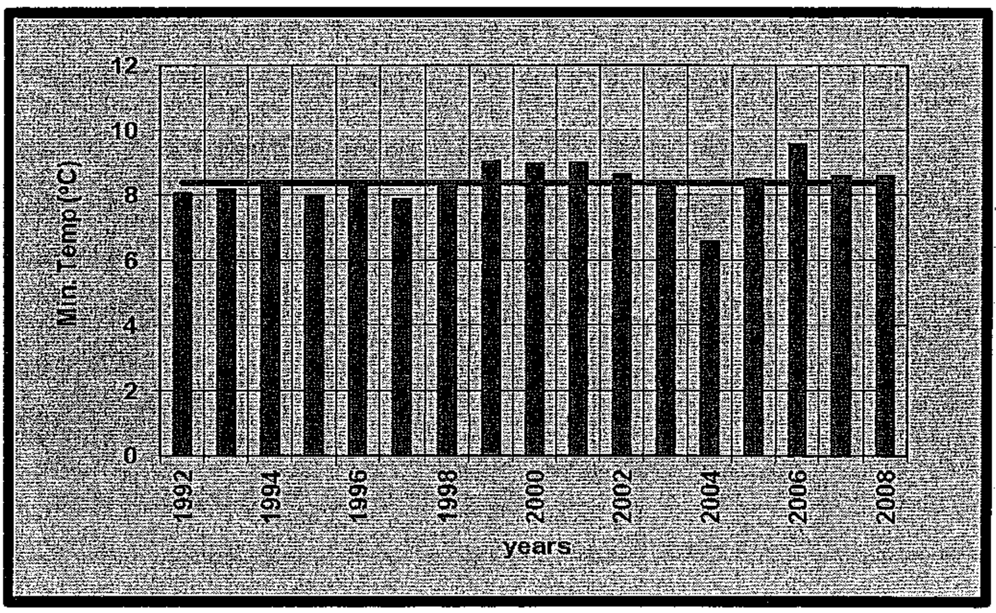

Figure 4.14: Mean Annual Minimum Temperature of Chitral (1992 to 2008).

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4.4 Drainage Basin

Regionally, Chitral is situated in the extreme northern part of Pakistan, bordered for about 480 km along Afghanistan the area of Chitral about 14,850 km^2.The area is sandwiched between Hindu Kush Range in the north and the Hindu Raj Range in the south and has an approximate NE-SE trend. Located further east are the Great Himalayas. The entire Chitral valley is mountainous region cut into deep and steep sided valleys by Chitral River and its numerous tributaries. The mountain elevations generally range from 3500m to Terchmir the highest peak 7700m in that region. Development of relief is greatest in the north where it is not common for valley bottom stobe 3000- 000m below the elevation of the higher peak.

The drainage area of Arkari Gol upto proposed Weir site is about 1036 km^2. Several streams drain into the Arkari Gol upstream of proposed site and contribute appreciable amount of water for hydropower. These streams include Muzhigram Gol, Besti Gol, Dir Gol, Rohni Gol, Ispana Gol, Shah Arkari, Ribat Gol, Shekhjal Gol, Agram Gol, Khuda Barma and Kurobakho Gol etc. The Valley of Arkari Gol descends from an elevation of 6952 meters above mean sea level (masl) and at Uchhatur up to 2169.80 masl at proposed weir site.

Arkari Gol is a left tributary of Lutkho River. Arkari Go joins Lutkho River about one Km upstream Shoghore Village to form Lutkho River. The way to Garam chashma/Shah Saleem Pass is through Lutkho River valley. The identified weir site is about 11.4 km upstream of Shoghore village in Arkari Gol valley near Uchhatur Village. The powerhouse is proposed near Andhaht Village at the junction of Arkari Gol and Lutkho River, one km upstream of Shoghore Village. The elevation of intake is 2181.00 m, the co-ordinates of the intake are the following.

Site	Latitude	Longitude
Weir	$36^0 - 03' - 57''$	$71^0 - 41' - 37''$
Powerhouse	$36^0 - 01' - 10''$	$71^0 - 44' - 11''$

4.4.1 River Network Generation

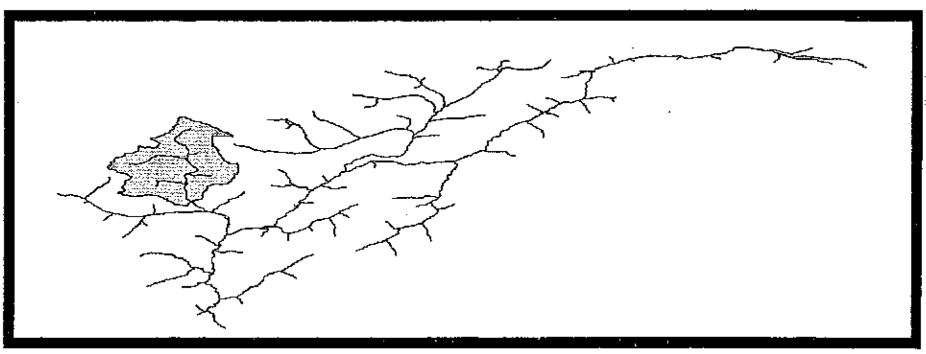

Figure 4.15:River Network of Chitral River Basin and watershed boundary Arkari weir site

KAD

The river network for the study area was generated by using SRTM 90 m grid resolution dataset. The 90 m DEM was re-sampled to 100 m for easy interpretation of the data in area units.

The Digital Elevation Model data was first corrected for sinks and filled DEM was used to generate the flow direction map and then flow accumulation map using a GIS softwareArc/info. The drainage network was generated by assuming various thresholds (1000, 500, and 100 cells) and finally the drainage network with a threshold value of 500 cells was found appropriate for the study area. The river network grid then was converted into drainage line coverage.The generated river network for the Chitral river Basin is shown in Figure 2.15.

4.4.2 Delineation of the Watershed

For the delineation of the watershed boundary, one pour point was selected on the River Arkari at the coordinates of proposed Arkari weir site. The watershed boundary and the generated river network are shown in Figure 7.16. The delineated watershed area of the river Arkari at Arkari weir site was worked out as 1036 km^2, whereas, watershed area of Balakot Powerhouse site was determined as 1060 km^2.

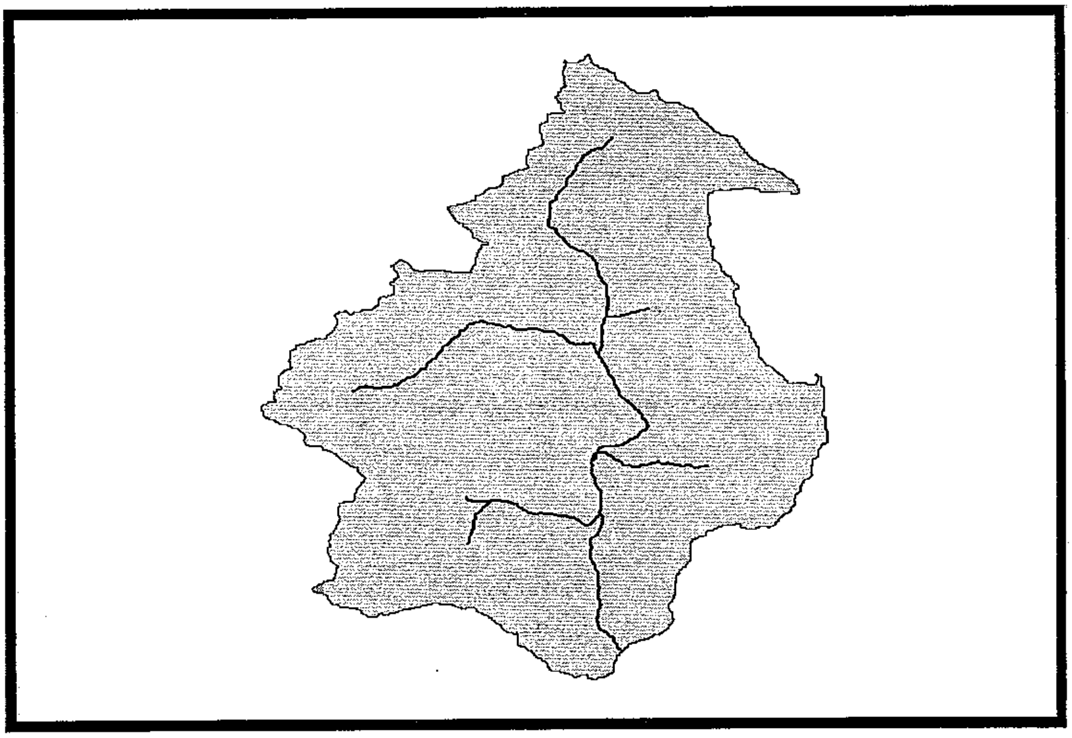

Figure 4.16: Watershed boundary and generated river network for Arkari weir site

4.4.3 Topography of the Watershed

On the basis of the 100 m DEM, the elevation in the watershed varies from 2172 m to 6732 m.a.s.l as shown in **Figure 4.17**. The mean elevation of the watershed is 4156.5 m.a.s.l with a standard deviation of 721.6 m.

Rao

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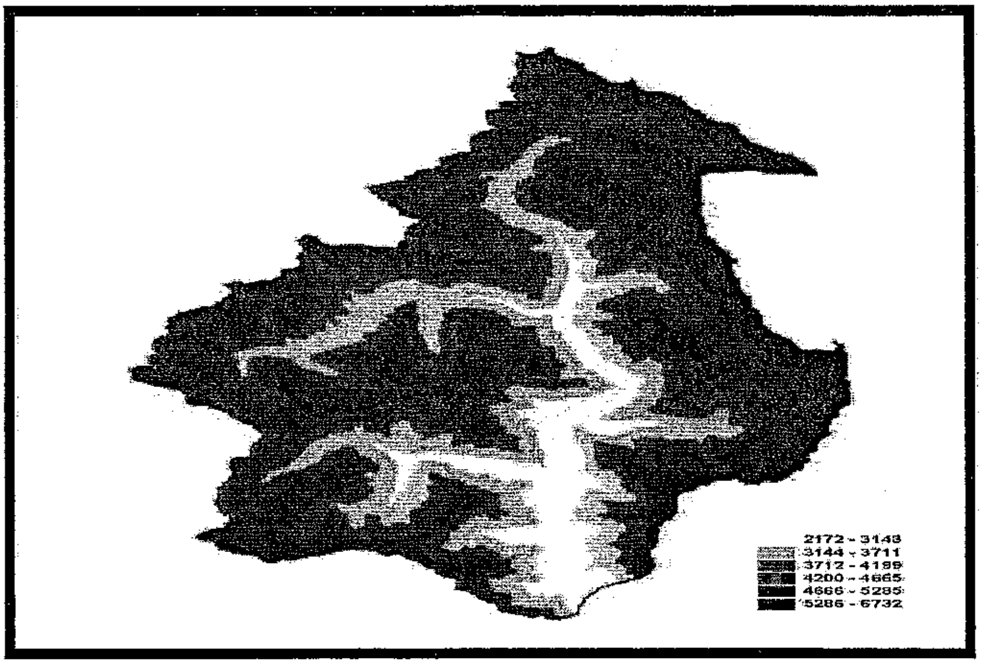

Figure 4.17: SRTM Digital Elevation Model for the proposed Arkari weir site Watershed

4.5 Flow Study

Though about 06 years continuous flow data record is available at Arkari Gol stream Gauging station from January, 2006 to December, 2011, but the record tells that very few discharge observations per year were taken. Then flow observations were resumed at the gauging station from September, 2012 to date in which more frequent discharge observations were made using current meter.

Considering the quality of the available flow data record at the Arkari stream gauging station, the flow study for the project was carried out in two phases, initially by regional analysis approach to establish the mean annual flow at the site and then by utilizing the Arkari gauge data to have its temporal distribution.

To carry out the flow study using regional analysis approach flow data of 8 stream gauging station were collected and used. List of these stream gauging stations with source of the data, location of the gauging station, data record length, watershed area, mean annual flow, specific discharge and elevation are given in Table 4.4.

Table 4.4: Stream Gauging Stations Selected For the Regional Flow Study of Arkari HPP.

Sr. No	River Name	Gauging Station	Source	Cordinates		Data Years	Data Length (years)	Area (km^2)	Mean Annual Flow (cumecs)	Specific Q (Litre/sec/km²)	Elevation (masl)
				Latitude	Longitude						
1	Lutkho	Shagore	SHYDO	36° 00' 54"	71° 00' 50"	2006-2010	5	1990	34.17	17.17	1800.00
2	Lutkho	Shah-e-Resham	SWHP	-	-	1986-1987	2	2443	39.37	16.12	
3	Ojhar Gol	Shogore	SHYDO	36° 01' 25"	71° 45' 33"	1995-1998	4	180	4.37	24.28	1860.00
4	Chitral	Chitral	SWHP	35° 51' 48"	71° 47' 15"	1964-2011	48	11396	280.57	24.62	1500.00
5	Golen Gol	Mastuj Bridge	SWHP	35° 56' 32"	71° 58' 49"	1996-2010	15	518	14.23	27.47	1649.00
6	Reshun Gol	Reshun	SHYDO	36° 08' 45"	72° 07' 25"	1989-1992, 1994-1997	8	102	2.85	27.94	2050.00
7	Mastuj	Miragram	SHYDO	36° 16' 00"	72° 21' 25"	2006-2011	6	4375	139.57	31.90	2080.00
8	Golen Gol	Babuka	SWHP	35° 55' 50"	71° 55' 55"	1993-1997, 2002	6	500	16.69	33.38	2010.00

As at various stream gauging stations length of flow data records were different, hence mean annual flows were generated for 48 years (1964-2011) for all stream gauging stations by developing correlations for each station flows and Chitral stream gauging station flows. The computed mean annual flows based on 48 years data record for 08 stream gauging stations are given in Table 4.5.

Table 4.5: Mean Annual Flows Computed For Stream Gauging Stations Considering 48 Years Generated Flow Data

Sr. No	River Name	Gauging Station	Source	Cordinates		Data Years	Data Length (years)	Area (km^2)	Mean Annual Flow (cumecs)	Specific Q (Litre/sec/km²)	Elevation (masl)
				Latitude	Longitude						
1	Lutkho	Shagore	SHYDO	36° 00' 54"	71° 00' 50"	1964-2011	48	1990	30.82	15.49	1800.00
2	Lutkho	Shah-e-Resham	SWHP	-	-	1964-2011	48	2443	39.98	16.37	
3	Ojhar Gol	Shogore	SHYDO	36° 01' 25"	71° 45' 33"	1964-2011	48	180	4.33	24.06	1860.00
4	Chitral	Chitral	SWHP	35° 51' 48"	71° 47' 15"	1964-2011	48	11396	280.57	24.62	1500.00
5	Golen Gol	Mastuj Bridge	SWHP	35° 56' 32"	71° 58' 49"	1964-2011	48	518	13.51	26.08	1649.00
6	Reshun Gol	Reshun	SHYDO	36° 08' 45"	72° 07' 25"	1964-2011	48	102	2.77	27.16	2050.00
7	Golen Gol	Babuka	SWHP	35° 55' 50"	71° 55' 55"	1964-2011	48	500	16.29	32.58	2010.00
8	Shishi Gol	Drosh	SWHP	35° 35' 20"	71° 48' 32"	1964-2011	48	394	16.14	40.96	

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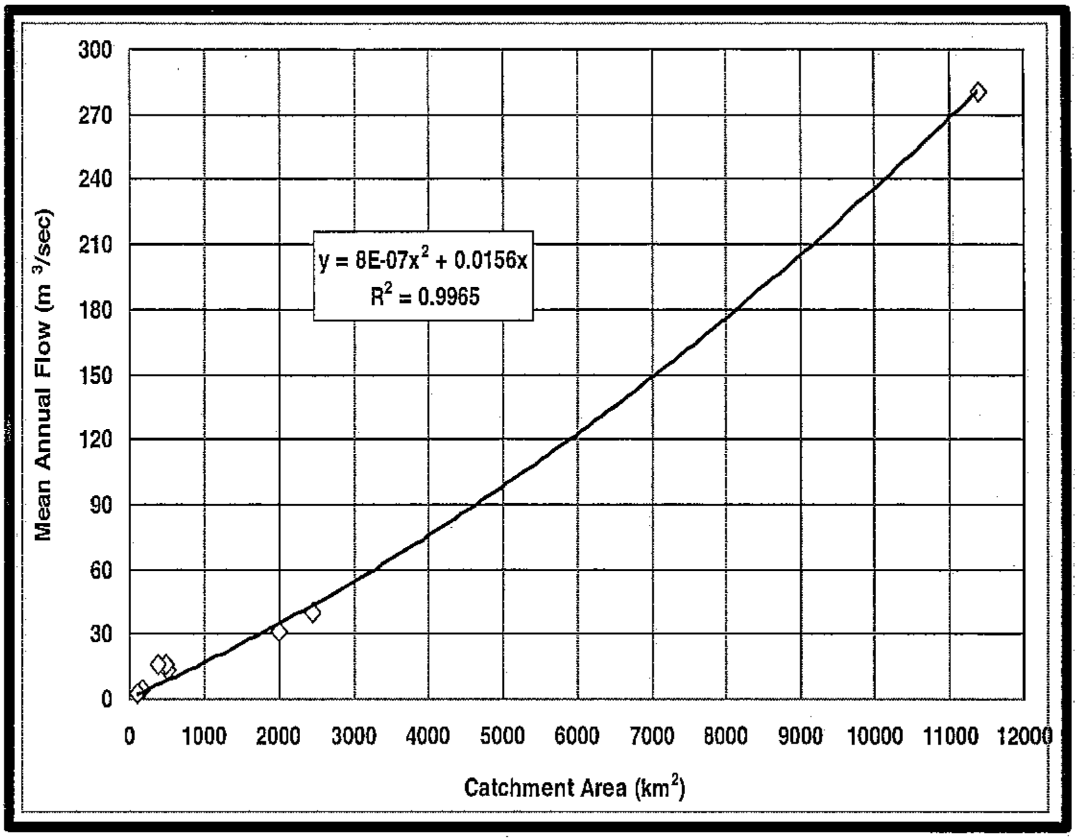

Figure 4.18: Results of the Regional Analysis for flows in Chitral Region

Results of the local regional analysis for flows are shown in Figure 4.18. The developed equation for flows as a function of the watershed area in Chitral region is presented in Equation (4.1).

$$Q = (8X10^{-7})\ A^2 + 0.015\ A \qquad (4.1)$$

Using Equation (4.1), for a value of watershed area of Arkari Gauge as 1015 km^2, the mean annual flow at the gauging site was computed as 16.67 cumecs.

The summary of mean monthly observed flows at Chitral is given in Table 2.6. The mean annual flow at Chitral stream gauging station on the basis of 48 years of data record is 280.57 cumecs.

Table 4.6: Observed Mean Monthly Flows At Chitral Stream Gauging Station (1964-2011)

S. No.	Year	Mean Monthly Flows (m^3/s)												Annual Flow		
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Cumecs	MCM	(MAF)
1	1964	62.70	57.12	60.28	84.30	97.62	254.80	437.97	584.27	311.16	128.96	93.08	79.05	187.61	5,916.42	4.80
2	1965	68.41	61.19	63.70	85.75	231.93	558.58	818.70	596.15	244.24	149.67	94.13	77.18	254.14	8,014.47	6.50
3	1966	66.77	58.81	60.24	87.77	158.51	572.00	720.69	684.20	288.44	143.07	101.76	80.58	251.90	7,944.04	6.45
4	1967	71.80	65.48	60.40	78.14	126.00	409.53	717.12	707.61	342.84	133.74	100.75	85.33	241.56	7,617.87	6.18
5	1968	72.41	64.49	61.82	78.02	146.62	495.77	871.83	882.16	290.82	147.79	115.18	91.24	276.51	8,720.08	7.08
6	1969	82.14	80.82	90.22	138.13	216.08	486.49	839.55	789.99	292.08	156.15	109.73	95.85	281.44	8,875.40	7.20
7	1970	80.60	72.56	68.87	95.19	205.41	493.58	613.03	753.19	506.03	179.08	115.07	90.49	272.76	8,601.68	6.98
8	1971	75.58	68.71	69.88	80.40	202.94	691.99	757.26	741.72	315.52	151.24	139.13	123.38	284.81	8,981.86	7.29
9	1972	111.05	103.93	104.22	122.18	196.58	513.61	697.83	667.38	377.01	153.66	109.12	88.77	270.44	8,528.66	6.92
10	1973	78.62	72.81	73.07	124.06	324.88	774.01	1138.08	922.24	516.87	161.52	119.29	89.89	366.28	11,550.96	9.37
11	1974	76.78	73.17	78.45	92.06	141.34	420.83	727.00	644.61	282.45	120.82	92.08	76.56	235.51	7,427.12	6.03
12	1975	66.02	61.12	60.32	94.67	183.01	498.87	753.24	802.43	406.29	154.38	107.28	90.20	273.15	8,614.13	6.99
13	1976	76.03	67.99	65.65	90.79	194.33	409.43	810.38	696.46	351.41	150.27	104.20	83.46	258.37	8,147.82	6.61
14	1977	74.60	68.52	68.44	72.30	122.35	436.31	841.65	713.46	259.88	148.31	97.76	79.61	248.60	7,839.84	6.36
15	1978	70.03	60.46	59.41	86.23	190.15	576.26	866.52	782.59	392.01	184.67	110.14	87.05	288.79	9,107.38	7.39
16	1979	73.16	66.41	62.25	107.05	175.31	417.56	780.12	681.55	305.63	171.21	123.78	97.40	255.12	8,045.42	6.53
17	1980	84.28	74.57	65.75	98.06	187.49	497.07	774.82	675.15	348.42	146.55	103.45	88.04	261.97	8,261.52	6.70
18	1981	74.40	65.60	61.15	86.82	168.18	472.89	828.30	719.50	327.59	170.45	105.18	86.28	263.86	8,321.18	6.75
19	1982	74.21	62.14	57.89	79.76	143.75	325.21	531.33	793.93	285.47	128.12	88.24	75.10	220.43	6,951.41	5.64
20	1983	69.08	61.92	56.40	68.49	157.28	369.98	661.25	862.32	438.96	163.58	109.78	86.54	258.80	8,161.47	6.62
21	1984	75.67	67.77	65.41	84.14	170.43	684.43	872.28	1005.32	415.63	144.55	103.38	85.95	314.58	9,920.62	8.05
22	1985	72.89	68.04	67.95	74.97	122.78	420.40	920.38	783.04	412.75	174.53	106.30	90.91	276.25	8,711.68	7.07
23	1986	82.46	68.85	67.77	82.31	165.17	376.07	847.41	704.14	303.73	184.49	116.65	92.88	257.66	8,125.59	6.59
24	1987	77.30	67.00	69.05	102.59	159.93	371.47	593.41	680.09	459.02	162.19	113.42	91.57	245.59	7,744.81	6.28
25	1988	80.05	69.63	69.76	132.62	295.85	606.67	1085.88	820.17	332.47	172.21	114.68	89.69	322.47	10,169.52	8.25
26	1989	73.69	65.66	64.11	76.66	140.88	406.89	671.12	611.57	313.96	182.93	119.23	91.61	234.86	7,406.47	6.01
27	1990	73.24	66.48	68.47	82.72	282.43	493.43	842.72	771.72	550.90	225.92	115.64	87.09	305.06	9,620.47	7.81
28	1991	77.64	74.27	76.56	94.19	139.28	460.35	818.88	787.27	497.78	199.75	139.54	109.08	289.55	9,131.19	7.41
29	1992	84.77	75.07	71.20	96.30	211.42	509.04	1042.04	880.41	480.67	192.80	120.71	98.52	321.91	10,151.84	8.24
30	1993	95.91	80.58	86.32	154.38	229.93	480.81	746.93	519.68	452.29	214.52	140.56	112.94	276.24	8,711.47	7.07
31	1994	69.43	59.64	61.23	85.61	169.17	486.80	1143.03	993.57	375.81	155.06	114.91	94.87	317.43	10,010.37	8.12
32	1995	77.63	65.83	63.13	80.40	122.32	499.11	969.28	733.83	301.70	183.81	115.07	88.66	275.06	8,674.41	7.04
33	1996	78.89	67.90	72.42	113.12	288.15	577.01	704.27	844.22	426.78	186.85	129.09	99.73	299.03	9,430.34	7.65
34	1997	82.63	73.31	69.08	100.10	170.41	439.62	998.19	699.30	393.87	181.81	109.36	87.81	283.79	8,949.65	7.26
35	1998	76.49	69.75	64.91	100.82	203.90	373.80	1018.11	777.92	392.10	192.44	116.90	94.71	290.15	9,150.31	7.43
36	1999	83.71	72.68	68.88	96.26	244.90	514.43	826.82	724.60	428.40	189.93	122.63	101.94	289.60	9,132.76	7.41
37	2000	83.53	73.11	70.06	92.25	248.50	433.74	778.90	608.41	410.00	155.51	112.71	85.33	262.67	8,283.58	6.72
38	2001	75.16	65.89	65.28	73.92	236.84	591.10	936.60	677.73	348.70	144.34	103.70	81.06	283.36	8,936.04	7.25
39	2002	72.75	64.87	64.04	90.14	186.20	595.60	694.10	767.12	338.71	176.54	108.54	86.47	270.42	8,528.07	6.92
40	2003	74.88	65.76	67.19	98.98	146.80	565.82	1123.00	734.71	390.30	166.60	125.00	100.03	304.92	9,616.03	7.80
41	2004	77.97	66.59	66.42	92.16	209.70	529.31	710.30	654.20	389.70	171.21	121.96	98.65	265.68	8,378.53	6.80
42	2005	84.78	75.32	80.50	137.82	256.90	664.70	1255.00	868.00	499.51	208.92	148.20	107.40	365.59	11,529.15	9.36
43	2006	92.90	83.35	77.44	99.61	324.44	458.27	908.09	893.97	331.98	156.29	119.24	100.03	303.80	9,580.65	7.77
44	2007	106.84	122.54	132.03	147.71	262.90	547.19	1010.19	769.75	378.07	157.98	132.99	111.50	324.97	10,248.37	8.32
45	2008	103.209	92.197	85.699	119.009	286.045	718.737	1394.262	994.669	470.855	148.070	128.300	116.647	388.14	12,240.43	9.93
46	2009	90.816	90.395	86.668	95.246	115.021	273.763	552.578	649.957	449.397	172.095	147.251	119.196	236.87	7,469.78	6.06
47	2010	88.666	86.513	94.471	120.021	162.981	412.483	848.242	1442.165	666.338	339.681	124.574	122.567	375.73	11,848.87	9.61
48	2011	120.571	112.065	106.277	111.415	185.935	307.271	547.419	516.401	356.852	188.379	128.823	125.689	233.92	7,377.05	5.99
Maximum		120.57	122.54	132.03	154.38	324.88	774.01	1,394.26	1,442.16	666.34	339.68	148.20	125.69	478.73	15,097.21	12.25
Minimum		62.70	57.12	56.40	68.49	97.62	254.80	437.97	516.40	244.24	120.82	88.24	75.10	173.32	5,465.95	4.44
Mean		80.07	72.48	71.89	97.62	194.35	489.02	834.29	762.81	384.40	170.26	115.38	94.26	280.57	8,848.06	7.18
Standard Dev.		11.60	13.15	14.34	20.31	57.00	111.57	191.25	150.54	85.08	33.72	13.92	12.77	39.96	1,260.17	1.02

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4.5.1 Estimation of Extended Flows at Arkari Gol Gauge Site

As flow data record is available approximately for 8 years from 2006 to 2013 at Arkari gauge on Arkari River, a correlation was developed between mean monthly flows at Arkari gauge and mean monthly flows at Chitral stream gauging station as shown in Figure 4.19. Considering the developed regression model, the long term mean annual flow at the gauging site was computed as 12.23 cumecs.

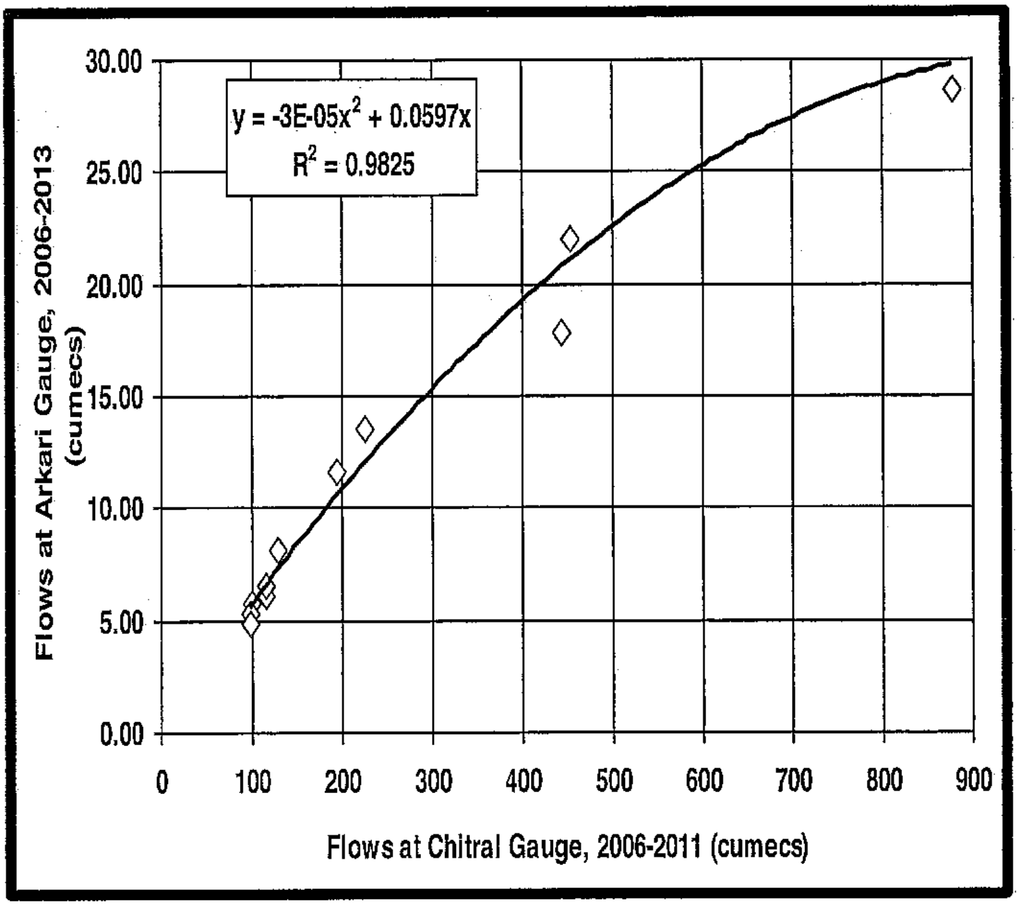

Figure 4.19: Correlation between mean monthly flow of Arkari Gol and Chitral stream gauging stations

To obtain the mean annual flows at Arkari gauge same as computed from regional analysis, a multiplication factor of (16.66/12.23) was used. The final regression model to compute flows at the Arkari Gauging site is given in Equation (4.2).

$$Q_{Arkari\_Gauge} = \left[(-3X10^{-5})\ (Q_{Chitral})^2 + 0.0597\,(Q_{Chitral})\right]\left(\frac{16.67}{12.23}\right) \quad (4.2)$$

4.5.2 Availability of River Flows at Arkari Gol Gauge Site

Computing the mean monthly flows at the gauge site for 48 years from 1964 to 2011 by using the Model as mentioned in Equation (7.2), summary of mean monthly and annual flows have been computed at the gauge site which are given in Table 4.7.

Table 4.7: Generated Mean Monthly Flows for Arkari stream gauging station using Regional Analysis and Regression Model (1964-2011)

S. No.	Year	Mean Monthly Flows (m^3/s)												Annual Flow		
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Cumecs	MCM	(MAF)
1	1964	4.99	4.56	4.81	6.64	7.63	18.27	28.09	33.94	21.59	9.92	7.30	6.24	12.83	404.67	0.33
2	1965	5.43	4.88	5.07	6.75	16.85	33.04	39.63	34.34	17.62	11.38	7.37	6.10	15.71	495.29	0.40
3	1966	5.31	4.69	4.80	6.90	12.00	33.52	37.80	36.92	20.28	10.92	7.94	6.36	15.62	492.60	0.40
4	1967	5.69	5.21	4.82	6.17	9.71	26.75	37.72	37.50	23.34	10.26	7.87	6.72	15.15	477.62	0.39
5	1968	5.74	5.13	4.93	6.16	11.17	30.61	40.29	40.39	20.42	11.25	8.92	7.16	16.01	505.02	0.41
6	1969	6.48	6.38	7.08	10.57	15.84	30.23	39.91	39.18	20.49	11.83	8.53	7.50	17.00	536.17	0.44
7	1970	6.36	5.75	5.47	7.45	15.15	30.52	34.88	38.50	31.03	13.40	8.92	7.10	17.04	537.52	0.44
8	1971	5.98	5.46	5.55	6.35	14.99	37.12	38.58	38.26	21.83	11.49	10.64	9.52	17.15	540.72	0.44
9	1972	8.62	8.10	8.12	9.43	14.57	31.34	37.26	36.48	25.13	11.66	8.48	6.97	17.18	541.81	0.44
10	1973	6.21	5.77	5.79	9.57	22.36	38.89	40.07	40.69	31.47	12.20	9.22	7.06	19.11	602.59	0.49
11	1974	6.07	5.80	6.20	7.22	10.80	27.29	37.94	35.84	19.93	9.33	7.22	6.05	14.97	472.24	0.38
12	1975	5.25	4.87	4.81	7.42	13.67	30.74	38.50	39.38	26.59	11.71	8.35	7.08	16.53	521.29	0.42
13	1976	6.01	5.40	5.22	7.13	14.42	26.74	39.50	37.23	23.80	11.42	8.12	6.58	15.96	503.45	0.41
14	1977	5.90	5.44	5.43	5.73	9.44	28.01	39.94	37.64	18.58	11.29	7.64	6.29	15.11	476.57	0.39
15	1978	5.56	4.82	4.74	6.78	14.14	33.67	40.23	39.05	25.89	13.78	8.56	6.85	17.00	536.26	0.44
16	1979	5.79	5.28	4.96	8.33	13.15	27.13	39.00	36.85	21.27	12.87	9.55	7.62	15.98	504.07	0.41
17	1980	6.64	5.90	5.23	7.67	13.97	30.67	38.91	36.69	23.64	11.16	8.07	6.92	16.29	513.64	0.42
18	1981	5.89	5.22	4.87	6.83	12.66	29.65	39.76	37.78	22.51	12.82	8.19	6.79	16.08	507.10	0.41
19	1982	5.88	4.95	4.62	6.30	10.97	22.37	32.03	39.24	20.11	9.86	6.93	5.94	14.10	444.65	0.36
20	1983	5.48	4.93	4.51	5.44	11.91	24.77	36.31	40.19	28.14	12.35	8.53	6.81	15.78	497.63	0.40
21	1984	5.99	5.38	5.20	6.63	12.82	36.93	40.29	40.91	27.04	11.02	8.06	6.76	17.25	544.07	0.44
22	1985	5.77	5.40	5.40	5.93	9.47	27.27	40.68	39.06	26.90	13.09	8.27	7.13	16.20	510.88	0.41
23	1986	6.50	5.47	5.38	6.49	12.46	25.08	40.01	37.42	21.17	13.77	9.03	7.28	15.84	499.45	0.41
24	1987	6.11	5.32	5.48	8.00	12.09	24.85	34.25	36.81	29.04	12.25	8.80	7.18	15.85	499.83	0.41
25	1988	6.32	5.53	5.54	10.18	20.71	34.68	40.57	39.65	22.77	12.94	8.89	7.04	17.90	564.53	0.46
26	1989	5.84	5.22	5.10	6.06	10.77	26.62	36.58	34.84	21.75	13.66	9.22	7.19	15.24	480.48	0.39
27	1990	5.80	5.28	5.44	6.52	19.93	30.52	39.95	38.85	32.76	16.47	8.96	6.85	18.11	571.15	0.46
28	1991	6.14	5.88	6.05	7.38	10.65	29.10	39.63	39.13	30.70	14.78	10.67	8.48	17.38	548.16	0.44
29	1992	6.67	5.94	5.65	7.54	15.54	31.15	40.82	40.37	29.98	14.32	9.32	7.70	17.92	565.04	0.46
30	1993	7.51	6.36	6.79	11.71	16.72	29.99	38.37	31.58	28.74	15.74	10.74	8.76	17.75	559.79	0.45
31	1994	5.51	4.76	4.88	6.74	12.73	30.24	40.01	40.91	25.07	11.76	8.90	7.43	16.58	522.80	0.42
32	1995	6.13	5.23	5.03	6.34	9.44	30.75	40.89	38.09	21.05	13.72	8.92	6.97	16.05	506.06	0.41
33	1996	6.23	5.39	5.74	8.77	20.27	33.69	37.42	39.97	27.57	13.92	9.93	7.79	18.06	569.48	0.46
34	1997	6.51	5.81	5.48	7.82	12.81	28.17	40.91	37.30	25.98	13.59	8.50	6.90	16.65	525.02	0.43
35	1998	6.05	5.53	5.16	7.87	15.05	24.97	40.89	38.97	25.89	14.30	9.05	7.42	16.76	528.60	0.43
36	1999	6.59	5.76	5.47	7.53	17.66	31.37	39.74	37.89	27.65	14.13	9.46	7.95	17.60	555.06	0.45
37	2000	6.58	5.79	5.56	7.23	17.88	27.89	38.98	34.74	26.77	11.79	8.74	6.72	16.56	522.14	0.42
38	2001	5.95	5.24	5.19	5.85	17.16	34.17	40.77	36.75	23.65	11.01	8.08	6.39	16.69	526.19	0.43
39	2002	5.76	5.16	5.10	7.08	13.88	34.32	37.17	38.77	23.11	13.23	8.44	6.80	16.57	522.50	0.42
40	2003	5.93	5.23	5.34	7.73	11.18	33.30	40.24	38.11	25.80	12.55	9.63	7.81	16.91	533.12	0.43
41	2004	6.16	5.29	5.28	7.23	15.43	31.95	37.56	36.11	25.77	12.87	9.42	7.71	16.73	527.66	0.43
42	2005	6.67	5.96	6.35	10.55	18.40	36.40	38.12	40.25	30.77	15.38	11.28	8.36	19.04	600.46	0.49
43	2006	9.81	8.80	8.17	7.81	18.67	25.44	39.77	36.02	20.23	16.09	9.05	8.65	17.38	547.97	0.44
44	2007	6.70	5.94	6.08	11.31	31.69	45.48	57.75	39.11	25.05	13.69	9.09	7.10	21.58	680.60	0.55
45	2008	6.48	5.96	5.58	6.03	9.46	16.78	24.18	24.80	14.72	10.54	8.40	7.30	11.68	368.49	0.30
46	2009	6.89	6.51	6.26	6.95	9.73	15.62	30.13	38.68	23.99	13.90	9.56	8.29	14.71	463.84	0.38
47	2010	7.96	7.64	6.68	9.57	18.98	28.86	53.56	64.50	42.04	25.48	17.55	12.25	24.59	775.43	0.63
48	2011	9.29	8.01	6.49	7.02	15.91	22.93	30.80	31.48	24.11	16.03	12.19	9.84	16.18	510.10	0.41
Maximum		9.81	8.80	8.17	11.71	31.69	45.48	57.75	64.50	42.04	25.48	17.55	12.25	**24.59**	**775.43**	**0.63**
Minimum		4.99	4.56	4.51	5.44	7.63	15.62	24.18	24.80	14.72	9.33	6.93	5.94	**11.68**	**368.49**	**0.30**
Mean		6.32	5.67	5.56	7.51	14.43	29.58	38.68	38.07	24.87	12.98	9.05	7.37	16.67	525.83	0.43
Standard Dev.		0.94	0.88	0.80	1.49	4.29	5.46	5.05	4.83	4.68	2.52	1.62	1.10	**1.94**	**61.11**	**0.05**
No of Days		31	28.25	31	30	31	30	31	31	30	31	30	31			
Volume (MCM)		16.92	13.85	14.89	19.48	38.66	76.67	103.59	101.95	64.46	34.76	23.46	19.74			

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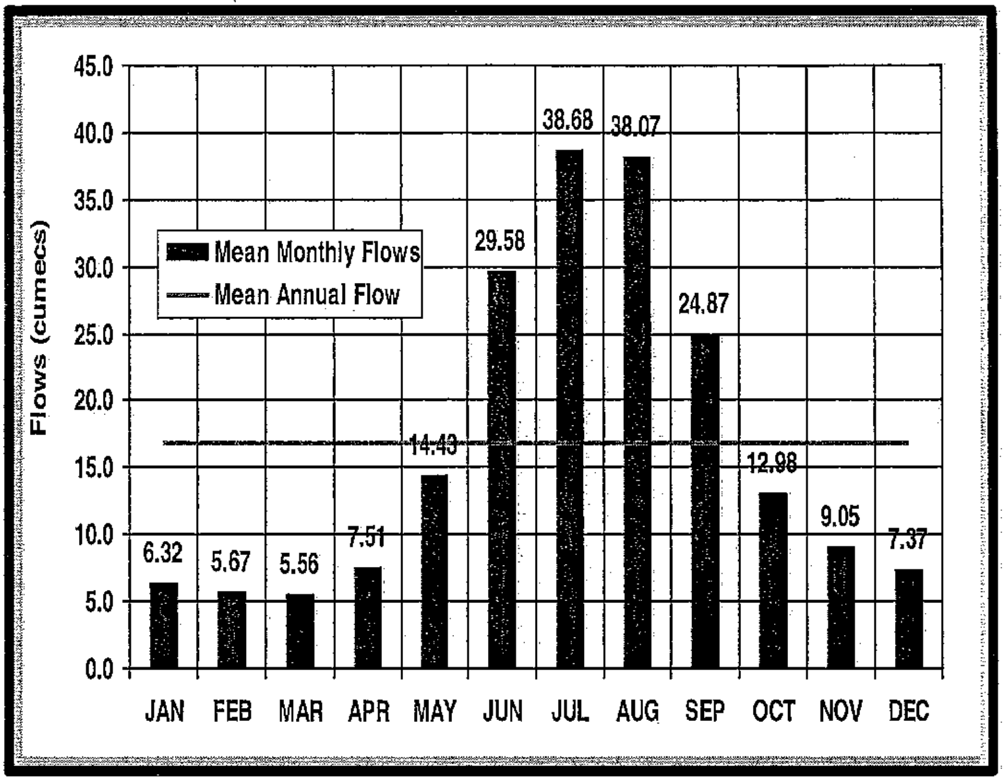

Figure 4.20: Generated mean monthly flows at Arkari Gol Stream-Gauging Station (1964-2011)

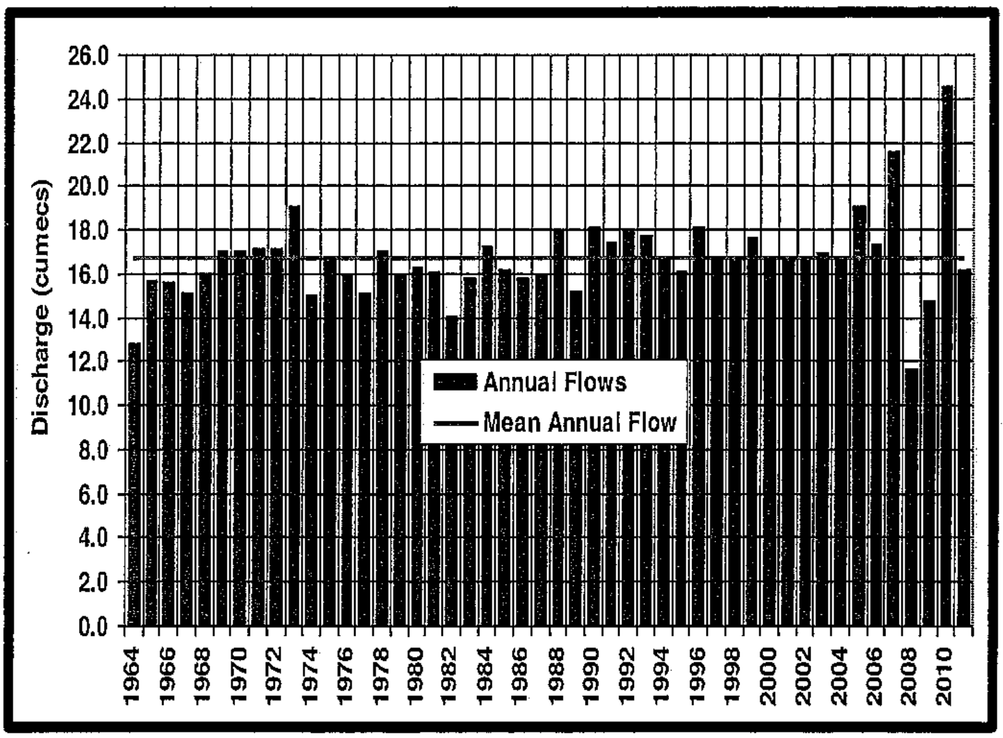

Figure 4.21: Generated Mean annual flows of Arkari Gol at Gauge site (1964-2011)

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Generated mean monthly flows at the Arkari Gauging site are shown in Figure 2.20. March has the lowest and July has the highest mean monthly flows. Generated mean annual flows for 48 years at the Arkari Gol gauging site are shown in Figure 4.21. Year 2008 was having lowest mean annual flow value; whereas, year 2010 was having the highest mean annual flow value.

4.5.3 Generation of River Flows at Arkari Weir Site.

As the Arkari gauging station is situated at upstream of the proposed Arkari weir site, the daily flows at Arkari Gol gauge site has been transferred to Arkari weir site by adopting appropriate approach as discussed below;

The watershed area of Arkari stream gauging station and the Arkari weir site are 1015 and 1036 km^2, respectively. The multiplication factor for the Arkari weir site is about 1.021, which is much smaller. Hence for the flow generation of the weir site, flows were transformed from Arkari Gol Gauging station to the Arkari Gol weir site by adopting appropriate multiplication factor of 1.021. The final equation to compute mean monthly flows at the Arkari weir site is given in Equation (4.3).

$$Q_{Arkari\_Weir} = \left[(-3X10^{-5})\ (Q_{Chitral})^2 + 0.0597\ (Q_{Chitral})\right]\left(\frac{16.67}{12.23}\right)\left(\frac{1036}{1015}\right) \quad 4.3$$

4.5.4 Mean Daily Flow Hydrograph

After generation of the daily flows at the weir site from Arkari Gol stream gauging station using 48 years data record, the mean daily flows were computed for the weir site and plotted as shown in Figure 4.22. The peak value of mean daily discharge is 40 m^3/s and appears in the month of July. The lowest value of main daily discharge is 5.74 m^3/s and appears in March.

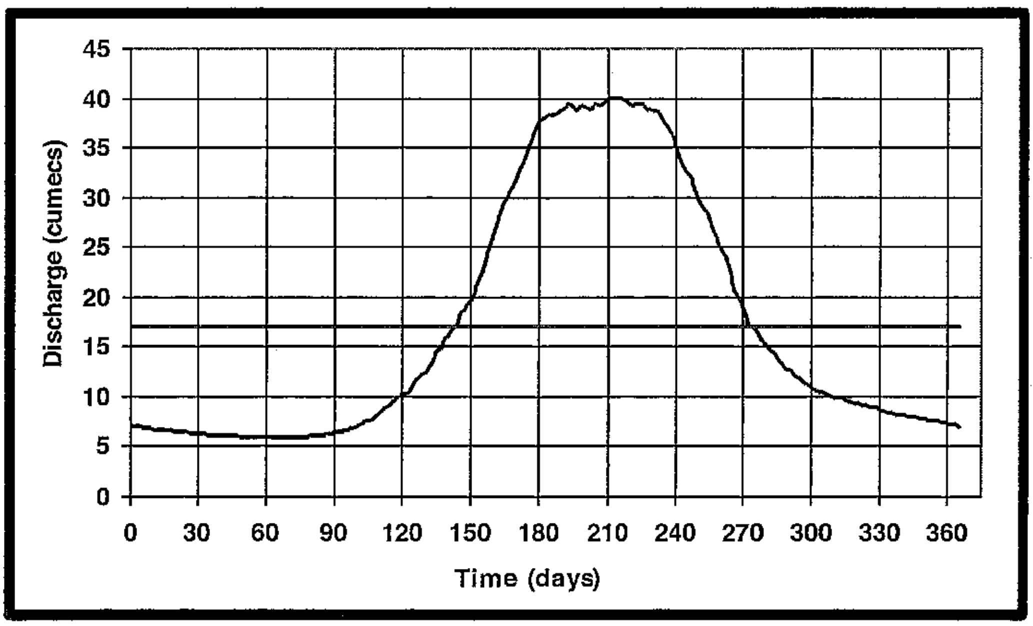

Figure 4.22: Generated Mean daily flows at Arkari Gol Weir Site (1964-2011)

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Table 4.8: Generated Mean Monthly Flows for Arkari weir site (1964-2011)

S. No.	Year	Mean Monthly Flows (m^3/s)												Annual Flow		
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Cumecs	MCM	(MAF)
1	1964	5.10	4.66	4.91	6.78	7.79	18.65	28.67	34.64	22.03	10.12	7.45	6.37	13.10	413.04	0.34
2	1965	5.54	4.98	5.18	6.89	17.20	33.73	40.45	35.05	17.98	11.62	7.53	6.23	16.03	505.54	0.41
3	1966	5.42	4.79	4.90	7.04	12.25	34.21	38.59	37.68	20.70	11.15	8.10	6.49	15.94	502.80	0.41
4	1967	5.81	5.32	4.92	6.30	9.91	27.30	38.50	38.28	23.82	10.47	8.03	6.86	15.46	487.50	0.40
5	1968	5.86	5.24	5.03	6.29	11.40	31.25	41.12	41.22	20.84	11.48	9.11	7.31	16.35	515.47	0.42
6	1969	6.61	6.51	7.23	10.79	16.17	30.85	40.74	39.99	20.92	12.08	8.70	7.66	17.35	547.26	0.44
7	1970	6.49	5.87	5.58	7.61	15.46	31.15	35.60	39.29	31.67	13.68	9.10	7.25	17.40	548.64	0.45
8	1971	6.10	5.57	5.66	6.48	15.30	37.89	39.38	39.05	22.29	11.73	10.86	9.71	17.50	551.91	0.45
9	1972	8.80	8.27	8.29	9.63	14.87	31.98	38.03	37.23	25.65	11.90	8.66	7.12	17.54	553.02	0.45
10	1973	6.34	5.89	5.91	9.76	22.82	39.70	40.90	41.54	32.12	12.46	9.41	7.20	19.50	615.05	0.50
11	1974	6.20	5.92	6.33	7.37	11.02	27.85	38.73	36.58	20.34	9.53	7.37	6.18	15.28	482.01	0.39
12	1975	5.36	4.97	4.91	7.57	13.95	31.38	39.29	40.20	27.14	11.95	8.52	7.23	16.87	532.08	0.43
13	1976	6.14	5.51	5.33	7.27	14.72	27.30	40.32	38.00	24.29	11.66	8.29	6.71	16.29	513.87	0.42
14	1977	6.03	5.55	5.55	5.85	9.64	28.59	40.77	38.42	18.97	11.52	7.80	6.42	15.42	486.43	0.39
15	1978	5.67	4.92	4.84	6.92	14.44	34.36	41.06	39.86	26.42	14.06	8.73	6.99	17.36	547.35	0.44
16	1979	5.91	5.39	5.06	8.50	13.42	27.70	39.81	37.62	21.71	13.13	9.74	7.78	16.31	514.50	0.42
17	1980	6.78	6.02	5.34	7.83	14.25	31.30	39.71	37.44	24.13	11.40	8.23	7.06	16.62	524.26	0.43
18	1981	6.01	5.33	4.98	6.97	12.92	30.26	40.59	38.56	22.97	13.08	8.36	6.93	16.41	517.60	0.42
19	1982	6.00	5.05	4.72	6.43	11.19	22.84	32.69	40.05	20.52	10.06	7.08	6.07	14.39	453.85	0.37
20	1983	5.60	5.04	4.60	5.55	12.16	25.28	37.06	41.02	28.72	12.60	8.71	6.95	16.11	507.93	0.41
21	1984	6.11	5.60	5.31	6.76	13.08	37.69	41.12	41.75	27.60	11.25	8.23	6.90	17.61	555.33	0.45
22	1985	5.89	5.52	5.51	6.06	9.67	27.83	41.52	39.86	27.46	13.36	8.45	7.28	16.53	521.45	0.42
23	1986	6.64	5.58	5.49	6.62	12.71	25.60	40.84	38.19	21.60	14.05	9.22	7.43	16.17	509.78	0.41
24	1987	6.24	5.43	5.59	8.17	12.35	25.36	34.96	37.58	29.64	12.50	8.98	7.33	16.18	510.17	0.41
25	1988	6.45	5.64	5.65	10.39	21.14	35.40	41.41	40.47	23.24	13.20	9.07	7.19	18.27	576.21	0.47
26	1989	5.96	5.33	5.21	6.19	10.99	27.17	37.33	35.56	22.20	13.94	9.41	7.34	15.65	490.42	0.40
27	1990	5.92	5.39	5.55	6.65	20.34	31.15	40.78	39.66	33.44	16.81	9.14	6.99	18.49	582.97	0.47
28	1991	6.26	6.00	6.18	7.53	10.87	29.70	40.45	39.94	31.33	15.08	10.89	8.65	17.74	559.50	0.45
29	1992	6.81	6.06	5.76	7.69	15.86	31.80	41.67	41.21	30.60	14.62	9.52	7.86	18.29	576.73	0.47
30	1993	7.66	6.49	6.93	11.95	17.07	30.61	39.16	32.23	29.34	16.07	10.97	8.94	18.12	571.37	0.46
31	1994	5.62	4.86	4.98	6.88	12.99	30.87	40.83	41.76	25.59	12.00	9.09	7.58	16.92	533.62	0.43
32	1995	6.26	5.34	5.13	6.48	9.64	31.39	41.73	38.88	21.48	14.00	9.10	7.11	16.38	516.53	0.42
33	1996	6.36	5.50	6.86	8.96	20.68	34.39	38.19	40.80	28.14	14.21	10.13	7.95	18.43	581.26	0.47
34	1997	6.65	5.93	5.60	7.98	13.08	28.75	41.76	38.07	26.52	13.87	8.68	7.05	16.99	535.88	0.43
35	1998	6.17	5.65	6.27	8.03	15.36	25.48	41.74	39.77	26.43	14.59	9.24	7.57	17.11	539.54	0.44
36	1999	6.73	5.88	5.58	7.69	18.03	32.02	40.57	38.68	28.22	14.42	9.66	8.12	17.97	566.55	0.46
37	2000	6.72	5.91	5.67	7.38	18.25	28.47	39.79	35.46	27.32	12.03	8.92	6.86	16.90	532.94	0.43
38	2001	6.07	5.35	5.30	5.97	17.51	34.88	41.62	37.51	24.14	11.24	8.25	6.53	17.03	537.08	0.44
39	2002	5.88	5.27	5.20	7.22	14.17	35.03	37.94	39.57	23.59	13.50	8.61	6.94	16.91	533.31	0.43
40	2003	6.05	5.34	5.45	7.90	11.41	33.99	41.07	38.90	26.34	12.81	9.83	7.97	17.25	544.15	0.44
41	2004	6.29	5.40	5.39	7.38	15.75	32.61	38.34	36.86	26.30	13.13	9.61	7.87	17.08	538.57	0.44
42	2005	6.81	6.08	6.48	10.77	18.78	37.16	38.91	41.08	31.40	15.70	11.51	8.53	19.43	612.88	0.50
43	2006	10.01	8.98	8.34	7.97	19.06	25.97	40.59	36.76	20.65	16.43	9.24	8.83	17.74	559.31	0.45
44	2007	6.84	6.06	6.20	11.54	32.35	46.42	58.95	39.92	25.57	13.97	9.28	7.24	22.03	694.68	0.56
45	2008	6.62	6.08	5.70	6.15	9.65	17.13	24.68	25.32	15.02	10.76	8.57	7.45	11.93	376.11	0.31
46	2009	7.03	6.64	6.39	7.09	9.93	15.94	30.75	39.48	24.49	14.19	9.75	8.47	15.01	473.44	0.38
47	2010	8.12	7.80	6.82	9.77	19.37	29.46	54.66	65.84	42.91	26.00	17.92	12.50	25.10	791.47	0.64
48	2011	9.48	8.17	6.62	7.17	16.24	23.40	31.43	32.13	24.61	16.36	12.45	10.04	16.51	520.65	0.42
Maximum		10.01	8.98	8.34	11.95	32.35	46.42	58.95	65.84	42.91	26.00	17.92	12.50	25.10	791.47	0.64
Minimum		5.10	4.66	4.60	5.55	7.79	15.94	24.68	25.32	15.02	9.53	7.08	6.07	11.93	376.11	0.31
Mean		6.45	5.79	5.68	7.67	14.73	30.19	39.48	38.85	25.38	13.25	9.24	7.52	17.02	536.71	0.44
Standard Dev.		0.96	0.89	0.81	1.52	4.38	5.57	5.15	4.93	4.77	2.57	1.66	1.12	1.98	62.37	0.05
No of Days		31	28.25	31	30	31	30	31	31	30	31	30	31			
Volume (MCM)		17.27	14.13	15.20	19.88	39.46	78.26	105.73	104.06	65.79	35.48	23.95	20.15			

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4.5.5 Mean Monthly Flows for Arkari Weir site

Using the Equation (7.3), the daily flows were generated at the weir Site for 48 years from 1964 to 2011, the minimum, mean and maximum daily flows were found as 5.55, 17.02 and 65.84 m^3/s, respectively.

Considering the generated daily flows at the weir site for 48 years from 1964 to 2011 by using the model as mentioned in Equation (7.3), mean monthly and annual flows have been computed at the weir site which is given in the Table 4.8.

The mean monthly flows at weir site are shown in Figure 4.23. The highest mean monthly flow appears in the month of July with a value of 39.48 m^3/s and minimum in the month of March with a value of 5.68 m^3/s. The mean monthly flow at dam site comes as 17.02 m^3/s.

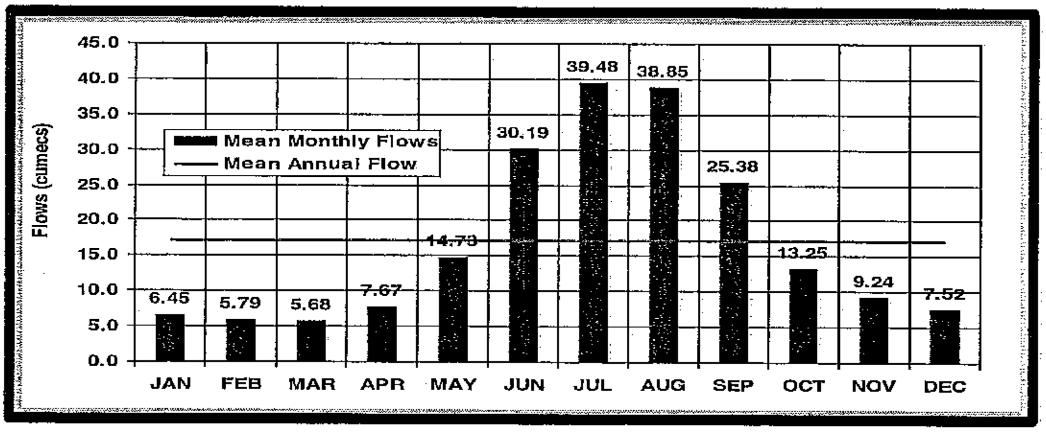

Figure 4.23: Mean monthly flows at Arkari Gol Weir Site (1964-2011)

4.5.6 Mean Annual Flows

The temporal distribution of the mean annual flows at Arkari weir site is given in Figure 4.24 from 1964 to 2011. The Figure shows that mean annual flow was highest in 2010 having a value of 25.10m^3/s and minimum mean annual flow was in 2008 with a value of 11.93 m^3/s. The computed mean annual flow for the Arkari weir site is estimated at 17.02 cumecs.

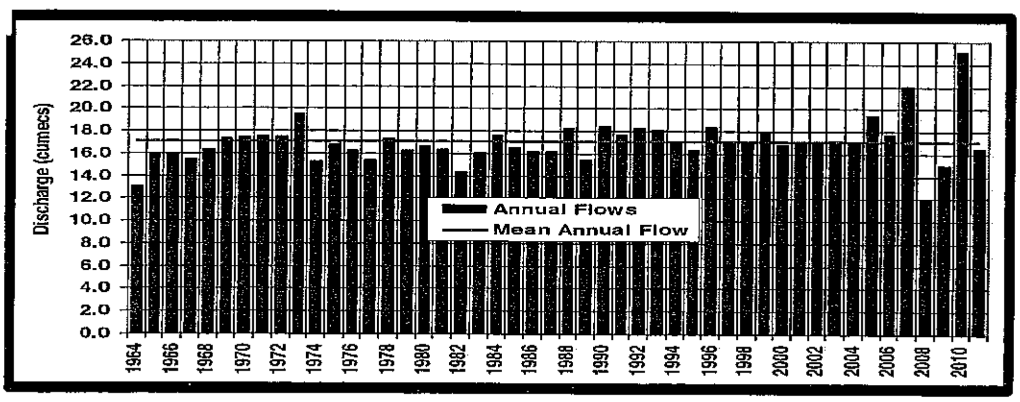

Figure 4.22: Generated Mean annual Flows at Arkari Weir site (1964-2011)

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4.5.7. Approach of Flow Generation for Powerhouse Site

As the Arkari gauging station is upstream of the proposed Arkari Power House site, the daily flows at Arkari Gol gauge site has been transferred to Arkari Power House site by adopting appropriate approach as discussed below;

The watershed area of Arkari stream gauging station and the Arkari Power House site are 1036 and 1060 km^2, respectively. The multiplication factor of the Arkari gauging station and Arkari Power House site is about 1.044, which is much lower and for flow generation of the Power House site, flows were transformed from Arkari Gol Gauging station to the Arkari Gol Power House site by adopting appropriate multiplication factor of 1.044. Hence, Model developed to estimate the flows at the Arkari powerhouse site by regional analysis is given by Equation (7.4).

$$Q_{Arkari\_PH} = \left[(-3X10^{-5})\ (Q_{Chitral})^2 + 0.0597\ (Q_{Chitral})\right]\left(\frac{16.68}{12.23}\right)\left(\frac{1060}{1015}\right) \qquad (4.4)$$

4.5.8 Generated Mean Monthly Flows for Arkari Powerhouse site

Using the Equation (7.4), the daily flows were generated at the Powerhouse Site for 48 years from 1964 to 2011. The minimum, mean and maximum daily flows were found as 8.81, 17.41 and 40.39 m^3/s, respectively.

Considering the generated daily flows at the weir site for 48 years from 1964 to 2011 by using the model as mentioned in Equation (7.4), the mean monthly and annual flows have been computed at the Powerhouse site by regional analysis and are presented in Table 4.9. as follows.

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Table 4.9: Generated Mean Monthly Flows for Arkari Powerhouse Site (1964-2011)

S. No.	Year	Mean Monthly Flows (m^3/s)												Annual Flow		
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Cumecs	MCM	(MAF)
1	1964	5.21	4.76	5.02	6.93	7.97	19.08	29.34	35.45	22.54	10.36	7.62	6.52	13.40	422.61	0.343
2	1965	5.67	5.09	5.30	7.05	17.60	34.61	41.39	35.86	18.40	11.89	7.70	6.37	16.40	517.25	0.420
3	1966	5.54	4.90	5.02	7.21	12.53	35.00	39.48	38.56	21.18	11.40	8.29	6.64	16.31	514.44	0.417
4	1967	5.94	5.44	5.03	6.45	10.14	27.93	39.39	39.16	24.37	10.71	8.21	7.01	15.82	498.79	0.405
5	1968	5.99	5.36	5.14	6.44	11.66	31.97	42.07	42.18	21.33	11.75	9.32	7.48	16.72	527.41	0.428
6	1969	6.76	6.66	7.40	11.04	16.54	31.57	41.68	40.91	21.40	12.36	8.90	7.84	17.76	559.94	0.454
7	1970	6.64	6.00	5.71	7.78	15.82	31.88	36.43	40.20	32.41	14.00	9.31	7.42	17.80	561.35	0.456
8	1971	6.24	5.70	5.79	6.63	15.65	38.76	40.29	39.96	22.80	12.00	11.11	9.94	17.91	564.69	0.458
9	1972	9.00	8.46	8.48	9.85	15.21	32.73	38.92	38.09	28.24	12.18	8.86	7.28	17.94	565.83	0.459
10	1973	6.49	6.02	6.05	9.99	23.35	40.62	41.84	42.50	32.86	12.75	9.63	7.37	19.96	629.30	0.511
11	1974	6.34	6.05	6.47	7.54	11.28	28.50	39.63	37.43	20.81	9.75	7.54	6.32	15.64	493.17	0.400
12	1975	5.48	5.09	5.02	7.74	14.27	32.10	40.20	41.13	27.77	12.23	8.72	7.40	17.26	544.40	0.442
13	1976	6.28	5.64	5.45	7.44	15.06	27.93	41.26	38.88	24.85	11.93	8.48	6.87	16.67	525.77	0.427
14	1977	6.17	5.68	5.68	5.98	9.86	29.26	41.71	39.31	19.40	11.79	7.98	6.56	15.78	497.70	0.404
15	1978	5.80	5.03	4.95	7.09	14.77	35.16	42.01	40.78	27.03	14.39	8.94	7.15	17.76	560.03	0.454
16	1979	6.05	5.51	5.18	8.70	13.73	28.34	40.73	38.49	22.22	13.44	9.97	7.96	16.69	526.41	0.427
17	1980	6.93	6.16	5.46	8.01	14.58	32.03	40.63	38.31	24.68	11.66	8.42	7.23	17.01	536.41	0.435
18	1981	6.15	5.45	5.09	7.13	13.22	30.96	41.53	39.45	23.50	13.38	8.56	7.09	16.79	529.59	0.430
19	1982	6.14	5.17	4.83	6.58	11.45	23.37	33.45	40.98	21.00	10.29	7.24	6.21	14.73	464.37	0.377
20	1983	5.73	5.15	4.71	5.68	12.44	25.87	37.92	41.97	29.38	12.89	8.91	7.11	16.48	519.70	0.422
21	1984	6.25	5.62	5.43	6.92	13.38	38.56	42.08	42.72	28.24	11.51	8.42	7.06	18.02	568.19	0.461
22	1985	6.03	5.64	5.64	6.20	9.89	28.48	42.49	40.79	28.10	13.67	8.64	7.45	16.92	533.53	0.433
23	1986	6.79	5.71	5.62	6.78	13.01	26.19	41.79	39.08	22.10	14.38	9.43	7.60	16.54	521.59	0.423
24	1987	6.38	5.56	5.72	8.36	12.63	25.95	35.77	38.45	30.33	12.79	9.19	7.50	16.55	521.99	0.424
25	1988	6.60	5.77	5.78	10.63	21.63	36.22	42.37	41.41	23.78	13.51	9.28	7.36	18.69	589.56	0.478
26	1989	6.09	5.45	5.33	6.33	11.24	27.80	38.20	36.38	22.71	14.27	9.63	7.51	15.91	501.78	0.407
27	1990	6.06	5.52	5.68	6.81	20.81	31.87	41.73	40.58	34.21	17.20	9.35	7.15	18.91	596.47	0.484
28	1991	6.41	6.14	6.32	7.71	11.12	30.39	41.39	40.86	32.06	15.43	11.14	8.85	18.15	572.46	0.465
29	1992	6.97	6.20	5.90	7.87	16.23	32.53	42.63	42.16	31.31	14.95	9.74	8.04	18.71	590.09	0.479
30	1993	7.84	6.64	7.09	12.23	17.47	31.32	40.07	32.98	30.02	16.44	11.22	9.15	18.54	584.61	0.474
31	1994	5.75	4.97	5.10	7.04	13.29	31.58	41.78	42.73	26.18	12.28	9.30	7.76	17.31	545.98	0.443
32	1995	6.41	5.47	5.25	6.63	9.86	32.11	42.70	39.78	21.98	14.33	9.31	7.28	16.76	528.49	0.429
33	1996	6.51	5.63	5.99	9.16	21.16	35.19	39.08	41.75	28.79	14.54	10.37	8.14	18.86	594.73	0.483
34	1997	6.80	6.06	5.73	8.16	13.38	29.42	42.73	38.95	27.13	14.19	8.88	7.21	17.39	548.30	0.445
35	1998	6.32	5.78	5.39	8.22	15.72	26.07	42.70	40.69	27.04	14.93	9.45	7.75	17.51	552.04	0.448
36	1999	6.89	6.01	5.71	7.87	18.44	32.76	41.51	39.57	28.87	14.76	9.88	8.31	18.38	579.67	0.470
37	2000	6.87	6.05	5.81	7.56	18.68	29.13	40.71	36.28	27.96	12.31	9.13	7.01	17.29	545.29	0.442
38	2001	6.21	5.47	5.42	6.11	17.92	35.69	42.58	38.38	24.70	11.50	8.44	6.68	17.43	549.52	0.446
39	2002	6.02	5.39	5.32	7.39	14.49	35.84	38.82	40.49	24.14	13.82	8.81	7.10	17.30	545.67	0.443
40	2003	6.19	5.46	5.58	8.08	11.68	34.78	42.02	39.80	26.95	13.11	10.06	8.16	17.65	556.76	0.452
41	2004	6.43	5.53	5.51	7.55	16.11	33.37	39.23	37.71	26.91	13.44	9.83	8.05	17.47	551.05	0.447
42	2005	6.97	6.22	6.63	11.02	19.21	38.02	39.81	42.03	32.13	16.06	11.78	8.73	19.88	627.08	0.509
43	2006	10.24	9.19	8.53	8.15	19.50	26.57	41.53	37.61	21.13	16.81	9.45	9.04	18.15	572.26	0.464
44	2007	7.00	6.20	6.34	11.61	33.10	47.49	60.31	40.84	26.16	14.30	9.49	7.41	22.54	710.78	0.577
45	2008	6.77	6.22	5.83	6.29	9.88	17.52	25.25	25.90	15.37	11.00	8.77	7.62	12.20	384.82	0.312
46	2009	7.20	6.80	6.54	7.26	10.16	16.31	31.46	40.39	25.05	14.52	9.98	8.66	15.36	484.41	0.393
47	2010	8.31	7.98	6.98	9.99	19.82	30.14	55.93	67.36	43.91	26.61	18.33	12.79	25.68	809.81	0.657
48	2011	9.70	8.36	6.77	7.34	16.62	23.95	32.16	32.88	25.18	16.74	12.73	10.28	16.89	532.71	0.432
Maximum		10.24	9.19	8.53	12.23	33.10	47.49	60.31	67.36	43.91	26.61	18.33	12.79	25.68	809.81	0.66
Minimum		5.21	4.76	4.71	5.68	7.97	16.31	25.25	25.90	15.37	9.75	7.24	6.21	12.20	384.82	0.31
Mean		6.60	5.93	5.81	7.85	15.07	30.89	40.39	39.75	25.97	13.55	9.45	7.70	17.41	549.14	0.45
Standard Dev.		0.98	0.91	0.83	1.56	4.49	5.70	5.27	5.05	4.88	2.63	1.69	1.15	2.02	63.82	0.05
No of Days		31	28.25	31	30	31	30	31	31	30	31	30	31			
Volume (MCM)		17.67	14.46	15.55	20.34	40.38	80.07	108.18	106.47	67.32	36.30	24.50	20.61			

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4.5.9 Mean Daily Flow Hydrograph

After generation of the daily flows at the Powerhouse site from Arkari Gol stream gauging station using 48 years data record, the mean daily flows were computed and plotted as shown in Figure 4.25. The peak value of mean daily discharge is 40.88 m^3/s and appears in the month of July. The lowest value of mean daily discharge is 5.88 m^3/s and appears in March.

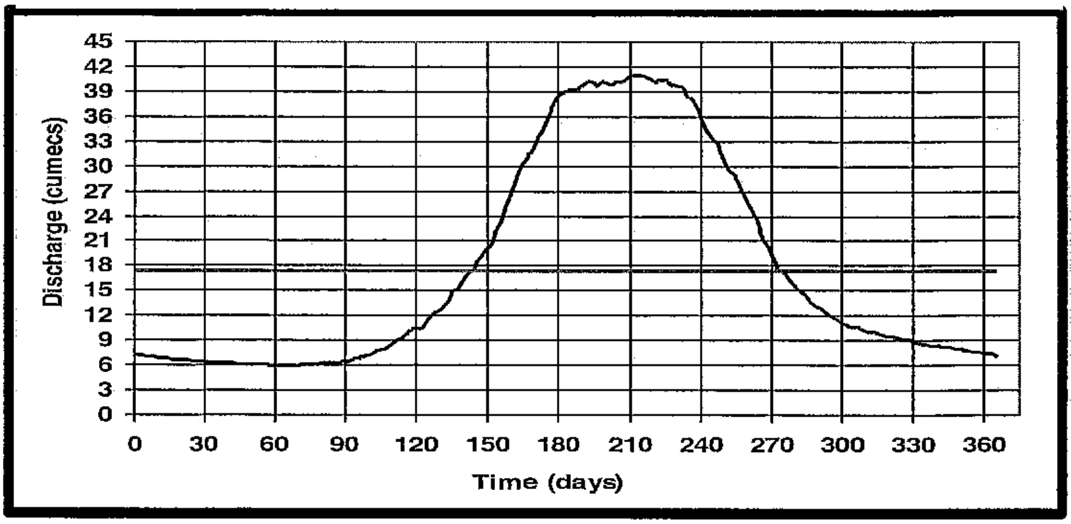

Figure 4.25: Mean daily flows at Arkari Gol Powerhouse Site (1964-2011)

4.5.10 Mean Monthly Flows

The mean monthly flows at Powerhouse site are shown in Figure 2.26. The highest mean monthly flow appears in the month of July with a value of 40.39 m^3/s and minimum in the month of March with a value of 5.81m^3/s. The estimated mean monthly flow at the Arkari powerhouse site by regional analysis is 17.41m^3/s.

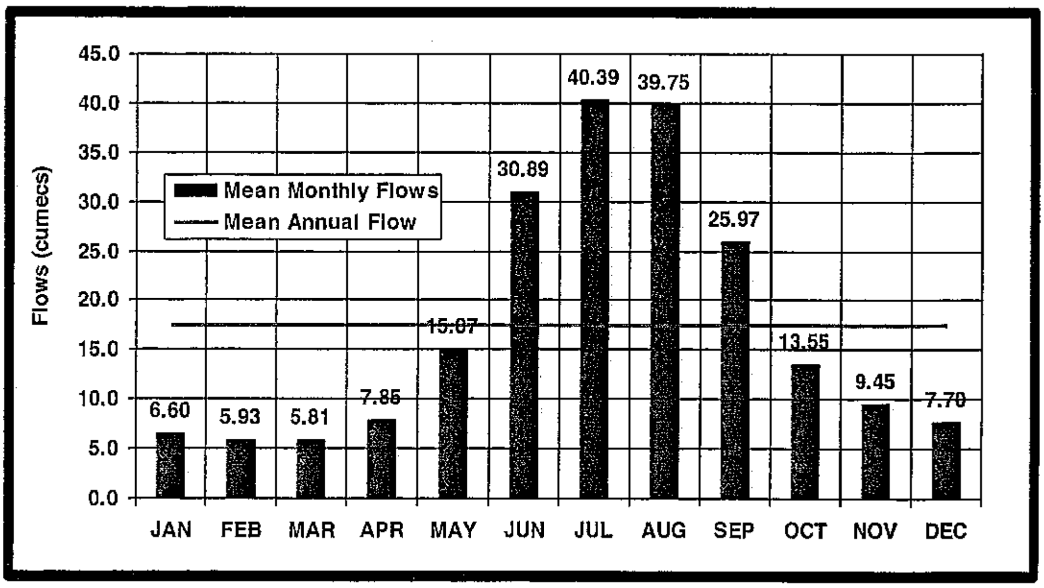

Figure- 4.25: Mean monthly flows at Arkari Gol Powerhouse Site (1964-2011)

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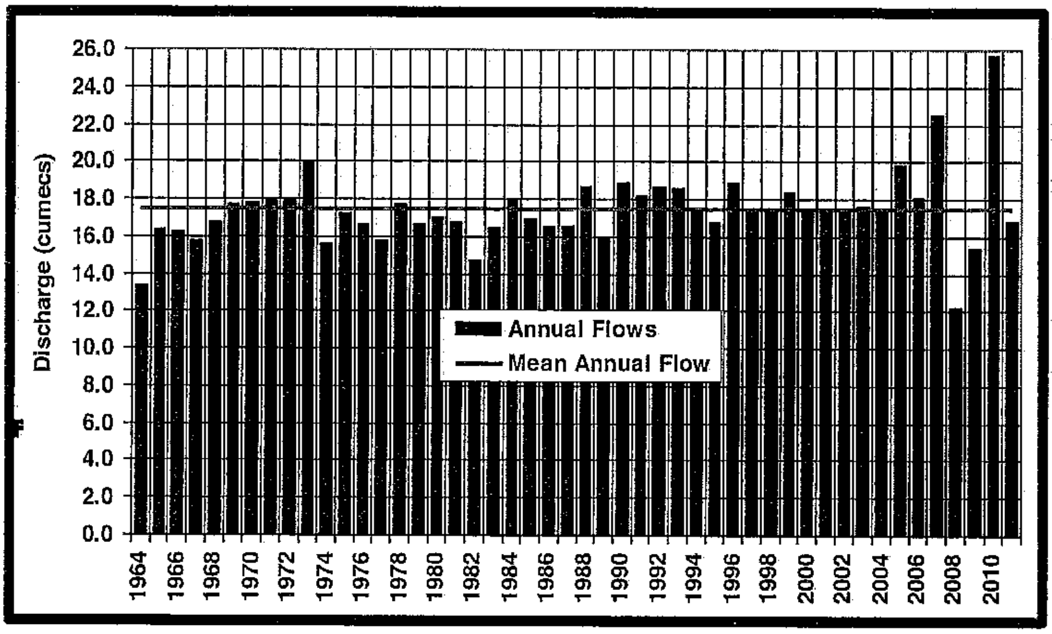
4.5.11 Mean Annual Flows

The temporal distribution of the mean annual flows at Arkari Powerhouse site is given in Figure 4.27 from 1964 to 2011. The Figure shows that mean annual flow was highest in 2010 having a value of 25.68 m^3/s and minimum mean annual flow was in 2008 with a value of 12.2 $0m^3/s$, respectively.



4.5.12 Flow Duration Curves

Flow duration data is required to represent time variability of water discharges. This information is used to plan a possible capacity sizing of a power plant. A flow duration curve represents relationship between magnitude and frequency of daily stream flows for a particular river basin at a particular location. This provides estimation of cumulative percentage of time a given stream flow was equaled or exceeded over the given period of time.

In the present study, flow duration curves for the Arkari Gol HPP weir site are prepared using mean daily flow time series.

4.5.13 Flow Duration Curve for Weir Site

With the series of extended daily flows generated for the weir site, a flow duration curve was obtained using the facilities available in DBHYDRO.

Five flow duration curves at the weir site are prepared and presented in the report. One flow duration curve is based on average daily flows (1964-2011), second flow duration curve is based on the all daily flows of 48 years (1964-2011), 3rd flow duration curve is for the driest year (1964) daily discharge data, fourth flow duration curve is for the average flow year (1969) daily discharge data and fifth flow duration curve is for the wettest year (2008) daily discharge data.

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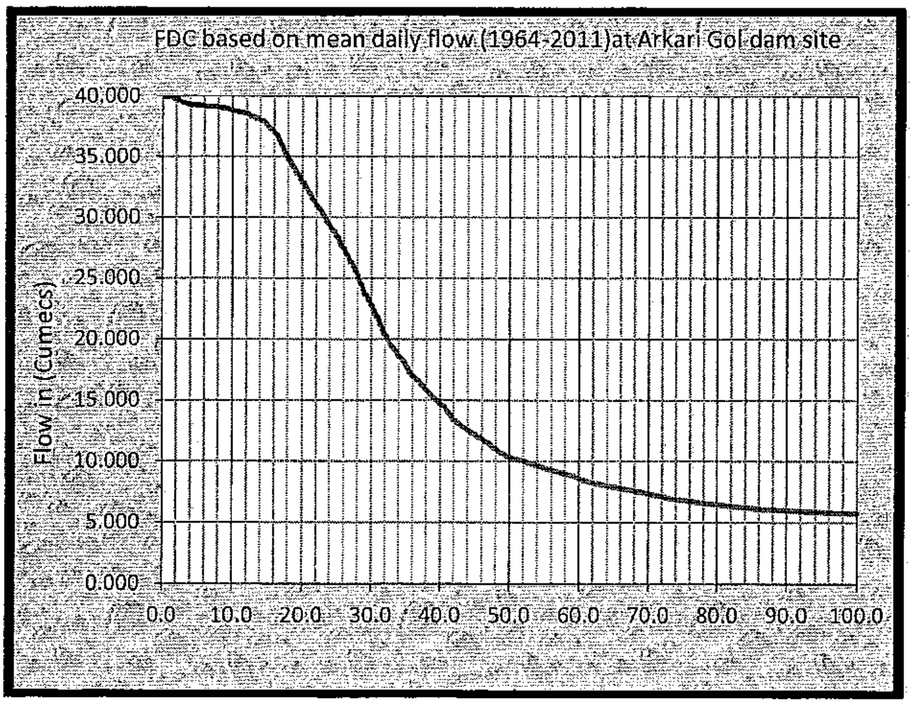
Flow duration curve in tabular form based on average daily flows (1964-2011) at the weir site of Arkari Gol is given in Table 4.10 and also shown in Figure 4.28.

Table 4.10: Flow Duration Curve For Weir Site Based On Mean Daily Flow Data (1964-2011)

S. No.	Percentage Exceedance Time	Discharge m^3/s
1	0.01	39.953
2	10	38.802
3	20	32.822
4	30	22.855
6	40	14.750
7	50	10.305
8	60	8.599
9	70	7.360
10	80	6.478
11	90	5.987
12	100	5.740

Figure 4.28: Flow duration curve based on average daily flows (1964-2011) at the Arkari weir site



Flow duration curve in tabular form based on all daily flows (1964-2011) at the weir site is given in Table 4.11 and Figure in 4.29.

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Table 4.11: Flow Duration Curve For Weir Site Based On All Daily Flow Data (1964-2011)		
S. No.	Percentage Exceedance	Discharge m^3/s
1	0.01	42.45
2	10	39.84
3	20	32.61
4	30	22.43
6	40	13.96
7	50	10.33
8	60	8.61
9	70	7.25
10	80	6.35
11	90	5.65
12	100	2.39

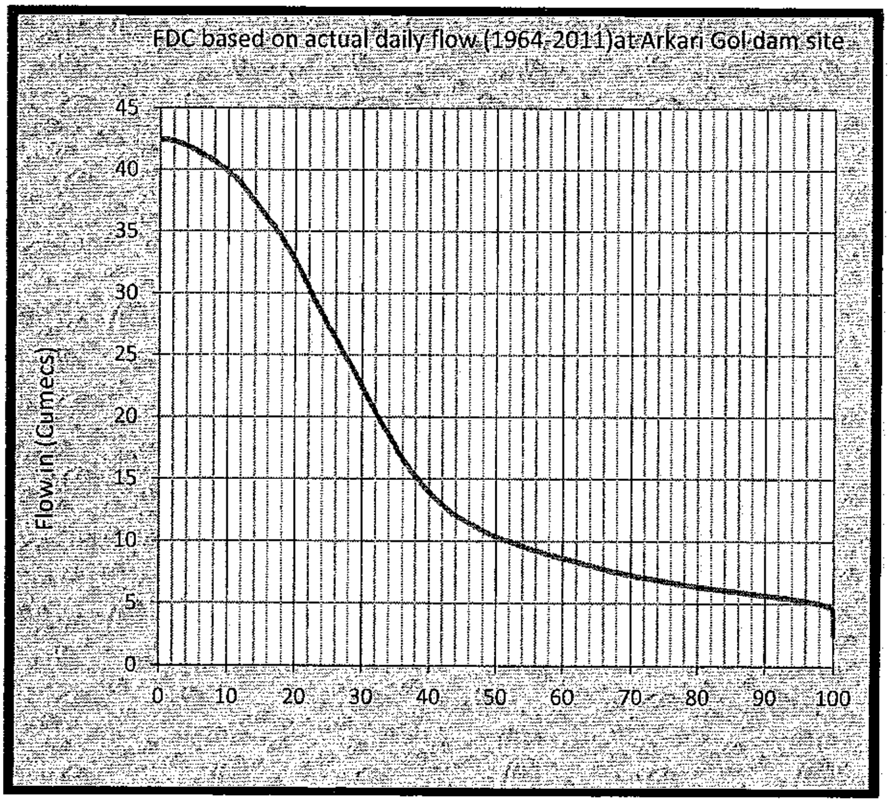

Figure 4.29: Flow duration curve based all daily flows (1964-2011) at Arkari Gol weir site

Flow duration curve for the driest year (1964) is shown in **Figure 4.30,** the maximum flow rate is 40.35m^3/s and minimum flow which will remain available throughout the 100% exceedance time is 3.87m^3/s.

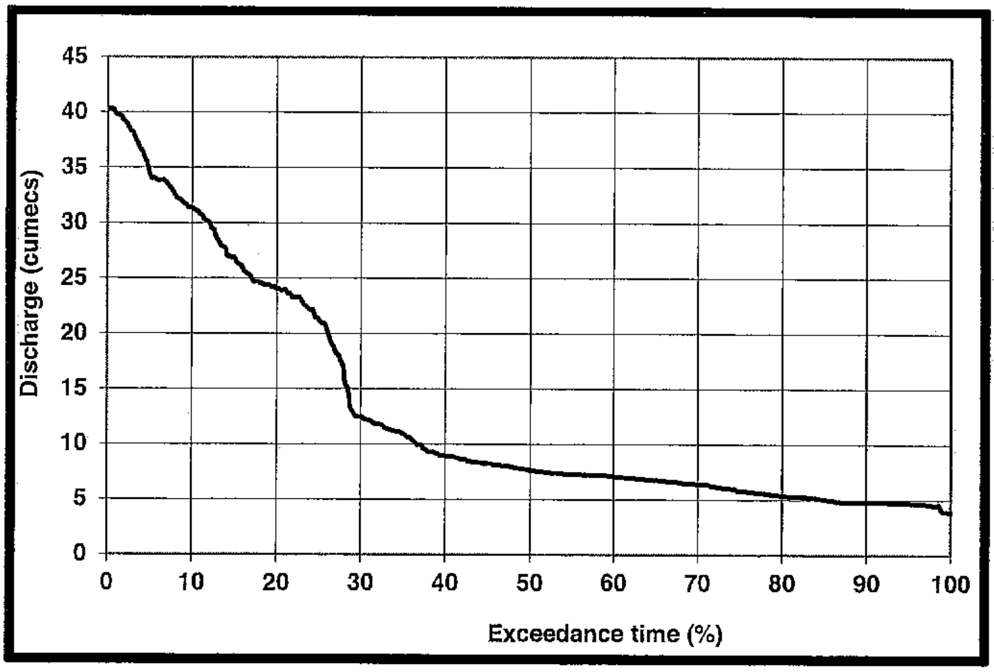

Figure 4.30: Flow duration curve for the driest year at weir site (1964)

Flow duration curve for the average flow year (2004) is shown in **Figure 4.31,** the maximum flow rate is 42.45m^3/sand minimum which will remain available throughout the 100% exceedance time is 4.97m^3/s.

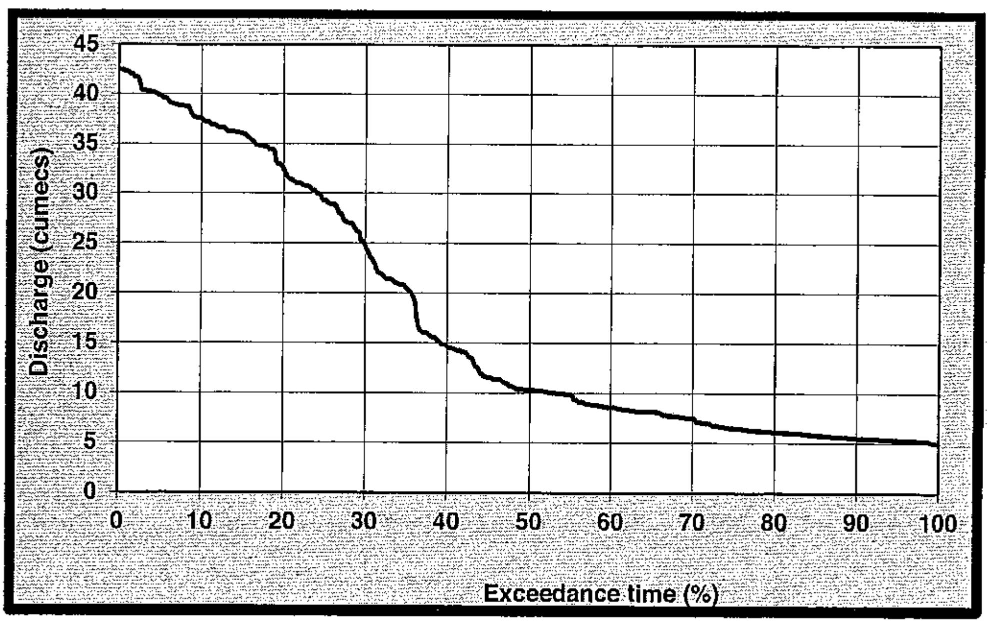

Figure 4.31: Flow duration curve for the average year at weir site (2004)

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Flow duration curve for the wettest year (1973) is shown in **Figure 4.32,** the maximum flow rate is 42.45m3/s and minimum which will remain available throughout the 100% exceedance time is 5.70m^3/s.

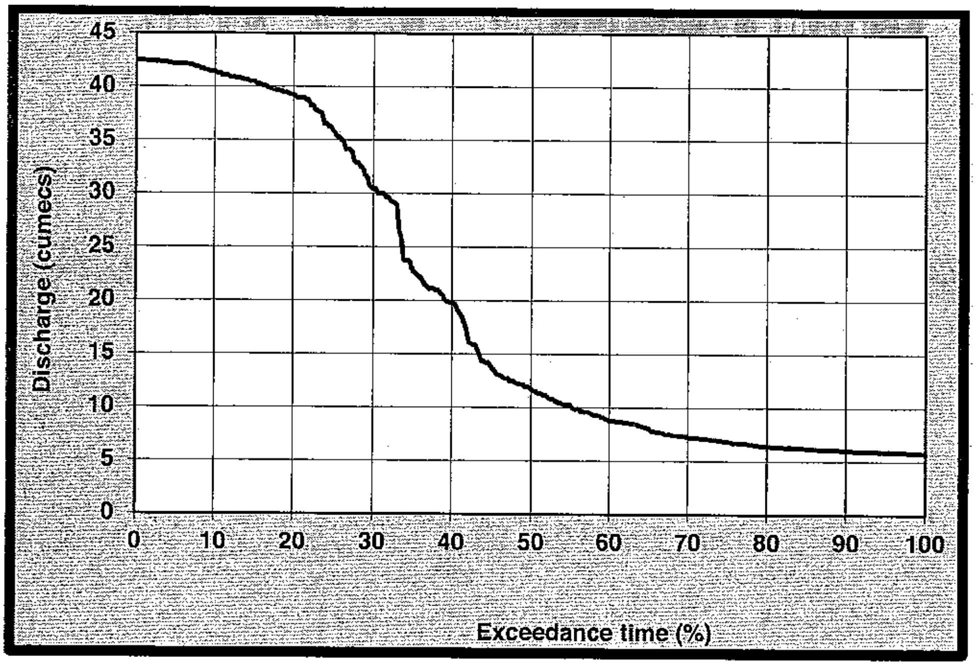

Figure 4.32: Flow duration curve for the wettest year at weir site (1973)

Flow duration curve based on mean daily flow is shown in **Figure 4.33,** the maximum flow rate is 40.0m3/s and minimum which will remain available throughout the 100% exceedance time is 5.74 m^3/s.

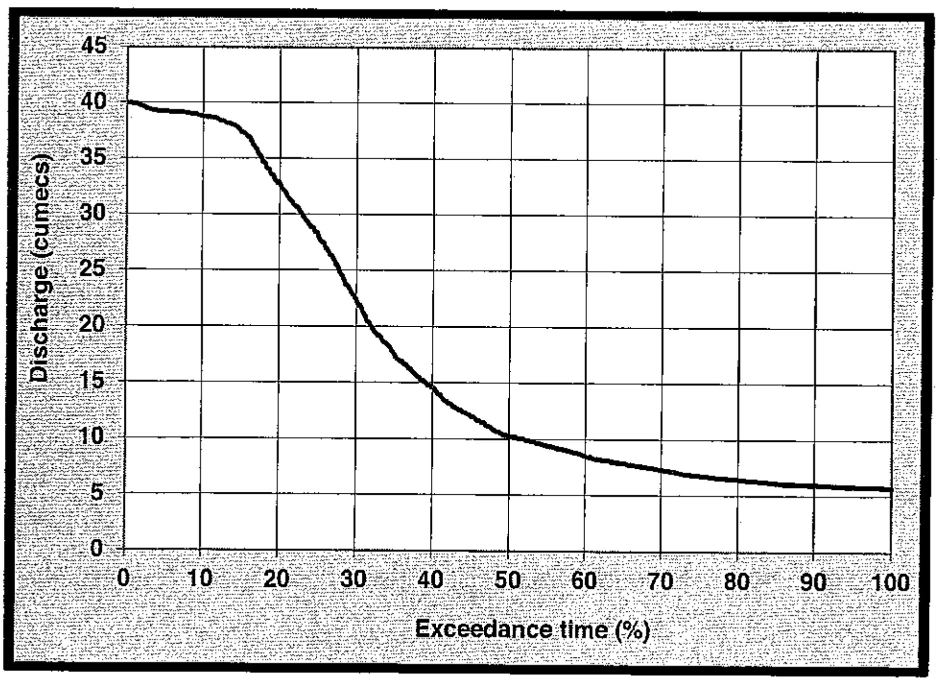

Figure 4.33: Flow duration curve based Mean Daily Flow at weir site

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Four flow duration curves for the driest flow year, wettest flow year, average flow year and flow duration curved, based on mean daily flows, are shown jointly in Figure 4.34

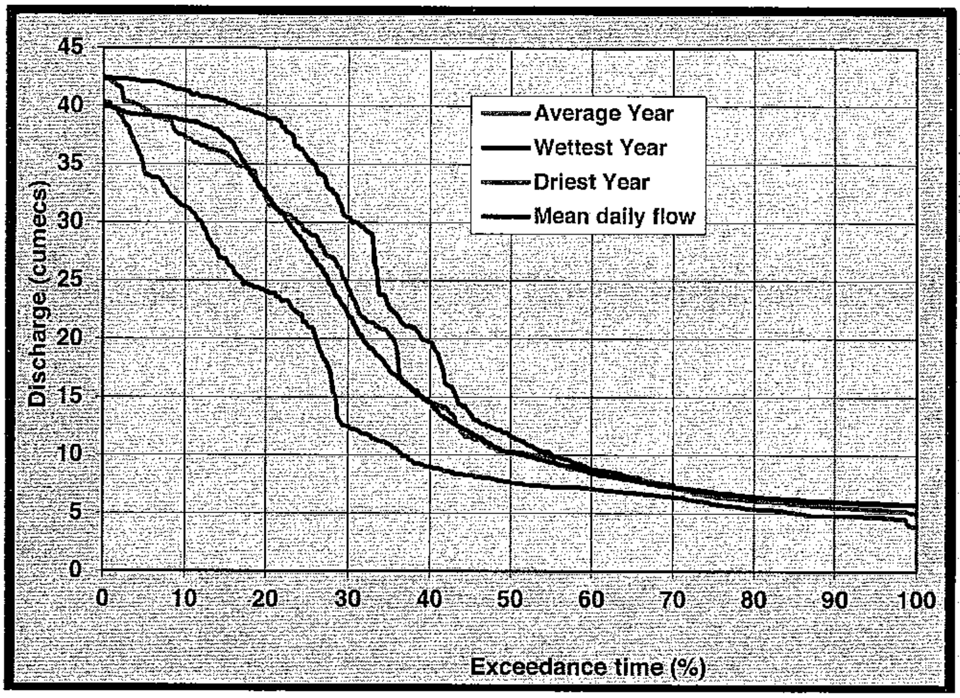

Figure 4.34: FDCs for Driest year (1964), wettestyear (1973), Average Year (2004) and mean daily Flow duration curves at weir site (1964-2011)

4.5.14 Flow Duration Curve for Powerhouse Site

Five flow duration curves for the powerhouse site are prepared and presented in the report. One flow duration curve is based on average daily flows (1964-2011), second flow duration curve is based on the all daily flows of 48 years (1964-2011), 3rd flow duration curve is for the driest year (1964) daily discharge data, fourth flow duration curve is for the average flow year (2004) daily discharge data and fifth flow duration curve is for the wettest year (1973) daily discharge data.

Flow duration curve in tabular form based on mean daily flows (1964-2011) at the powerhouse site of Arkari Gol is given in Table 4.12 and also shown in Figure 4.35.

Table 4.12: Flow Duration Curve For Powerhouse Site Based On Mean Daily Flow Data (1964-2011

S. No.	Percentage Exceedance	Discharge m^3/s
1	0.01	40.88
2	10	39.70
3	20	35.58
4	30	23.38

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Table 4.12: Flow Duration Curve For Powerhouse Site Based On Mean Daily Flow Data (1964-2011)		
S. No.	Percentage Exceedance	Discharge m^3/s
6	40	15.09
7	50	10.54
8	60	8.80
9	70	7.53
10	80	6.63
11	90	6.13
12	100	5.88

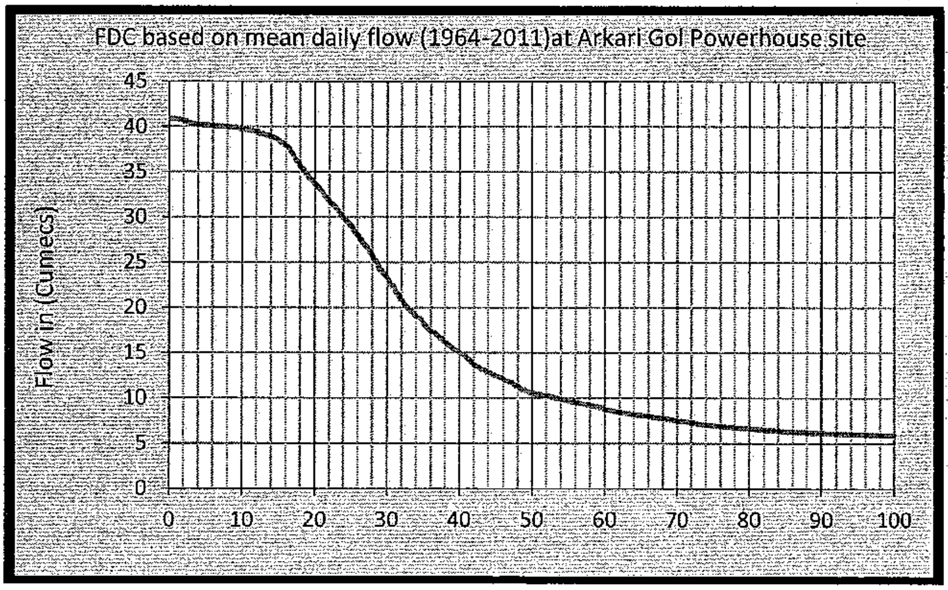

Figure 4.35: Flow duration curve based on mean daily flows (1964-2011) at the Powerhouse site

Flow duration curve based on all daily flows (1964-2011) in tabular form at the Powerhouse site is given in Table 4.13 and Figure 4.36.

Table 4.13: Flow Duration Curve For Powerhouse Site Based On All Daily Flow Data (1964-2011)		
S. No.	Percentage Exceedance	Discharge m^3/s
1	0.01	43.43
2	10	40.76
3	20	33.36
4	30	22.95
6	40	14.28
7	50	10.57
8	60	8.81
9	70	7.42
10	80	6.49
11	90	5.78
12	100	2.45

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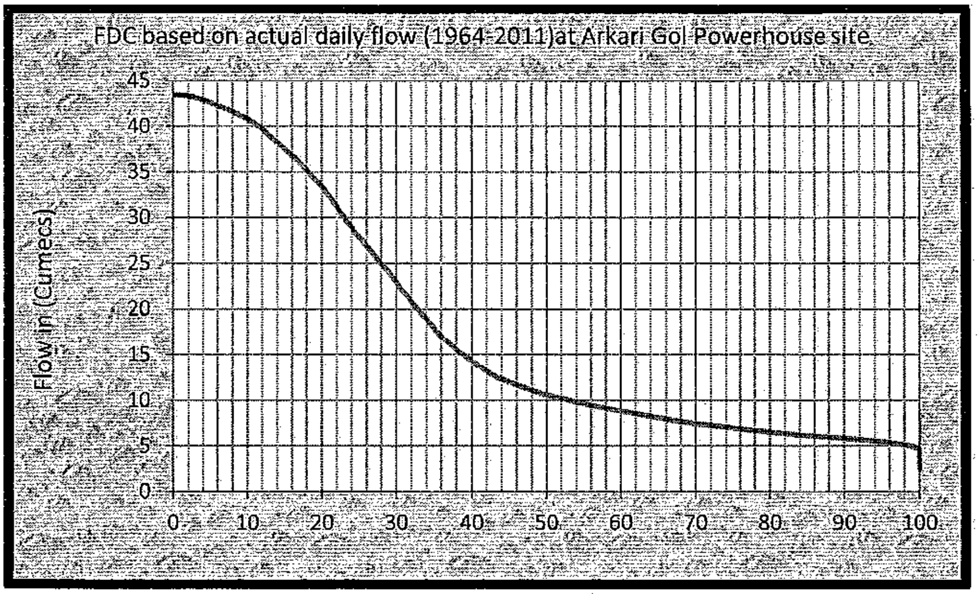

Figure 4.36: Flow duration curve based all on daily flows (1964-2011) at Arkari Gol Powerhouse site

Flow duration curve for the driest year (1964) is shown in **Figure 4.37,** the maximum flow rate is 41.29 m^3/sand minimum flow which will remain available throughout the 100% exceedance time is 3.96 m^3/s.

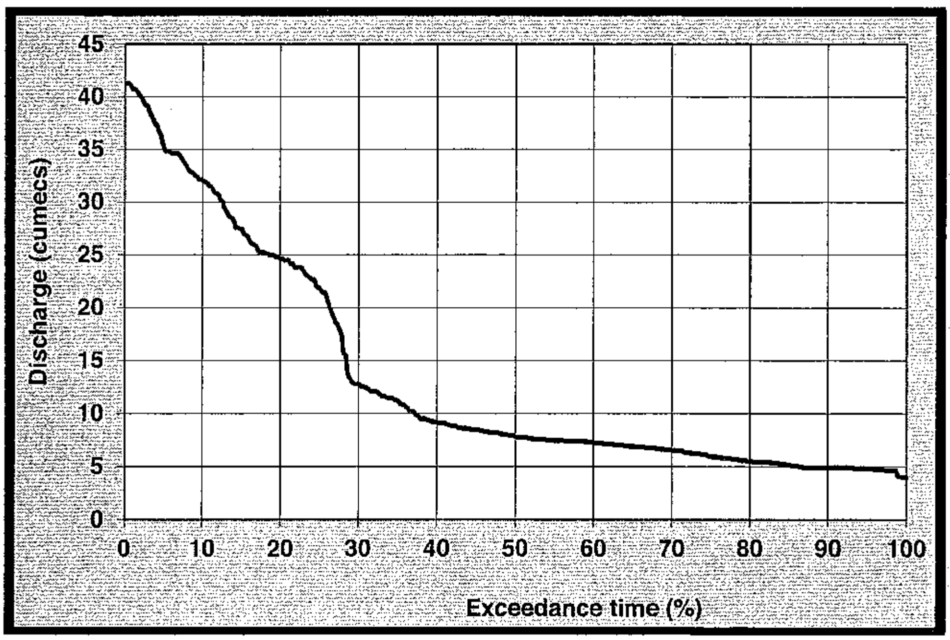

Figure 4.37: Flow duration curve for the driest year at Powerhouse (1964)

Flow duration curve for the average flow year (2004) is shown in **Figure 4.38,** the maximum flow rate is 43.43m^3/sand minimum which will remain available throughout the 100% exceedance time is 5.08 m^3/s.

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Figure 4.38: Flow duration curve for the average flow year at Powerhouse site (1969)

Flow duration curve for the wettest year (1973) is shown in **Figure 4.39,** the maximum flow rate is 43.43 m^3/s and minimum which will remain available throughout the 100% exceedance time is 5.83 m^3/s.

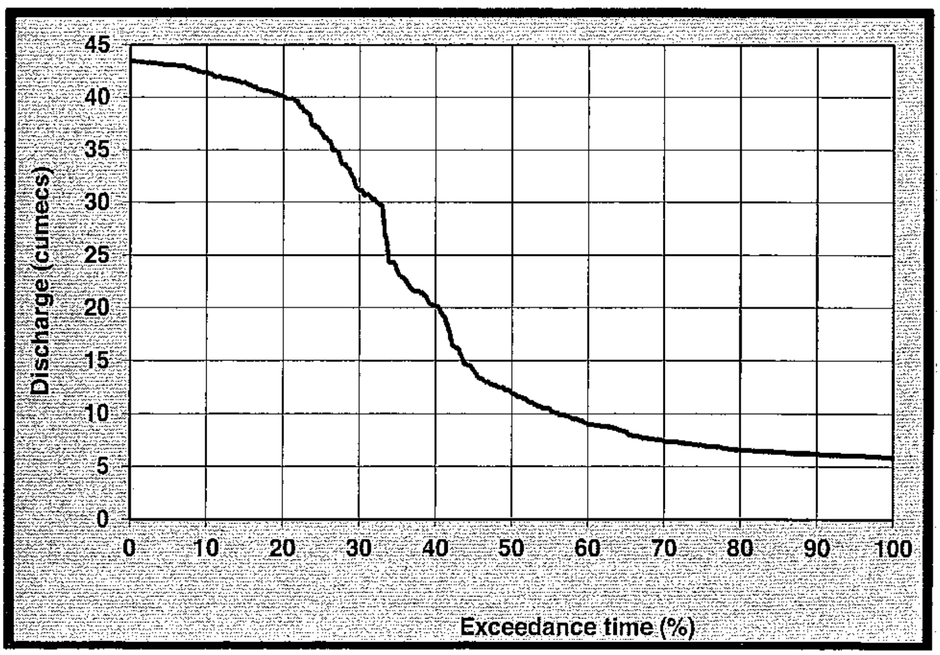

Figure 4.39: Flow duration curve for the wettest year at Powerhouse site (2008)

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Flow duration curve based on mean daily flow is shown in **Figure 2.40,** the maximum flow rate is 40.88m3/s and minimum which will remain available throughout the 100% exceedance time is 5.88m^3/s.

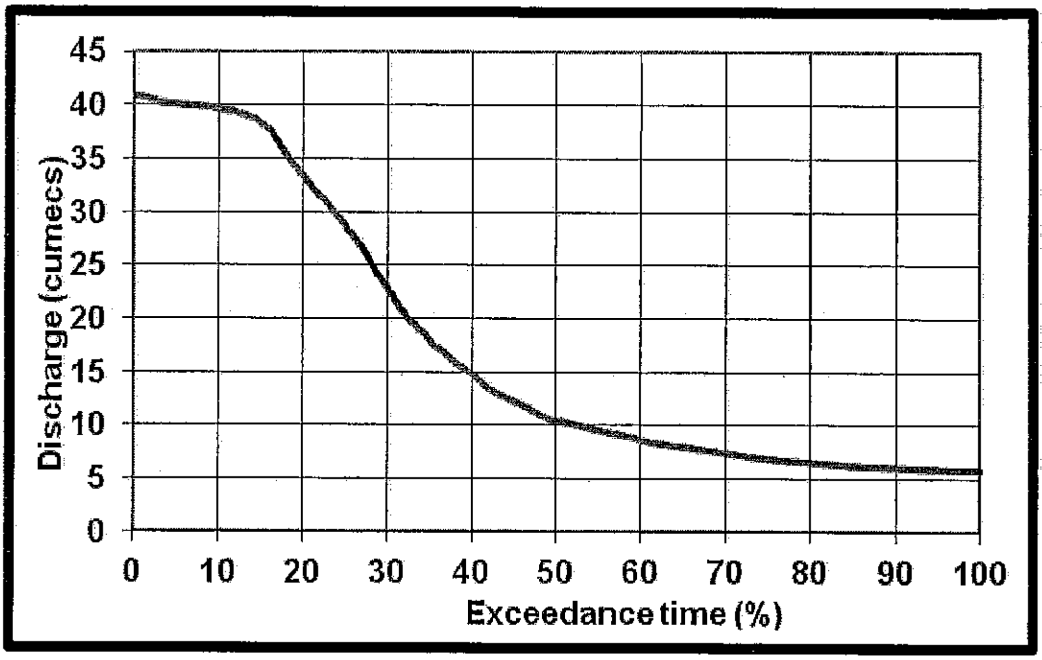

Figure 4. 40: Flow duration curve based Mean Daily Flow at Powerhouse site

Four flow duration curves for driest flow year, wettest flow year, average flow year and flow duration curved based on mean daily flows at the powerhouse site are shown jointly in Figure 4.41.

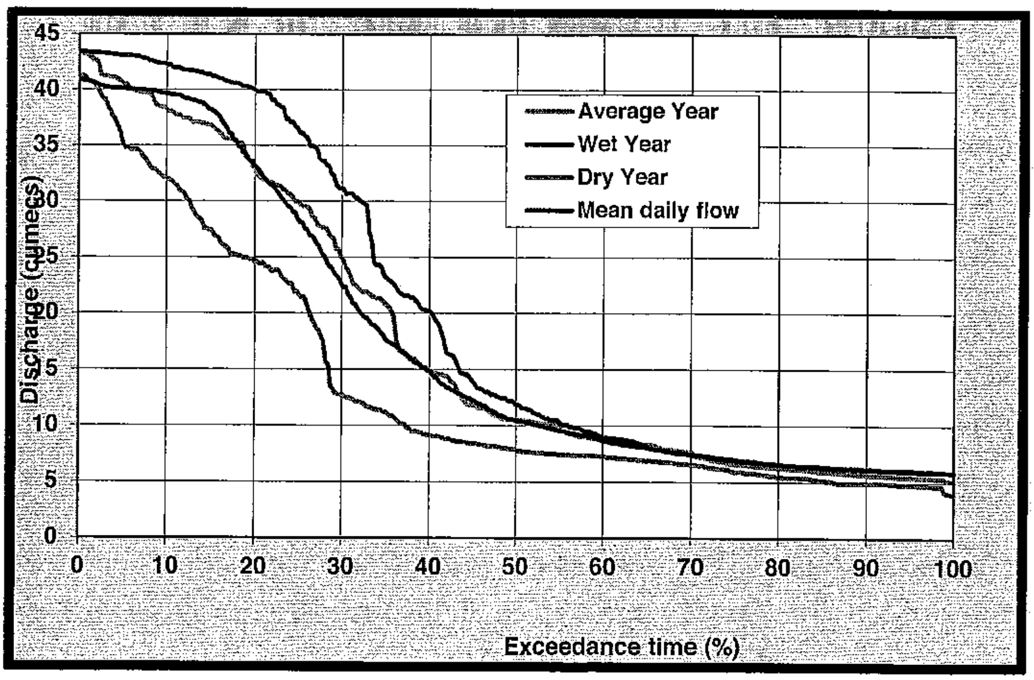

Figure 4.41: FDCs for Driest year (1964), wettest year (1973), Average year (2004) and mean daily Flow duration curves at Arkari powerhouse site (1964-2011)

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4.6 Flood Study

As at Arkari Gauging site, no longer flood data record is available (instantaneous maximum discharges only for 8 years from 2006 to 2013), hence Flood Frequency Analysis Approach cannot be used for assessing the flood magnitudes corresponding to various return periods. As watershed is snowy (non-tropical), hence hydro-meteorological approach is also not appropriate for the site. GTZ regional analysis approach is based on flood data of all Northern areas of Pakistan and hence not specific for the region. Considering all constraints, flood study for the project has been carried out by applying Local Regional Analysis Approach, GTZ Regional Analysis Approach and Statistical Approach.

4.6.1 Local Regional Analysis Approach

For this purpose, Consultants had collected instantaneous maximum discharges for each year at 10 stream gauging stations as given in Table 4.12, the same data were used to determine the flood magnitudes corresponding to various return periods for each station by carrying out the flood frequency analysis using Gumbel Method.

Table 4.14: Stream Gauging stations used for Regional Flood Frequency Analysis

Sr. No.	River Name	Gauging Station	Source	Cordinates		Duration of Data	Data Years	Catchment Area (km^2)	Elevation (masl)
				Latitude	Longitude				
1	Chitral	Chitral	SWHP	35° 51' 48"	71° 47' 15"	(1964-2010)	47	11396	1500.00
2	Golen Gol	Mastuj Bridge	SWHP	35° 56' 32"	71° 58' 49"	(1996-2010)	15	518	1649.00
3	Golen Gol	Babuka	SWHP	35° 55' 50"	71° 55' 55"	(1993-1997)& (2002-2003)	7	500	2010.00
4	Lutkho	Shah-e-Resham	SWHP	-	-	(1986-1987)	2	2443	
5	Shishi Gol	Drosh	SWHP	35° 35' 20"	71° 48' 32"	(1986-1987), (2006-2010)	7	394	
6	Lutkho	Shagore	SHYDO	36° 00' 54"	71° 00' 50"	2005-2011	7	1990	1800.00
7	Ojhar Gol	Shogore	SHYDO	36° 01' 25"	71° 45' 33"	(1995-1999)	5	180	1860.00
8	Reshun Gol	Reshun	SHYDO	36° 08' 45"	72° 07' 25"	1988 - 1997	10	102	2050.00
9	Mastuj	Mira gram	SHYDO	36° 16' 00"	72° 21' 25"	2005-2011	7	4375	2080.00
10	Arkari Gol	Uchhature	SHYDO	36° 04' 17"	71° 41' 27"	2006-2012	7	1015	2178.00

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It is noted that the stream gauging stations used for the development of regional equations have more similarity with the hydro-meteorological characteristics of the Arkari watershed. And hence Local Regional Analysis Approach is more reliable for the study area as compared to GTZ Regional Analysis Approach. Flood magnitudes computed for various stream gauging stations corresponding to various return periods are given in Table 4.15.

Table 4.15: Flood Magnitudes for Various Stream Gauging Stations Using Gumbel Method

Sr. No.	Gauging Station	Estimated flood by using Gumbel Distribution (cumecs)								
		2	5	10	25	50	100	200	1000	10000
1	Chitral	1152	1405	1573	1785	1943	2099	2254	2615	3130
2	Mastuj Bridge	49	94	124	162	191	219	246	311	403
3	Babuka	57	88	109	136	156	175	195	240	305
4	Shah-e-Resham	120	158	183	215	238	261	284	338	415
5	Drosh	82	197	273	369	441	512	582	746	980
6	Shagore	94	135	162	196	222	247	273	331	415
7	Shogore	22	34	42	52	60	67	75	92	117
8	Reshun	2	4	5	7	8	9	10	13	16
9	Mira gram	656	1017	1256	1558	1782	2005	2226	2740	3473
10	Uchhature	46	59	67	78	86	94	101	119	145

Flood Frequency Distribution curves were plotted for each return period, and flood estimation equations were developed for various return periods which are given below:

$$Q_2 = 0.0434\,(A)^{1.0875} \quad (4.5)$$

$$Q_5 = 0.1241\,(A)^{1.0001} \quad (4.6)$$

$$Q_{10} = 0.188\,(A)^{0.9697} \quad (4.7)$$

$$Q_{25} = 0.276\,(A)^{0.9442} \quad (4.8)$$

$$Q_{50} = 0.345\,(A)^{0.9306} \quad (4.9)$$

$$Q_{100} = 0.4158\,(A)^{0.92} \quad (4.10)$$

$$Q_{200} = 0.488\,(A)^{0.9113} \quad (4.11)$$

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$$Q_{1000} = 0.6608\,(A)^{0.8963} \qquad (4.12)$$

$$Q_{10,000} = 0.9161\,(A)^{0.8823} \qquad (4.13)$$

Where Q is the flood magnitude (m^3/s) and its subscript is the return period and A is the watershed area in km^2.

Using Equations (4.5) to (4.13), flood magnitudes for the Arkari weir site were computed corresponding to various return periods and are presented in Table 4.16.

Table 4.16: Flood magnitudes corresponding to various return periods for Arkari weir site using Local Regional Analysis Approach

S. No.	Return Period	Flood (Cumecs)
1	2	83
2	5	128
3	10	158
4	25	194
5	50	221
6	100	247
7	200	273
8	1000	333
9	10000	419

Using Local Regional Analysis approach, flood magnitudes computed for the Arkari weir site corresponding to 10, 100, 1000 and 10,000 years return periods are 158, 247, 333 and 419 cumecs, respectively.

Similarly flood magnitudes for the Arkari powerhouse site were computed corresponding to various return periods and are presented in Table 4.17. Using Regional Analysis approach, flood magnitudes computed for the Arkari powerhouse site corresponding to 10, 100, 1000 and 10,000 years return periods are 161, 252, 340 and 428 cumecs, respectively.

Table 4.17: Flood magnitudes corresponding to various return periods for Arkari powerhouse site using Local Regional Analysis Approach

S. No.	Return Period	Flood (Cumecs)
1	2	85
2	5	132
3	10	161
4	25	198
5	50	226
6	100	252
7	200	279
8	1000	340
9	10000	428

4.6.2. GTZ Regional Analysis Approach

GTZ had collected instantaneous maximum discharge data of various stream gauging stations of Northern areas of Pakistan including snowmelt runoff and glacier melt runoff watersheds (which have no hydro-metereological similarity with the study area) and had developed correlations for the peak floods as a function of watershed areas for various return periods. Regression equations were developed for each return period by the GTZ and are given in the First Report as below:

$$Q_5 = 11.97\ (A)^{0.59} \qquad (4.14)$$

$$Q_{10} = 15.60\ (A)^{0.57} \qquad (4.15)$$

$$Q_{100} = 40.45\ (A)^{0.50} \qquad (4.16)$$

$$Q_{1000} = 64.05\ (A)^{0.47} \qquad (4.17)$$

$$Q_{10000} = 84.85\ (A)^{0.48} \qquad (4.18)$$

Where Q is the maximum instantaneous discharge (m^3/s) and its subscript is the return period and A is the watershed area in km^2.

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Table 4.18: Estimated floods using GTZ Regional Analysis Approach

Return Period (Years)	Flood for Arkari Weir Site (cumecs)	Flood for Arkari PH site (cumecs)
5	720	729
10	816	827
100	1302	1317
1,000	1674	1692
10,000	2069	2091

These equations were used for the estimation of floods corresponding to various return periods. The results of the GTZ approach for flood magnitudes are also presented in Table 4.18 shows that GTZ Regional Analysis Approach yields higher values for floods against various return periods for the study area. The computed 100 and 1000 years return period floods for weir site were estimated as 1302 and 2069 m^3/s, respectively.

4.6.3. Statistical Approach

For transposing the floods from Chitral Stream gauging station to the dam site, initially flood frequency analysis was carried out on the Chitral flood data of 47 years from 1964 to 2010 as shown in Figure 4.42.

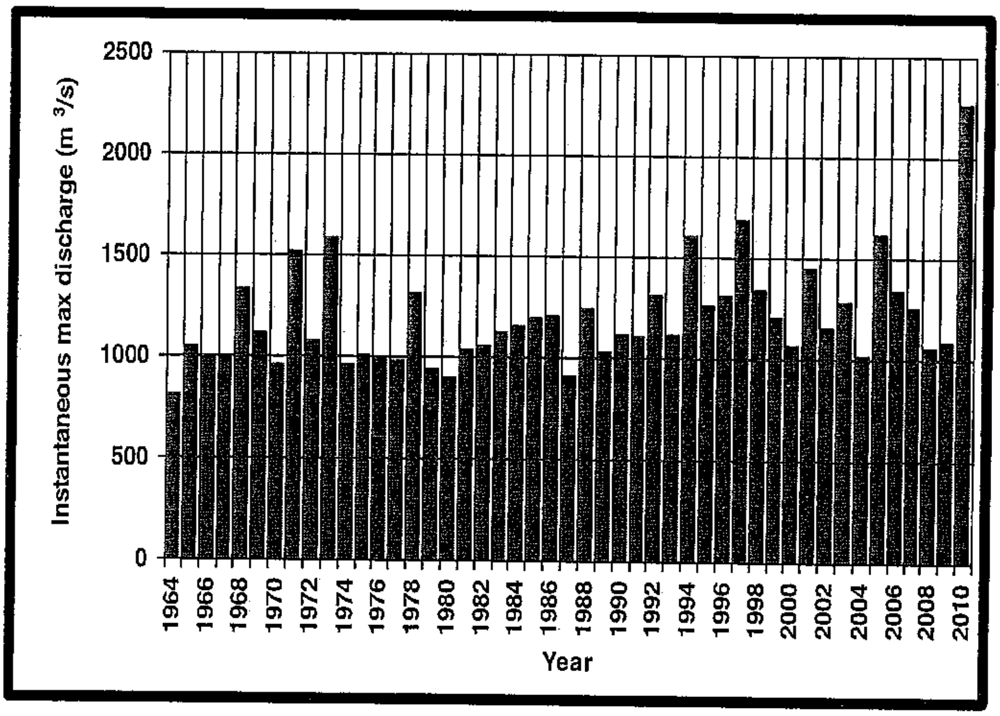

Figure 4.42: Instantaneous maximum discharges observed at Chitral stream gauging station

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Floods corresponding to 2, 5, 10, 50, 100, 500, 1000 and 10,000 years return period were computed using six flood frequency distribution functions, i.e. Normal, 2 Parameter Log Normal, 3 Parameter Log Normal, Gamma, Pearson Type-III, and Gumbel. Relative Mean Deviations were also computed for each distribution function results. Results of the flood frequency analysis for Chitral stream gauging station are shown in Table 4.19. Considering the results of the MRD, it is revealed that Log Pearson Type-III distribution function with Method of Maximum Likely hood best fits the observed flood data of Chitral.

Table 4.19: Results of Flood Frequency Analysis for Chitral Stream Gauging Station

Return Period (Yrs)	NORMAL DISTRIBUTION	2-PAR LOGNORMAL DISTRIBUTION	3-PAR LOGNORMAL DISTRIBUTION	GAMMA DISTRIBUTION	LOG PEARSON TYPE-III	GUMBEL DISTRIBUTION	NORMAL DISTRIBUTION	2-PAR LOGNORMAL DISTRIBUTION	GAMMA DISTRIBUTION	GUMBEL DISTRIBUTION
	Method of Moments						Method of Maximum Likelihood			
2	1196	1169	1137	1178	1131	1154	1196	1169	1181	1153
5	1415	1400	1360	1407	1352	1383	1415	1400	1390	1353
10	1529	1539	1522	1538	1520	1535	1529	1539	1508	1485
20	1623	1663	1687	1652	1697	1680	1623	1663	1611	1612
25	1650	1701	1742	1687	1756	1726	1650	1701	1641	1652
50	1729	1816	1915	1767	1950	1869	1729	1816	1732	1776
100	1800	1925	2097	1881	2160	2010	1800	1925	1816	1899
500	1943	2166	2555	2081	2724	2338	1943	2168	1994	2183
1000	1998	2267	2770	2162	3006	2476	1998	2267	2065	2305
10000	2161	2594	3567	2413	4155	2942	2161	2594	2287	2711
MRD	5.51	3.58	1.64	4.21	1.63	2.35	5.51	3.58	3.88	2.21

Considering watershed areas of Arkari weir site and Chitral stream gauging station, and transposition factor of 0.7, conversion factors of 0.187 and 0.19 were computed for the weir site and powerhouse site, respectively. The flood magnitudes corresponding to various return periods computed for Chitral stream gauging station were multiplied by these conversion factors to obtain flood magnitudes at weir and powerhouse locations of the Arkari HPP. Flood magnitudes computed for the weir and powerhouse sites using statistical approach and transposing to the weir and powerhouse sites are presented in Tables 4.20 and 4.21, respectively

Table 4.20: Floods estimated for Arkari river at Arkari weir site using Statistical Approach

Floods (m^3/s) for Arkari weir Site										Conversion factor 0.1870
Return Period (Yrs)	NORMAL DISTRIBUTION	2-PAR LOGNORMAL DISTRIBUTION	3-PAR LOGNORMAL DISTRIBUTION	GAMMA DISTRIBUTION	LOG PEARSON TYPE-III	GUMBEL DISTRIBUTION	NORMAL DISTRIBUTION	2-PAR LOGNORMAL DISTRIBUTION	GAMMA DISTRIBUTION	GUMBEL DISTRIBUTION
	Method of Moments						Method of Maximum Likelihood			
2	224	219	213	220	211	216	224	219	221	216
5	265	262	254	263	253	259	265	262	260	253
10	286	288	285	288	284	287	286	288	282	278
20	303	311	316	309	317	314	303	311	301	301
25	309	318	326	315	328	323	309	318	307	309
50	323	339	358	334	365	349	323	339	324	332
100	337	360	392	352	404	376	337	360	340	355
500	363	405	478	389	509	437	363	405	373	408
1000	374	424	518	404	562	463	374	424	386	431
10000	404	485	667	451	777	550	404	485	428	507

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Table 4.21: Floods estimated for Arkari river at Arkari powerhouse site using Statistical Approach

Floods (m^3/s) for Proposed Power House Site of Arkari HPP Site										Conversion factor: 0.1900
Return Period (Yrs)	NORMAL DISTRIBUTION	2-PAR LOGNORMAL DISTRIBUTION	3-PAR LOGNORMAL DISTRIBUTION	GAMMA DISTRIBUTION	LOG PEARSON TYPE-III	GUMBEL DISTRIBUTION	NORMAL DISTRIBUTION	2-PAR LOGNORMAL DISTRIBUTION	GAMMA DISTRIBUTION	GUMBEL DISTRIBUTION
	Method of Moments						Method of Maximum Likelihood			
2	227	222	216	224	215	219	227	222	224	219
5	269	266	258	267	257	263	269	266	264	257
10	290	292	289	292	289	292	290	292	287	282
20	308	316	321	314	322	319	308	316	306	306
25	314	323	331	320	334	328	314	323	312	314
50	328	345	364	340	371	355	328	345	329	337
100	342	366	398	357	410	382	342	366	345	361
500	369	412	485	395	518	444	369	412	379	415
1000	380	431	526	411	571	470	380	431	392	438
10000	411	493	678	458	789	559	411	493	434	515

Comparison of computed floods by various approaches is given in Table 4.22 and 4.23 for Arkari weir and powerhouse sites, respectively.

Table 4.22: Computed Floods for Arkari Weir Site

Sr. No.	Return Period (years)	Flood Magnitude (cumecs)		
		GTZ Regional Approach	Local Regional Approach	Statistical Approach
1	2		83	211
2	5	720	128	253
3	10	816	158	284
4	50		221	365
5	100	1302	247	404
6	500			509
7	1,000	1674	333	562
8	10,000	2069	419	777

Table 4.23: Computed Floods for Arkari Powerhouse Site

As Statistical Approach looks best for the Arkari HPP site, hence flood magnitudes are recommended by this method. Table 4.24 contains the recommended flood magnitudes corresponding to various return periods for Arkari weir and powerhouse sites.

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Table 4.24: Recommended Floods for Arkari HPP sites

Sr. No.	Return Period (years)	Flood Magnitude (cumecs)		
		GTZ Regional Approach	Local Regional Approach	Statistical Approach
1	2		85	215
2	5	729	132	257
3	10	827	161	289
4	50		226	371
5	100	1,317	252	410
6	500			518
7	1,000	1,992	340	571
8	10,000	2,091	428	789

Return Period (years)	Floods at Arkari Weir Site (cumces)	Floods at Arkari Powerhouse Site (cumces)
2	211	215
5	253	257
10	284	289
50	365	371
100	404	410
500	509	518
1,000	562	571
10,000	777	789

4.7 Hydrological Field Investigations

Hydrological field investigations includes installation of a stream gauging station, measurements of stages at the rate of at least three times per day, water and sediment discharge measurements for one year's cycle at the rate of thrice per month, and collection of three pit samples.

Consultants have installed a stream gauging station at Uchhatur which is situated 1 km upstream of the proposed Arkari Gol weir site on 25th September, 2012. The measurement activities have been started from 25 September 2012 and shall be an ongoing activity even after completion of this feasibility study.

All the hydrological investigations have been carried out under the direct supervision of field hydrologist posted at Chitral, with a team of vast experienced professionals. During these investigations highly sophisticated equipment are being used and most appropriate procedures are adopted.

4.7.1 Setting of Infrastructure

4.7.2 Setting of Site Office

A site office on monthly rent basis is established at Chitral. This office is well equipped with all facilities pertaining to needs and requirements to supervise all the field work being carried out during hydrological studies at weir and powerhouse sites. Staff members stay at site office during collection of samples and field investigations.

4.7.3 Staffing

A team of qualified personals having a vast experience in the relevant field has been recruited accordingly and is posted at site for under taking hydrological observations and sediment sampling as provided in term of references during the feasibility study of project.

4.7.4 Team Structure

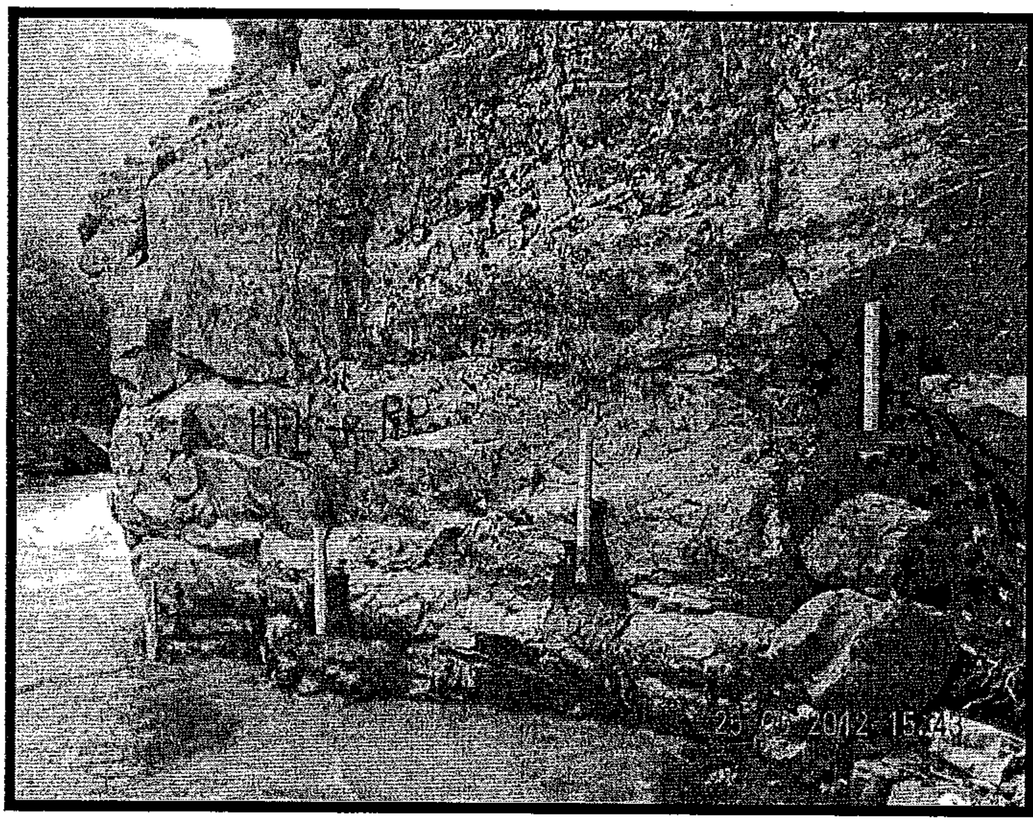
A team of professional was comprised of:

I. Field manager
II. Hydrographic Surveyor
III. Field assistants
IV. Field Helpers
V. Gauge Readers

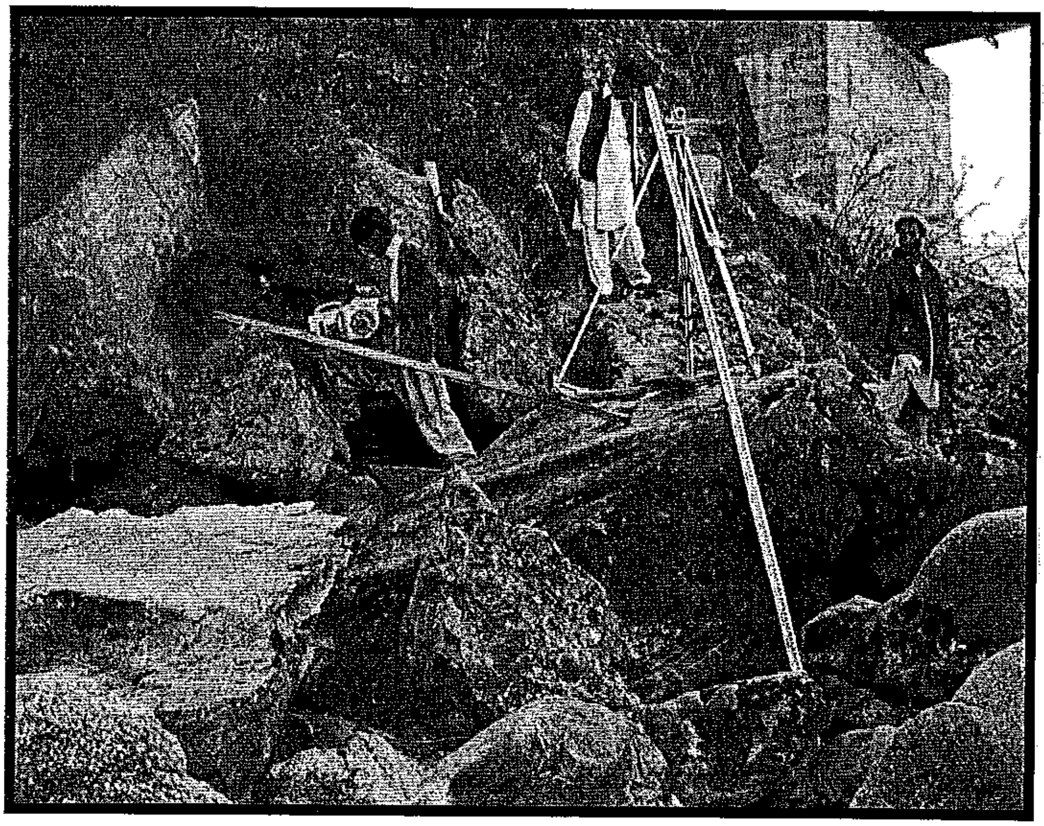
There are many types of stream gauges. The selection of type depends upon their use topography of area, river cross section cost size and on technical basis. All of these gauges measure the stage of stream (height of water surface above at datum). Stage values can be converted into discharge values if rating curve has been established. At present staff gauge is selected to observe daily gauge height data at the gauge station.

Site selection has been very important before installation of any gauging station. Usually, the gauging station is installed where river cross section is narrow with relatively smooth flows and site is easily accessible. Safety of the gauging station is also very important factor.

For the Arkari Gol Hydropower project, a stream gauging station has been established by the Consultants at Uchhatur which is situated 1 km upstream of the proposed Arkari Gol weir site. On stream gauging station, staff gauges have been installed where flow measurements are being made at 08:00 A.M, 12:00 P.M and 04:00 P.M. A view of the installed gauges and river cross section at the point of installation are presented in the following pictures.



Location of Staff Gauge station at Arkari Gol



Drilling and survey work for installation of gauges

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4.7.5 Establishment of Discharge Observation Station

Gauging station has been established considering;

I. At selected site, complete river cross section has been observed and surveyed in order to determine Zero RL of the gauging station.

II. The gauge has been installed using the most reliable technology and materials with standard specifications.

III. The gauge has been installed up to high flood levels.

4.7.6 Discharge Measurements

In the present study, discharge measurements have been measured at Uchhatur Bridge just downstream of the Gauging station.

4.7.7 Discharge Measuring Equipment

The following equipment is being used for measurement of discharge:

a. Current Meter AA Type
b. E-Type Reel with D-connector
c. LED Sounding Weights 50lbs, 75lbs and 100lbs
d. 4-Wheel Crane
e. Head Phone
f. Stop Watch
g. Measuring Sheets
h. Measuring Tape

Staff gauges were installed at the following location, to observe daily gauge height data of stations in Project area.

Table 4.25: Salient Features of Gauge Station at Arkari Gol Near village Uchhatur

Name of River	Station/ Village	C. A in Km^2	Elevation (m)	Slope (%)	Co-ordinates	Code
Arkari Gol	Uchhatur	1015	2178	2.20	36 04 17 71 41 27	36711701

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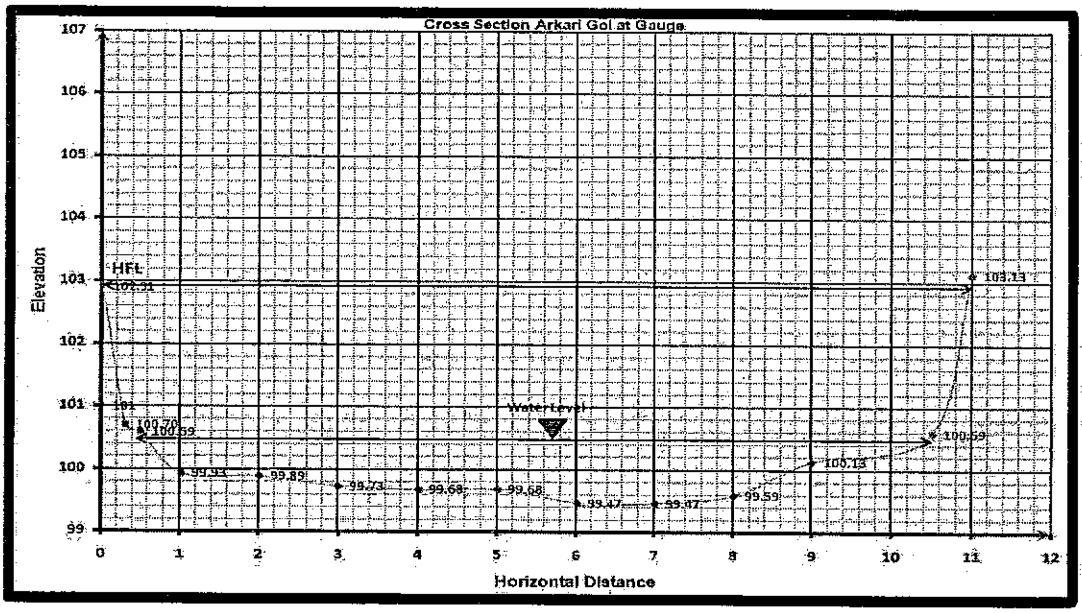
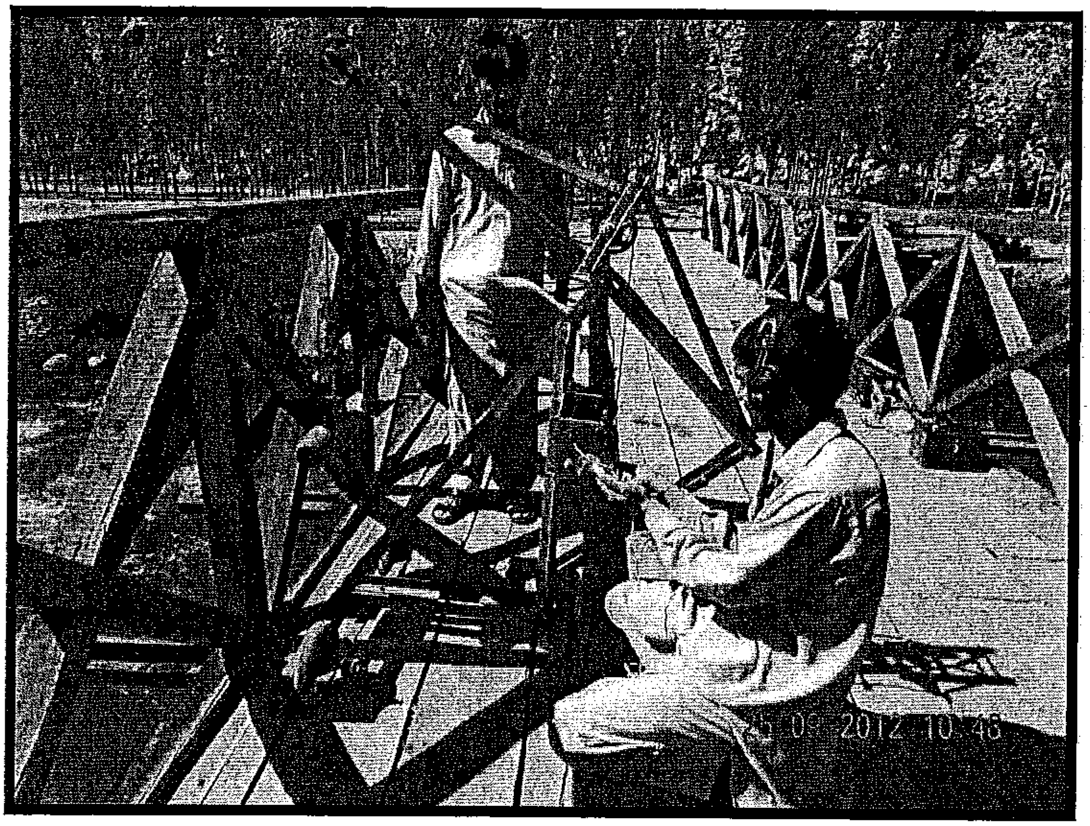


Figure 4.43: River cross section at the Gauging Station

AA - Type Gurley Current Meter with vertical axis fitted with hanger strips is used for discharge measurement during the present study.

The discharges have been measured at stream gauging station (see pictures below) by velocity - area method. The observed discharge at the Gauging station is given below.



Flow measurement with AA Type Current Meter by Crane

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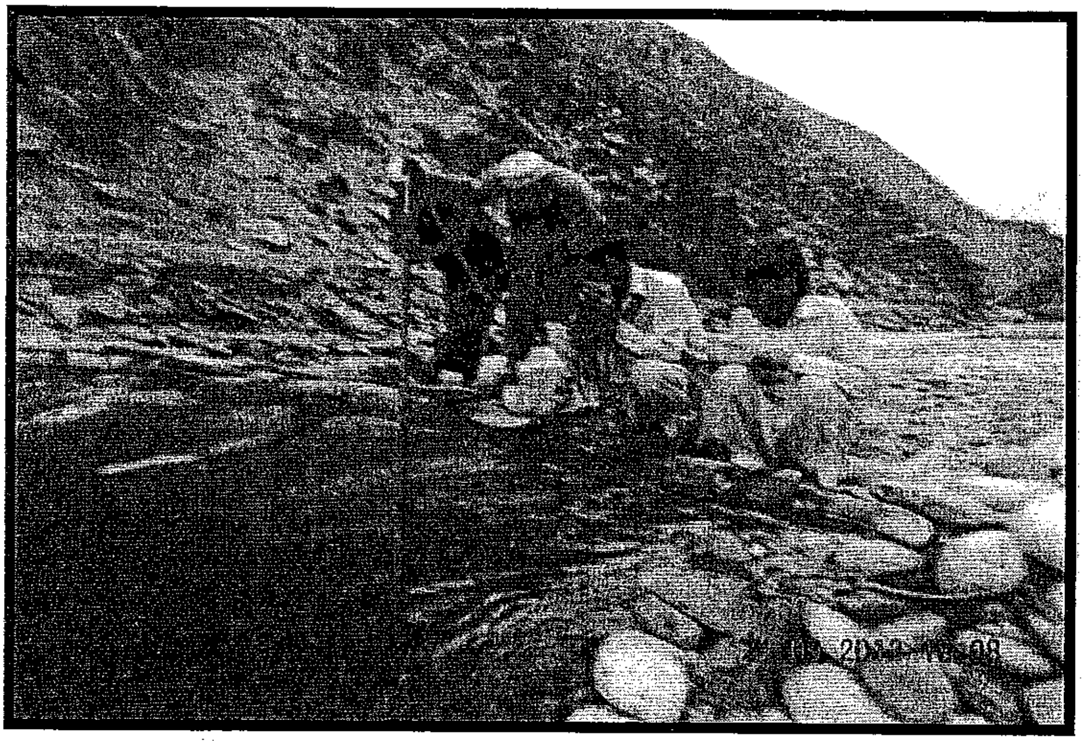

Flow measurement with AA Type Current Meter by wading

4.7.8 Methodology (Installation of Gauging Stations):

Prior to collection of the flow data of a stream, a proper gauging location is necessary for installation of the gauge station. For flow measurement, it is necessary to choose a site where variations in the discharge will cause the least modification to the cross section. Ideally, a site where all discharge can be contained within the banks should be used. The second major requisite of a good gauging station is a well regulated stable bed profile.

Continuous measuring of the river flow is essential to assess water availability but it is not a practical proposition to make continuous measurement of flow velocities. However, a fixed and constant relationship between the river stage and discharge at a gauging station solves the matter. This occurs along stretches of a regular channel in uniform flow condition where the stage-discharge relationship is under channel control. In case of reaches of non-uniform flow, it is important to find a natural bed control where critical flow occurs with a tranquil flow condition. In both cases, the discharge is function of stage. The stage, being the most important measurement in hydrometry, is measured with respect to a datum e.g. benchmark.

4.7.9 Staff Gauges

This is generally a graduated staff fixed vertically on the riverbank at a stable point in the river, which is not affected by turbulence of river flow. In case of permanent structure such as bridge, it can be easily attached to the upstream side of a bridge abutment. The graduations on the staff can be in any measuring system (metric in our case) and should extend from the datum or lowest flow depth or stage to the highest stage expected in the river. The length of a staff gauge is usually one meter and a series of vertical staff gauges can be stepped up on the bank side with appropriate overlaps to give continuity. Single readings of the stage at fixed time intervals of the day provide a useful record. This may be adequate on large mature rivers but inadequate for flashy streams and rivers. For monitoring irregular river flows, continuous level Recording is essential.

4.7.10 Collection of Hydrologic Data

The collection of data of various hydrology variables are summarized in detail as below:

4.7.11 Time and Gauge Height Reading (TIGER)

The river stage data is collecting by the appointed gauge readers by observing staff gauge. The gauge reader is observing and recorded the gauge reading three times a day i.e., at 0800 hrs, 1200 hrs, and 1800 hrs daily during low flow and at more frequently during floods.

4.7.12 Stream Flow Measurement

Discharge data of a river is mostly obtained by the velocity-area method. In this method the flow velocities are measured at selected intervals of known depth across a measured cross section of the river.

4.7.13 Operational Methods

There are many operational methods for measuring the discharge of a stream. However, the Hydrographer is trained to adopt the following two methods for low flow and high flow measurement, respectively.

2.7.14 Wading:

This method is practicable in shallow streams with low or moderate velocities. In this method, the current meter is fixed on a calibrated wading rod and held in position by the gauge reader standing on the stream bed downstream of the instrument. This is an ideal method and the operation is in full control of the Hydrographer.

4.7.15 Bridge / Cableway:

Rivers where wading is not practicable, a bridge can be used for discharge measurement. A tripod can be used to lower the current meter with the help of a sounding reel. In the absence of bridge, a cable way can be constructed with essential accessories to facilitate gauging.

4.7.16 Coding System for Gauging Stations

A numerical coding system has been adopted for identification of stations. The numerical coding system for a gauging station is assign by following method.

Latitude	:	35	02	18
Longitude	:	71	53	05

The first four digits = 3571

The fifth and sixth digits are assigned by dividing minutes by six. Through this procedure the fifth and sixth digits =08

The seventh and eight digits are free digits and can be assigned as 01, 02, and 03. Thus the eight digits code =35710801.

4.7.17 Calculation Procedure

Daily flows are calculating using the computing facilities available in DBHYDRO program, developed by Pakistan-German Technical Cooperation Program. The computer program was created to develop a comprehensive hydrological data bank available in Pakistan. Regarding processing of flows, the program includes facilities for data entry (field observation and calculated values), to scrutinize field measurements, for processing of flows measurements used to produce rating curves, and to calculate daily flows for rating curves and river levels. The facilities included in the program facilitate the processing, that otherwise will be time consuming and lengthy. The following observed station specific daily flow data were collected by the Consultant of this study and calculated in DBHYDRO program, developed by Pakistan-German Technical Cooperation Program.

Table 4.19: Observed Daily Flows For 2012 On Arkari Gol At Uchhatur

STREAMFLOW DATA

2012

BASIC SERVICES HYDROLOGY

CODE:	36711701	LATITUDE:	36 04 17	AGENCY:	SHYDO
STATION:	Uchhatur	LONGITUDE:	71 41 27	PROVINCE:	KP
RIVER BASIN:	Arkari Gol	ELEVATION:	2178 m.a.s.l	INSTALLED:	24/09/012
BASIN:	Chitral	CATCHMENT AREA:	1015 km^2		

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	13.790	9.349	7.046
2	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	13.440	9.124	7.046
3	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	13.230	9.124	7.046
4	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	13.090	9.124	6.854
5	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	13.510	9.124	6.854
6	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	12.820	9.124	7.046
7	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	12.820	8.903	7.046
8	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	12.160	8.903	6.854
9	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	11.770	8.684	6.801
10	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	11.570	8.469	6.741
11	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	11.510	8.469	6.700
12	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	11.460	8.469	6.664
13	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	11.430	8.469	6.621
14	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	11.260	8.469	6.585
15	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	11.359	8.257	6.532
16	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	11.325	8.201	6.493
17	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	11.260	8.147	6.666
18	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	11.010	8.102	6.697
19	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	11.010	8.077	6.481
20	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	10.580	8.047	6.402
21	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	11.260	7.841	6.398
22	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	10.640	7.841	6.363
23	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	10.520	7.638	6.341
24	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	15.690	10.280	7.638	6.327
25	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	15.160	10.040	7.638	6.315
26	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	15.090	10.040	7.437	6.300
27	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	14.290	9.807	7.437	6.298
28	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	14.000	9.807	7.638	6.297
29	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	13.790	9.807	7.638	6.481
30	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	13.790	9.577	7.046	6.298
31	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	9.577	-1.000	5.942
MONTHLY SUMMARY												
Mean	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	14.54	11.35	8.28	6.60
Spec D	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	14.33	11.18	8.16	6.50
Run-off	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	8.67	29.94	21.15	17.41
Volume	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	-1.000	8.80	30.39	21.46	17.67

Table 4.19: Observed Daily Flows For 2012-2013 On Arkari Gol At Uchhatur

STREAM FLOW DATA

2013

BASIC SERVICES HYDROLOGY

CODE:	36711701	**LATITUDE:**	36 04 17	**AGENCY:**	SHYDO
STATION:	Uchhatur	**LONGITUDE:**	71 41 27	**PROVINCE:**	KP
RIVER BASIN:	Arkari Gol	**ELEVATION:**	2178 m.a.s.l	**INSTALLED:**	24/09/012
BASIN:	Chitral	**CATCHMENT AREA:**	1015 km^2		

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1	5.661	5.661	5.661	6.538	8.160	23.134	42.673	53.170	27.741	14.415	8.769	-
2	5.498	5.661	5.661	6.538	8.612	23.134	42.673	71.865	25.085	14.252	8.119	-
3	5.498	5.829	5.661	6.175	8.845	28.624	33.044	73.108	26.456	14.035	8.444	-
4	5.498	6.354	5.661	6.000	10.619	28.624	35.095	53.170	24.421	14.198	8.552	-
5	5.661	6.354	5.661	6.000	10.086	31.729	33.717	53.658	22.023	13.817	8.336	-
6	5.829	5.661	5.829	6.000	11.175	35.095	35.095	45.611	21.902	13.599	9.852	-
7	6.175	5.661	5.829	6.000	12.051	35.095	43.496	51.489	22.511	13.763	8.986	-
8	6.175	5.661	5.829	6.000	10.619	35.095	51.489	51.965	22.759	13.327	8.823	-
9	6.175	6.000	5.661	6.000	11.461	35.095	51.489	52.927	27.164	13.599	7.903	-
10	6.000	6.175	5.661	6.000	11.461	42.673	42.673	53.904	21.902	14.198	7.903	-
11	6.000	6.175	5.661	6.725	11.461	61.688	38.738	44.122	22.511	13.980	8.011	-
12	6.354	6.175	5.829	6.725	13.965	61.688	35.801	38.361	22.884	13.273	7.795	-
13	5.829	5.829	5.829	6.725	13.965	61.688	38.738	37.615	21.542	13.164	7.741	-
14	5.829	5.829	5.829	6.725	13.630	51.489	42.673	36.881	21.424	12.566	7.470	-
15	6.175	5.661	5.829	6.725	13.965	42.673	43.496	34.057	21.781	12.240	7.687	-
16	6.000	5.338	5.829	8.612	14.654	38.738	36.518	34.401	20.038	11.969	7.254	-
17	5.829	5.338	5.829	6.725	14.654	35.095	51.489	31.891	17.380	12.240	8.065	-
18	6.000	5.338	5.829	6.725	14.654	33.717	53.414	34.057	16.303	11.154	8.119	-
19	5.829	5.338	5.498	6.725	16.494	33.044	51.489	30.613	16.207	11.154	7.254	-
20	5.829	5.338	5.661	6.725	16.494	35.447	51.489	28.624	17.481	10.503	7.038	-
21	5.829	5.498	5.661	6.917	16.494	42.673	51.489	27.451	17.582	10.178	7.254	-
22	5.661	5.498	5.661	6.538	18.513	42.673	52.445	25.085	17.380	10.069	7.687	-
23	5.661	5.498	5.661	6.725	18.513	51.489	51.489	25.085	16.494	10.178	7.795	-
24	5.661	5.498	5.661	7.314	23.134	61.688	51.489	24.029	15.924	9.961	7.903	-
25	5.661	5.498	5.661	7.728	21.188	61.688	56.406	27.164	15.008	10.178	7.687	-
26	5.661	5.498	5.661	6.725	18.513	73.421	65.039	27.164	15.553	9.961	7.903	-
27	5.829	5.498	5.829	6.725	18.513	61.688	61.688	25.901	14.830	9.690	7.687	-
28	5.829	5.498	5.829	6.725	14.654	61.688	73.421	28.179	15.553	9.094	7.470	-
29	5.661	-1.000	5.829	7.728	14.654	61.688	63.906	28.327	15.831	9.311	7.038	-
30	5.661	-1.000	5.829	7.728	16.494	51.489	62.789	28.032	15.370	9.527	6.930	-
31	5.829	-1.000	5.829	-1.000	22.144	-1.000	57.433	28.923	-1.000	8.769	-1.000	-
MONTHLY SUMMARY												
Mean	5.830	5.690	5.740	6.710	14.510	44.790	48.480	38.930	19.970	11.990	7.920	-
Spec D	5.750	5.610	5.650	6.610	14.300	44.130	47.760	38.350	19.670	11.810	7.800	-
Run-off	15.390	13.570	15.140	17.130	38.290	114.380	127.930	102.730	50.990	30.610	20.210	-
Volume	15.620	13.770	15.370	17.390	38.870	116.100	129.850	104.270	51.760	31.070	20.520	-

Table 4.20: Mean Monthly Arkari Gol HPP

Table 4.20: Mean Monthly Flow

Year	2012				2013										
Month	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Mean	14.54	11.35	8.28	6.60	5.83	5.69	5.74	6.71	14.51	44.79	48.48	38.93	19.97	11.99	7.92

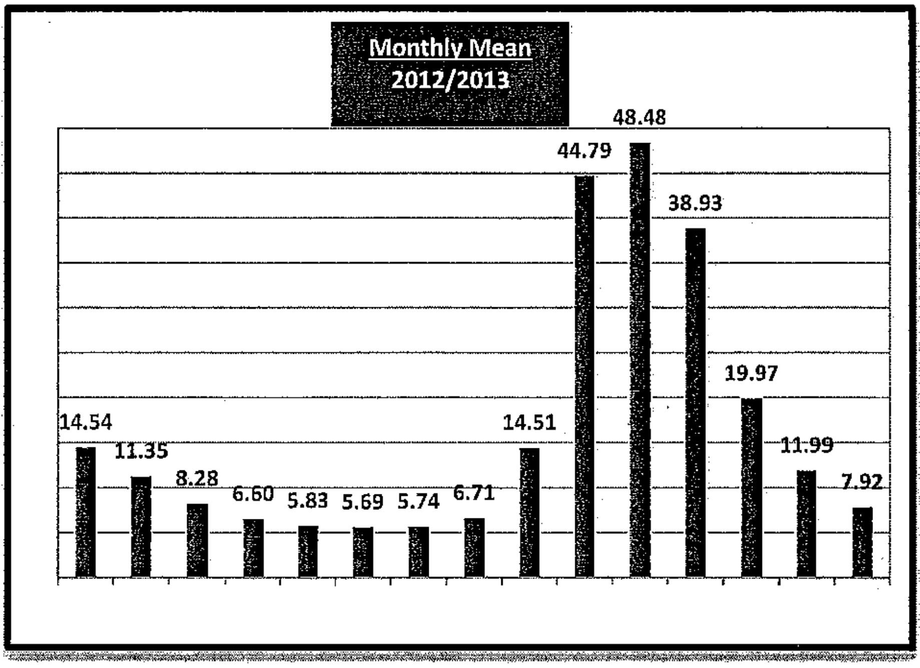

Figure 2.45: Mean Monthly Graph of Arkari Gol (Sep 2012- Nov 2013)

4.8 Sedimentation Studies

4.8.1 Introduction

This section of the report describes the sedimentation study for watershed area related to the proposed weir site and reservoir of Arkari Hydropower Project on River Arkari.

It covers description of previous sedimentation studies for the weir site, sediment yield of the watershed, sediment transport pattern of the river at the weir site, computation of suspended sediment inflow to the reservoir using the nearby sediment gauging stations in the Chitral region, computations for the bed load, total sediment inflow to the reservoir, efficiency of the proposed reservoir in trapping sediments, life of reservoir without any flushing option, sediment flushing through the reservoir, life of the reservoir considering the flushing option and provision of Boulder Trap to further enhance the life of the reservoir.

To carryout detailed sediment analysis of the watershed area, data of eight sediment gauging stations were collected and used. Sediment loads for the weir site are calculated by the Regional Analysis approach and its temporal distribution was kept same as observed at Uchhatur stream gauging station at river Arkari.

Results of sediment study reveal that the total mean annual sediment inflow to the reservoir is about 0.288 M Tons and life of Arkari reservoir without flushing would be around 09 years. In these circumstances, construction of a Boulder Trap at the mouth of the reservoir, adoption of other watershed management practices and implementation of hydraulic methods for the removal of sediments from the reservoir are essentially required.

4.8.1.1 Previous Studies

It has been confirmed that, no in-depth sedimentation study was previously carried out for Arkari weir site, for its reservoir and the watershed area by any Consultant and organization. However, suspended sediments are being measured on river Arkari slightly upstream of the proposed weir site since year 2006.

4.8.2 Salient Features of the Proposed Reservoir

At proposed Arkari weir site, total reservoir capacity would be 2.155 MCM at Maximum Normal Operating Level (NOL) of 2190 m asl. The river bed level at weir site is 2172 m asl. Average slope of the river bed in the reservoir area is 0.022 and the length of reservoir would be around 1300 m. The width of river bed at the weir site is 17.5 m. There would be one Power Tunnels having 2.68 x 4.15 m diameter (horse show section) with sill level at 2181 m asl. For flushing of sediments through the reservoir, a provision is made of one flushing outlets having size of 6 x 6 m. The outlets inverts are placed at 2173.84 m asl.

4.8.3 Sediment Yield Characteristics of the Watershed

The drainage area of the Arkari weir site on the river Arkari is about 1036 km^2. Most of the watershed remains covered with snow and glaciers in winter season. The flow in the river is mainly due to glacier and snow melting. A slight contribution of rainfall-runoff is also available in some summer months.

The drainage area of Chitral River at Chitral is about 11,396 km^2. The mean annual runoff of Chitral River for 47 years of record (1964-2010) is 8726 Mm^3. The record of the Chitral gauging station shows that maximum mean annual flow has occurred in the year 2010 and minimum in the year 1964. The river is snow fed and flows steadily throughout the year with additional runoff during monsoon in June through September.

There is little vegetation cover over the watershed. It is due to the fact that most of the watershed remains covered with glaciers and snow for most of the time of the year.

Sediment discharge data of eight sediment gauging stations were collected from the SWHP, WAPDA and Sarhad Hydel Development Organization (SHYDO) (Recently renamed as PHYDO) which was used for the estimation of sediment yield for the watershed using regional analysis approach. The collected data with names of the sediment gauging stations, source, duration of data, data years, watershed areas, suspended sediment loads and specific suspended sediment loads are given in Table 4.28.

Table 4.28: Suspended Sediment Yield Characteristics of Watersheds in the Chitral Region

S. No.	River Name	Gauging Station	Source	Duration of Data	Data Years	Watershed Area (km^2)	Susp Sed Load (MT)	SSSY (tons/km2/year)
1	Chitral	Chitral	SWHP	1964-2010	47	11400	23.087	2025
2	Mastuj	Miragram	SHYDO	2006-2011	6	4375	6.770	1547
3	Golen Gol	Babuka	SWHP	1993-1997	4	500	0.431	862
4	Shishi	Drosh	SWHP	1986, 2006-2010	14	394	0.232	589
5	Lutkho	Shogore	SHYDO	2006-2011	6	1990	0.270	136
6	Golen Gol	Mastuj Br	SWHP	1997-2010	14	518	0.064	124
7	Lutkho	Shah Re Sham	SWHP	1987-1988	1	2443	0.288	118
8	Arkari Gol	Uchhatur	SHYDO	2006-2013	8	1015	0.053	52

Figure 4.45 depicts the specific suspended sediment yields of various streams / rivers situated in Chitral region. These values of specific suspended sediment yields show that at higher elevations its value is smaller and at lower elevations its values are greater, it is mainly due to rainfall runoff erosion and sediment transport.

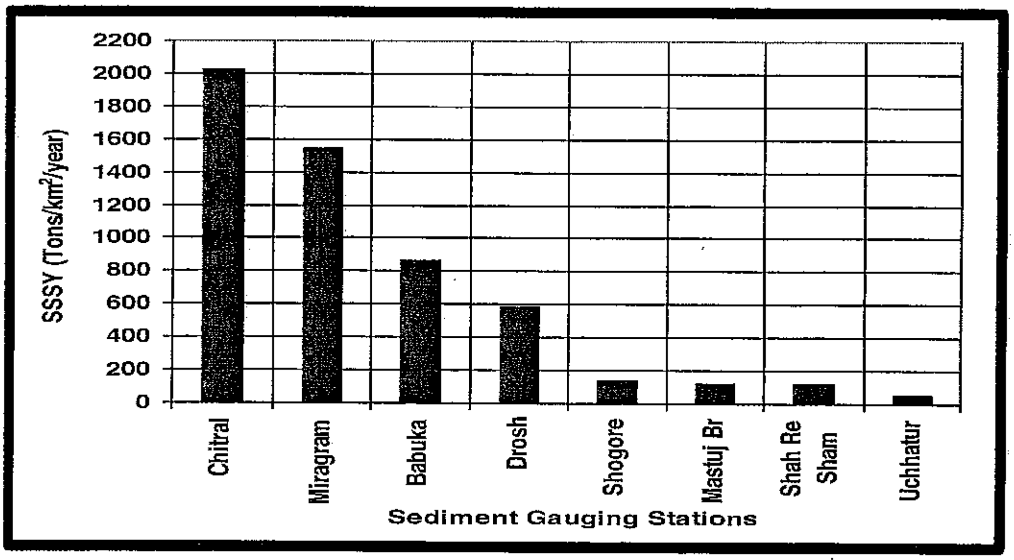

Figure 4.45: Specific Suspended Sediment Yields of Various Sediment Gauging Stations in the Region

Figure 4.45 also shows that River Chitral at Chitral gauging station has highest value of specific suspended sediment yield in the region, whereas, this is lowest at Uchhatur on river Arkari, being respectively 2025 and 52 tons/km^2/year.

Considering the long term generated data record (1964-2013), total mean annual sediment inflow to the Arkari weir site and numerical value of its watershed area, the specific suspended sediment yield for the Arkari weir site has been worked out to 241 Tons/km^2/year.

4.8.4 Existing Sediment Data

4.8.4.1 Topography

Topography of watershed plays an important role in the sediment transport in a river. To study the topographic conditions of the watershed, available topographical maps at a scale of 1:50,000 were collected from Survey of Pakistan, and topographic information was also collected during present survey by the Consultants. The longitudinal slope of the Arkari River has a mean gradient of approximately 0.022.

4.8.4.2 Bed Material Gradation

One of the important parameter for most of the sediment transport calculations is the grain size distribution of the bed material in the riverbed. It determines the resistance of the riverbed to the shear stresses caused by flow. The bed of gravel-bed Rivers are characterized by armoring effects. The armor layer of a mountain river consists of coarse material on the surface of the bed, which protects the finer sediment material in the subsurface layer.

Present Consultants have collected 03 bed material samples from the reservoir area.

4.8.4.3 Bed Load

Bed load transport rates in the Arkari River at the proposed reservoir area of Arkari HPP have not been measured earlier. In the present study an effort has been made to compute the bed load from empirical formulae but results were not found satisfactory. Therefore for the assessment of the bed load for this project, state of the art guidelines provided by USBR have been adopted.

4.8.4.4 Suspended Sediment Load

A stream gauging station has been established in 2006 by the PHYDO at River Arkari to measure water and suspended sediment concentrations for the proposed weir site. In addition, suspended sediment load data of 07 sediment gauging stations in the Chitral glaciated region were collected from SWHP, WAPDA and Pukhtunkhawa Hydel Development Organization (PHYDO). Numerical values of discharges and corresponding concentrations for the 07 stream gauging stations in Chitral region are given in **Appendix 4.** Discharge and suspended sediment data of Uchhatur is given in **Appendix** 4 which also shows suspended sediment and bed material gradation data.

4.8.5 Sediment Field Investigations / Sampling

Field investigations carried out by the Consultants for the sedimentation studies of Arkari HPP, by installation of a stream gauging station in the vicinity of the weir site, stage and discharge measurements, suspended sediment discharge measurements, bed material sampling, bed material pit sampling and Petrographic Analysis for the suspended sediments.

4.8.5.1 Installation of Sediment Gauging Station

As mentioned earlier, a stream gauging station has been installed at Uchhatur Bridge about 200 m upstream of the Arkari weir.

4.8.5.2 Water Discharge Measurements

For the present study, discharge measurements are being made at Uchhatur stream gauging station. Current meter method has been used in the present study. There are different modes of discharge measurements by current meter depending upon the kind of support used by the observer in crossing the stream and the manner in which the meter is held in position. The mode of measurement by current meter in present study is bridge measurement.

4.8.5.3 Suspended Sediment Discharge Measurements

For the determination of suspended sediment concentration (ppm) and particle size distribution of River Arkari at the gauging site, suspended sediment samples are being collected during flow measurements. Five number of sediment samples are being collected during each flow measurement and the same were composed into one sample. In this way total of three number of composed suspended samples are being obtained during each month, and sent for analysis to Geotechnical Engineering Laboratory of CED, UET, Peshawar for detailed analysis.

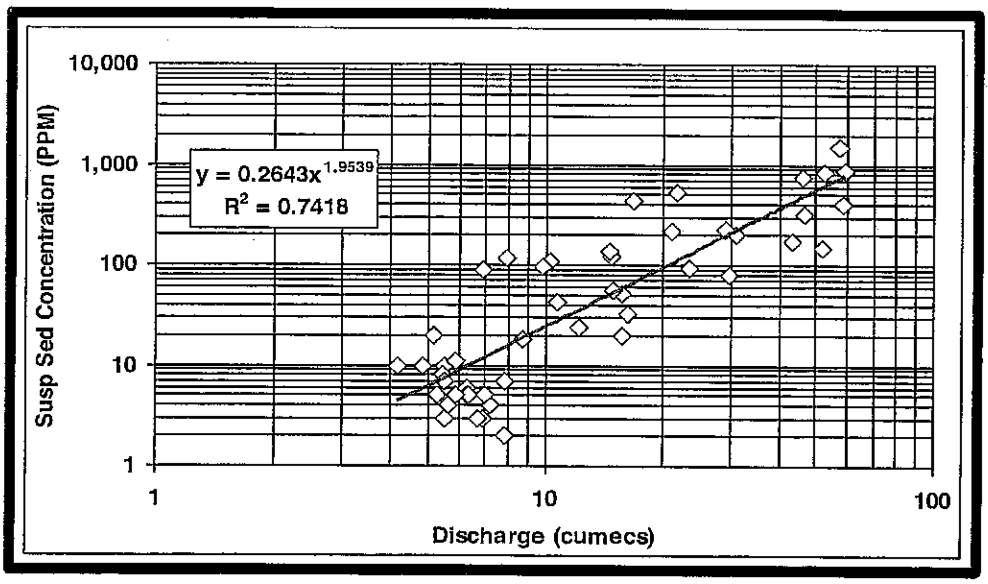

Figure 4.46: Observed Suspended Sediment Concentration Rating Curve at the Uchhatur Stream gauging station (2006-2013)

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The percentages of the sand and silt & clay contents in the suspended load for the weir site at Uchhatur have been measured by the Consultants as 57 % and 43 %, respectively. The content of sand in the suspension, at the weir site is high which is used for the assessment of trap efficiency of the reservoir.

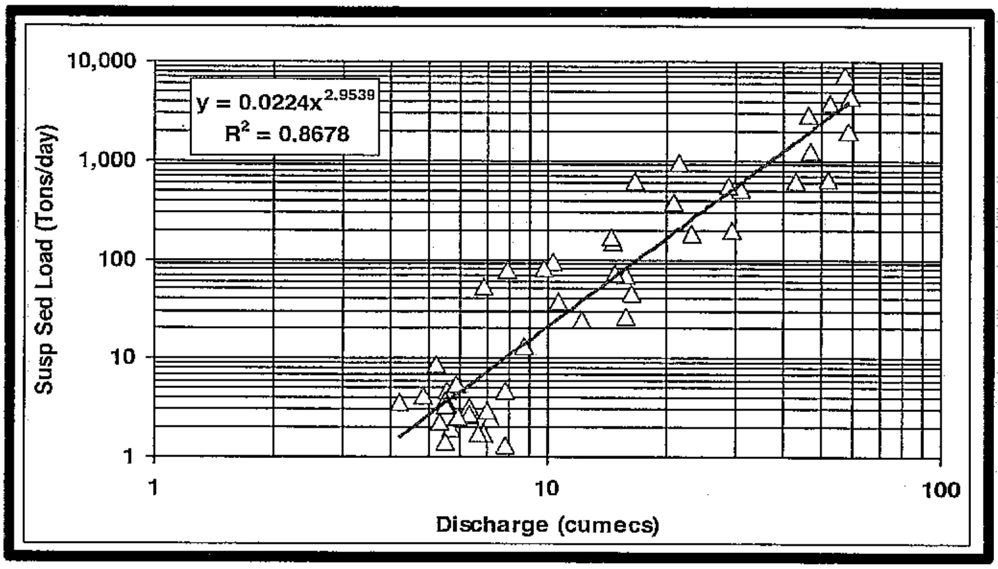

Figure 4.47: Suspended Sediment Rating Curve at the Uchhatur Stream gauging station (2006-2013)

Suspended sediment samples are being collected from River Arkari in the area of proposed reservoir at the rate of twice per week in the high flow season and three per month in the low flow season.

Table 4.29: Observed Suspended Sediment loads at the Gauging Site

Observed Mean Monthly Suspended Sediment Discharges at Uchhatur Gauge (Tons)													
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Annual
2006	236	156	137	117	2351	4223	15038	11917	2071	1060	183	164	37654
2007	77	47	74	781	9464	30109	39721	12555	3277	578	170	86	96939
2008	69	49	44	56	481	2162	3383	3282	696	271	138	94	10726
2009	83	61	65	97	262	1369	9844	12195	2861	599	200	135	27770
2010	128	98	87	238	1789	9054	49069	56718	15090	3605	1187	411	137475
2011	202	120	70	93	1149	3069	7128	7461	3420	1026	441	240	24419
2012	73	42	45	129	290	1797	12221	19096	3665	938	352	184	38833
2013	127	108	121	190	2270	65027	74915	47809	5186	1113	309	184	197360
Mean	125	85	80	213	2257	14601	26415	21379	4533	1149	372	187	71397

The average measured suspended sediment concentration by the consultants at Arkari weir site is 159 PPM, whereas, minimum and maximum sediment concentrations measured were 2 and 1490 PPM, respectively. The Suspended Sediment Concentration Rating curve is shown in Figure 4.46. Figure 4.47 shows the suspended sediment rating curve.

Collected suspended sediment concentrations were converted into daily suspended sediment loads, then monthly sediment loads were computed which are presented in Table 4.29. The observed mean annual suspended sediment load (2006-2013) comes to 0.071 M Tons. This value is relatively small perhaps due to the reason that sediment observations were not made enough in high flow season, moreover, there were very few observations from 2006 to 2009.

4.8.5.4 Bed Material Sampling

For the sedimentation study, it was necessary to have sufficient bed material gradation curves. Therefore, consultants have collected 02 samples from the reservoir area.

Bed material samples were sent to the Geotechnical Engineering Laboratory of University of Engineering & Technology, Peshawar for the analysis and preparation of gradation curves. The combined gradation curves for the samples are shown in Figure 4.48.

The bed material at the weir site consists largely of gravel, sand and silts, however, collected bed material samples show median diameter of 2 mm. The average d_{90} for the bed material samples was determined as 15 mm.

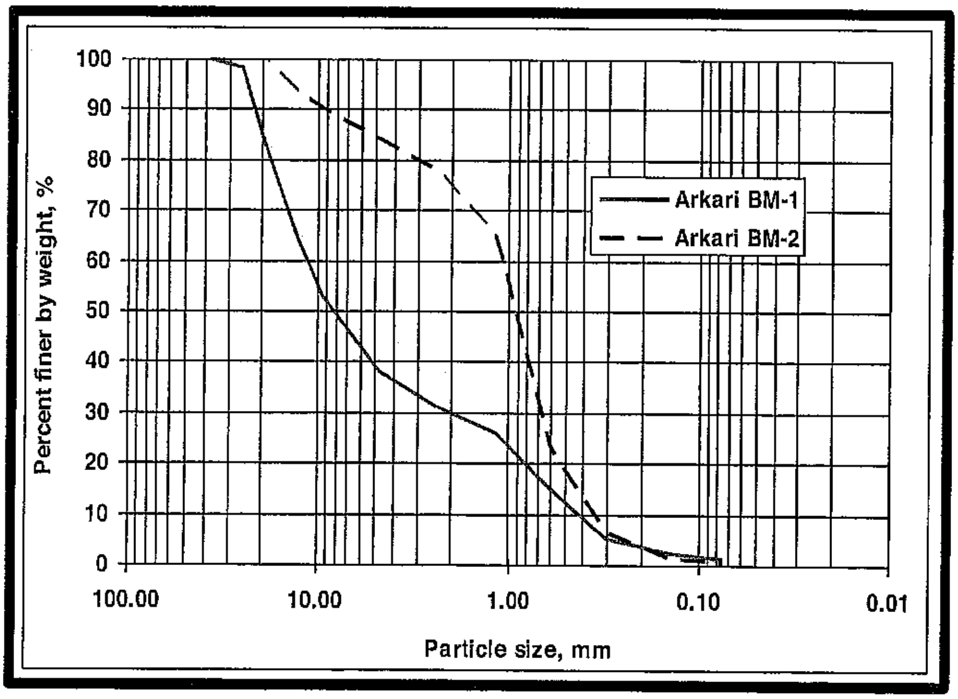

Figure 4.48: Bed Material Gradation Curves at various locations in the Arkari Reservoir

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7.8.5.5 Petrographic Analysis of Suspended Sediments

One suspended sediment sample was collected from the River Arkari on 8th August, 2013 by the Consultants near the weir site to determine the mineralogical composition through petrographic analysis of the suspended material and were sent to the Geological Engineering testing laboratory of UET, Peshawar for Petrographic analysis. The detailed results for petrographic analysis are given in **Annexure 4.5**.

4.8.6 Sediment Inflow

4.8.6.1 Computations for Suspended Sediment Load

Suspended Sediment inflow to the reservoir has been computed by using suspended sediment load from regional analysis considering sediment discharge data of eight sediment gauging stations in the Chitral region of Pakistan having similar hydro-meteorological characteristics. List of the sediment gauging stations along with their length of data record, average annual suspended sediment loads and average specific suspended sediment discharges are given in Table 4.28.

The result of the sediment regional analysis is shown in Figure 4.49. Following equation was developed to estimate the Suspended sediment load as a function of watershed area.

$$(SSL) = 1X10^{-5}\ A^{1.4583} \qquad \textbf{(4.19)}$$

Using the developed equation for an area of 1015 km^2, the suspended sediment load for the Uchhatur stream gauging station has been worked out to 0.242 M Tons per annum.

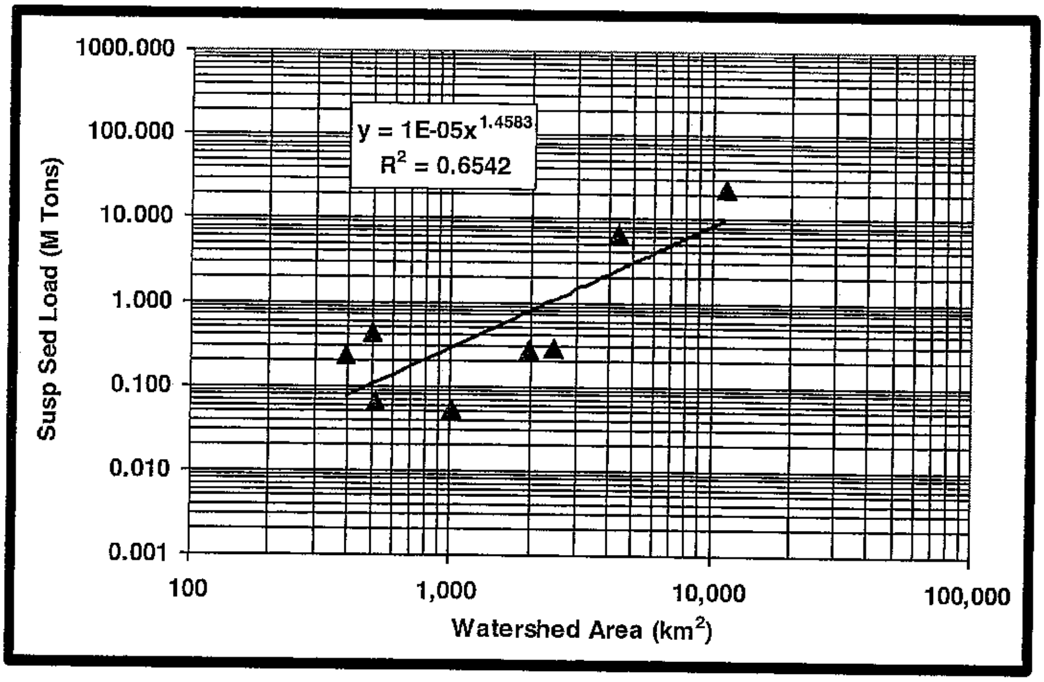

Figure 4.49: Regional Analysis for Suspended Sediment Yield in the Chitral Region

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For computing the temporal distribution of mean monthly sediment loads at the Uchhatur, the temporal distribution of the observed suspended sediments loads at Uchhatur were used.

Table 4.29 gives the values of observed mean monthly and annual suspended sediment loads for the Uchhatur gauging site from 2006 to 2013. The observed mean annual suspended sediment load at the gauging site is computed as 0.071 M Tons.

For the purpose of present analysis, observed mean monthly and annual values of SSL for Chitral gauging station and Arkari gauging station have been utilized. The observed mean monthly suspended sediment loads for the Chitral strean gauging station are shown in Table 4.30, which shows that mean annual suspended sediment load on the basis of 05 years (2006-2010) is 25.884 M Tons.

Table 4.30: Collected Suspended Sediment loads at Chitral Gauging site

Observed Monthly Suspended Sediments at Chitral (06-10)																
S. No.	Year	Monthly Suspended Sediment (Tons)												Annual Susp Sed		
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	M Tons	MCM	AF
1	2006	51,768	39,180	38,474	57,383	419,897	714,159	2,151,834	2,116,403	412,075	121,404	75,165	58,445	6.256	6.473	5,248
2	2007	20,309	13,996	19,266	184,842	888,791	6,790,300	14,629,800	7,040,411	1,487,715	187,606	77,443	43,942	31.384	32.470	26,328
3	2008	25,949	18,087	18,546	29,418	451,562	7,556,246	8,925,975	7,428,504	491,815	105,305	34,932	22,886	25.109	25.978	21,064
4	2009	27,963	21,071	26,560	37,453	154,642	422,488	2,596,042	2,559,499	557,505	119,020	54,389	38,636	6.615	6.844	5,549
5	2010	24,682	25,418	29,179	103,427	733,457	4,402,458	24,069,882	28,105,437	2,092,224	271,970	117,973	77,252	60.053	62.131	50,378
Maximum		51,768	39,180	38,474	184,842	888,791	7,556,246	24,069,882	28,105,437	2,092,224	271,970	117,973	77,252	60.053	62.131	50,378
Minimum		20,309	13,996	18,546	29,418	154,642	422,488	2,151,834	2,116,403	412,075	105,305	34,932	22,886	6.256	6.473	5,248
Mean		30,134	23,550	26,405	82,504	529,670	3,977,130	10,474,707	9,450,051	1,008,267	161,061	71,980	48,232	25.884	26.779	21,713
Standard Dev.		12,415	9,683	8,157	64,011	286,921	3,323,679	9,162,910	10,714,226	746,691	69,739	30,973	20,611	22.107	22.872	18,545

A correlation was developed between mean monthly suspended sediment loads of Uchhatur (2006-2013) and mean monthly suspended sediment loads of Chitral sediment station (2006-2010). The developed graphical correlation is shown in Figure 4.50 and its best fit equation is given in Equation (4.20).

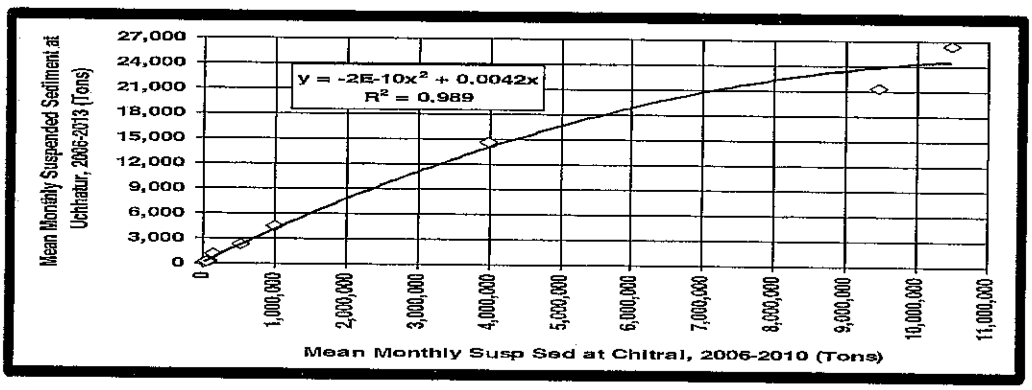

Figure 4.50: Correlation between mean monthly suspended sediment loads at Uchhatur and Chitral stream gauging stations.

$$(SSL)_{Uchhatur} = -2X10^{-10}\ (SSL)_{Chitral} + 0.0042\ (SSL)_{Chitral} \tag{4.20}$$

Utilizing long term suspended sediment data record at Chitral (1964-2010) as shown in Table 4.31, long term suspended sediment data at the Uchhatur stream gauging station was developed. On the basis of 47 years data record, the mean annual suspended sediment load at Chitral stream gauging station is worked out as 23.087 M Tons.

Table 4.31: Observed Suspended Sediment Loads at Chitral Stream Gauging Station

Observed Monthly Suspended Sediments at Chitral (64-10)																
S. No.	Year	Monthly Suspended Sediment (Tons)												Annual Susp Sed		
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	M Tons	MCM	AF
1	1964	6,245	4,398	5,670	14,324	23,091	541,362	1,981,555	4,723,907	795,178	52,917	18,908	12,143	8.180	8.463	6,862
2	1965	11,615	7,786	9,575	21,525	380,385	2,843,140	7,658,402	3,306,131	347,793	99,922	26,141	15,832	14.728	15.238	12,355
3	1966	26,159	17,752	20,775	48,930	185,475	3,971,034	5,482,315	5,113,149	702,823	146,514	65,322	39,709	15.820	16.367	13,271
4	1967	14,283	10,220	9,111	20,907	67,392	1,417,452	5,733,231	5,777,034	949,614	72,764	33,312	22,318	14.128	14.616	11,851
5	1968	8,908	5,968	5,887	12,243	58,013	1,418,821	6,152,173	4,294,974	326,291	60,784	28,928	16,293	12.389	12.818	10,393
6	1969	14,029	12,123	18,291	57,466	227,367	1,788,816	7,823,984	7,483,987	478,451	83,330	29,990	21,406	18.039	18.663	15,133
7	1970	84,415	62,480	62,634	115,017	585,121	2,739,422	3,965,673	5,805,917	3,118,526	389,603	161,327	105,341	17.195	17.790	14,425
8	1971	16,656	11,802	13,700	19,490	323,508	4,673,256	6,345,307	6,060,744	896,235	96,925	75,759	57,834	18.591	19.234	15,596
9	1972	39,709	30,010	33,485	50,116	211,796	2,824,391	5,383,777	5,206,177	1,145,607	100,932	36,964	21,930	15.085	15.607	12,654
10	1973	41,810	31,889	35,644	128,245	979,843	6,562,306	15,348,352	9,222,241	2,815,245	196,268	101,267	56,262	35.519	36.748	29,796
11	1974	14,200	11,232	15,432	23,581	89,140	1,682,857	7,218,434	5,096,563	536,156	51,724	22,813	14,101	14.776	15.287	12,395
12	1975	4,695	3,314	3,562	15,315	207,588	2,999,171	9,948,181	12,839,105	1,563,102	73,673	21,074	12,451	27.691	28.649	23,230
13	1976	13,914	9,155	8,736	28,865	250,974	1,704,009	12,927,043	8,006,854	1,517,621	106,357	33,423	18,206	24.625	25.477	20,658
14	1977	4,436	3,030	3,364	3,912	40,248	3,230,922	13,035,154	9,568,264	297,742	50,886	10,626	5,540	26.254	27.162	22,024
15	1978	16,828	11,150	11,897	26,427	147,043	1,515,501	3,426,922	2,675,503	602,054	144,504	42,195	26,553	8.647	8.946	7,253
16	1979	8,402	6,060	5,769	22,273	64,436	603,298	2,065,141	1,653,128	232,072	60,997	27,459	18,359	4.765	4.930	3,998
17	1980	29,567	19,442	15,250	45,744	278,621	3,824,635	10,925,734	8,056,474	1,561,587	139,763	49,447	33,303	24.980	25.844	20,955
18	1981	18,571	12,828	12,190	41,332	638,489	2,470,854	11,981,413	8,481,180	1,119,395	186,066	51,363	28,376	25.042	25.908	21,007
19	1982	25,450	14,660	13,559	31,451	148,862	1,171,693	4,619,481	11,328,391	824,309	104,526	38,384	26,180	18.347	18.982	15,391
20	1983	34,484	24,155	21,570	33,785	273,466	1,953,935	7,277,206	12,716,233	3,240,707	267,419	99,009	58,504	26.000	26.900	21,811
21	1984	34,130	23,873	24,208	45,781	282,186	6,952,013	11,446,868	15,978,681	2,542,899	163,972	69,586	46,445	37.613	38.914	31,552
22	1985	21,929	16,627	18,385	23,286	102,860	2,081,764	14,320,310	9,526,520	1,807,863	228,925	55,700	38,346	28.243	29.219	23,692
23	1986	21,552	11,891	12,624	21,876	145,569	1,879,971	12,123,619	8,568,813	788,552	210,229	53,425	29,769	23.888	24.714	20,039
24	1987	56,745	37,336	44,302	112,051	299,498	1,807,265	5,264,230	7,195,821	3,180,786	298,143	128,809	82,576	18.508	19.148	15,526
25	1988	72,044	48,642	53,804	249,014	1,241,630	6,102,286	18,760,424	11,300,620	1,498,433	402,157	150,632	92,147	39.972	41.355	33,532
26	1989	36,467	25,077	26,371	38,772	230,464	2,170,346	7,409,325	5,775,342	1,118,603	322,049	112,833	61,542	17.327	17.927	14,535
27	1990	75,276	55,636	65,467	94,979	1,327,075	4,327,535	11,342,779	9,522,722	4,531,116	809,046	185,693	107,508	32.445	33.567	27,217
28	1991	61,273	50,095	59,619	91,856	229,423	3,333,670	11,804,306	10,882,952	3,987,378	525,958	218,333	132,082	31.377	32.462	26,321
29	1992	65,616	46,677	44,229	89,690	576,491	4,041,300	19,288,171	13,121,333	3,682,706	435,896	142,233	92,300	41.627	43.067	34,920
30	1993	178,303	118,962	136,027	252,029	964,020	4,198,187	10,122,972	5,750,758	3,316,307	524,068	248,053	177,179	25.987	26.886	21,800
31	1994	30,107	18,787	22,322	48,308	275,611	4,249,428	22,873,996	16,530,699	2,328,713	204,644	95,521	62,603	46.741	48.358	39,210
32	1995	87,595	56,316	57,374	91,529	229,695	4,663,996	16,626,446	9,254,544	1,518,091	542,753	191,572	115,240	33.435	34.592	28,048
33	1996	202,520	149,048	176,573	368,303	1,695,932	4,968,265	7,204,450	9,756,147	3,043,762	832,724	435,846	296,384	29.130	30.138	24,437
34	1997	85,509	60,361	58,952	133,570	408,186	2,866,080	15,998,722	7,512,653	2,156,828	452,839	149,506	97,036	29.980	31.017	25,150
35	1998	68,712	51,380	49,185	122,986	565,968	1,851,894	13,529,127	7,844,172	2,078,401	465,056	158,356	106,173	26.891	27.822	22,559
36	1999	59,946	39,712	39,021	83,056	733,523	3,379,371	9,564,203	7,582,819	2,210,735	378,302	135,385	93,017	24.299	25.140	20,384
37	2000	20,081	13,076	12,440	27,159	453,803	2,113,963	9,764,977	4,953,546	1,808,865	115,972	44,349	21,286	19.350	20.019	16,232
38	2001	31,748	23,352	25,477	29,967	204,138	782,626	1,652,546	996,916	362,235	88,337	50,871	35,755	4.284	4.432	3,594
39	2002	22,166	16,291	17,638	33,199	131,835	965,566	1,301,657	1,587,003	362,739	111,601	44,146	30,251	4.624	4.784	3,879
40	2003	23,949	17,970	20,535	35,141	63,332	438,464	1,133,504	633,010	246,479	75,666	48,098	36,199	2.772	2.868	2,326
41	2004	69,347	50,930	54,187	87,947	331,750	1,273,710	2,071,273	1,786,850	798,337	232,138	132,938	99,169	6.989	7.230	5,863
42	2005	81,322	56,553	72,606	245,497	932,363	9,551,848	29,630,989	13,461,371	4,416,088	552,412	227,801	136,520	59.365	61.419	49,800
43	2006	51,768	39,180	38,474	57,383	419,897	714,159	2,151,834	2,116,403	412,075	121,404	75,165	58,445	6.256	6.473	5,248
44	2007	20,309	13,996	19,266	184,842	888,791	6,790,300	14,629,800	7,040,411	1,487,715	187,606	77,443	43,942	31.384	32.470	26,328
45	2008	25,949	18,087	18,546	29,418	451,562	7,556,246	8,925,975	7,428,504	491,815	105,305	34,932	22,886	25.109	25.978	21,064
46	2009	27,963	21,071	26,560	37,453	154,642	422,488	2,596,042	2,559,499	557,505	119,020	54,389	38,636	6.615	6.844	5,549
47	2010	24,682	25,418	29,179	103,427	733,457	4,402,458	24,069,882	28,105,437	2,092,224	271,970	117,973	77,252	60.053	62.131	50,378
Maximum		202,520	149,048	176,573	368,303	1,695,932	9,551,848	29,630,989	28,105,437	4,531,116	832,724	435,846	296,384	60.053	62.131	50,378
Minimum		4,436	3,030	3,364	3,912	23,091	422,488	1,133,504	633,010	232,072	50,886	10,626	5,540	2.772	2.868	2,326
Mean		42,370	30,123	32,967	74,457	409,671	3,060,044	9,678,934	7,749,138	1,614,846	239,661	93,900	60,411	23.087	23.885	19,367
Standard Dev.		39,886	28,318	32,568	75,836	373,247	2,087,826	6,415,703	4,903,194	1,206,501	195,569	80,029	53,189	13.242	13.701	11,109

Computed mean annual suspended sediment load at the Uchhatur gauging site comes to 0.055 M Tons. To bring this value to the value of suspended sediment load obtained by the regional analysis, these values were multiplied by a factor of (0.242/0.055). Further to transform this sediment load to the Arkari weir site a multiplication factor of (1036/1015) is used. Final equation to compute suspended sediment load at weir site Equation (4.21) is proposed.

$$(SSL)_{weir} = \left(\frac{0.242}{0.055}\right)\left(\frac{1036}{1015}\right)[-2X10^{-10}\ (SSL)_{Chitral} + 0.0042\ (SSL)_{Chitral}] \qquad (4.21)$$

Computed mean monthly suspended sediment loads and annual suspended sediment loads for the Arkari weir site are shown in Figure 4.51 and 4.52, respectively.

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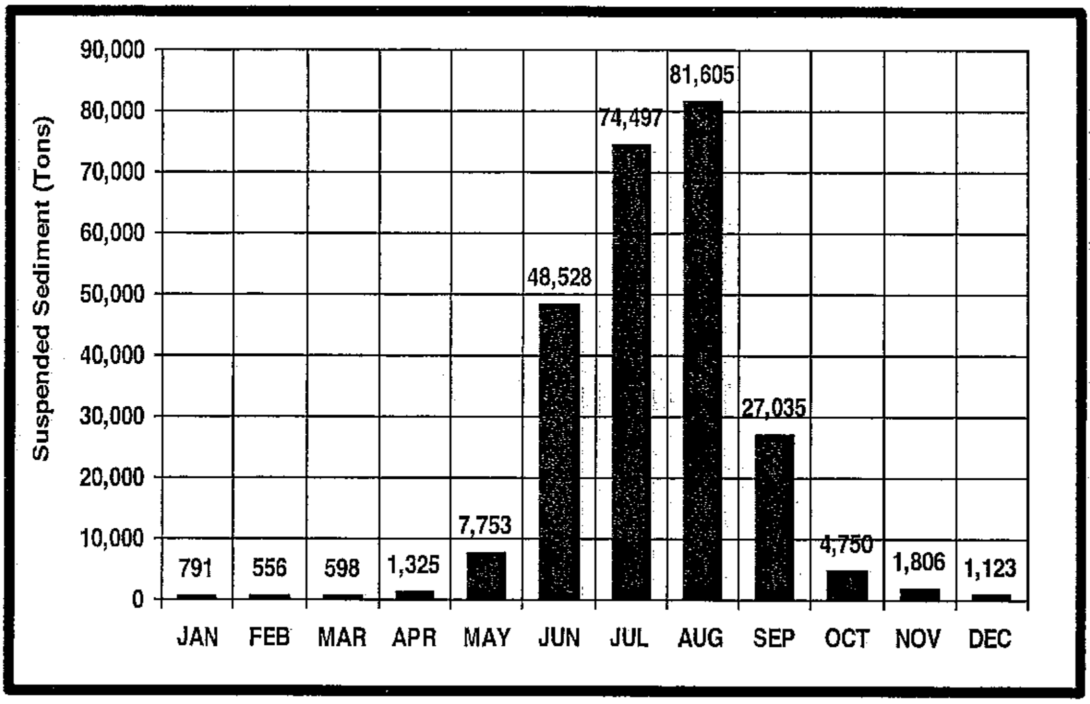

Figure 4.51: Computed mean monthly suspended sediment loads at Arkari weir site

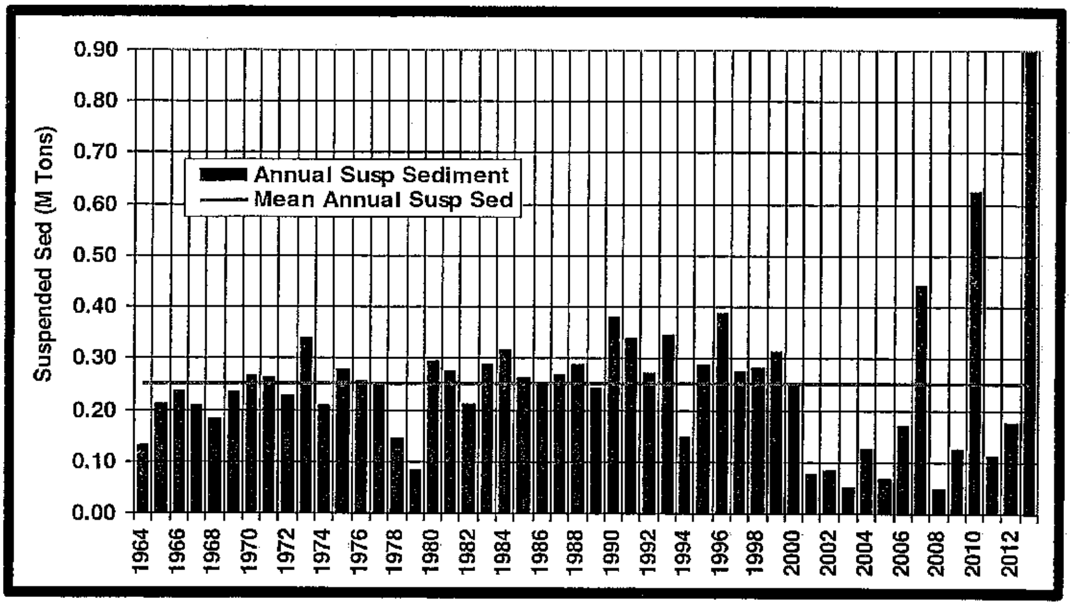

Figure 4.52: Computed annual suspended sediment loads at Arkari weir site

Figure 4.51 shows that the mean monthly suspended sediment load is lowest in February and highest in August with values of 556 and 81,605 Tons, respectively.

Figure 4.52 depicts that year 2008 contained minimum annual suspended sediment load and year 2010 maximum. On the basis of long term data record of 50 years (1964-2013), the mean annual suspended sediment load at the Arkari

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weir site has been estimated as 0.25 M Tons.

Taking the specific weight of freshly deposited sediments same as at Chitral as 982.4 kg /m^3 (61.3 Lbs/cft), the computed mean annual suspended sediment load for the Arkari weir site comes to 0.259 MCM.

4.8.6.2 Bed Load Computations

Bed load is the rate of movement of sediment particles along stream bed in the processes of rolling, sliding and/or hopping (saltation). Generally, amount of bed load transported by a large, deep river is about 5 to 25 % of the suspended load (Simon, 1992).

Bed loads for Arkari weir site were computed on daily basis for entire temporal range of one year for which average suspended sediment discharge data is available. Bed load computations were made by using Meyer Peter & Muller formula, Parker formula, Einstein-brown formula, Duboys formula and Shields formula. It has been noticed that these formulae are either estimating extremely high values of the bed load, or very little, therefore could not be applied directly for the present case.

For the purpose of this study bed load has been estimated by using the state of the art guide lines provided by USBR, 1987, i.e. Modified Einstein Procedures for Unmeasured Sediment load.

A useful guide for evaluating the unmeasured sediment load is the bed load correction shown in Table 4.32 (Bureau, 1987). Five conditions are given for defining bed load depending upon suspended sediment concentration and size analysis of stream bed and suspended materials.

Table 4.32: Modified Einstein's Bed Load Transport Rate Guidelines

Condition	Suspended sediment concentration (mg/L)	Stream bed material	Texture of suspended material	Percentage bed load in terms of suspended load
[1]1	<1000	Sand	20 to 50% sand	25 to 150
[1]2	1000 to 7500	Sand	20 to 50% sand	10 to 35
3	>7500	Sand	20 to 50% sand	5
[2]4	Any concentration	Compacted clay, gravel, cobbles, or boulders	Up to 25% sand	5 to 15
5	Any concentration	Clay and silt	No sand	<2

1- Special sampling program for Modified Einstein computations required under these conditions.

2- A bed load sampler such as the Helley-Smith bed load sampler may be used, or computations made by use of two or more of the bed load equations when bed material is gravel or cobble size.

According to Modified Einstein procedure, condition 4 of Table 4.32 of bed load correction is very close to site conditions. Hence, recommended %age of bed load in terms of suspended load is 5 to 15%.

Considering the site conditions and to be on conservative side an upper value was selected for the assessment of the bed load, hence Modified Einstein procedure with 15% of total suspended load is recommended for estimation of bed load for the weir site.

Average annual bed load for Arkari weir site is thus recommended as = 0.25 x 0.15 = 0.0375 M Tons (0.039 MCM).

4.8.6.3 Total Sediment Inflow to the Arkari Reservoir

Finally total sediment inflow to the weir site were computed by adding the bed load and suspended sediment load as follows:

$$(TSL)_{weir} = (SSL)_{weir} + (BL)_{weir} = 1.15\ (SSL)_{weir} \quad (4.22)$$

The summary of computed sediment loads at Arkari weir site is shown in Table 4.33. The computed mean annual total sediment inflow to the Arkari reservoir has been estimated as 0.288 M Tons (0.297 MCM).

Table 4.33: Summary of Computed Sediment Loads for Arkari Weir Site

S. No.	Item	Value	Units	Value	Units
1	Mean Annual Susp Load	0.25	M Tons	0.259	MCM
2	Mean Annual Bed Load	0.0375	M Tons	0.039	MCM
3	**Total Mean Annual Sed Load**	**0.288**	**M Tons**	**0.297**	**MCM**

4.8.7 Life of Reservoir without Flushing Option

Methods for estimating reservoir trap efficiency are empirically based upon measured sediment deposits in a large number of reservoirs. The most famous methods are Brune Envelope Curve method (1953) and M. A. Churchill method (1948). M. A. Churchill developed a relationship between percentage of incoming sediment passing through a reservoir and sedimentation Index of reservoir.

Trap efficiency of a reservoir primarily depends upon fall velocity of sediment particle and on rate of flow through reservoir. Particle fall velocity may be influenced by the size and shape of particles, their specific gravity, viscosity of water, temperature and the chemical composition of water. Rate of inflow through reservoir is determined by the volume of inflow with respect to available storage and by rate of outflow.

For present study, trap efficiency of Arkari reservoir is computed by using Churchill curve method which is more suitable for small and continuously sluiced reservoirs. Trap efficiency of the reservoir was also computed considering the percentage of sands and material coarser than sands in the total sediment load.

The reservoir capacity is 2.155 MCM (1748 AF), whereas average annual inflow for Arkari weir site is about 536.7 MCM (0.435 MAF), ratio between the two is 0.004, consulting Churchill curve (Bureau, 1987), trap efficiency comes out to 35 %, and then trap efficiency reduces with age.

A very important factor in determining the trap efficiency of the reservoir is the percentage of coarser materials (sands and coarser than sands). The average percentage of sands in suspension was taken as 57 % of the suspended load as recorded at Uchhatur stream gauging station. As bed load is 15 % of suspended load, hence, percentages of suspended load and bed load would be 87 and 13 %, respectively of the total sediment load at the weir site. As bed material gradation curves show that about 99% material is coarser than the sands, hence bed load percentage coarser than sands would be 12.9 %. The percentage of sands in suspension would be 49.6. Thus the total percentage of coarser materials would be 62.5 % of the total sediment load, the same is taken as trap efficiency of the reservoir.

The life of the Arkari reservoir without considering any flushing operation on the basis of fixing trap efficiency of 62.5 % for all years, which is more realistic value, comes equal to 09 years. The calculations for the reservoir life are presented in Table 4.34.

Table 4.34: Life of Arkari Reservoir without Flushing based on constant Trap Efficiency

Year	MAF	Res Cap	Ratio	Trap Eff	Trap Vol.	Res Cap	
	(MCM)	(MCM)		(%)	(MCM)	(MCM)	(%)
1	536.7	2.155	0.0040	62.5	0.186	1.969	91.39
2	536.7	1.969	0.0037	62.5	0.186	1.784	82.77
3	536.7	1.784	0.0033	62.5	0.186	1.598	74.16
4	536.7	1.598	0.0030	62.5	0.186	1.413	65.55
5	536.7	1.413	0.0026	62.5	0.186	1.227	56.93
6	536.7	1.227	0.0023	62.5	0.186	1.041	48.32
7	536.7	1.041	0.0019	62.5	0.186	0.856	39.70
8	536.7	0.856	0.0016	62.5	0.186	0.670	31.09
9	536.7	0.670	0.0012	62.5	0.186	0.484	22.48
10	536.7	0.484	0.0009	62.5	0.186	0.299	13.86

Hence the computed life of Arkari reservoir without considering any flushing option would be around 09 years. Therefore, flushing of the sediments through the reservoir would be essential to enhance the life of the reservoir to a feasible span thereby making the project feasible

4.8.8 Life of Arkari Reservoir with Flushing

For Arkari reservoir, flushing discharges are recommended from 20 to 40 cumecs. Considering the HEC-RAS Model results, it is revealed that during flushing process with a flushing discharge of 30 cumces, the minimum velocity of flow in the reservoir can flush sediment particles having diameters from 20 to 80 mm, average 40 mm as shown on the ASCE Task Committee Diagram for critical velocity.

Table 4.35: Life of Reservoir with Flushing Option

Year	MAF	Res Cap	Ratio	Trap Eff	Trap Vol.	Res Cap	
	(MCM)	(MCM)		(%)	(MCM)	(MCM)	(%)
1	536.7	2.155	0.0040	5.200	0.015	2.140	99.3
2	536.7	2.140	0.0040	5.200	0.015	2.124	98.6
3	536.7	2.124	0.0040	5.200	0.015	2.109	97.9
4	536.7	2.109	0.0039	5.200	0.015	2.093	97.1
5	536.7	2.093	0.0039	5.200	0.015	2.078	96.4
6	536.7	2.078	0.0039	5.200	0.015	2.062	95.7
7	536.7	2.062	0.0038	5.200	0.015	2.047	95.0
8	536.7	2.047	0.0038	5.200	0.015	2.031	94.3
9	536.7	2.031	0.0038	5.200	0.015	2.016	93.6
10	536.7	2.016	0.0038	5.200	0.015	2.001	92.8
11	536.7	2.001	0.0037	5.200	0.015	1.985	92.1
12	536.7	1.985	0.0037	5.200	0.015	1.970	91.4
13	536.7	1.970	0.0037	5.200	0.015	1.954	90.7
14	536.7	1.954	0.0036	5.200	0.015	1.939	90.0
15	536.7	1.939	0.0036	5.200	0.015	1.923	89.3
16	536.7	1.923	0.0036	5.200	0.015	1.908	88.5
17	536.7	1.908	0.0036	5.200	0.015	1.892	87.8
18	536.7	1.892	0.0035	5.200	0.015	1.877	87.1
19	536.7	1.877	0.0035	5.200	0.015	1.862	86.4
20	536.7	1.862	0.0035	5.200	0.015	1.846	85.7
21	536.7	1.846	0.0034	5.200	0.015	1.831	85.0
22	536.7	1.831	0.0034	5.200	0.015	1.815	84.2
23	536.7	1.815	0.0034	5.200	0.015	1.800	83.5
24	536.7	1.800	0.0034	5.200	0.015	1.784	82.8
25	536.7	1.784	0.0033	5.200	0.015	1.769	82.1
26	536.7	1.769	0.0033	5.200	0.015	1.753	81.4
27	536.7	1.753	0.0033	5.200	0.015	1.738	80.7
28	536.7	1.738	0.0032	5.200	0.015	1.723	79.9
29	536.7	1.723	0.0032	5.200	0.015	1.707	79.2
30	536.7	1.707	0.0032	5.200	0.015	1.692	78.5
31	536.7	1.692	0.0032	5.200	0.015	1.676	77.8
32	536.7	1.676	0.0031	5.200	0.015	1.661	77.1
33	536.7	1.661	0.0031	5.200	0.015	1.645	76.4
34	536.7	1.645	0.0031	5.200	0.015	1.630	75.6
35	536.7	1.630	0.0030	5.200	0.015	1.614	74.9
36	536.7	1.614	0.0030	5.200	0.015	1.599	74.2
37	536.7	1.599	0.0030	5.200	0.015	1.584	73.5

Year	MAF (MCM)	Res Cap (MCM)	Ratio	Trap Eff (%)	Trap Vol. (MCM)	Res Cap (MCM)	Res Cap (%)
38	536.7	1.584	0.0030	5.200	0.015	1.568	72.8
39	536.7	1.568	0.0029	5.200	0.015	1.553	72.1
40	536.7	1.553	0.0029	5.200	0.015	1.537	71.3
41	536.7	1.537	0.0029	5.200	0.015	1.522	70.6
42	536.7	1.522	0.0028	5.200	0.015	1.506	69.9
43	536.7	1.506	0.0028	5.200	0.015	1.491	69.2
44	536.7	1.491	0.0028	5.200	0.015	1.475	68.5
45	536.7	1.475	0.0027	5.200	0.015	1.460	67.8
46	536.7	1.460	0.0027	5.200	0.015	1.445	67.0
47	536.7	1.445	0.0027	5.200	0.015	1.429	66.3
48	536.7	1.429	0.0027	5.200	0.015	1.414	65.6
49	536.7	1.414	0.0026	5.200	0.015	1.398	64.9
50	536.7	1.398	0.0026	5.200	0.015	1.383	64.2
51	536.7	1.383	0.0026	5.200	0.015	1.367	63.5
52	536.7	1.367	0.0025	5.200	0.015	1.352	62.7
53	536.7	1.352	0.0025	5.200	0.015	1.336	62.0
54	536.7	1.336	0.0025	5.200	0.015	1.321	61.3
55	536.7	1.321	0.0025	5.200	0.015	1.306	60.6
56	536.7	1.306	0.0024	5.200	0.015	1.290	59.9
57	536.7	1.290	0.0024	5.200	0.015	1.275	59.2
58	536.7	1.275	0.0024	5.200	0.015	1.259	58.4
59	536.7	1.259	0.0023	5.200	0.015	1.244	57.7
60	536.7	1.244	0.0023	5.200	0.015	1.228	57.0
61	536.7	1.228	0.0023	5.200	0.015	1.213	56.3
62	536.7	1.213	0.0023	5.200	0.015	1.197	55.6
63	536.7	1.197	0.0022	5.200	0.015	1.182	54.9
64	536.7	1.182	0.0022	5.200	0.015	1.167	54.1
65	536.7	1.167	0.0022	5.200	0.015	1.151	53.4
66	536.7	1.151	0.0021	5.200	0.015	1.136	52.7
67	536.7	1.136	0.0021	5.200	0.015	1.120	52.0
68	536.7	1.120	0.0021	5.200	0.015	1.105	51.3
69	536.7	1.105	0.0021	5.200	0.015	1.089	50.6
70	536.7	1.089	0.0020	5.200	0.015	1.074	49.8
71	536.7	1.074	0.0020	5.200	0.015	1.058	49.1
72	536.7	1.058	0.0020	5.200	0.015	1.043	48.4
73	536.7	1.043	0.0019	5.200	0.015	1.028	47.7
74	536.7	1.028	0.0019	5.200	0.015	1.012	47.0
75	536.7	1.012	0.0019	5.200	0.015	0.997	46.3
76	536.7	0.997	0.0019	5.200	0.015	0.981	45.5
77	536.7	0.981	0.0018	5.200	0.015	0.966	44.8
78	536.7	0.966	0.0018	5.200	0.015	0.950	44.1
79	536.7	0.950	0.0018	5.200	0.015	0.935	43.4
80	536.7	0.935	0.0017	5.200	0.015	0.919	42.7
81	536.7	0.919	0.0017	5.200	0.015	0.904	42.0
82	536.7	0.904	0.0017	5.200	0.015	0.889	41.2
83	536.7	0.889	0.0017	5.200	0.015	0.873	40.5
84	536.7	0.873	0.0016	5.200	0.015	0.858	39.8
85	536.7	0.858	0.0016	5.200	0.015	0.842	39.1
86	536.7	0.842	0.0016	5.200	0.015	0.827	38.4
87	536.7	0.827	0.0015	5.200	0.015	0.811	37.7
88	536.7	0.811	0.0015	5.200	0.015	0.796	36.9

Year	MAF	Res Cap	Ratio	Trap Eff	Trap Vol.	Res Cap	
	(MCM)	(MCM)		(%)	(MCM)	(MCM)	(%)
89	536.7	0.796	0.0015	5.200	0.015	0.780	36.2
90	536.7	0.780	0.0015	5.200	0.015	0.765	35.5
91	536.7	0.765	0.0014	5.200	0.015	0.750	34.8
92	536.7	0.750	0.0014	5.200	0.015	0.734	34.1
93	536.7	0.734	0.0014	5.200	0.015	0.719	33.4
94	536.7	0.719	0.0013	5.200	0.015	0.703	32.6
95	536.7	0.703	0.0013	5.200	0.015	0.688	31.9
96	536.7	0.688	0.0013	5.200	0.015	0.672	31.2
97	536.7	0.672	0.0013	5.200	0.015	0.657	30.5
98	536.7	0.657	0.0012	5.200	0.015	0.641	29.8
99	536.7	0.641	0.0012	5.200	0.015	0.626	29.1
100	536.7	0.626	0.0012	5.200	0.015	0.611	28.3
101	536.7	0.611	0.0011	5.200	0.015	0.595	27.6
102	536.7	0.595	0.0011	5.200	0.015	0.580	26.9
103	536.7	0.580	0.0011	5.200	0.015	0.564	26.2
104	536.7	0.564	0.0011	5.200	0.015	0.549	25.5
105	536.7	0.549	0.0010	5.200	0.015	0.533	24.8
106	536.7	0.533	0.0010	5.200	0.015	0.518	24.0
107	536.7	0.518	0.0010	5.200	0.015	0.502	23.3
108	536.7	0.502	0.0009	5.200	0.015	0.487	22.6
109	536.7	0.487	0.0009	5.200	0.015	0.472	21.9
110	536.7	0.472	0.0009	5.200	0.015	0.456	21.2
111	536.7	0.456	0.0008	5.200	0.015	0.441	20.5

Modified Trap efficiency considering the flushing operation of the reservoir was determined based on the percentage of non flushable material in the total sediment load. Total flushable material was computed as the sum of flushable bedload and flushable suspended load. Total suspended load was assumed to be flushable which is 87 % of total sediment load. Bed load was assessed as 15% of suspended load or 13 % of the total sediment load. Assuming the percentage of particles lesser than 60 mm in the bed material is 7.8, so the flushable bed load comes equal to 7.5% of total sediment load. Therefore, total flushable material through the reservoir would be 94.8 % and the modified trap efficiency of the Arkari reservoir comes equal to 5.2%.

The life of reservoir was then computed using this modified trap efficiency value considering un-flushed material left in the reservoir and its accumulation over time. The life of the reservoir with flushing scenario comes equal to about 110 years as given in Table 4.35.

Flushing of the reservoir should be carried out at the rate of once per year of duration of 3 to 10 days depending on the volume of deposited material to be flushed and the magnitude of the flushing discharge.

4.8.9 Boulder Trap

Life of Arkari reservoir can be further extended beyond 110 years by adopting suitable watershed management options including construction of boulder trap or check dam particularly on river Arkari at the mouth of the Arkari reservoir. In this way bedload movement consisting of boulders can be stopped to enter into the reservoir. Dredging of the boulders at the upstream of the boulder trap is essentially required at the rate of once in two years.

Hence, for the Arkari reservoir Flushing and dredging strategy is required to prolong its life to a very large span. And construction of boulder trap and its occasional dredging from its reservoir is strongly recommended for further life enhancement.

4.8.10 Conclusions of Sedimentation Studies

Mean annual specific suspended sediment yield at Arkari weir site is about 241 Tons/km^2/year.

Mean annual suspended sediment load at the weir site is about 0.259 MCM.

The recommended density of deposited sediments is taken as 982.4 kg/m^3 (61.3 Pcf).

Mean annual bed load at the weir site is about 0.039 MCM.

Mean annual total sediment inflow to the Arkari reservoir is about 0.297 MCM.

Trap efficiency of reservoir computed on the basis of Churchill curve is 35 %. The recommended trap efficiency is 62.5 % based on total sands and coarser material.

Mean annual trapped sediment load in the proposed reservoir would be 0.015 MCM.

The life of the Arkari reservoir without considering any flushing would be only 09 years.

Flushing discharge required to carry out flushing of the reservoir would be 20 to 40 m^3/s, whereas flushing duration required would be around 3-10 days depending on the amount of deposited sediments to be flushed and the flow rate available for this purpose.
The life of the Arkari reservoir can be enhanced to about 110 years with appropriate flushing operations at the rate of one flushing per year in the month of August or whenever flushing discharges are available.

It is essential to construct a Boulder Trap at the upstream end of the proposed reservoir to stop the entry of boulders in the reservoir and to enhance further the reservoir life.

Dredging of the boulders from upstream of the boulder trap is recommended at the rate of once per two years to keep the reservoir life longer.

To carry out efficient flushing, the sediment delta in the reservoir should be monitored every year before flushing. Moreover, operator must be fully vigilant on the incoming forecasted flows in advance which may offer suitable flushing opportunity.

4.8.11 References

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4.9 Summary

The mean monthly temperatures at Chitral Gauging Station shows that July is the hottest month and January is the coldest month with highest and lowest mean monthly temperatures of 36.42 and -0.76 ^{O}C, respectively. At Chitral Climatological station, mean annual values of precipitation and relative humidity are estimated as 471.9 mm and 36.15 %, respectively.

Mean annual flows estimated for the Arkari stream gauging station, Arkari weir site and Arkari powerhouse site are 16.66, 17.02 and 17.41 cumecs, respectively.

As Statistical Approach looks best for the Arkari HPP site, hence flood magnitudes are recommended by this method. Table 4.24 contains the recommended flood magnitudes corresponding to various return periods for Arkari weir and powerhouse sites, and the recommended flood magnitudes corresponding to 1000 year return period are 562 and 571 cumecs, respectively

A stream gauging station was installed by the Consultants along river Arkari to measure flows for the Arkari weir site at Uchhatur Bridge which is situated at 200m upstream of the proposed weir site. Water and sediment discharge measurements were commenced at this station on 25th September 2012 and will remain continued up to completion of Feasibility Study Period.

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PART – I: GEOTECHNICAL INVESTIGATIONS

5.1.0 Introduction

GEOENGINEERS has been retained by CIV-TECH & EPAC on behalf of PHYDO to provide geotechnical engineering services in support of the feasibility study for the proposed Arkari Gol Hydropower Project.

The authorization to proceed and scope of work was communicated to GEOENGINEERS through letter dated November, 2012. In general, the scope of the geotechnical engineering services consisted of,

1. Field reconnaissance for planning of investigation program
2. Review of previous investigations and studies on the project area
3. Prepare surface and subsurface geological maps
4. Advance boreholes at project site
5. Conduct laboratory tests on the collected soil/rock samples.
6. Prepare geotechnical investigation and design report.

5.2.0 Site Description

The project area is located in Chitral district at Arkari Gol River in the northern part of Khyber Pakhtunkhwa (KPK), Pakistan between 35^0 to 37^0 Latitude and 71^0 to 74^0 Longitudes. The project area is identifiable on G.T. sheet no 37-P/12. The weir and the Powerhouse sites are located along Arkari Gol River with an approximate separation of 7 km. The approximate location of project site is presented in Figure 5-1. The weir and Powerhouse sites are accessible through Garam Chashma and Arkari Gol roads during the months of March to December. Locations along the tunnel alignment are accessible only by foot

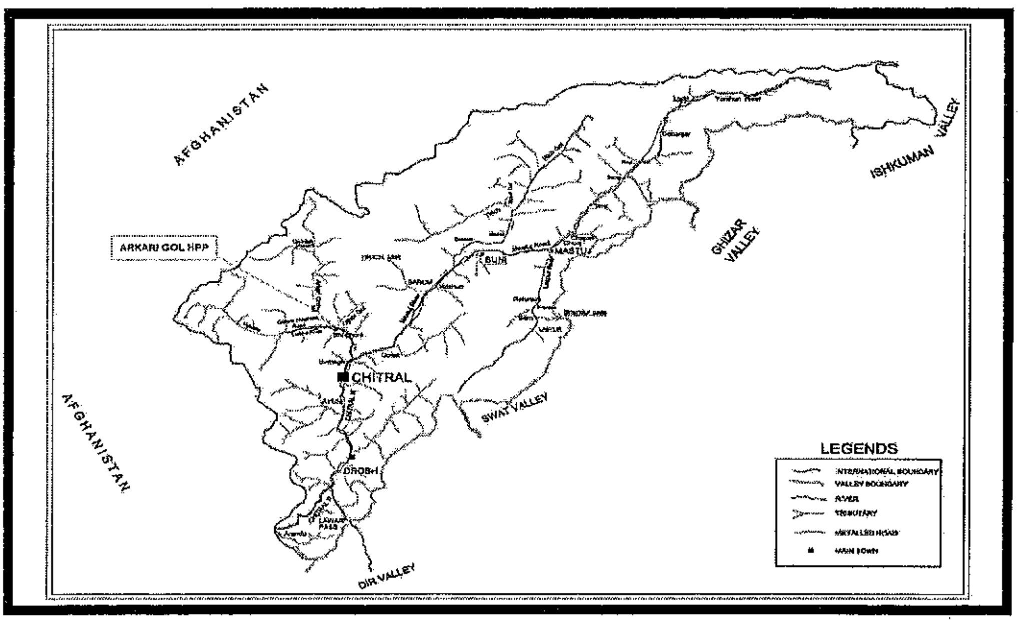

Figure 5-1: Showing the Location of Project Area

5.3.0 Subsurface Investigations

5.3.1 Previous Investigations

To harness the hydropower potential of 10 km lower stretch of Arkari Gol, GTZ, (German Agency for Technical Co-operation) identified a project layout on the right bank of Arkari River with powerhouse near Lutkho River. Arkari Gol is the left tributary of Lutkho River with confluence 25 km north east of Chitral town in District Chitral of Khyber Pakhtunkhwa Province.

The potential river stretch was studied two times to harness the indigenous resources. First under the study: "Regional Power Development of Lower Chitral" in 1988 to identify a scheme with firm capacity to meet the local power demand of Chitral valley. Then under the study "High Head power projects in Chitral" in 2001, the same river stretch was considered with a different project layout to utilize the summer flows for higher installed capacity. The identified potential project was studied along with other medium size projects for a probable interconnection with National grid.

Alternative project layouts have been considered in this study to plan a scheme for optimum utilization of potential resources with technically sound and economically viable project layout. The average gradient of River in the project area is about 4.5%. The identified layout involves a diversion weir with daily peaking storage, 6.0 km long low pressure tunnel and surface powerhouse near Lutkho River, 390 km from Peshawar and 520 km from Islamabad.

Arkari Gol in its lower 10 km stretch has steep river gradient of 44 m/km. To harness the hydropower potential of Arkari Gol, the potential site was studied twice by German Agency for Technical Co-operation (GTZ).

In 1988, Regional Power Development study was carried out with PHYDO on tributaries in Chitral valley to identify hydropower schemes to meet regional power demand of local load centres. All schemes identified in Upper and Lower Chitral was based on winter flows available 90% time of the year.

Arkari Gol Hydropower Project in 1988

The project layout was identified to in the study "Regional Power Development Study Lower Chitral" in 1988, prepared by Pakhtunkhwa Hydel Development Organization PHYDO, Government of NWFP in collaboration with GTZ, the German Agency for Technical Co-operation.

Two alternative layouts were studied with one weir axis and two location of powerhouse and listed as scheme no. 7 and 8 of that study. Both alternative layouts have a common weir intake 1 km upstream of Uchhatur village, 9 km from Arkari confluence with Lutkho river.

Scheme no. 8 has powerhouse within Arkari Gol valley upstream on Momi village. The elevation difference from intake to powerhouse has been checked with topographic has been found as 270 m against the gross head of 335 m mentioned in that study. Scheme no. is not found attractive as to utilize the potential of shorter river stretch.

Scheme no. 7 has powerhouse on the left bank of Lutkho River near Shoghore Ghari village, 3.5 km upstream of Arkari Gol confluence.

Uchhatur-Andakht Hydropower Project in 2001

The main weir as diversion structure is proposed on Arkari river near Uchhatur village at Latitude 36-03'-57" and Longitude 71- 41'- 37" about 8 km upstream of its confluence with Lutkho river at Andakht village. The weir site is located on Arkari River, near Uchhatur Village. At the weir site, rock is exposed on either side and the river width is more than the requirement for flood release. The rock in the river bed is assumed at more than 30 m. The river flows along the left bank and jeepable road is located along the right bank. The slope on either side varies from 60° to 70^0.

5.3.2 Current Investigations

GEOENGINEERS were engaged to conduct the geological and geotechnical investigations. The investigation program was carried out from December 2012. The program typically consisted of geological mapping, advancing of boreholes, Laboratory testing, Seismic Refraction Survey, 2-D imaging method with Dipole-Dipole survey (DES) and Electrical Resistivity Surveys (ERS). Following subsections presents the details of current investigations.

5.3.3 Geological Mapping

Geological mapping was based initially on the interpretation of remote sensing information including satellite imagery which provided a basic regional map identifying features such as regional structures, faults, joints, rivers, nullahs, streams, and general topography. Detailed geological mapping was carried out for major structures relevant to the selected project layout.

Areas of the individual project components were mapped at appropriate scales, such as 1:1000. The surface geological mapping was conducted with the help of hand held GPS and total station including the attitude of the bedding/foliations, type of the bed rock, marking of the folds, faults, joints attitude and traces. Geological maps, long sections, and cross section were then prepared indicating the type of rock; rock outcrops, soil-talus cover, alluvial deposits, dip and strike of faults, fractured zones, and unstable areas borrow and quarry areas, and pondage area. Rock and soil samples were collected at various locations and sent to the laboratory for further testing.

Potential sources of borrow materials were assessed to determine their suitability for use in construction. The extents of deposits were also mapped and the depths of the deposits were determined by test pits.

5.3.4 Boreholes

The field work for subsurface investigations for the proposed hydro project was carried out between December 2012 to November, 2013 using drill rigs supplied and operated by GEOENGINEERS. 4 no's of boreholes were drilled at the weir site, 4 no's of boreholes were drilled at the powerhouse site. The boreholes were advanced to depths ranging from 35 m to 60 m with a total drilling of 335 m for the project. The location plan of the boreholes is presented in Figures 5-2 to 5-4 and details of boreholes are presented in Table 5-1. The borehole logs are included in geotechnical investigation report in Appendix-IV.

Table 5-1: Depths and Location of Boreholes

S. No.	Borehole No.	Location	Depth (m)	Angle (^{0})
1	W-BH-01	Weir site	35 m	90^0
2	W-BH-02		50 m	90^0
3	W-BH-03		35 m	90^0
4	W-BH-04		40 m	90^0
5	PH-BH-01	Powerhouse	35 m	90^0
6	PH-BH-02		35 m	90^0
7	PH-BH-03		45 m	90^0
8	PH-BH-04		60 m	90^0

Boreholes were drilled using straight rotary drill rigs. A total of three drill rigs were deployed to carry out the drilling program. The boreholes were advanced by continuous coring utilizing NQ diameter, side discharge diamond bit and double tube core barrels. In sound rock single tube core barrels were also used. While drilling through the overburden at some locations, steel casing was used for stabilizing boreholes. The cores and the collected samples were stored in the core boxes for transportation to laboratories and further testing. During drilling, detailed field borehole logs were prepared by the site geologist and reviewed by the Chief

Geologist. Borehole logs generally included core recovery and Rock Quality Designation (RQD) percentage along with the detailed description of the encountered materials. A typical borehole log includes the following information:

- Borehole no., orientation, inclination and elevations
- Description of the stratigraphical units
- Length of runs and percentage of core recovery
- Rock Quality Designation (RQD)
- Rock types and degree of weathering

- Permeability values
- Water Pressure Test (WPT's)/Lugeon values in rock masses

5.3.5 In-Situ Testing

In-situ tests were performed during the drilling of boreholes to evaluate the strength and permeability of the subsurface stratigraphic units at regular intervals but not larger than 5 m. The following in-situ tests were carried out in the boreholes;

- Constant Head Permeability test (D 2434 - 68).
- Water pressure Permeability test (Lugeon value).
- Standard penetration tests (D 1586).

Water pressure Permeability test (Lugeon method) was performed and evaluated using procedures recommended by Hulson (1976). The field test was analyzed in the office and the permeability values were determined and recorded in the final borehole logs. Summary of the test
are given in the table 5-2.

Table 5-2: Details of Permeability Tests for Powerhouse and Weir Site

S. No.	Bore Hole	Depth (m)	Location	Constant Head (cm/sec)	Lugeon (LU)	Strata
01	PH-BH-01	05-------------------10	Powerhouse	-	Water loss	Phyllite
02		10-------------------15		-	Water loss	Phyllite
03		15-------------------20		-	8.05	Phyllite
04		20-------------------25		-	6.87	Phyllite
05		25-------------------30		-	5.20	Phyllite
06		30-------------------35		-	4.48	Phyllite
07	PH-BH-02	05-------------------10	Powerhouse	-	20.27	Phyllite
08		10-------------------15		-	11.89	Phyllite
09		15-------------------20		-	8.58	Phyllite
10		20-------------------25		-	6.42	Phyllite
11		25-------------------30		-	4.34	Phyllite
12		30-------------------35		-	3.72	Phyllite
13	PH-BH-03	05	Powerhouse	6.3 X 10^{-2}	-	Overburden
14		10		3.1 X 10^{-2}	-	Overburden
15		15		1.4 X 10^{-2}	-	Overburden
16		20		9.7 X 10^{-3}	-	Overburden
17		25		1.3 X 10^{-2}	-	Overburden
18		30		9.7 X 10^{-3}	-	Overburden
19		35		8.1 X 10^{-3}	-	Overburden
20		40		8.5 X 10^{-3}	-	Overburden
21		45		2.3 X 10^{-2}	-	Overburden
22	PH-BH-04	05	Powerhouse	2.6 X 10^{-2}	-	Overburden
23		10		2.1 X 10^{-2}	-	Overburden
24		15		1.4 X 10^{-2}	-	Overburden
25		20		1.0 X 10^{-2}	-	Overburden
26		25		1.1 X 10^{-2}	-	Overburden
27		30		2.0 X 10^{-2}	-	Overburden
28		35		1.5 X 10^{-2}	-	Overburden

29	PH-BH-04	40		7.3×10^{-3}	-	Overburden
30		45		2.1×10^{-2}	-	Overburden
31	WS-BH-01	00------------05	Weir site (Right Abutment)	-	48.49	Granite (Momi Gneiss)
32		05------------10		-	59.42	Granite (Momi Gneiss)
33		10------------15		-	22.72	Granite (Momi Gneiss)
34		15------------20		-	20.65	Granite (Momi Gneiss)
35		20------------25		-	11.81	Granite (Momi Gneiss)
36		25------------30		-	9.94	Granite (Momi Gneiss)
37		30------------35		-	13.54	Granite (Momi Gneiss)
38	WS-BH-02	05		1.4×10^{-2}	-	Overburden
39		10		3.8×10^{-3}	-	Overburden
40		15		3.8×10^{-3}	-	Overburden
41	WS-BH-03	05	Weir site (Left Abutment)	1.3×10^{-3}	-	Overburden
42		10		1.2×10^{-3}	-	Overburden
43		25--------------30		-	27.30	Granite (Momi Gneiss)
44		30--------------35		-	18.57	Granite (Momi Gneiss)
45	WS-BH-04	10	Weir site (Right Abutment)	6.8×10^{-3}	-	Overburden
46		15		3.8×10^{-3}	-	Overburden
47		20--------------25		-	32.15	Granite (Momi Gneiss)
48		25--------------30		-	22.06	Granite (Momi Gneiss)
49		30--------------35		-	18.74	Granite (Momi Gneiss)
50		35--------------40		-	16.92	Granite (Momi Gneiss)

5.3.6 Laboratory Testing

The samples of soils/ rocks collected during the geotechnical investigations were transported to the testing laboratories for specified tests. The testing facilities of Construction Works Organization (CWO) and Central Material Testing Laboratory (CMTL) were contracted for the laboratory tests.

Table 5-3 presents the details of laboratory testing for Rock, to evaluate the physical and chemical properties of the subsurface soil, surface/ground water, and construction materials. Laboratory tests were performed materials such as classification, strength / deformation characteristics, material permeability characteristics, potential suitability for use as fill material or as aggregate, and identification of deleterious materials. Laboratory test results are presented in geotechnical investigation report in Appendix-VI.

Table 5-3: Description of Laboratory Tests

Rock	Soil	water	Aggregate
-UCS Test -Porosity -Void index	-Gradation -Atterberg's Limits	-Organic matter -Sulphate content -Chloride content	-Specific Gravity -Absorption -Abrasion test

Table 5-3: Description of Laboratory Tests			
Rock	Soil	water	Aggregate
-Rock modulus -Tensile strength -Point Load Test -Direct Shear Test -Unit Weight -Petrography -Schmidt rebound		-pH value -TDS	-Soundness -Crushing value -Bulk density -Impact value -Gradation -Flakiness -Elongation -Petrography -AAR

5.3.7 Geophysical Surveys

Geophysical surveys conducted with seismic refraction survey method, 2-D imaging method and Electrical Resistivity Survey method.

Seismic Refraction survey conducted about 2000 m length at weir site, powerhouse and tunnel alignment. The geological sections and TX-plots are presented in appendix-IIIc in geotechnical investigation report. The details are given in following Table 5-4.

Table 5-4: Details of Seismic Refraction Survey for Project Area

S. NO.	PROFILE	LOCATION	PROFILE LENGTH (m)	REMARKS
01	GS: B - B′	Weir site	440	Detail results are given in Geotechnical Investigation report
02	GS: D - D′	Along tunnel route	240	
03	GS: F - F′		670	
04	GS: G - G′		260	
05	GS: I - I′	Powerhouse	390	

2-D imaging method with dipole – dipole survey (DES) conducted about 2000 m length at weir site, powerhouse and tunnel alignment. The locations are presented in figure 5-2 to 5-4. The lithological sections along DES profiles are presented in geotechnical investigation report in Appendix-IIIb. The details are given in following Table 5-5.

Table 5-5: Details of 2-D Imaging Method with Dipole-Dipole Electrical Survey (DES)

S. NO	LOCATION	DES PROFILE	DES PROFILE LENGTH (m)
01	Weir site	GS – B	300
02	Powerhouse	GS – D	120
03		GS – E	120
04	Tunnel route	GS – F	280
05		GS – G	260
06		GS – H	240
07		GS – I	360
08		GS – J	260

Electrical Resistivity survey was performed at the weir, powerhouse sites and along the tunnel alignment. A total of twenty eight (28) locations were surveyed using ERS. The locations of ERS are presented in Figures 5-2 to 5-4. Electrical Resistivity Surveys were conducted using Schlumberger electrode configuration. Lithological columns are presented in appendix-IIIa in geotechnical investigation report.

The geophysical surveys were used to obtain additional information on the depth of overburden, extent of moderately weathered rock and top of sound rocks at the specific locations of project, and to supplement borehole investigations.

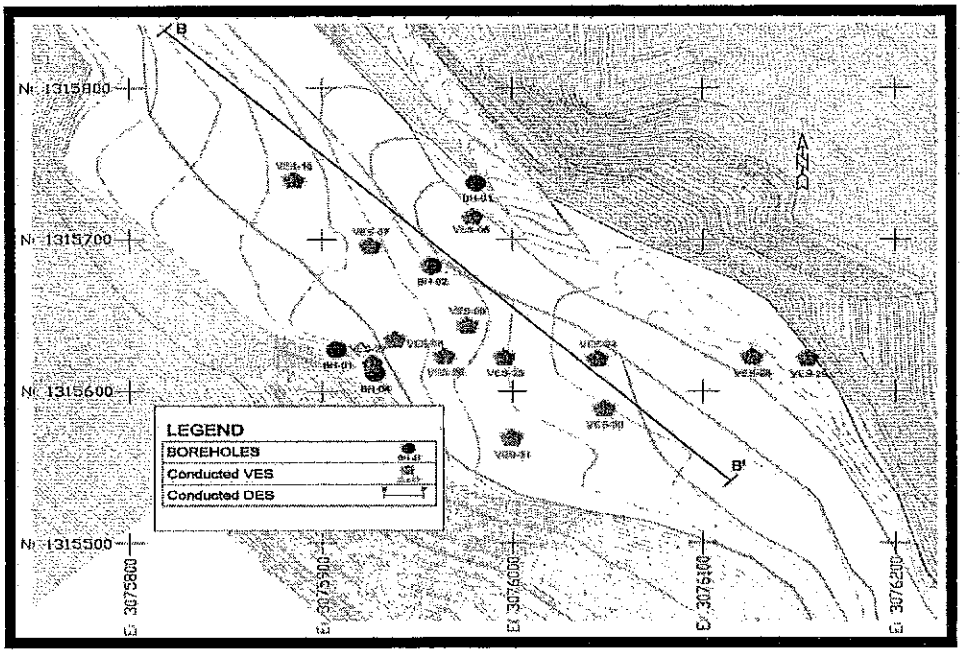

Figure 5-2: Location of Boreholes, DES and ERS at Weir Site

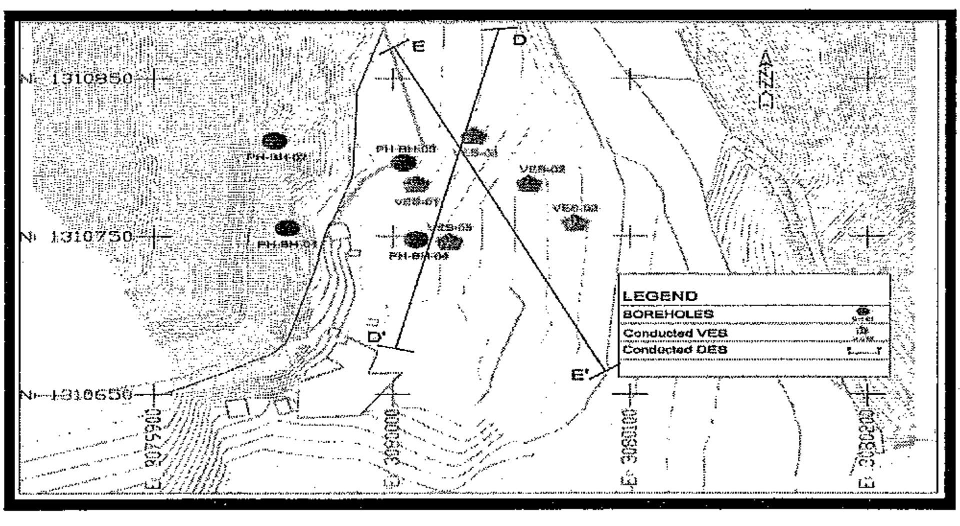

Figure 5.3 Location of Boreholes, DES & ERS at Powerhouse Site

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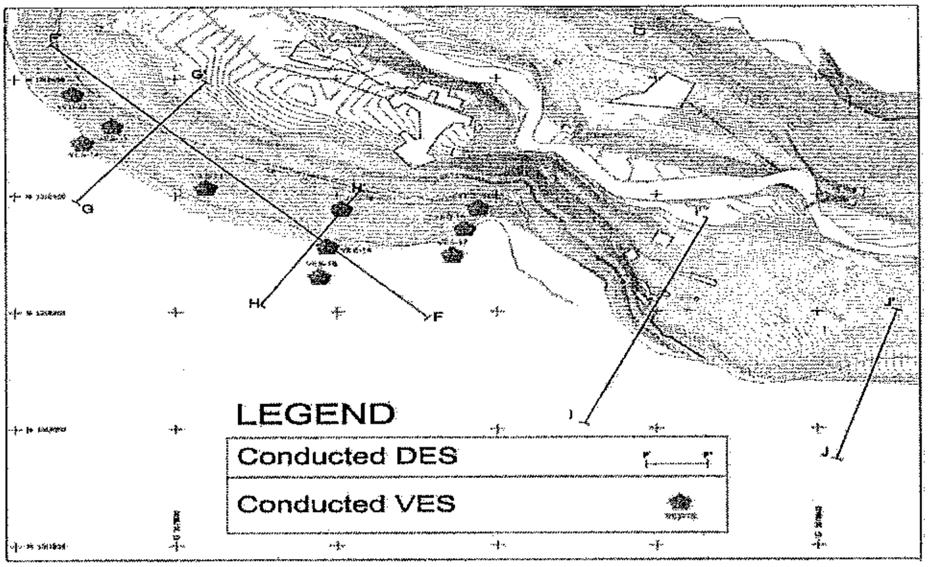

Figure 5-4: Location of DES and ERS along the Tunnel Alignment

5.4.0 Site Geology and Subsurface Conditions

5.4.1 Regional and Site Geology

Geographically the Chitral region occupies the northeastern extremities of 1200 km long Hindu Kush range where it represents a diffuse boundary with the Karakorum Range at Hindu Raj mountain chain, east of Yarkhun valley. Technically the area represents the western extremities of Himalayan Orogenic belt. Geologically the region comprises thick upper Paleozoic to Mesozoic and Tertiary tectono Stratigraphic sedimentary and volcano plutonic sequences

The entire Chitral district comprises of meta-sediments intruded by igneous bodies of acidic and basic composition. The Meta sediments include the slates, schist, gneisses an quartzite. These usually form the deeply curved valleys. The igneous rocks are dominantly granite, Granodiorite, amphibolites, Volcanics, gabbros and peridotite. The higher ranges and peaks i-e. Tirich Mir 7708m and BuniZom 6552m are of igneous bodies.

The North-Western unit is composed of the Paleozoic Meta sediments, which have been intruded by the Hindu Kush granitoids. The Meta sediments include the Charan quartzite, Shogram formation, Sarikol shales, Wakhan formation, Atark unit and isolated quartzite and minor limestone of Ordovician age.

The Central unit between the Reshun fault and Main Karakoram Thrust (MKT) is composed of Mesozoic meta sediments included by the Western Karakoram granitoids bodies. The Wakhan formation, green schist, Chitral slates and the Reshun formation are included in this unit. The Melange zone between the Eurasian and Indian plates is composed of Volcanics, sedimentary and serpentine blocks in slate matrix.

The South-Eastern block i.e. the Kohistan block consists of cretaceous meta sediments and Volcanics intruded by granites, Tonalite, diorites and Kohistan batholiths. Geologically, and in particular tectonically, Chitral and its surroundings are characterized by a suture zone between the Asian and Indian Plate. The southern continental margin of the Asian plate and the Cretaceous Kohistan Island Arc are colliding here. The resulting Middle Cretaceous Northern Suture runs as a wide Melange zone along the north-south trending Shishi Valley. It contains green and calcareous Schist, Clastic material, Meta volcanic and Carbonatic rocks.

The lithological content of the Asian Plate in Chitral is determined by thick more or less metamorphic Paleozoic to Lower Mesozoic sedimentary series intruded by (Cretaceous to) Tertiary Magmatites. The southern rim of this plate is basically formed by two tectonic units (Northwest Unit and Central Unit), which are separated by a steeply north-dipping fault and the Reshun Fault. It is also the border line between the Paleozoic sediments and the Cretaceous carbonates (Desio1963, Buchroithner and Gamerith1986).

The so-called Kohistan Island Arc is mainly formed by the Kohistan Batholith, an Upper Cretaceous Paleocene gabbro diorite to granite. This pluton intruded from south to north into various Paleozoic to Lower Mesozoic formations. More details on the geology of the area can be taken from the three theses of Kriegl (1991), Heiss (1992), and Bauer (1994) as well as from Buchroithner and Gamerith (1986) and Pudseyet al. (1985). The geological map compiled by Zanchi *et alii*, (2000) is old but not yet too much outdated and gives an excellent overview over the whole region of Gilgit, Chitral and the Wakkan.

Geology of the Chitral region, in a broad sense, is represented by the occurrences of thick Paleozoic to Mesozoic sedimentary series of Hindukush Karakoram (Asia) plate to the north, and a dominant Cretaceous volcano-sedimentary sequence to the south(figure-5.5). The Paleozoic to Mesozoic rock belts were strongly compressed and tectonically folded and faulted during the Cretaceous-Teritiary orogenic activites and were subjected to the emplacement of subduction related volcano plutonic complexes.

From North to South the following Stratigraphic- tectonic units can be distinguished in Chitral.

- Mesozoic sequence (Arkari Series)
- Paleozoic sequence (Series of Owir)
- Paleozoic to Triassic (Wakhan Formation)
- Cretaceous to Tertiary (Reshun Formation)
- Cretaceous to Tertiary (Chitral Slates)
- Upper Paleozoic (Golen Gol Series)
- Cretaceous to Tertiary (Shishi Series)

Stratigraphic unit in the project area are as:

- Wakhan formation
- Tirich Mir Granite

5.4.2 Regional Tectonic Structures

Regional tectonic setting of the Chitral district is characterized by the continental collision between Eurasian Plate, Indian Plate and the intervening Kohistan Island arc (Fig-5-6).

The Chitral district has three main mountain ranges, known as Hindu Kush, Karakoram and Kohistan.

The Hindu Kush and Karakoram ranges are the parts of Eurasian plate while the Kohistan range is part of Indian plate. The Indian plate is under thrusted and the Eurasian plate is upper thrusted. Both the plates are separated by a Main Karakoram Thrust (MKT) which trends in NE-SW direction, through Shishi valley, Rizhun Gol and passes through Harchin from Chitral district. The crushing zone between the MKT and Kohistan is known as Northern Suture Mélange zone (NSM).

On the basis of structural evolution the Chitral district has been divided in three units as under:

1) The North Western Unit: This unit starts from Reshun fault; continue towards North West and Central Afghanistan and Tirich Mir Boundary Zone (TBZ).

2) Central Unit: This unit is bounded by Reshun fault in the North-West and Karakoram Thrust (MKT) in the South-East.

3) The Main South-Eastern Unit: In this unit Karakoram - Kohistan suture zone and Kohistan Arc block (Fig-5-6).

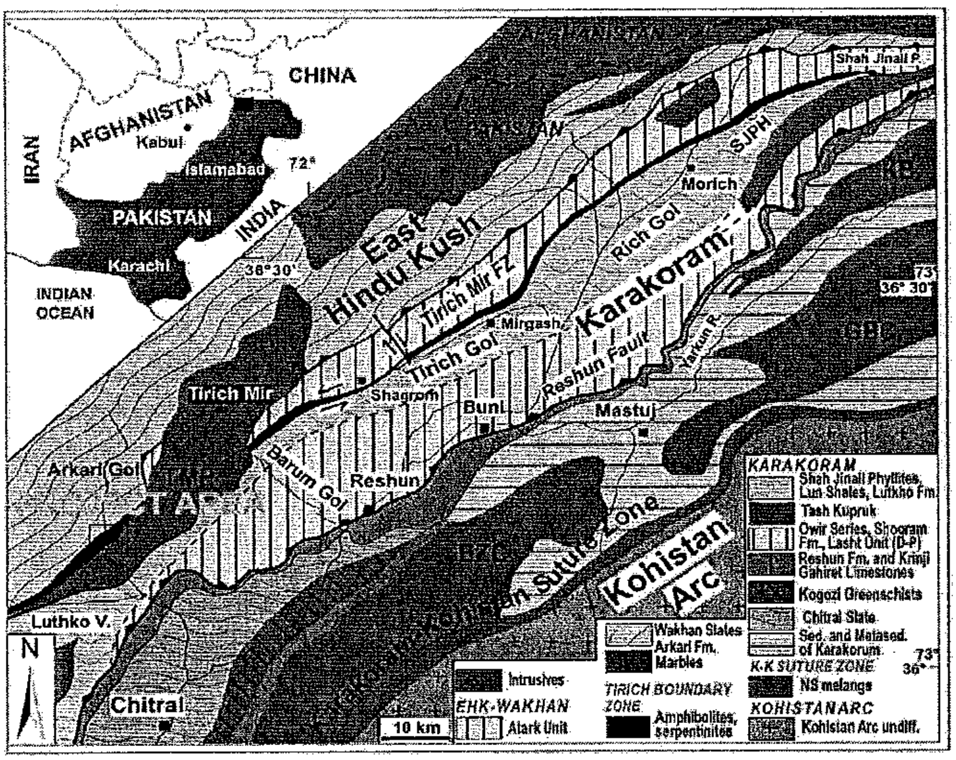

Figure 5-5: Regional Geological Map for Project Area

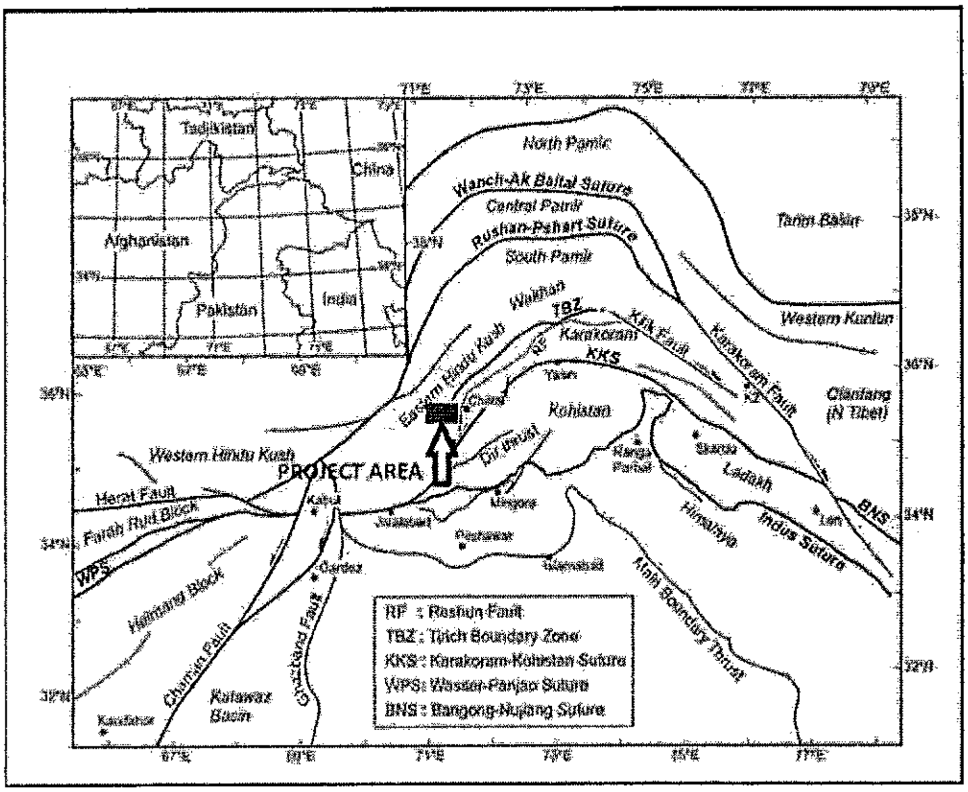

Figure 5-6: Significant Tectonic Structures around the Project Area

5.4.3 Geology of Weir Site

The weir is located in the granitic outcrop. The granite body is intruded along the strike of the Wakhan formation which consists of slate, gneiss and quartzite. The contact of granite is with Amphibolites (figure-5.25). The contact with granite is considered to be faulted but it could be a normal igneous contact as all the granite in Chitral has igneous normal contact in the Karakorum and Hindu Kush range and Tirich Mir granite is one having similar origin may have normal igneous contact with the Wakhan formation in the Project area.

Granite

The rocks at both the bank of Arkari Gol at weir site are granitoids of Tirich Mir granite. The granite is white color; pheno crystalline, large crystals up to 2 inches (figure 5-19) are common. It is dominantly composed of quartz, plagioclase, feldspar, biotite and muscovite. Albite twining gives mirror shine throughout the granitic body. It is very hard, well jointed and weathered with spheroidal weathering/exfoliation (figure 5-17).It is highest range form of rock and resistant to weathering and erosion. Sample no: A-8 collected for the Petrographic studies, details given in geotechnical investigation report.

Amphibolies

It is medium to high grade metamorphic rocks formed by the metamorphism of green schist and composed of garnet, hornblende and plagioclase. It is course grained. This rock is exposed upstream of weir. It is also a hard rock, resistant to weathering and erosional agencies. A number of granite intrusions from Tirich Mir granite have been intruded in the form of dykes (figure 5-18). The Petrographic study of sample no. A-11 gives the Petrographic study details. Petrography results are presented in geotechnical investigation report.

Scanline Survey

Scanline survey conducted at the weir site and location of Scanline is given in figure 5-12 & 5-21. Rock properties recorded from the right and left bank exposure. Rocks on the proposed weir site are igneous intrusion. The survey was conducted following the same procedure i-e by using Brunton compass and tape. Different joints sets recorded and their properties were obtained.

Joints dipping in different directions, dip ranging from 45^0-74^0, and dip direction ranging from 12^0-355^0. Joints are very close to widely spaced, 20-2000 mm. Persistence of the joints range from 3-10 m, while some joints have more than 15 m persistence. Surface is slightly rough planer to very rough non planner. Joint aperture is extremely close to medium <2mm-200mm. Most of the joints have no filling material but some joints have soft filling i-e inactive clay. Water condition is dry. The data is plotted on stereonet and rose diagram (RD-W) shown in Appendix-I.

5.4.4 Geology of Tunnel Route

Tunnel Corridor: The tunnel corridor from Powerhouse to Weir passes through various lithologic units as under:

Gneiss: It is a type of schist but the foliation is interrupted by the granular minerals like quartz, feldspar and garnet. These rocks are formed from the pre-existing sedimentary and igneous rocks due to increased temperature, pressure and shearing forces at considerable depth in the earth crust. These rocks are exposed in the area of Powerhouse, surge tank and tailrace area (figure 5-13 and 5-14) showing its breaking along the joint and foliation planes. The strike is N45^{0}E and dip toward 54^{0}NW i-e upstream.

Phyllitic Slates: slates are dark color, exceedingly fine grained, low grade metamorphic rocks. It has remarkable Slaty cleavages which permit them to be split into thin broad sheets. These have the tendency to split easily along the bedding plane. The rocks are exposed as a thick unit in the way of tunnel. The slate unit has a number of white and grey color quartzite and two mapable beds of quartzite have been marked on the geological map and L-section for project area (Figure 5-9 & 5-10). Quartzite is metamorphic rocks formed by the metamorphism of sandstone. It is very hard, cliff forming, thin to thick bedded, fine to medium grained, well bedded, well jointed, fractured (figure 5-15 and 5-16).

Granite: Granite is acidic plutonic and light color rocks, essentially composed of potash-feldspar and quartz, common accessory minerals are mica and hornblende. Texture varies from fine to very course grained and sometime porphyritic. It occurs as major intrusive bodies such as Batholith and blocks.

More than 50% of the tunnel length from the weir is passing through granite body which the extension of Tirich Mir Granite. It is white color, very course grained and very phenol crystalline. The phenol crystals are of plagioclase with Albite twining having mirror shine (figure 5-19). The crystals are up to 2 inches long. It is very hard and form the highest range in Chitral with peak of 7708 m. being igneous rocks there is no bedding but will joint.

Scanline Survey

Discontinuity data was collected along the tunnel alignment. As tunnel runs across through metamorphic rock i.e. phyllite, schist and igneous rocks of granite.

Scanline survey was conducted on each rock unit. The Scanline survey was initiated at upstream of powerhouse and location of Scanline is given in figures 5-22 to 5-24.

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Data was collected from the foliations and joints. Foliation shows the dip ranging from 35^0-70^0, while the dip direction ranges less than from 165^0-215^0. Foliation is close to very close spaced, 20-200mm. Persistence is less than 10m, the surface of the foliation is smooth planer to slightly rough planer. Aperture is extremely narrow less than 2mm. overall water condition is dry with no water observed.

Joints dipping in different directions, dip ranging from 32^0-78^0, and dip direction ranging from 020^0-320^0, Joint spacing is very close to wide i.e. 20-2000 mm. Persistence of the joints range from 5-10 m, while some joints have more than 20m persistence. Surface is slightly rough planer to medium rough planer. Aperture is very narrow 2-6mm and extremely narrow less than 2 mm. water condition is almost dry. The data is plotted on stereonet and rose diagram (RD-TA) shown in appendix-I.

5.4.5 Geology of Powerhouse Site

The rocks at Powerhouse area are gneissic type and phyllite, well bedded, medium to thick bedded, medium to hard, splintery. The general strike is in NE-SW direction and dipping toward NW with 40^0 to 60^0 angle of dip, well jointed, large numbers of big and rectangular big blocks (figure 5-13) are lying at the site due to the gravitational falling and many others are inclined to fall from the ridge (figure 5-14).

As powerhouse is located at confluence of Arkari Gol and Lutkho river the quaternary deposits like scree and alluvium are present. The whole terrace is covered by cultivated land. The bed rock is covered under these deposits. The thickness of overburden material is confirmed by drilling boreholes. Bed rock encountered at 48m depth. Overburden material composed of boulder, gravel and cobbles bounded in silt clay matrix. Sample no: A-1, A-2 and A3 have been collected which gives the composition and texture. Petrography results are presented in geotechnical investigation report.

Scanline Survey

It is generally accepted in the engineering geological community that discontinuities play a major role in projects that involve discontinuous rock masses. Particularly the characterization of the discontinuities (orientation, number offsets, spacing, persistence, roughness) is very important in the design and construction phase for tunnels, foundations, excavations and slope stability analysis. Traditionally, a structured recording of discontinuity properties of a rock mass is achieved by conducting a Scanline survey or cell mapping (Priest & Hudson, 1981; Priest, 1993). The measurement of discontinuity orientation and position at exposed rock faces is carried out using hand-held equipment such as a geological compass-clinometer device and measuring tape.

Scanline survey was performed at powerhouse site to record the characteristics of discontinuities and location of Scanline is given in figure 5-11 & 5-20. Survey was conducted by using Brunton compass and measuring tape. The survey was started from Andakhti road just crossing the bridge on Lutkho River toward the powerhouse near Andakhti turn. Total 180 m of Scanline conducted at powerhouse, section was divided into 30 m sections. Foliations and joints were observed during the survey. Foliation shows the dip ranging from 40^0-60^0, while the dip direction ranging from 010^0-070^0. Foliation is very narrowly spaced, 6-20mm and 200mm. Persistence is >10m, the surface of the foliation is smooth planer to slightly rough planer. Aperture is extremely narrow <2mm. overall water condition is dry no water observed.

The rock is well jointed. Joints dipping in different directions, dip ranging from 30^0-80^0, and dip direction ranging from 020^0-325^0. Joint spacing is medium to very close i-e, 20-600 mm. Persistence of the joints range from 3-10 m, while some joints have >10 persistence. Surface is slightly rough planer <1mm to medium rough planer. Aperture is very narrow 2-6mm and extremely narrow <2 mm. water conditions are almost dry. The data is plotted on stereonet and rose diagram is prepared.

The data is plotted on stereonet and rose diagram (RD-PH) as presented in Appendix 5 of this study

5.4.6 Overview of Subsurface Conditions

An overview of subsurface conditions at the weir site, tunnel route, and powerhouse site is provided below. Appendix-V, of this study present the borehole logs, results of the ins-situ tests, and results of the laboratory testing.

The Stratigraphic boundaries shown the borehole logs and on the interpreted Stratigraphic sections and profiles are inferred from non-continuous sampling and therefore represents transitions between types of geo materials rather than exact planes of geological change. The subsurface condition will vary beyond the locations of investigations such as boreholes, ERS, and test pits.

5.4.6.1 Weir Site

The subsurface conditions encountered in boreholes or interpreted through ERS at weir site consist of extensive deposits of cobbles and boulders with silty clay and silty sand containing some alternating layers of gravelly sand. The deposit of sandy gravel with boulders and cobbles is present at weir site. The depth to the bedrock (Momi gneiss) along the axis of weir varies from 0 m at the abutments and up to 150 m in the center of the weir. Momi gneiss is moderately to highly weathered. Figure 5-7 presents the inferred subsurface model for weir site.

Unconsolidated gravel and cobbles with coarse sand and some boulders

The thickness of this layer varies from 0 to 10.0 m along the axis of the weir. Layer of gravel and cobbles with coarse sand and some boulders represents soil type in overburden at the weir site.

Loose gravel and cobbles with silty sand

The thickness of this layer varies from 10.0 to 20.0 m along the axis of the weir. Gravel and cobbles are angular to sub-angular of metamorphic origin with silty sand. This layer represents dominant soil type in overburden at the weir site.

Gravel and cobbles with silty clay

A localized deposit of gravel and cobbles with silty clay is present at surface towards the left abutment of the weir. This deposit has a thickness vary from 20.0 to 49.5 m.

Dense to very dense sandy gravel with cobbles

The thickness of this layer varies from 49.5 to 150.0 m along the axis of the weir. Gravel and cobbles are angular to sub-angular of metamorphic origin with silty sand. This layer represents dominant soil type in overburden at the weir site.

5.4.6.2 Powerhouse Site

The subsurface conditions encountered in boreholes or interpreted through ERS at powerhouse site consists mainly an extensive deposit of Cobbles and boulders with silty clayey sand and sand. A layer of sandy gravel with boulders and cobbles is present at depth which is overlain and underlain by Cobbles and boulders with silty clayey sand. The depth to the bedrock (phyllite) at powerhouse site varies from 47 m to 50 m. Phylite is moderately to highly weathered. Figure 5-8 presents the inferred subsurface model for powerhouse site.

Cobbles and boulders with silty clayey sand

A first layer of Cobbles and boulders with silty clayey sand is present at the top with thickness ranging from 10 m to 12 m. The second layer of Cobbles and boulders with silty clayey sand starts at depths ranging from 20 m to 26 m from surface. This second layer extends up to bedrock with thicknesses ranging from 21 m to 25 m.

Sandy gravel with cobbles and boulders

A deposit of Sandy gravel with cobbles and boulders is encountered at depths ranging from 10 m to 12 m from surface. The layer has thicknesses ranging from 10 m to 15 m.

5.4.7 Groundwater Conditions

The observed water level in each of the open borehole following completion of the drilling are indicated on the borehole logs in geotechnical investigation report in Appendix-V. The water levels measured are summarized in Table 5-6.

Table 5-6: Measured Water Levels In Open Boreholes

Location	Borehole No.	Surface Elv. (m)	Groundwater Surface Elv. (m)	Date of Measurement
Weir	01	2179.5	2166.8	22-6-2013
Weir	02	2174.1	2166.4	12-11-2013
Weir	03	2172.3	2166.9	02-08-2013
Weir	04	2174.2	2162.5	28-07-2013
Powerhouse	01	1856.7	1828.9	16-4-2013
Powerhouse	02	1868.3	1844.9	16-4-2013
Powerhouse	03	1851.7	1837.0	5-3-2013
Powerhouse	04	1849.9	1827.2	24-4-2013

The observed groundwater depths measured from the surface at the weir site at 25 m. The groundwater becomes shallower towards the river and gradually becomes deeper towards the right bank of the river basin.

The groundwater was encountered at a depth in range from 14.0 to 28.0 m in boreholes advanced at the powerhouse site.

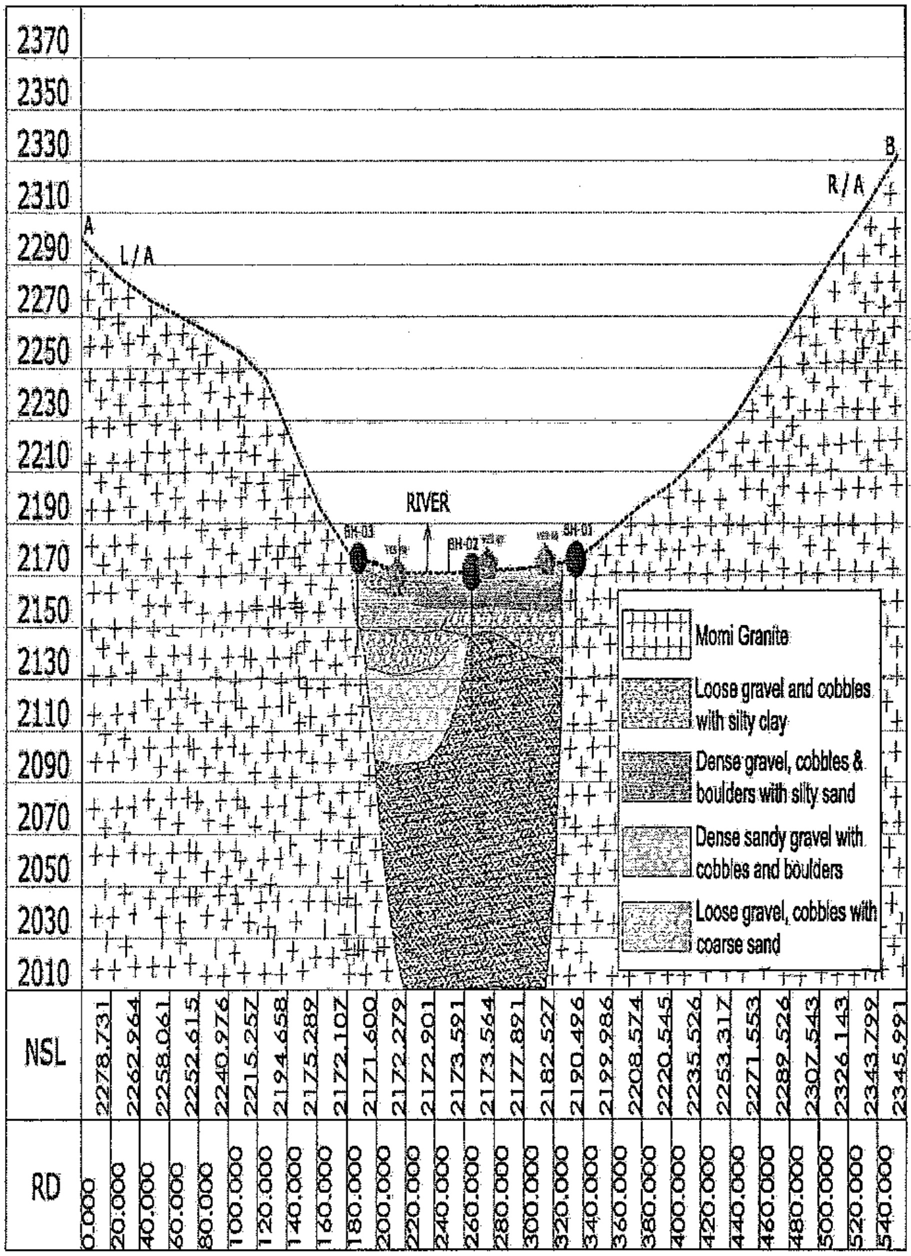


Figure 5-7: Sub-surface Stratigraphy of the Weir Site

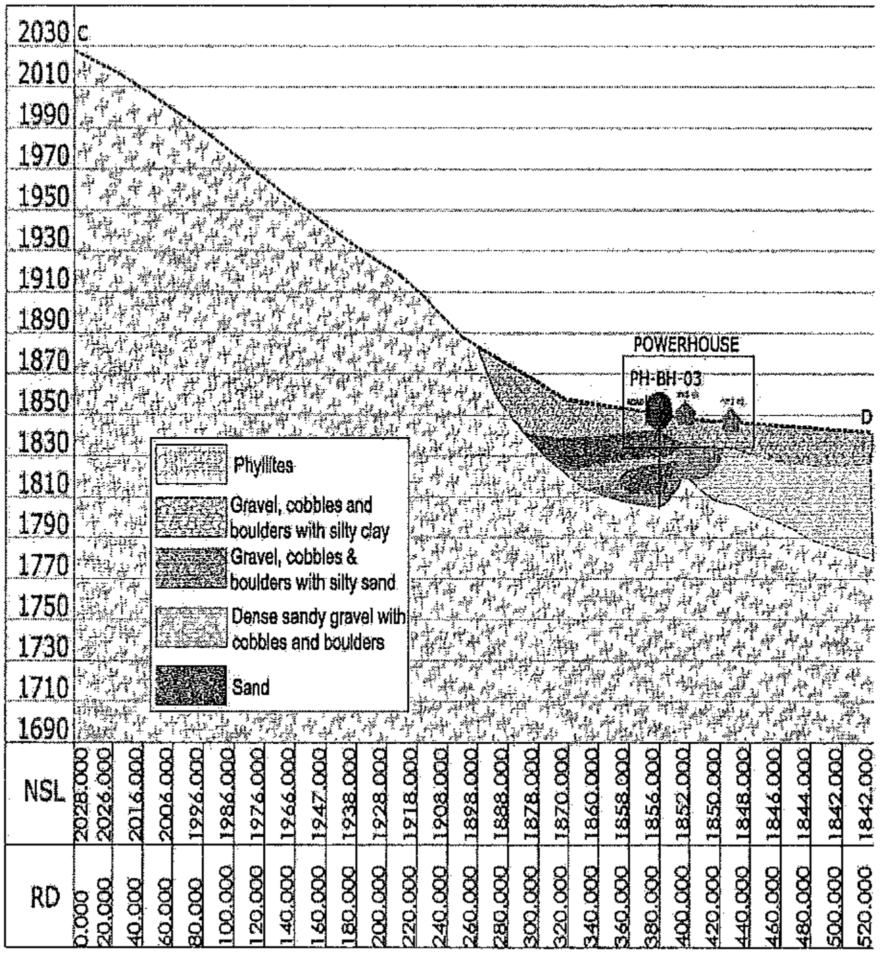


Figure 5-8: Sub-surface Stratigraphy of the Powerhouse Site

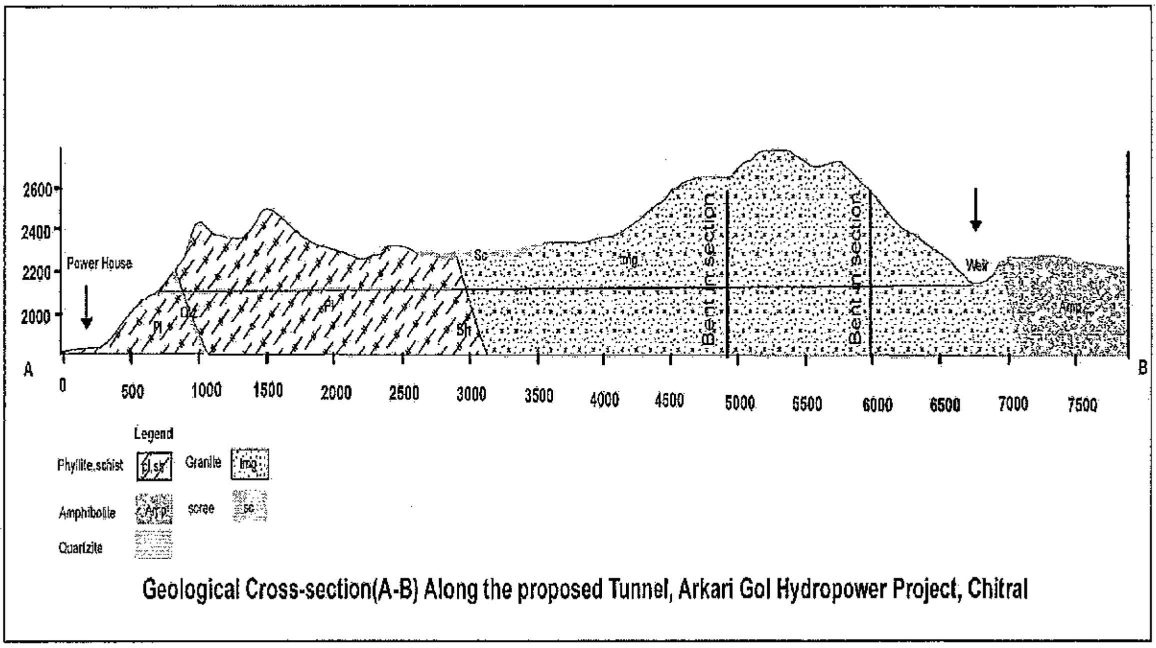


Figure 5-9: Sub-surface Geological L-section along the Tunnel Alignment

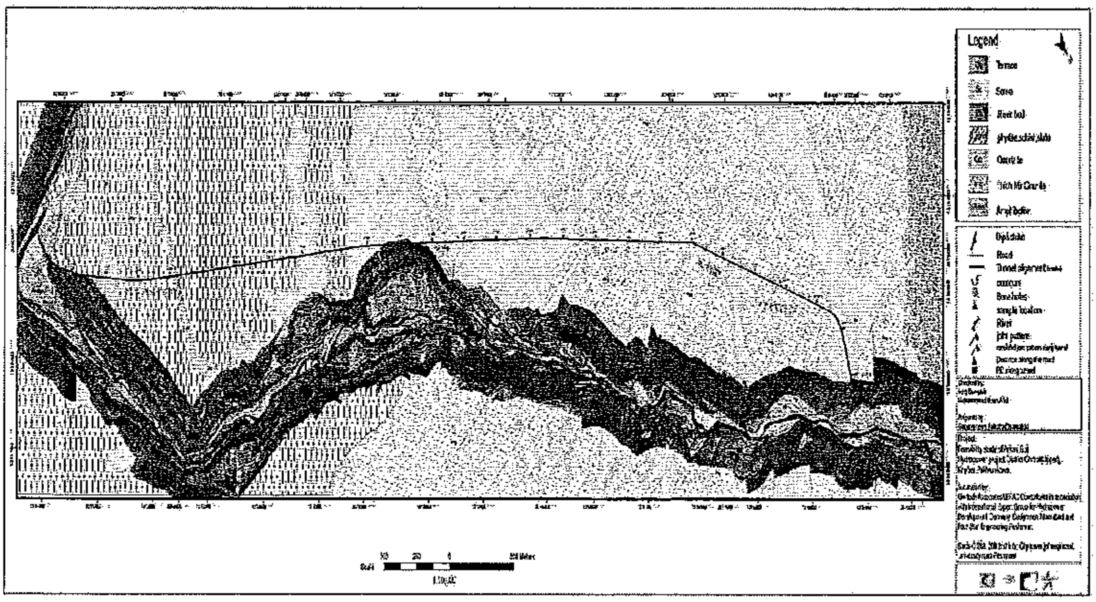


Figure 5-10: Surface Geological Map for Project Area

Figure 5-11: Surface Geological Map for Powerhouse Site

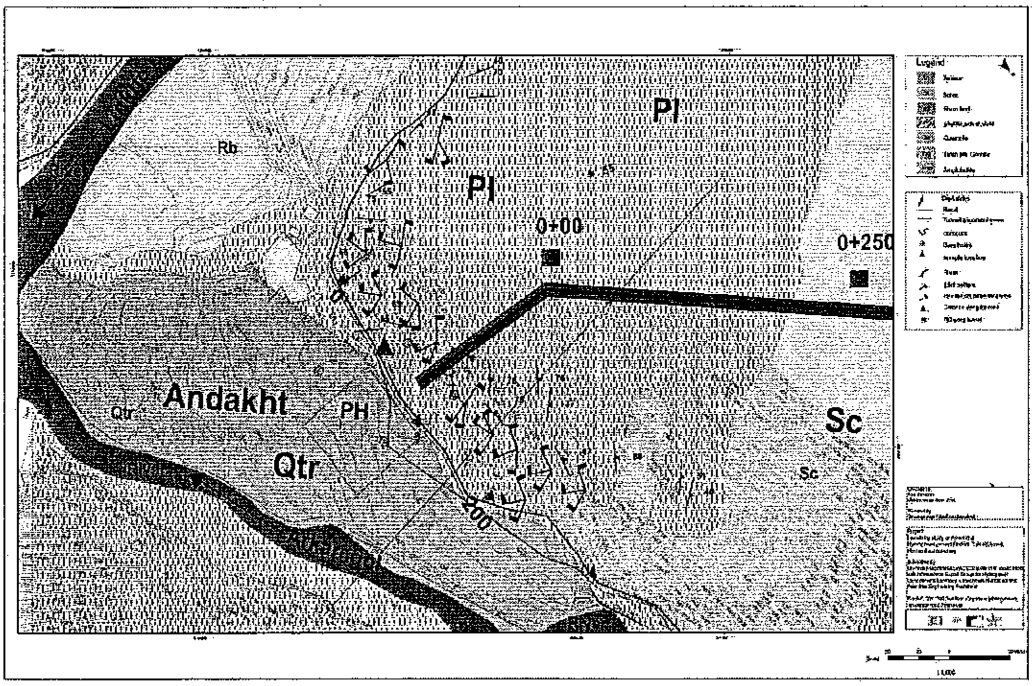


Figure 5-12: Surface Geological Map for Weir Site

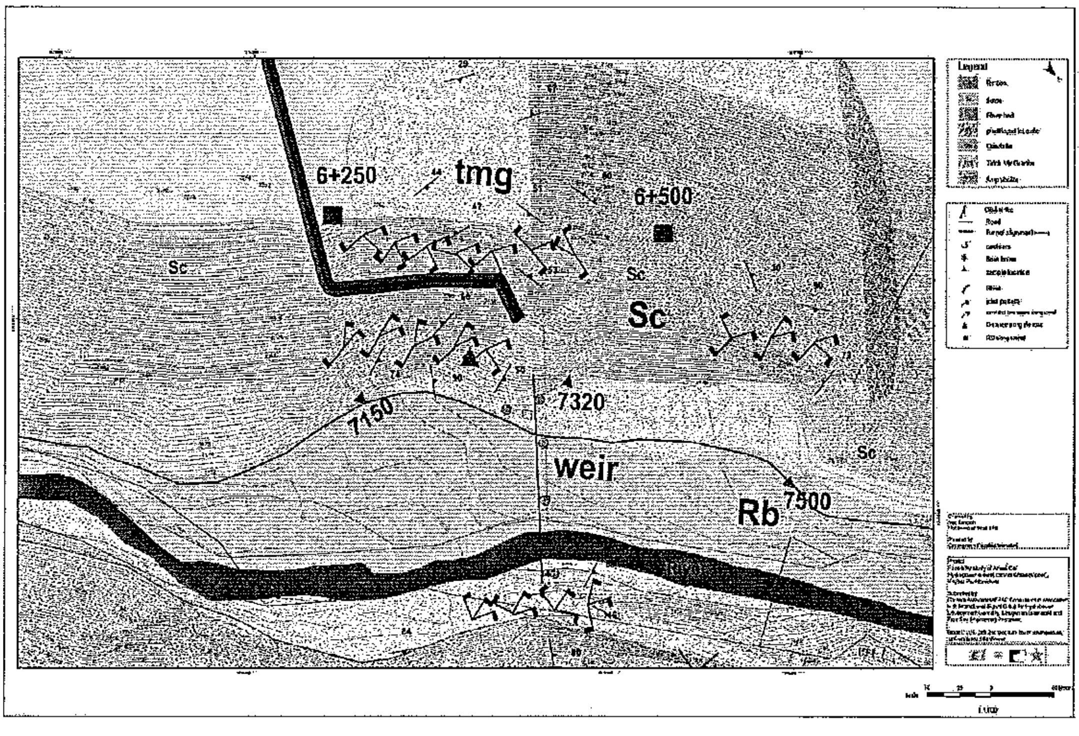
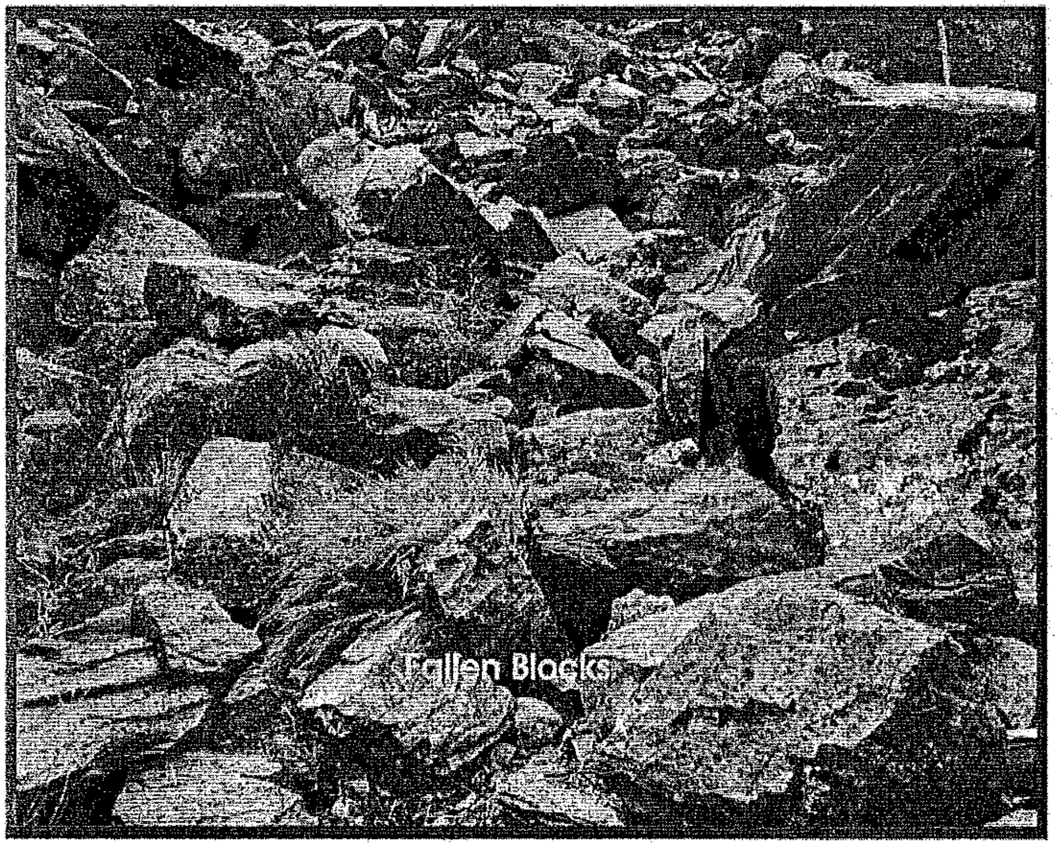


Figure 5-13: showing the fallen blocks of Gneiss at Powerhouse



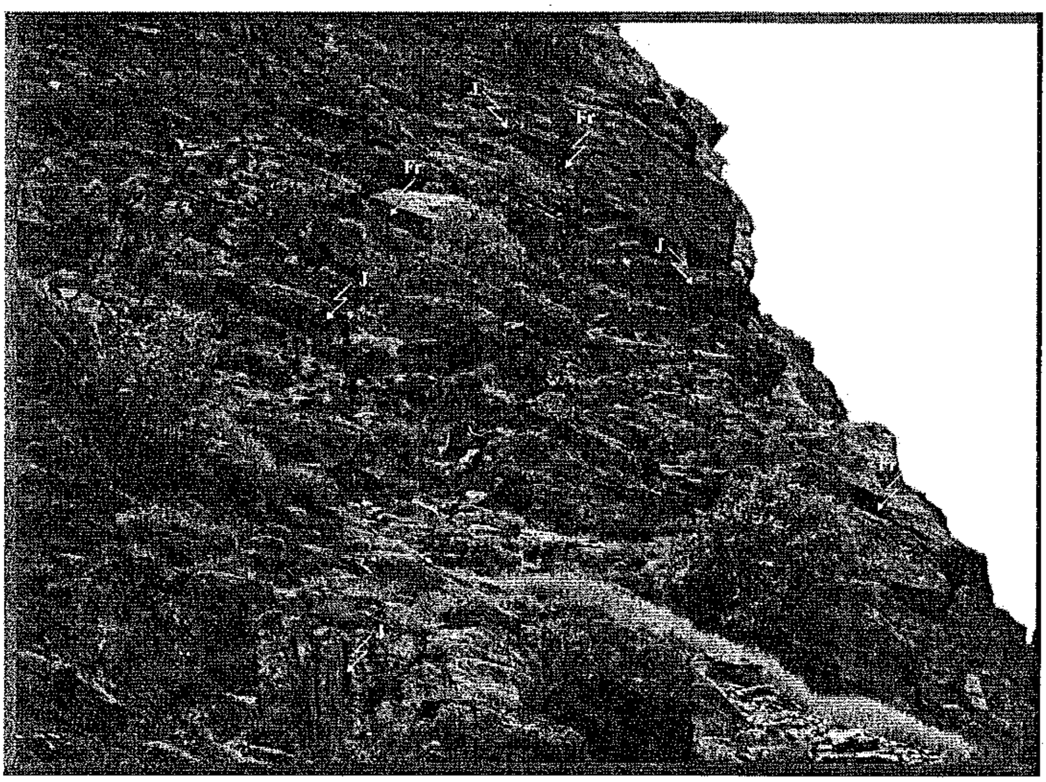


Figure 5-14: showing the highly fractured and jointed rock at Surge Tank location

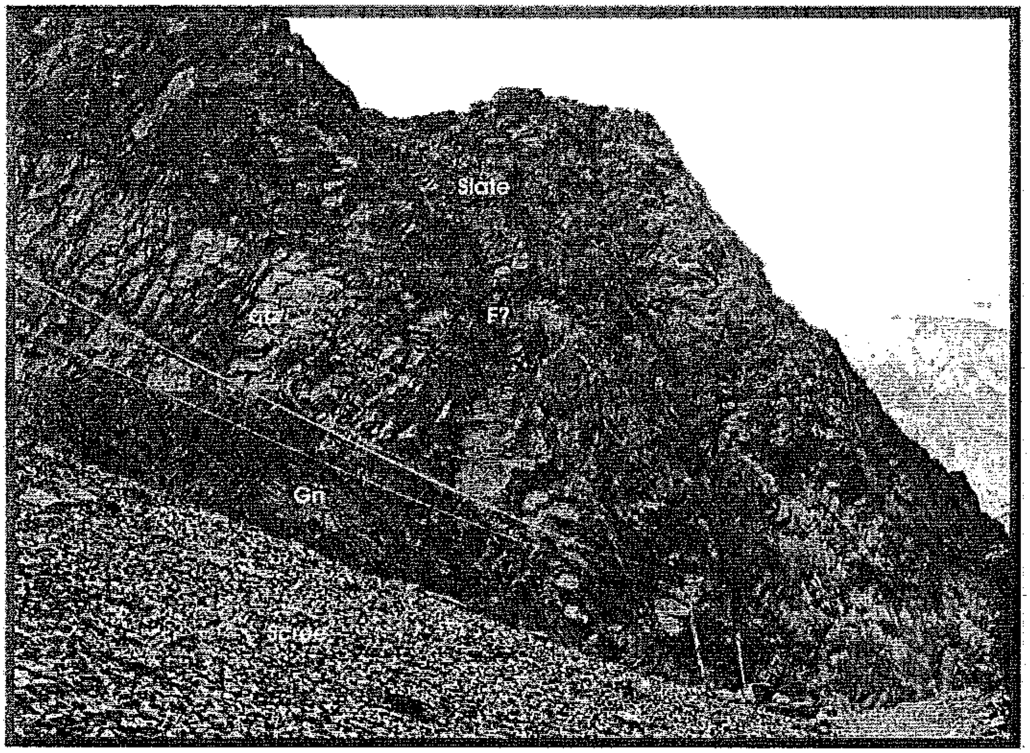


Figure 5-15: showing contact between three types of rock i.e Gneiss (gn) Quartzite (qtz) and Slate

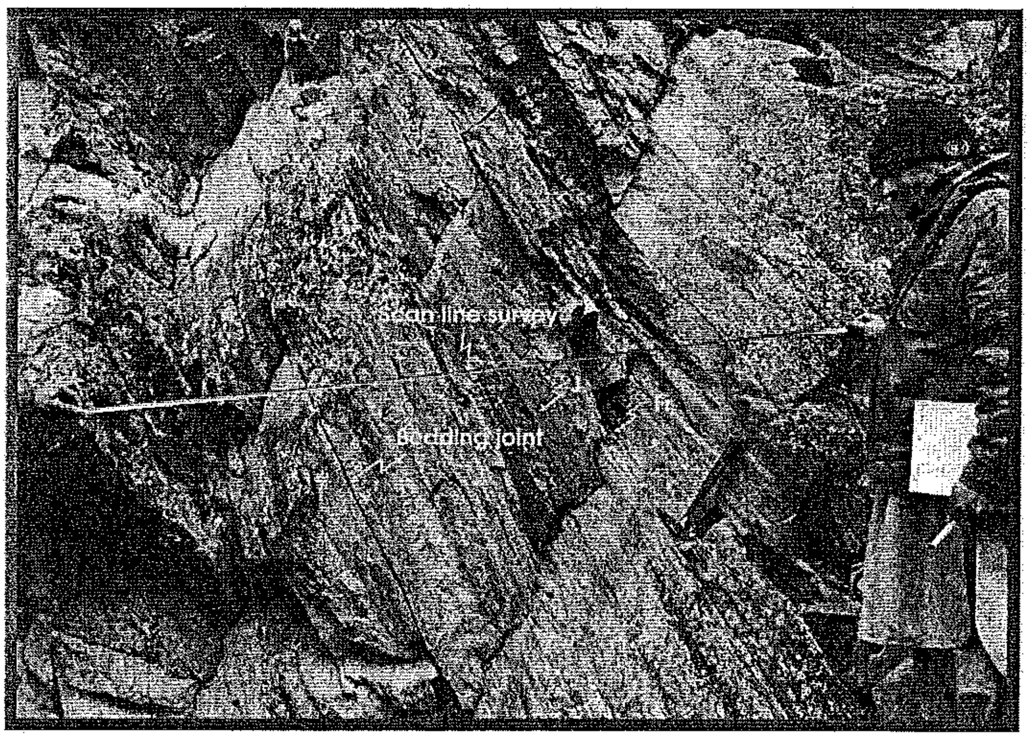


Figure 5-16: showing the bedding and jointing pattern in Quartzite in the cliff

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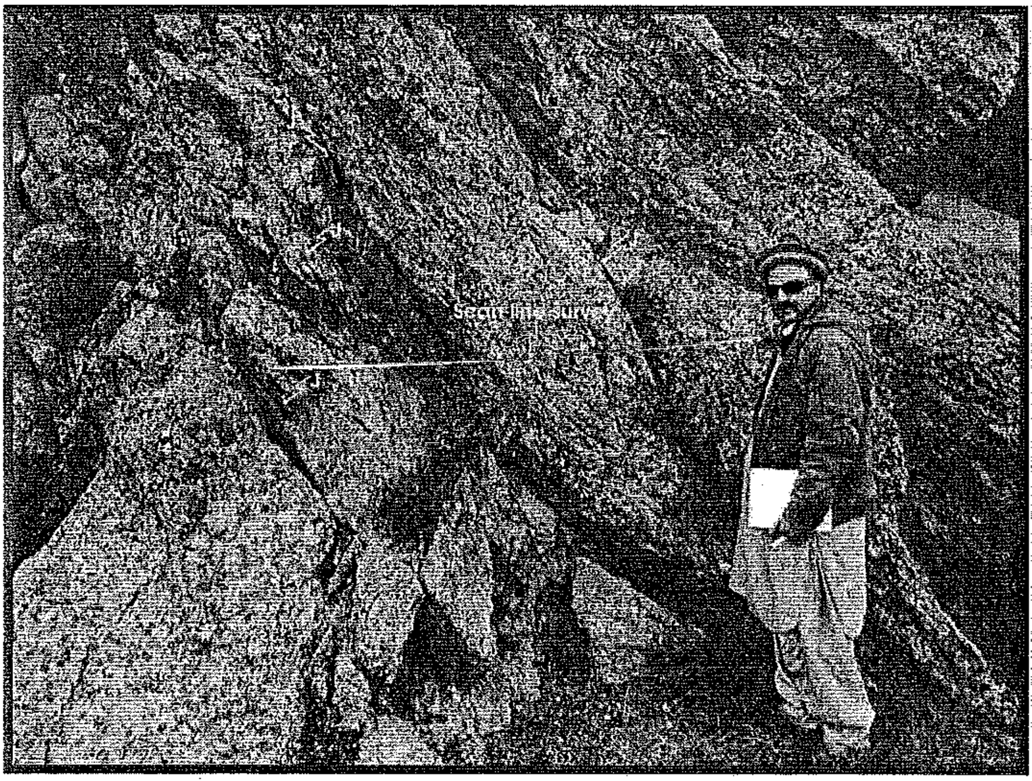

Figure 5-17: showing the jointing pattern and spheroidal weathering

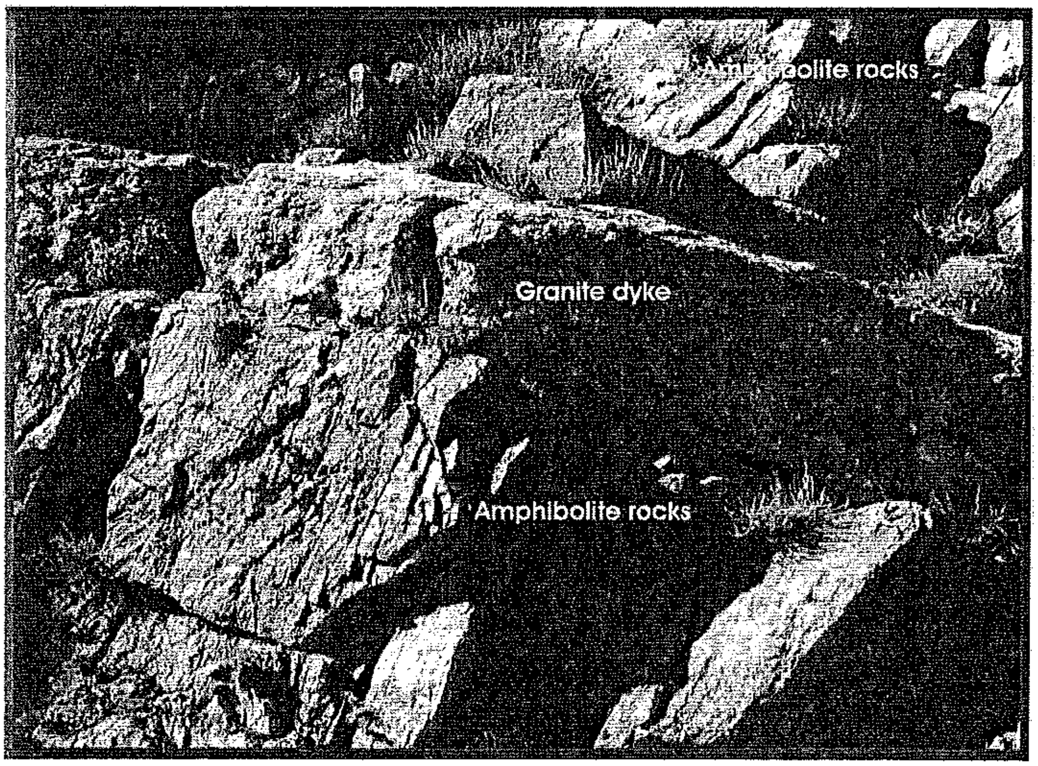

Figure 5-18: Amphibolite rock containing Granite Dyke intruded from the Tirich Mir Granite

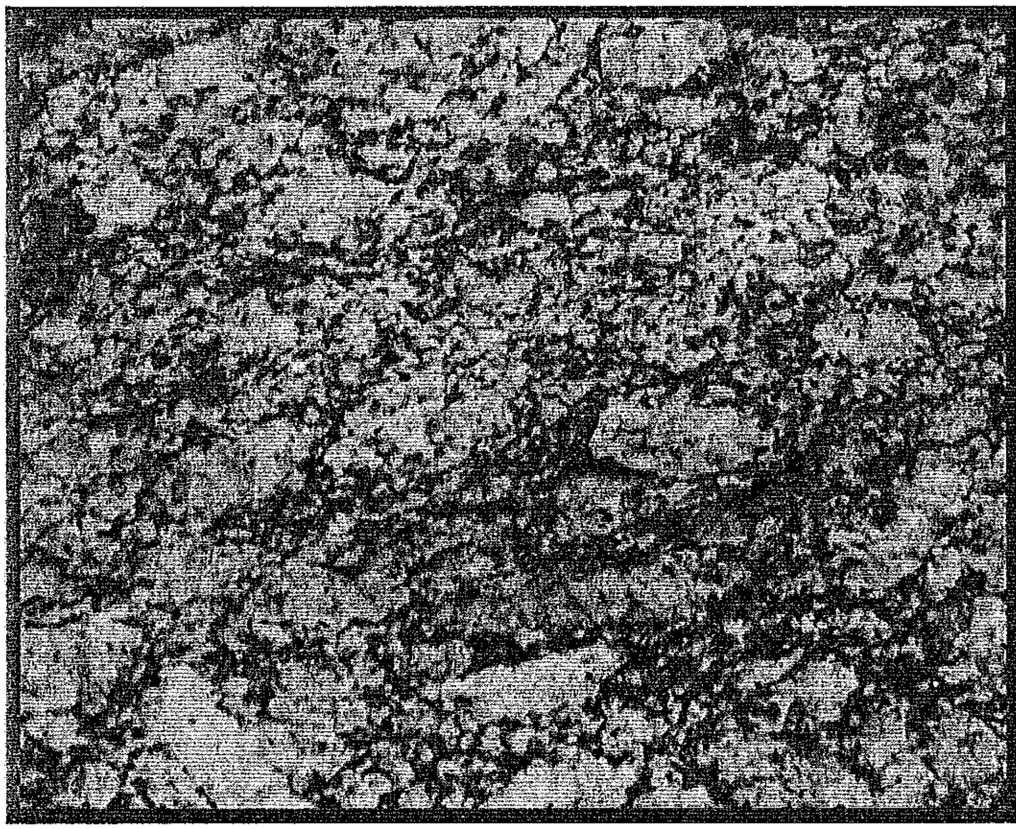

Figure 5-19: showing the close view of Tirich Mir Granite with phenocryst of Quartz, Plagioclase with accessory minerals like Hornblende, Biotite and Muscovite

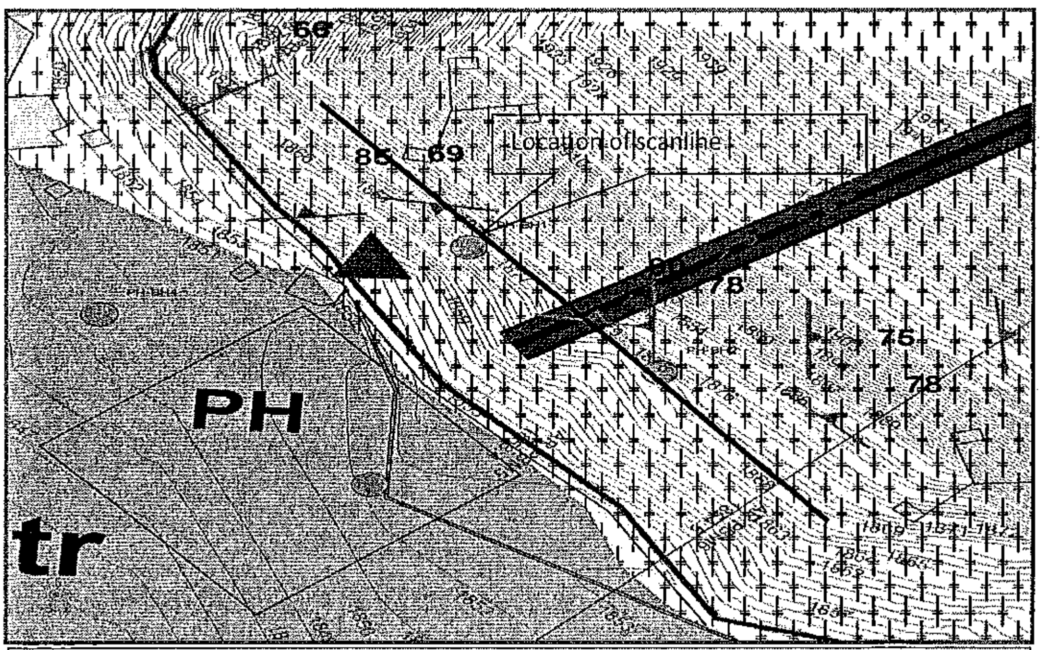

Figure 5-20: showing the location of Scanline (SL-01) at Powerhouse

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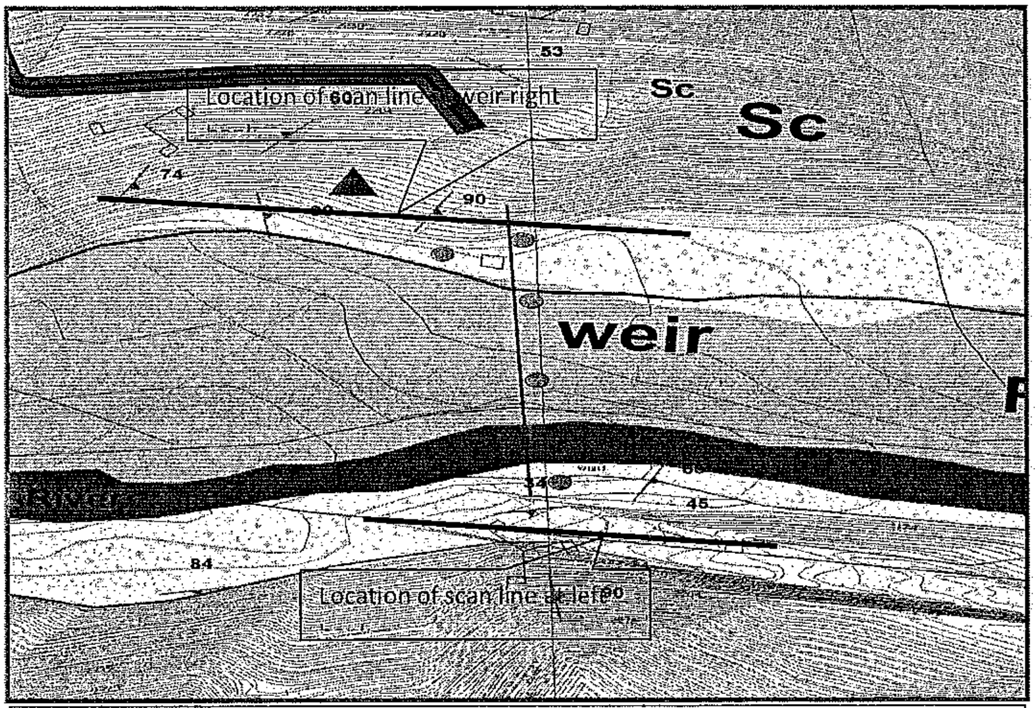

Figure 5-21: showing the location of Scanline (SL-02) at Weir site (left & right banks)

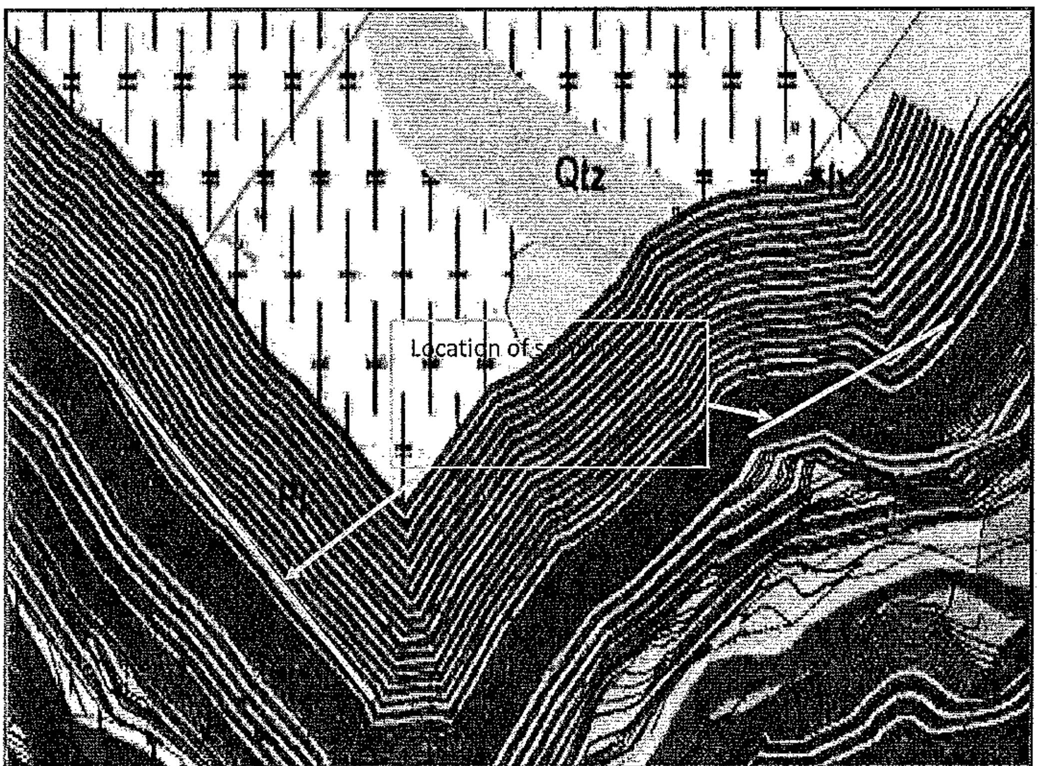

Figure 5-22: Location of Scanline (SL-3a) along Tunnel Alignment

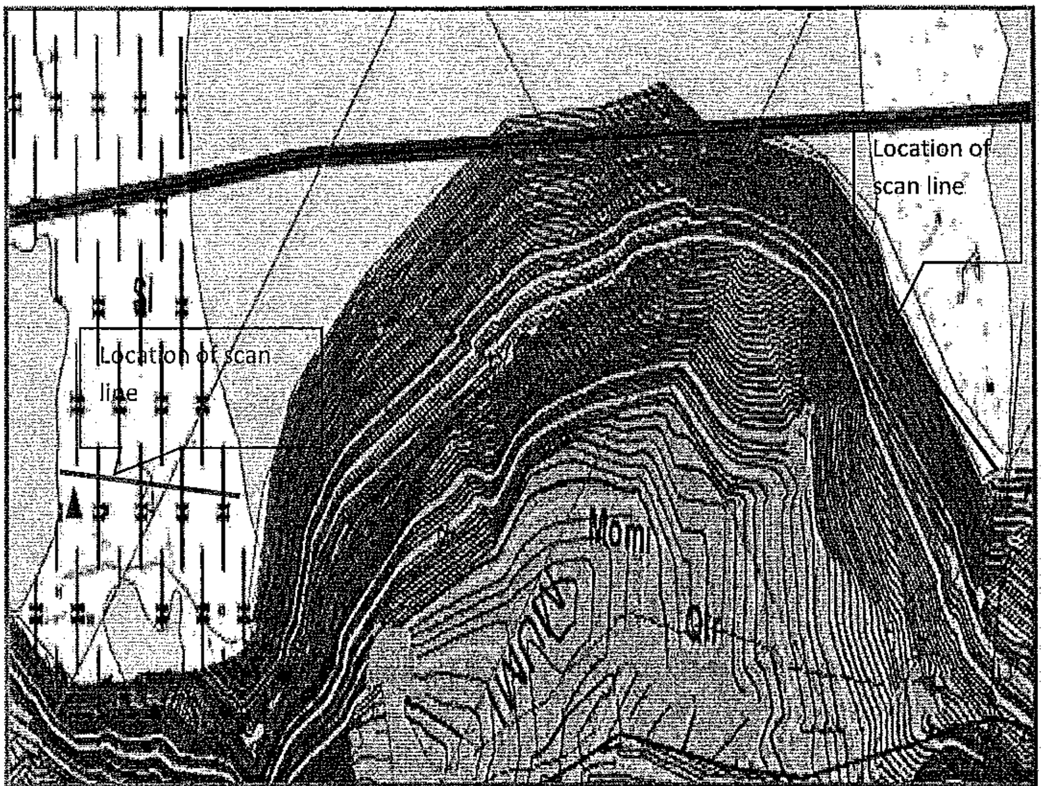

Figure 5-23: Location of Scanline (SL-3b) along Tunnel Alignment

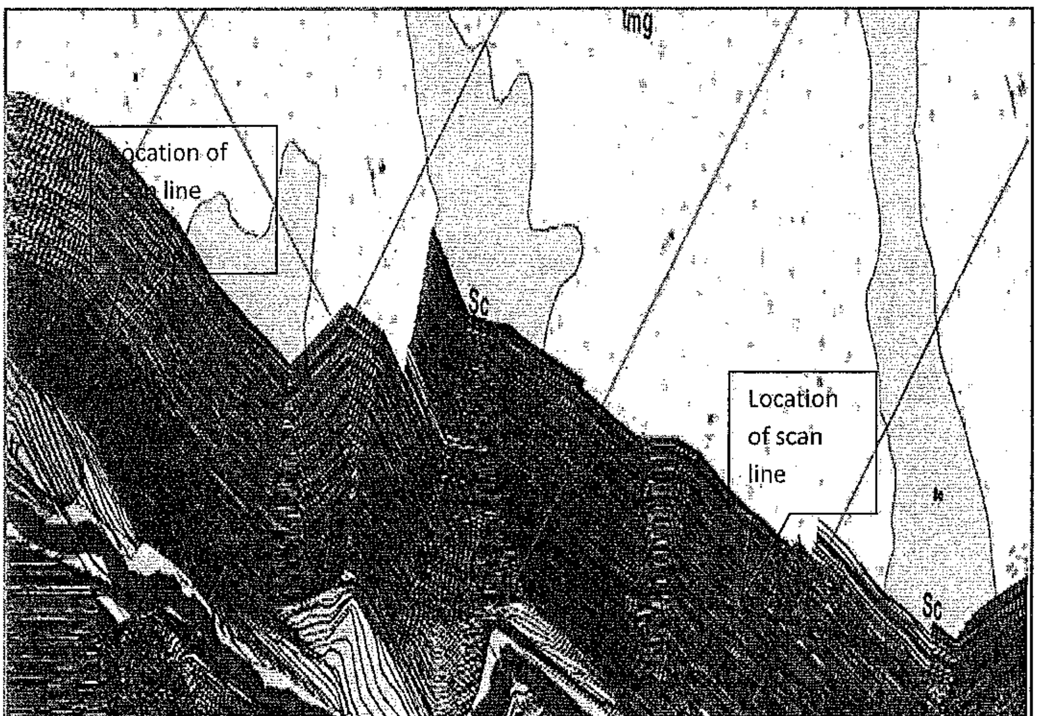

Figure 5-24: Location of Scanline (SL-3c) along Tunnel Alignment

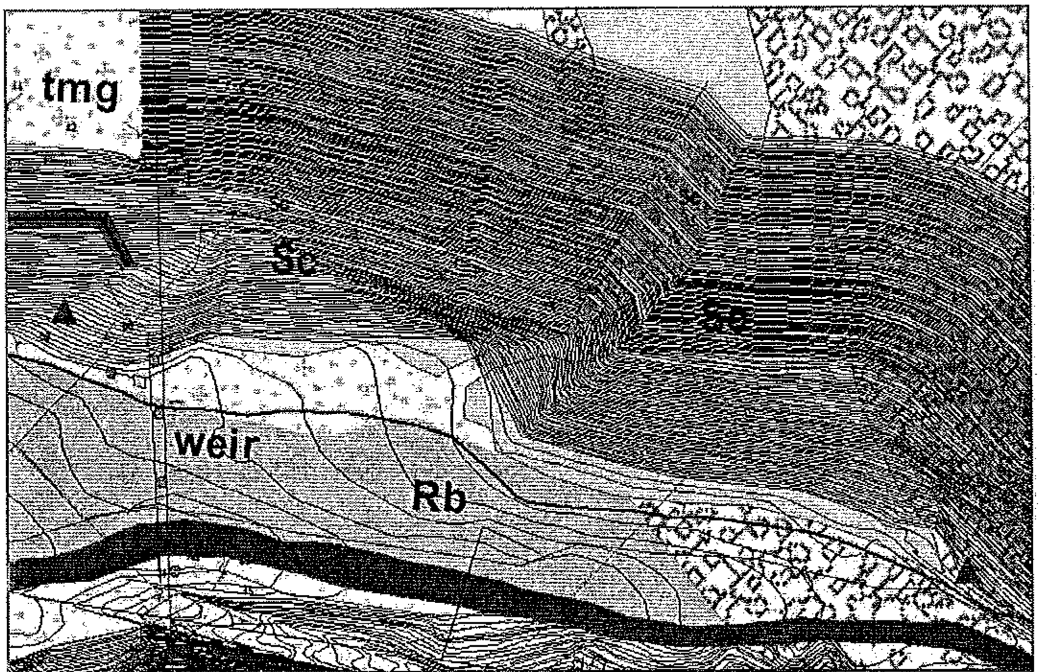

Figure 5-25: showing contact between Granite and Amphibolite upstream of Weir site near Uchhatur

5.4.8 Construction Materials

Materials required to carry out the construction of civil works for the project include concrete aggregates, cement, pozolons, various types of fill materials, steel products. Potential sources of these construction materials have been identified and investigated in accordance with the project requirements. In addition to identification of potential sources for materials, proven sources of some materials needed for the project have also been evaluated on the basis of data collected during previous studies carried out for other projects.

In order to identify the suitable sources, collected samples for coarse aggregates and fine aggregates and sent to laboratory testing. The details of construction material studies are given in Appendix-V of this study.

Sources of Coarse Aggregates

The following sources of coarse aggregates were identified and studied for their suitability for concrete production:

i. Rock mass from required excavations

ii. Potential sites for rock quarries

Rock from Required Excavations

Excavation of tunnels, desanders, and forebay shall result in production of huge quantity of muck comprising various rock types. In the weir area, the rocks expected from the excavation of desanders and the portion of headrace tunnel comprised of granitic gneisses and amphibolites. A large portion of the headrace tunnel from intake structure to powerhouse majorly runs through granitic gneisses, amphibolites, schist & phyllites, which do not appear suitable as concrete aggregates.

Potential site for quarries

Two huge deposits of crushed aggregate exist in the vicinity of Aawi village and are hardly 2 km from the Shoghore figure 5-26 & figure 5-27. Coarse aggregates of this area are being extensively used in construction of road building and concrete production. The existing production facility for coarse aggregate is owned by a local prince who can be taken on board to enlarge and improve the production facility to meet the requirement of the projects in the area. Samples were collected and lab tests were conducted, results of lab test are shown in table 5-7.

Fine Aggregates

General

During feasibility studies, possible sources of fine aggregates for concrete (which are defined as materials that pass 4.75 mm (No.4) sieve but are retained on the 75 micron (No. 200) sieves have also been explored in close vicinity of the project area. In the vicinity of the proposed weir & powerhouse areas, there are no known established sources of fine aggregates. However, near Chitral town two sources of the fine aggregates exist. One of the sources is Chitral River bed in the south of Chitral Town from where sand is mined presently for use by the locals.

As such the possible sources of fine aggregates include:

i) River alluvium
ii) Manufacture of fine aggregate from suitable rocks

River Alluvium

Chitral River in the vicinity of Chitral Airport and downstream of Chitral Town flows in relatively flat terrain. Fine aggregates are being mined in these areas for local use. In order to extract fine aggregates of desired quantities for use in the project from these deposits, considerable area will be required, in addition to some processing efforts. These two sources have strong potential of being developed into viable sources of fine aggregates which are expected to fulfill the project requirements. The gradation of the samples collected from the test pits excavated near the airport and south of Chitral Town. Limits of concrete sand as specified in ASTM C-33 are also plotted on the **figures 5-29** to **5-31**. The sand from these sources can be combined and processed for possible use as fine aggregate in the concrete.

Another possible source of fine aggregates is Chitral River alluvium existing upstream of Chitral Town, where river bed gets flatter and is spread over wide area in the valley.

Near Chitral Airport area

The river bed in the Chitral Airport area is wide and has a number of flood plains. This area can be used for sand deposits. Samples collected for laboratory testing and summary of laboratory test results are given in table 5-8.

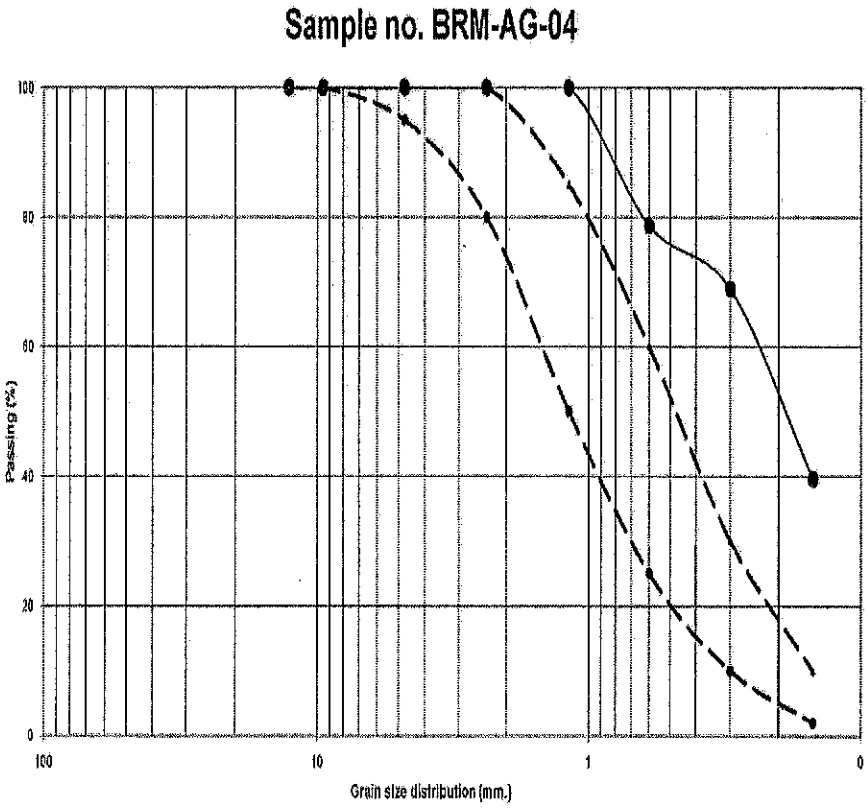

Figure 5-28: showing the Gradation of sand deposit along river near Chitral airport

The gradation analysis shows that extensive sieving would be required to produce the fine aggregate within the allowable limits as presented in **figure 5-28**

Ayun Area

In this area sand deposits in the flood plain are found which could be used for construction purposes. Samples collected for laboratory testing and summary of laboratory test results are given in **Table 5-8.**

Sample no. BRM-AG-05

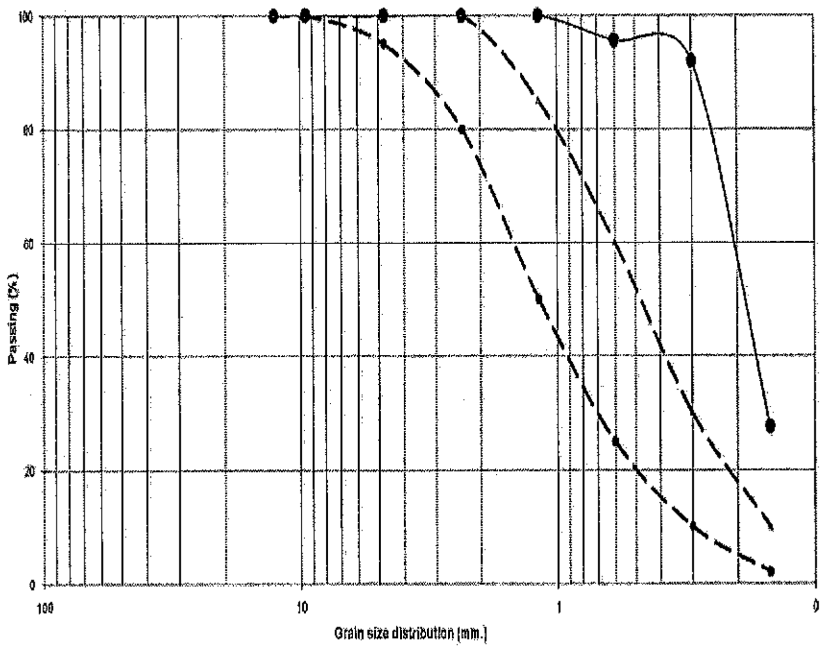

Figure 5-29: showing the Gradation of sand deposit along river at Ayun, Chitral

The gradation analysis shows that extensive sieving would be required to produce the fine aggregate within the allowable limits as presented in **figure 5-29.**

Andakht-Shoghore area

The river bed in the above mentioned localities is wide enough and the sand could be getting in the flood plains areas. Samples collected for laboratory testing and summary of laboratory test results are given in **Table 5-8.**

Sample no. BRM-AG-01

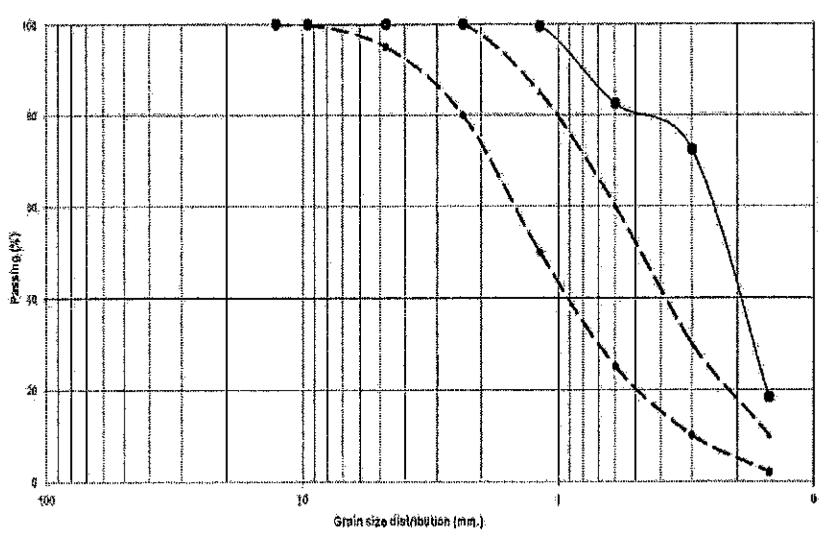

Figure 5-30: showing the Gradation of sand deposit along river near Andakhti village

The gradation analysis shows that extensive sieving would be required to produce the fine aggregate within the allowable limits as presented in **figure 5-30.**

Manufactured Fine Aggregate

The fine aggregates can also be produced by crushing of suitable rock. The rock can either be quarried or will be available from underground excavations. Keeping in view the availability of rock types, production of fine aggregates shall be possible in the powerhouse area and along the road where marble is exposed. However, the manufacturing process is expected to be significantly expensive and should be limited to minimum application in cases where required gradation is not available from natural sources i.e. river alluvium.

Table 5-7: Summary for Laboratory Test Results for Coarse Aggregates

Sample No.	Rock	Specific Gravity %	Absorption %	Impact Value of Aggregate %	Los Angles Abrasion Test %	Soundness of Aggregate %	Crushed Value %	Flakiness and elongation index %
AR-01	Limestone	2.717	0.39	25.6	33.3	1.42	26.4	6.75
AR-03	Marble	2.821	0.52	27.6	34.7	1.2	29.1	6.85
SH-01	Marble	2.868	0.88	18.4	18.2	0.79	-	-

Table 5-8: Summary for Laboratory Test Result for Fine Aggregates

SAMPLE NO.	LOCATION	MECHANICAL SIEVE ANALYSIS						SPECIFIC GRAVITY & ABSORPTION %		SAND EQUIVALENT %	UNIT WEIGHT	
		No. 04 %	No. 08 %	No. 16 %	No. 30 %	No. 50 %	No. 100 %	SG	ABSORPTION %		LOOSE	RODDED
BRM-AG-01	Andakht	100	100	99.5	82.5	72.5	18.3	2.542	1.28	92.9	1.260	1.337
BRM-AG-04	Near Chitral Airport	100	100	100	78.7	68.9	39.6	2.632	1.32	87.0	1.376	1.597
BRM-AG-05	Near Ayun	100	100	100	95.6	92.0	27.6	2.534	1.43	90.9	1.262	1.476

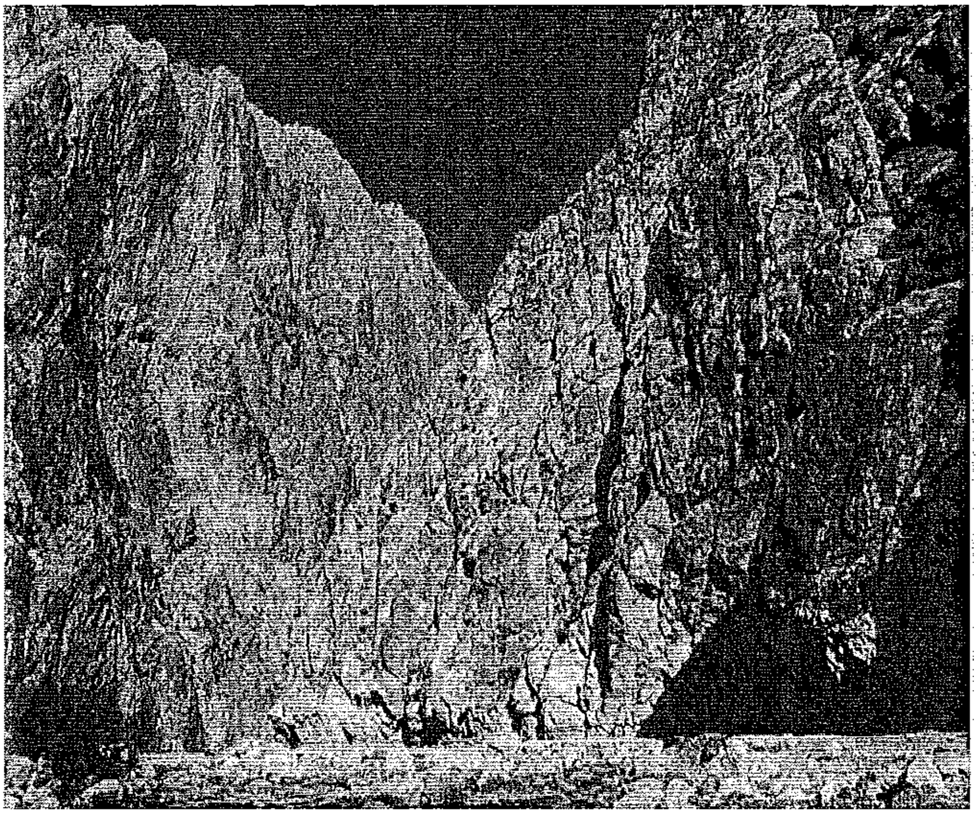

Figure 5-26: Showing The Outcrop Of Marble Near Shoghore

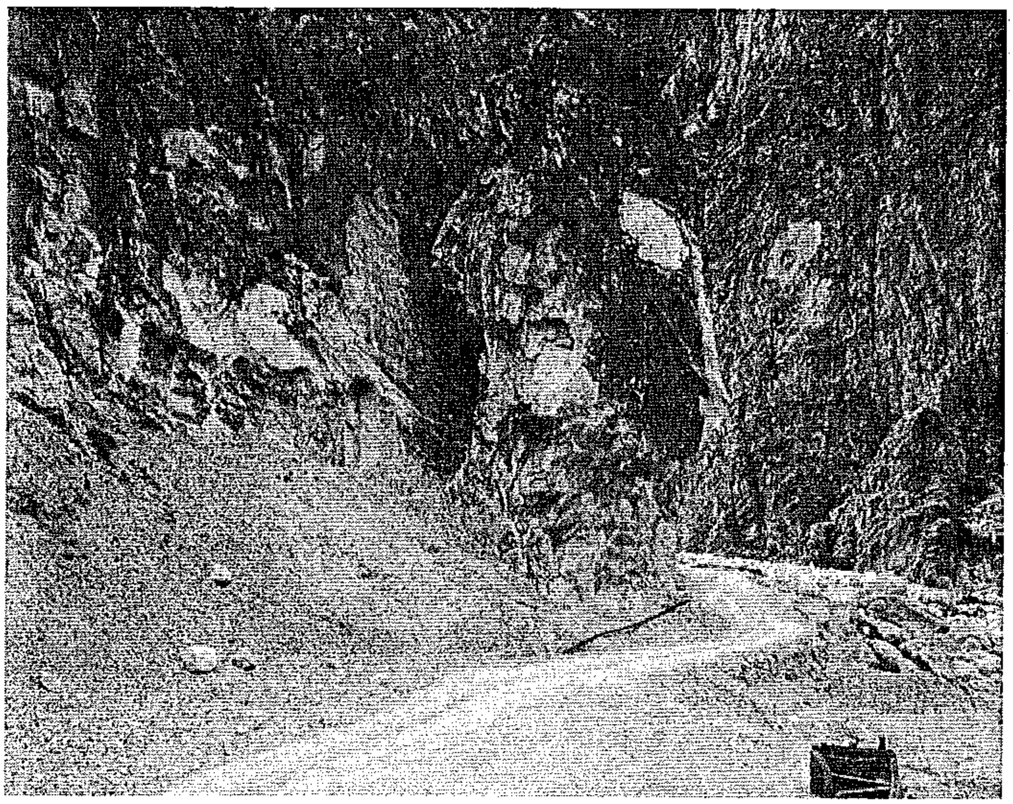

Figure 5-27: Showing The Location Of Grey To Bluish Grey, Limestone Approximately 3km Downstream Of Shoghore.

PART – II: DESIGN RECOMMENDATIONS

5.6.0 Discussion and Engineering Recommendations

5.6.1 General

This section of the report provides the geotechnical/foundation recommendations for the feasibility study of the proposed Arkari Gol hydro-power project which is anticipated to be a concrete faced rock fill dam (CFRD) with a maximum height of 30 m and a maximum crest length of 168 m between abutments. The recommendations are based on the interpretation of the factual data obtained during the past and current investigations. The discussions are general and are intended to highlight the suitability of foundation types, highlight construction issues, and discuss stability of tunnel and excavations.

Where comments are made on construction, they are provided to highlight those aspects that could affect the detailed design of the project and special provisions are required in contract documents. Those requiring information on the construction of the project should make their own interpretation of the factual data as such interpretation may affect equipment selection proposed construction method, and scheduling.

Boreholes advanced in the project area revealed extensive deposits of granular material consisting of loose to very dense deposits of Cobbles and boulders with silty clayey sand. This deposit is interred layered with sand with gravel at the weir site. The proposed alignment of tunnel traverses through three rock types of Mica Schists, Momi Gneiss (Granite), and Phyllites consisting of closely to widely spaced joints and slightly to highly weathered walls.

5.6.2 Foundations

Different foundation options are considered for weir and powerhouse sites. The structures can be founded on shallow foundations/structural rafts, deep foundations, and a combination of structural rafts and piles. Relative merits and demerits of each foundation option are discussed in the following sections.

5.6.2.1 Shallow Foundations / Structural Raft

Shallow foundations can be adopted to support the structures of the weir (if concrete weir is adopted) and powerhouse. The structural raft will provide sufficient bearing resistance at ultimate limit state to support the structural, live, and dynamic loads based on preliminary calculations. The structural raft is also anticipated to provide sufficient bearing resistance at serviceability limit state due to presence of very dense granular materials at depth (5 to 10 m from surface).

Further analysis of the capacities, moduli of subgrade reactions, and deformations can be performed during the detailed design stage of the project when the final dimensions of the raft become available. Table 5-9 & 5-10 however presents an estimate of bearing capacity of 100 m x 90 m structural raft founded on the layer of Cobbles and boulders with silty clayey.

The capacity of the structural raft will increase with depth. It is envisioned that the rafts will be placed at sufficient depth to warrant effective frost protection. Due to varying ground conditions within the foot print of both weir and the powerhouse, differential settlements are anticipated especially due to dynamic loads of turbines and earthquakes.

Table 5-9: Variation of Bearing Capacities with depth for Powerhouse

DEPTH OF FOOTING (m)	ELEVATION (NSL)	TYPE OF FOOTING	ALLOWABLE BEARING CAPACITY
3	1830m	Raft	1.0 ton/ft^2
4	1829m	Raft	1.4 ton/ft^2
5	1828m	Raft	1.8 ton/ft^2
6	1827m	Raft	2.2 ton/ft^2
7	1826m	Raft	2.6 ton/ft^2
8	1825m	Raft	3.0 ton/ft^2
9	1824m	Raft	3.4 ton/ft^2
10	1823m	Raft	3.8 ton/ft^2

Table 5-10: Variation of Bearing Capacities with depth for Weir site

DEPTH OF FOOTING (m)	ELEVATION (NSL)	TYPE OF FOOTING	ALLOWABLE BEARING CAPACITY
7	2165 m	Raft	1.2 ton/ft^2
8	2164 m	Raft	1.4 ton/ft^2
9	2163 m	Raft	1.6 ton/ft^2
10	2162 m	Raft	1.8 ton/ft^2
11	2161 m	Raft	2.0 ton/ft^2
12	2160 m	Raft	2.2 ton/ft^2

5.6.2.2 Raft and Piles

Structural raft founded on piles (caissons) provide a robust and rigid foundation alternative to structural raft alone. This foundation option can be adopted if higher capacity at serviceability limit state is desired. The hybrid foundation option typically result in economical foundation system; however, if differential settlements are the only reason to accommodate piles then this foundation system becomes expensive compared to other options.

The piles can be founded with in the layer of Cobbles and boulders with silty clayey sand at approximate depths of 25 m to 30 m from the surface at powerhouse site The piles at the weir site will require socketing in rock towards the banks and approximate depths of 30 to 35 m will be sufficient to provide the required resistance at serviceability limit state towards the middle of the weir.

5.6.2.3 Resistance to Lateral Loading

Resistance to lateral loading can be derived from the vertical piles as well as installation of battered piles if required. The resistance to lateral loading is solely derived from the soil present in front of the vertical piles and by the horizontal component of the inclined pile.

The resistance to lateral loading in front of a vertical pile may be calculated from subgrade reaction theory.

5.6.3 Stability of Tunnel

The tunnel is envisioned to be constructed following New Austrian Tunneling Method (NATM). Stability of tunnel is evaluated following the methods suggested by Bieniawski (1976) as a Rock Mass Rating (RMR) system. The strength of a rock mass largely depends on the density, nature and extent of the fractures within it. Rock mass strength also relates to rock strength, weathering and water conditions. The details of RMR system and Q-system (Bieniawski (1989)) are provided in Appendix-II. The following six parameters are used to classify a rock mass using the RMR system:

1. Uniaxial compressive strength of rock material
2. Rock Quality Designation (RQD)
3. Spacing of discontinuities
4. Condition of discontinuities
5. Groundwater conditions
6. Orientation of discontinuities

The calculated RMR values and Q values for the tunnel through three main rock units. It shall be noted that the rock and support recommended in the following sections are typical and additional or lesser support might be required when tunnel is being constructed due to expected variability of sub-surface conditions. The sub-surface L-section along Tunnel Route is presented as figure 5-31.

5.6.3.1 Rock Classes in Schist

The RMR values range from 35 to 45 and the Q values ranges from 2 to 5 suggesting a rock class III-IV. The most of the part of the tunnel route passing through Schist is of class III. The tunnel in schist will require temporary support in the form of systematic rock bolts 3 to 4 m long spaced at 1.5 m to 2 m centers followed by 100 mm to 200 mm shotcrete with wire mesh.

5.6.3.2 Rock Classes in Granite

The RMR values range from 62 to 67 and the Q values ranges from 5 to 19 suggesting a rock class II (Good Rock). The tunnel in granite will require temporary support in the form of spot rock bolts 3 m followed by 50 mm shotcrete with wire mesh if required in the crown.

5.6.3.3 Rock Classes in Phylite

The RMR values range from 36 to 43 and the Q values ranges from 1.5 to 4.5 suggesting a rock class III & IV (Fair to Poor Rock). The tunnel in Phyllite will require temporary support in the form of systematic rock bolts 4 m to 5 m long spaced at 1.0 m to 1.5 m centers followed by 100 mm to 200 mm shotcrete with wire mesh. Steel ribs of light section might be used where required at center to center spacing of 1.5 m.

5.6.3.4 Rock Pressures

Rock pressures in underground excavations are the result of overburden stresses, hydrostatic stresses, and stored crustal stresses due to deformation of lithosphere due to tectonic forces. Hydrostatic stresses are not expected to affect the design of permanent lining of the tunnel; however, temporary water pressures may build as a result of snow melts. These pressures are not expected to produce significant stress which can be drained through drainage pipes.

Shearing stresses are expected to occur at the location of Tirich Mir Boundary Zone and at the contact between granite and phyllites along the tunnel route. The support at this location shall be capable of absorbing or preventing the relative displacements between the foot wall and hanging wall.

At the detailed design stage the estimation of the rock load on the excavated section of power tunnel should be studied by the study of geological properties, deformation modlii of different rock units that will encounter orientations of the discontinuities and the effect of the tectonic stresses on the tunnel supports.

5.6.3.5 Stability of Slopes at Weir Site

The Arkari Gol valley at the weir site is a U type valley at Ucchattar. The rock is hard and competent with natural and gradual slope of approx. 30^0 - 40^0 on both the abutments of the weir site. Slope angles are within the angle of repose of the competent rock units exposed. The joint sets are projected along the hill slopes showing the discontinuity flux in abutment slopes.

The major joints set are dipping toward hill side that shows the slopes are safe to slide along the joints planes. The care/protection should be adopted during the construction stage that the minor joint set are not day lighted at the toe of the hill.

5.6.4 Lateral Earth Pressures

The lateral earth pressures acting on abutment stems, wing walls, and excavated trenches will largely depend on the type and method of placement of backfill, on nature of geo materials behind the backfill and on drainage conditions behind the backfill.

The calculation of coefficient of lateral earth pressure depends on the type of backfill and the condition of restraining system. The earth pressures shall be calculated by using coefficient of lateral earth pressure at rest (Ko) if non-yielding restrain system is designed and by using coefficient of lateral earth pressure for active case (Ka) if yielding restraining system is designed. Typical values of *Ko* and *Ka* shall range from 0.4 to 0.47 and from 0.25 to 0.30 respectively. Lower values are taken for engineered backfills.

5.6.5 Groundwater Control

Water inflow into an excavation can cause significant construction challenges. Based on the measurement of water levels within the project area, it is anticipated that groundwater ingress is expected into the excavation areas adjacent to the left abutment of the weir and dam site and works carried out within the flow of the river.

Dewatering may be required in this area to lower the water below the founding elevations of shallow foundations or pile cap if deep foundations are chosen. Alternatively, a cutoff in the form of sheet piles can be constructed. Driving of steel sheet piles; however, will be difficult or impractical due to presence of boulders and cobbles.

ANNEXURES

Table 1 Rock Mass Rating (RMR) System (After Bieniawski 1989)

A. CLASSIFICATION PARAMETERS AND THEIR RATINGS

	Parameter		Range of values						
1	Strength of intact rock material	Point-load strength index	>10 MPa	4 - 10 MPa	2 - 4 MPa	1 - 2 MPa	For this low range - uniaxial compressive test is preferred		
		Uniaxial comp. strength	>250 MPa	100 - 250 MPa	50 - 100 MPa	25 - 50 MPa	5 - 25 MPa	1 - 5 MPa	<1 MPa
	Rating		15	12	7	4	2	1	0
2	Drill core Quality RQD		90% - 100%	75% - 90%	50% - 75%	25% - 50%	<25%		
	Rating		20	17	13	8	3		
3	Spacing of discontinuities		>2 m	0.6 - 2 . m	200 - 600 mm	60 - 200 mm	<60 mm		
	Rating		20	15	10	8	5		
4	Condition of discontinuities (See E)		Very rough surfaces Not continuous No separation Unweathered wall rock	Slightly rough surfaces Separation < 1 mm Slightly weathered walls	Slightly rough surfaces Separation < 1 mm Highly weathered walls	Slickensided surfaces or Gouge < 5 mm thick or Separation 1-5 mm Continuous	Soft gouge >5 mm thick or Separation > 5 mm Continuous		
	Rating		30	25	20	10	0		
5	Groundwater	Inflow per 10 m tunnel length (l/m)	None	<10	10 - 25	25 - 125	> 125		
		(Joint water press)/ (Major principal σ)	0	<0.1	0.1, - 0.2	0.2 - 0.5	>0.5		
		General conditions	Completely dry	Damp	Wet	Dripping	Flowing		
	Rating		15	10	7	4	0		

B. RATING ADJUSTMENT FOR DISCONTINUITY ORIENTATIONS (See F)

Strike and dip orientations		Very favourable	Favourable	Fair	Unfavourable	Very Unfavourable
Ratings	Tunnels & mines	0	-2	-5	-10	-12
	Foundations	0	-2	-7	-15	-25
	Slopes	0	-5	-25	-50	

C. ROCK MASS CLASSES DETERMINED FROM TOTAL RATINGS

Rating	100 ← 81	80 ← 61	60 ← 41	40 ← 21	<21
Class number	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

D. MEANING OF ROCK CLASSES

Class number	I	II	III	IV	V
Average stand-up time	20 yrs for 15 m span	1 year for 10 m span	1 week for 5 m span	10 hrs for 2.5 m span	30 min for 1 m span
Cohesion of rock mass (kPa)	> 400	300 - 400	200 - 300	100 - 200	< 100
Friction angle of rock mass (deg)	> 45	35 - 45	25 - 35	15 - 25	< 15

E. GUIDELINES FOR CLASSIFICATION OF DISCONTINUITY conditions

Discontinuity length (persistence)	<1 m	1 - 3 m	3 - 10 m	10 - 20 m	> 20 m
Rating	6	4	2	1	0
Separation (aperture)	None	< 0.1 mm	0.1 - 1.0 mm	1 - 5 mm	> 5 mm
Rating	6	5	4	1	0
Roughness	Very rough	Rough	Slightly rough	Smooth	Slickensided
Rating	6	5	3	1	0
Infilling (gouge)	None	Hard filling < 5 mm	Hard filling > 5 mm	Soft filling < 5 mm	Soft filling > 5 mm
Rating	6	4	2	2	0
Weathering	Unweathered	Slightly weathered	Moderately weathered	Highly weathered	Decomposed
Ratings	6	5	3	1	0

F. EFFECT OF DISCONTINUITY STRIKE AND DIP ORIENTATION IN TUNNELLING**

Strike perpendicular to tunnel axis		Strike parallel to tunnel axis	
Drive with dip - Dip 45 - 90°	Drive with dip - Dip 20 - 45°	Dip 45 - 90°	Dip 20 - 45°
Very favourable	Favourable	Very unfavourable	Fair
Drive against dip - Dip 45-90°	Drive against dip - Dip 20-45°	Dip 0-20 - Irrespective of strike°	
Fair	Unfavourable	Fair	

* Some conditions are mutually exclusive. For example, if infilling is present, the roughness of the surface will be overshadowed by the influence of the gouge. In such cases use A.4 directly.

** Modified after Wickham et al (1972).

Table 2 Guidelines for excavation and support of less than 10 m span rock tunnels in accordance with the RMR system (After Bieniawski 1989)

Rock mass class	Excavation	Rock bolts (20 mm diameter, fully grouted)	Shotcrete	Steel sets
I - Very good rock *RMR*: 81-100	Full face, 3 m advance.	Generally no support required except spot bolting.		
II - Good rock *RMR*: 61-80	Full face., 1-1.5 m advance. Complete support 20 m from face.	Locally, bolts in crown 3 m long, spaced 2.5 m with occasional wire mesh.	50 mm in crown where required.	None.
III - Fair rock *RMR*: 41-60	Top heading and bench 1.5-3 m advance in top heading. Commence support after each blast. Complete support 10 m from face.	Systematic bolts 4 m long, spaced 1.5 - 2 m in crown and walls with wire mesh in crown.	50-100 mm in crown and 30 mm in sides.	None.
IV - Poor rock *RMR*: 21-40	Top heading and bench 1.0-1.5 m advance in top heading. Install support concurrently with excavation, 10 m from face.	Systematic bolts 4-5 m long, spaced 1-1.5 m in crown and walls with wire mesh.	100-150 mm in crown and 100 mm in sides.	Light to medium ribs spaced 1.5 m where required.
V – Very poor rock *RMR*: < 20	Multiple drifts 0.5-1.5 m advance in top heading. Install support concurrently with excavation. Shotcrete as soon as possible after blasting.	Systematic bolts 5-6 m long, spaced 1-1.5 m in crown and walls with wire mesh. Bolt invert.	150-200 mm in crown, 150 mm in sides, and 50 mm on face.	Medium to heavy ribs spaced 0.75 m with steel lagging and forepoling if required. Close invert.

Rock Tunneling Quality Index, Q

On the basis of an evaluation of a large number of case histories of underground excavations, Barton et al (1974) of the Norwegian Geotechnical Institute proposed a Tunneling Quality Index (Q) for the determination of rock mass characteristics and tunnel support requirements.

The Norwegian Q - value is then calculated as:-

Q = (RQD/Jn) x (Jr/Ja) x (Jw/SRF)

Where:

RQD	=	Rock quality Designation.
JR	=	Joint Roughness Number
Jw	=	Joint water factor
Jn	=	Joint set Number
Ja	=	Joint alteration Number

RMR AND Q VALUE FOR WEIR SITE					
Station No.	Location	Rock type	RMR	Class	Q value
1	Weir Right Bank	Granite	62	II	0.75
2	Weir Right Bank	Granite	56	III	1.5
3	Weir Right Bank	Granite	47	III	0.75
4	Weir Right Bank	Granite	53	III	1.5
5	Weir Right Bank	Granite	51	III	0.75
6	Weir Right Bank	Granite	53	III	1.5
7	Weir Right Bank	Granite	46	III	0.75
8	Weir Right Bank	Granite	53	III	1.5
9	Weir Right Bank	Granite	58	III	3
10	Weir Right Bank	Granite	53	III	3
11	Weir Right Bank	Granite	51	III	0.75
12	Weir Right Bank	Granite	48	III	3
13	Weir Right Bank	Granite	48	III	3
14	Weir Right Bank	Granite	47	III	3
15	Weir Right Bank	Granite	48	III	1.5
16	Weir Left Bank	Granite	51	III	0.75
17	Weir Left Bank	Granite	48	III	1.5
18	Weir Left Bank	Granite	48	III	1.5
19	Weir Left Bank	Granite	50	III	3
20	Weir Left Bank	Granite	55	III	3
21	Weir Left Bank	Granite	52	III	3
22	Weir Left Bank	Granite	55	III	3
23	Weir Left Bank	Granite	52	III	3
24	Weir Left Bank	Granite	48	III	3
25	Weir Left Bank	Granite	53	III	0.75
26	Weir Left Bank	Granite	45	III	3

RMR AND Q VALUE FOR WEIR SITE					
Station No.	**Location**	**Rock type**	**RMR**	**Class**	**Q value**
27	Weir Left Bank	Granite	50	III	3
28	Weir Left Bank	Granite	54	III	3
29	Weir Left Bank	Granite	57	III	3
30	Weir Left Bank	Granite	57	III	3
31	Weir Left Bank	Granite	54	III	1.5
32	Weir Left Bank	Granite	49	III	0.75
33	Weir Left Bank	Granite	52	III	3
34	Weir Left Bank	Granite	49	III	1.75
35	Weir Left Bank	Granite	43	III	0.75
36	Weir Left Bank	Granite	50	III	3
37	Weir Left Bank	Granite	48	III	3
38	Weir Left Bank	Granite	55	III	3
39	Weir Left Bank	Granite	50	III	3
40	Weir Left Bank	Granite	50	III	3
41	Weir Left Bank	Granite	50	III	3
42	Weir Left Bank	Granite	47	III	3
43	Weir Left Bank	Granite	53	III	3
44	Weir Left Bank	Granite	53	III	3
45	Weir Left Bank	Granite	53	III	3
46	Weir Left Bank	Granite	55	III	3
47	Weir Left Bank	Granite	55	III	3
48	Weir Left Bank	Granite	51	III	0.75
49	Weir Left Bank	Granite	50	III	1.5
50	Weir Left Bank	Granite	53	III	0.75
51	Weir Left Bank	Granite	44	III	0.75
52	Weir Left Bank	Granite	46	III	0.75

RMR AND Q VALUE FOR WEIR SITE					
Station No.	Location	Rock type	RMR	Class	Q value
53	Weir Left Bank	Granite	51	III	0.75
54	Weir Left Bank	Granite	51	III	0.75
55	Weir Left Bank	Granite	48	III	0.75
56	Weir Left Bank	Granite	53	III	0.75
57	Weir Left Bank	Granite	49	III	0.75
58	Weir Left Bank	Granite	53	III	0.75
59	Weir Left Bank	Granite	53	III	0.75
60	Weir Left Bank	Granite	55	III	0.75
61	Weir Left Bank	Granite	53	III	0.75
62	Weir Left Bank	Granite	52	III	3
63	Weir Left Bank	Granite	52	III	3
64	Weir Left Bank	Granite	55	III	3
65	Weir Left Bank	Granite	51	III	0.75
66	Weir Left Bank	Granite	53	III	0.75
67	Weir Left Bank	Granite	51	III	0.75
68	Weir Left Bank	Granite	49	III	0.75
69	Weir Left Bank	Granite	48	III	0.75
70	Weir Left Bank	Granite	49	III	0.75
71	Weir Left Bank	Granite	48	III	0.75
72	Weir Left Bank	Granite	51	III	0.75
73	Weir Left Bank	Granite	44	III	0.75
74	Weir Left Bank	Granite	48	III	0.75
75	Weir Left Bank	Granite	51	III	0.75
76	Weir Left Bank	Granite	44	III	0.75
77	Weir Left Bank	Granite	46	III	0.75
78	Weir Left Bank	Granite	44	III	0.75

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RMR AND Q VALUE FOR WEIR SITE					
Station No.	Location	Rock type	RMR	Class	Q value
79	Weir Left Bank	Granite	46	III	0.75
80	Weir Left Bank	Granite	46	III	0.75
81	Weir Left Bank	Granite	48	III	0.75
82	Weir Left Bank	Granite	45	III	0.75
83	Weir Left Bank	Granite	51	III	0.75
84	Weir Left Bank	Granite	51	III	0.75
85	Weir Left Bank	Granite	43	III	0.75
86	Weir Left Bank	Granite	53	III	3
87	Weir Left Bank	Granite	48	III	3
88	Weir Left Bank	Granite	48	III	3
89	Weir Left Bank	Granite	44	III	0.75
90	Weir Left Bank	Granite	49	III	0.75

Station No.	Location	Rock type	RMR	Class	Q value
1	Along Tunnel	Granite	51	III	0.75
2	Along Tunnel	Granite	53	III	3
3	Along Tunnel	Granite	55	III	3
4	Along Tunnel	Granite	55	III	3
5	Along Tunnel	Granite	55	III	3
6	Along Tunnel	Granite	53	III	3
7	Along Tunnel	Granite	46	III	0.75
8	Along Tunnel	Granite	46	III	0.75
9	Along Tunnel	Granite	51	III	0.75
10	Along Tunnel	Granite	44	III	0.75
11	Along Tunnel	Granite	55	III	3
12	Along Tunnel	Granite	55	III	3
13	Along Tunnel	Granite	52	III	3
14	Along Tunnel	Granite	55	III	3
15	Along Tunnel	Granite	55	III	3
16	Along Tunnel	Granite	55	III	3
17	Along Tunnel	Granite	53	III	3
18	Along Tunnel	Granite	51	III	0.75
19	Along Tunnel	Granite	49	III	0.75
20	Along Tunnel	Granite	44	III	0.75
21	Along Tunnel	Granite	49	III	0.75
22	Along Tunnel	Granite	48	III	3
23	Along Tunnel	Granite	46	III	0.75
24	Along Tunnel	Granite	48	III	3
25	Along Tunnel	Granite	48	III	3
26	Along Tunnel	Granite	48	III	3
27	Along Tunnel	Granite	48	III	3

Station No.	Location	Rock type	RMR	Class	Q value
28	Along Tunnel	Granite	48	III	3
29	Along Tunnel	Granite	48	III	0.25
30	Along Tunnel	Granite	55	III	3
31	Along Tunnel	Granite	51	III	0.75
32	Along Tunnel	Granite	51	III	0.75
33	Along Tunnel	Granite	51	III	0.75
34	Along Tunnel	Granite	47	III	0.75
35	Along Tunnel	Granite	51	III	0.75
36	Along Tunnel	Granite	55	III	3
37	Along Tunnel	Granite	48	III	0.75
38	Along Tunnel	Granite	55	III	3
39	Along Tunnel	Granite	53	III	3
40	Along Tunnel	Granite	48	III	3
41	Along Tunnel	Granite	55	III	3
42	Along Tunnel	Granite	50	III	3
43	Along Tunnel	Granite	55	III	3
44	Along Tunnel	Granite	55	III	3
45	Along Tunnel	Granite	53	III	0.75
46	Along Tunnel	Granite	46	III	0.75
47	Along Tunnel	Granite	44	III	0.75
48	Along Tunnel	Granite	44	III	0.75
49	Along Tunnel	Granite	49	III	0.75
50	Along Tunnel	Granite	47	III	0.75
51	Along Tunnel	Granite	51	III	0.75
52	Along Tunnel	Granite	49	III	0.75
53	Along Tunnel	Granite	49	III	0.75
54	Along Tunnel	Granite	52	III	3

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Station No.	Location	Rock type	RMR	Class	Q value
55	Along Tunnel	Granite	55	III	3
56	Along Tunnel	Granite	53	III	3
57	Along Tunnel	Granite	55	III	3
58	Along Tunnel	Granite	53	III	0.75
59	Along Tunnel	Granite	49	III	0.75
60	Along Tunnel	Granite	49	III	0.75
61	Along Tunnel	Granite	57	III	3
62	Along Tunnel	Granite	55	III	3
63	Along Tunnel	Granite	55	III	3
64	Along Tunnel	Granite	50	III	3
65	Along Tunnel	Granite	55	III	3
66	Along Tunnel	Granite	50	III	3
67	Along Tunnel	Granite	55	III	3
68	Along Tunnel	Granite	52	III	3
69	Along Tunnel	Granite	55	III	3
70	Along Tunnel	Granite	49	III	0.75
71	Along Tunnel	Granite	51	III	0.75
72	Along Tunnel	Granite	44	III	0.75
73	Along Tunnel	Granite	44	III	0.75
74	Along Tunnel	Granite	50	III	0.75
75	Along Tunnel	Granite	55	III	3
76	Along Tunnel	Granite	55	III	3
77	Along Tunnel	Granite	55	III	3
78	Along Tunnel	Granite	44	III	1
79	Along Tunnel	Granite	51	III	0.75
80	Along Tunnel	Granite	48	III	3
81	Along Tunnel	Granite	48	III	3

Station No.	Location	Rock type	RMR	Class	Q value
82	Along Tunnel	Granite	48	III	3
83	Along Tunnel	Granite	48	III	3
84	Along Tunnel	Granite	55	III	3
85	Along Tunnel	Granite	48	III	3
86	Along Tunnel	Granite	53	III	0.75
87	Along Tunnel	Granite	48	III	3
88	Along Tunnel	Granite	50	III	3
89	Along Tunnel	Granite	44	III	0.75
90	Along Tunnel	Granite	49	III	0.75
91	Along Tunnel	Granite	51	III	3
92	Along Tunnel	Granite	53	III	3
93	Along Tunnel	Granite	53	III	3
94	Along Tunnel	Granite	49	III	0.75
95	Along Tunnel	Granite	42	III	0.75
96	Along Tunnel	Granite	41	III	0.75
97	Along Tunnel	Granite	52	III	3
98	Along Tunnel	Granite	42	III	0.75
99	Along Tunnel	Granite	55	III	3
100	Along Tunnel	Granite	44	III	0.75
101	Along Tunnel	Granite	55	III	3
102	Along Tunnel	Granite	44	III	0.75
103	Along Tunnel	Granite	44	III	0.75
104	Along Tunnel	Granite	47	III	3
105	Along Tunnel	Granite	50	III	3
106	Along Tunnel	Granite	49	III	0.75
107	Along Tunnel	Granite	49	III	0.75
108	Along Tunnel	Granite	46	III	0.75

Station No.	Location	Rock type	RMR	Class	Q value
109	Along Tunnel	Granite	46	III	0.75
110	Along Tunnel	Granite	51	III	0.75
111	Along Tunnel	Granite	53	III	3
112	Along Tunnel	Granite	48	III	3
113	Along Tunnel	Granite	55	III	3
114	Along Tunnel	Granite	60	III	3
115	Along Tunnel	Granite	50	III	3
116	Along Tunnel	Granite	60	III	3
117	Along Tunnel	Granite	46	III	3
118	Along Tunnel	Granite	51	III	3
119	Along Tunnel	Granite	49	III	0.75
120	Along Tunnel	Granite	44	III	0.75
121	Along Tunnel	Granite	38	IV	0.75
122	Along Tunnel	Granite	38	IV	0.75
123	Along Tunnel	Granite	37	IV	0.75
124	Along Tunnel	Granite	35	IV	0.75
125	Along Tunnel	Granite	32	IV	0.5
126	Along Tunnel	Granite	33	IV	0.5
127	Along Tunnel	Granite	33	IV	0.5
128	Along Tunnel	Granite	33	IV	0.5
129	Along Tunnel	Granite	38	IV	0.5
130	Along Tunnel	Granite	37	IV	0.5
131	Along Tunnel	Granite	39	IV	0.75
132	Along Tunnel	Granite	38	IV	0.75
133	Along Tunnel	Granite	38	IV	0.75
134	Along Tunnel	Granite	38	IV	0.75
135	Along Tunnel	Granite	38	IV	0.75

Station No.	Location	Rock type	RMR	Class	Q value
136	Along Tunnel	Granite	40	III	0.75
137	Along Tunnel	Granite	40	III	0.75
138	Along Tunnel	Granite	40	III	0.75
139	Along Tunnel	Granite	42	III	0.75
140	Along Tunnel	Granite	40	III	0.75
141	Along Tunnel	Granite	40	III	0.75
142	Along Tunnel	Granite	40	III	0.75
143	Along Tunnel	Granite	39	IV	0.75
144	Along Tunnel	Granite	37	IV	0.5
145	Along Tunnel	Granite	37	IV	0.5
146	Along Tunnel	Granite	37	IV	0.5
147	Along Tunnel	Granite	39	IV	0.75
148	Along Tunnel	Granite	37	IV	0.75
149	Along Tunnel	Granite	38	IV	0.75
150	Along Tunnel	Granite	37	IV	0.75
151	Along Tunnel	Granite	38	IV	0.5
152	Along Tunnel	Granite	38	IV	0.5
153	Along Tunnel	Granite	38	IV	0.5
154	Along Tunnel	Granite	38	IV	0.5
155	Along Tunnel	Granite	38	IV	0.5
156	Along Tunnel	Granite	38	IV	0.5
157	Along Tunnel	Granite	38	IV	0.5
158	Along Tunnel	Granite	38	IV	0.75
159	Along Tunnel	Granite	40	III	0.75
160	Along Tunnel	Granite	40	III	0.75
161	Along Tunnel	Granite	42	III	0.75
162	Along Tunnel	Granite	42	III	0.75

Station No.	Location	Rock type	RMR	Class	Q value
163	Along Tunnel	Granite	42	III	0.75
164	Along Tunnel	Granite	42	III	0.75
165	Along Tunnel	Granite	42	III	0.75
166	Along Tunnel	Granite	36	IV	0.5
167	Along Tunnel	Granite	36	IV	0.5
168	Along Tunnel	Granite	36	IV	0.5
169	Along Tunnel	Granite	36	IV	0.5
170	Along Tunnel	Granite	36	IV	0.5
171	Along Tunnel	Granite	35	IV	0.5
172	Along Tunnel	Granite	40	III	2
173	Along Tunnel	Granite	42	III	3
174	Along Tunnel	Granite	41	III	3
175	Along Tunnel	Granite	42	III	3
176	Along Tunnel	Granite	40	III	2
177	Along Tunnel	Granite	39	IV	2
178	Along Tunnel	Granite	44	III	3
179	Along Tunnel	Granite	44	III	3
180	Along Tunnel	Granite	44	III	3
181	Along Tunnel	Granite	42	III	3
182	Along Tunnel	Granite	42	III	3
183	Along Tunnel	Granite	42	III	3
184	Along Tunnel	Granite	41	III	3
185	Along Tunnel	Granite	42	III	3
186	Along Tunnel	Granite	45	III	3
187	Along Tunnel	Granite	41	III	3
188	Along Tunnel	Granite	45	III	3
189	Along Tunnel	Granite	39	IV	0.75

Station No.	Location	Rock type	RMR	Class	Q value
190	Along Tunnel	Granite	35	IV	0.75
191	Along Tunnel	Granite	39	IV	0.75
192	Along Tunnel	Granite	39	IV	0.75
193	Along Tunnel	Granite	35	IV	0.75
194	Along Tunnel	Granite	39	IV	0.75
195	Along Tunnel	Granite	39	IV	0.75

Station No.	Location	Rock type	RMR	Class	Q value
1	Powerhouse	Phyllite	40	III	0.75
2	Powerhouse	Phyllite	40	III	0.75
3	Powerhouse	Phyllite	40	III	0.75
4	Powerhouse	Phyllite	40	III	0.75
5	Powerhouse	Phyllite	42	III	0.75
6	Powerhouse	Phyllite	42	III	0.75
7	Powerhouse	Phyllite	44	III	0.75
8	Powerhouse	Phyllite	42	III	0.75
9	Powerhouse	Phyllite	42	III	0.75
10	Powerhouse	Phyllite	42	III	0.75
11	Powerhouse	Phyllite	40	III	0.75
12	Powerhouse	Phyllite	38	IV	0.75
13	Powerhouse	Phyllite	40	III	0.75
14	Powerhouse	Phyllite	36	IV	0.75
15	Powerhouse	Phyllite	36	IV	0.75
16	Powerhouse	Phyllite	40	III	0.75
17	Powerhouse	Phyllite	42	III	0.75
18	Powerhouse	Phyllite	42	III	0.75
19	Powerhouse	Phyllite	44	III	0.75
20	Powerhouse	Phyllite	42	III	0.75
21	Powerhouse	Phyllite	38	IV	0.75
22	Powerhouse	Phyllite	38	IV	0.75
23	Powerhouse	Phyllite	42	III	0.75
24	Powerhouse	Phyllite	41	III	0.75
25	Powerhouse	Phyllite	39	IV	0.75
26	Powerhouse	Phyllite	40	III	0.75
27	Powerhouse	Phyllite	42	III	0.75

Station No.	Location	Rock type	RMR	Class	Q value
28	Powerhouse	Phyllite	42	III	0.75
29	Powerhouse	Phyllite	42	III	0.75
30	Powerhouse	Phyllite	42	III	0.75
31	Powerhouse	Phyllite	40	III	0.75
32	Powerhouse	Phyllite	40	III	0.75
33	Powerhouse	Phyllite	40	III	0.75
34	Powerhouse	Phyllite	41	III	0.75
35	Powerhouse	Phyllite	41	III	0.75
36	Powerhouse	Phyllite	39	IV	0.75
37	Powerhouse	Phyllite	39	IV	0.75
38	Powerhouse	Phyllite	39	IV	0.75
39	Powerhouse	Phyllite	39	IV	0.75
40	Powerhouse	Phyllite	39	IV	0.75
41	Powerhouse	Phyllite	39	IV	0.75
42	Powerhouse	Phyllite	39	IV	0.75
43	Powerhouse	Phyllite	39	IV	0.75
44	Powerhouse	Phyllite	39	IV	0.75
45	Powerhouse	Phyllite	39	IV	0.75
46	Powerhouse	Phyllite	40	III	0.75
47	Powerhouse	Phyllite	39	IV	0.75
48	Powerhouse	Phyllite	39	IV	0.75
49	Powerhouse	Phyllite	40	III	0.75
50	Powerhouse	Phyllite	40	III	0.75
51	Powerhouse	Phyllite	40	III	0.75
52	Powerhouse	Phyllite	40	III	0.75
53	Powerhouse	Phyllite	40	III	0.75
54	Powerhouse	Phyllite	40	III	0.75

Station No.	Location	Rock type	RMR	Class	Q value
55	Powerhouse	Phyllite	40	III	0.75
56	Powerhouse	Phyllite	36	IV	0.5
57	Powerhouse	Phyllite	36	IV	0.5
58	Powerhouse	Phyllite	38	IV	0.75
59	Powerhouse	Phyllite	38	IV	0.75
60	Powerhouse	Phyllite	38	IV	0.75
61	Powerhouse	Phyllite	42	III	0.75
62	Powerhouse	Phyllite	42	III	0.75
63	Powerhouse	Phyllite	42	III	0.75
64	Powerhouse	Phyllite	42	III	0.75
65	Powerhouse	Phyllite	42	III	0.75
66	Powerhouse	Phyllite	38	IV	0.75
67	Powerhouse	Phyllite	40	III	0.75
68	Powerhouse	Phyllite	38	IV	0.75
69	Powerhouse	Phyllite	40	III	0.75
70	Powerhouse	Phyllite	38	IV	0.75
71	Powerhouse	Phyllite	42	III	1.5
72	Powerhouse	Phyllite	40	III	1.5
73	Powerhouse	Phyllite	38	IV	0.75
74	Powerhouse	Phyllite	40	III	0.75
75	Powerhouse	Phyllite	40	III	0.75
76	Powerhouse	Phyllite	40	III	0.75
77	Powerhouse	Phyllite	39	IV	0.75
78	Powerhouse	Phyllite	39	IV	0.75
79	Powerhouse	Phyllite	40	III	0.75
80	Powerhouse	Phyllite	39	IV	0.75
81	Powerhouse	Phyllite	51	III	3

Station No.	Location	Rock type	RMR	Class	Q value
82	Powerhouse	Phyllite	45	III	3
83	Powerhouse	Phyllite	47	III	0.75
84	Powerhouse	Phyllite	40	III	0.75
85	Powerhouse	Phyllite	39	IV	0.75
86	Powerhouse	Phyllite	42	III	0.75
87	Powerhouse	Phyllite	40	III	0.75
88	Powerhouse	Phyllite	39	IV	0.75
89	Powerhouse	Phyllite	40	III	0.75
90	Powerhouse	Phyllite	47	III	0.75
91	Powerhouse	Phyllite	42	III	0.75
92	Powerhouse	Phyllite	48	III	3
93	Powerhouse	Phyllite	48	III	3
94	Powerhouse	Phyllite	39	IV	0.75
95	Powerhouse	Phyllite	40	III	0.75
96	Powerhouse	Phyllite	40	III	0.75
97	Powerhouse	Phyllite	39	IV	0.75
98	Powerhouse	Phyllite	40	III	0.75
99	Powerhouse	Phyllite	42	III	0.75
100	Powerhouse	Phyllite	42	III	0.75
101	Powerhouse	Phyllite	42	III	0.75
102	Powerhouse	Phyllite	42	III	0.75
103	Powerhouse	Phyllite	39	IV	0.75
104	Powerhouse	Phyllite	42	III	0.75
105	Powerhouse	Phyllite	42	III	0.75
106	Powerhouse	Phyllite	46	III	3
107	Powerhouse	Phyllite	45	III	3
108	Powerhouse	Phyllite	45	III	3

Station No.	Location	Rock type	RMR	Class	Q value
109	Powerhouse	Phyllite	45	III	3
110	Powerhouse	Phyllite	46	III	3
111	Powerhouse	Phyllite	46	III	3
112	Powerhouse	Phyllite	45	III	3
113	Powerhouse	Phyllite	41	III	0.75
114	Powerhouse	Phyllite	42	III	0.75
115	Powerhouse	Phyllite	41	III	0.75
116	Powerhouse	Phyllite	44	III	0.75
117	Powerhouse	Phyllite	44	III	0.75
118	Powerhouse	Phyllite	41	III	0.75
119	Powerhouse	Phyllite	42	III	0.75
120	Powerhouse	Phyllite	42	III	0.75
121	Powerhouse	Phyllite	48	III	3
122	Powerhouse	Phyllite	45	III	3
123	Powerhouse	Phyllite	40	III	0.75
124	Powerhouse	Phyllite	50	III	3
125	Powerhouse	Phyllite	46	III	3
126	Powerhouse	Phyllite	40	III	0.75
127	Powerhouse	Phyllite	45	III	0.75
128	Powerhouse	Phyllite	42	III	0.75
129	Powerhouse	Phyllite	42	III	0.75
130	Powerhouse	Phyllite	42	III	0.75
131	Powerhouse	Phyllite	42	III	0.75
132	Powerhouse	Phyllite	42	III	0.75
133	Powerhouse	Phyllite	37	IV	0.75
134	Powerhouse	Phyllite	40	III	0.75
135	Powerhouse	Phyllite	40	III	0.75

Station No.	Location	Rock type	RMR	Class	Q value
136	Powerhouse	Phyllite	46	III	3
137	Powerhouse	Phyllite	46	III	3
138	Powerhouse	Phyllite	46	III	3
139	Powerhouse	Phyllite	45	III	3
140	Powerhouse	Phyllite	46	III	3
141	Powerhouse	Phyllite	46	III	3
142	Powerhouse	Phyllite	45	III	3
143	Powerhouse	Phyllite	40	III	0.75
144	Powerhouse	Phyllite	39	IV	0.75
145	Powerhouse	Phyllite	42	III	0.75
146	Powerhouse	Phyllite	42	III	0.75
147	Powerhouse	Phyllite	42	III	0.75
148	Powerhouse	Phyllite	41	III	0.75
149	Powerhouse	Phyllite	42	III	0.75
150	Powerhouse	Phyllite	42	III	0.75
151	Powerhouse	Phyllite	46	III	3
152	Powerhouse	Phyllite	46	III	3
153	Powerhouse	Phyllite	46	III	3
154	Powerhouse	Phyllite	41	III	3
155	Powerhouse	Phyllite	45	III	3
156	Powerhouse	Phyllite	46	III	3
157	Powerhouse	Phyllite	46	III	3
158	Powerhouse	Phyllite	42	III	0.75
159	Powerhouse	Phyllite	44	III	0.75
160	Powerhouse	Phyllite	44	III	0.75
161	Powerhouse	Phyllite	44	III	0.75
162	Powerhouse	Phyllite	44	III	0.75

Station No.	Location	Rock type	RMR	Class	Q value
163	Powerhouse	Phyllite	37	IV	0.75
164	Powerhouse	Phyllite	42	III	0.75
165	Powerhouse	Phyllite	42	III	0.75
166	Powerhouse	Phyllite	46	III	3
167	Powerhouse	Phyllite	46	III	3
168	Powerhouse	Phyllite	46	III	3
169	Powerhouse	Phyllite	45	III	3
170	Powerhouse	Phyllite	46	III	3
171	Powerhouse	Phyllite	46	III	3
172	Powerhouse	Phyllite	40	III	3
173	Powerhouse	Phyllite	47	III	0.75
174	Powerhouse	Phyllite	40	III	0.75
175	Powerhouse	Phyllite	47	III	0.75
176	Powerhouse	Phyllite	42	III	0.75
177	Powerhouse	Phyllite	42	III	0.75
178	Powerhouse	Phyllite	40	III	0.75
179	Powerhouse	Phyllite	42	III	0.75
180	Powerhouse	Phyllite	42	III	0.75
181	Powerhouse	Phyllite	46	III	3
182	Powerhouse	Phyllite	45	III	3
183	Powerhouse	Phyllite	45	III	3
184	Powerhouse	Phyllite	45	III	3
185	Powerhouse	Phyllite	46	III	3
186	Powerhouse	Phyllite	46	III	3
187	Powerhouse	Phyllite	45	III	3
188	Powerhouse	Phyllite	42	III	0.75
189	Powerhouse	Phyllite	42	III	0.75

Station No.	Location	Rock type	RMR	Class	Q value
190	Powerhouse	Phyllite	41	III	0.75
191	Powerhouse	Phyllite	44	III	0.75
192	Powerhouse	Phyllite	44	III	0.75
193	Powerhouse	Phyllite	41	III	0.75
194	Powerhouse	Phyllite	42	III	0.75
195	Powerhouse	Phyllite	42	III	0.75

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CHAPTER - 6
SEISMIC HAZARD

SEISMIC HAZARD

6. Seismo-Tectonic Studies

6.1 Global and Regional Seismotectonics

The earth's crust is divided into plates, known as "Tectonic Plates", these are shown in **Figure 6-1**, along with their direction of movement. Most of the seismic events (about 85%) happen on the edges or borders of these plates, these are marked as dots in **Figure 6-2**. The relative movements of these plates generate or are a cause of generation of seismic activity. There are roughly 7 main plates, and 8 smaller or buffer plates, totaling 15.

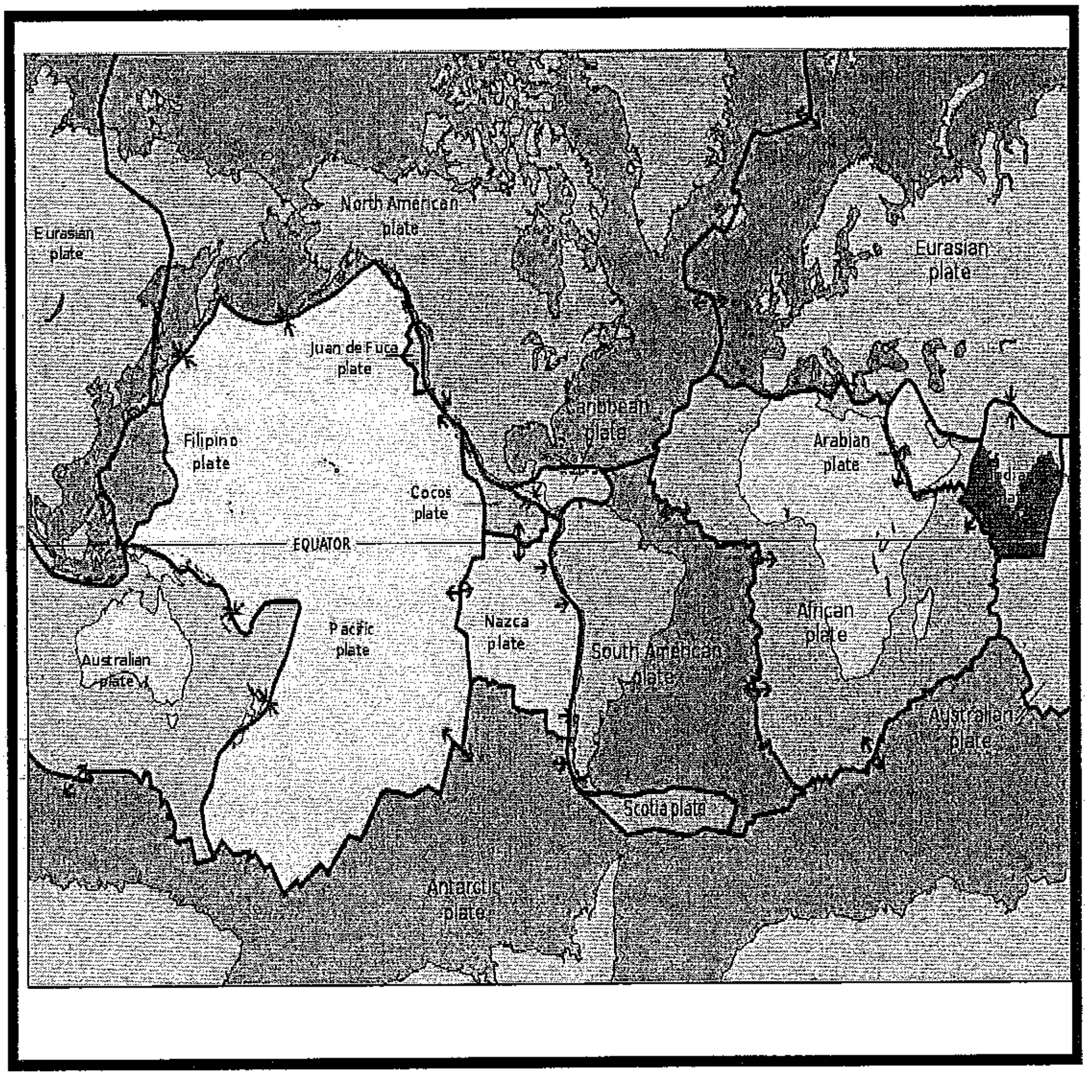


Figure 6-1: Tectonic Plates

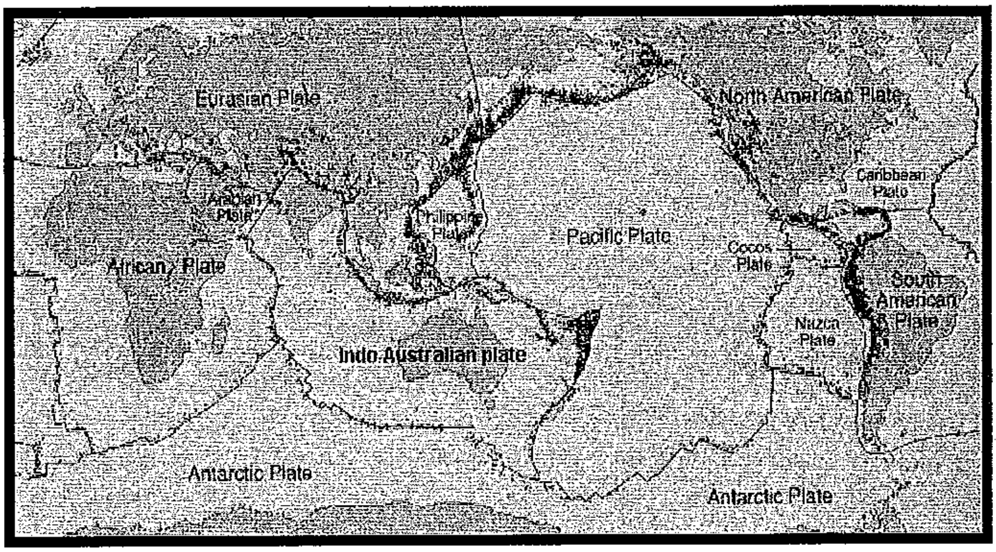


Figure 6-2: Seismic Event on Tectonic Plates

Further details about regional-seismo-tectonic aspects related to our site of interest are provided in the Geological Investigation Report. The project area of ArkariGol HPP is situated in Chitral District of KP, located at the NW corner of Pakistan and is a part of the Eastern Hindu Kush Range (See **Figure 6-3**).

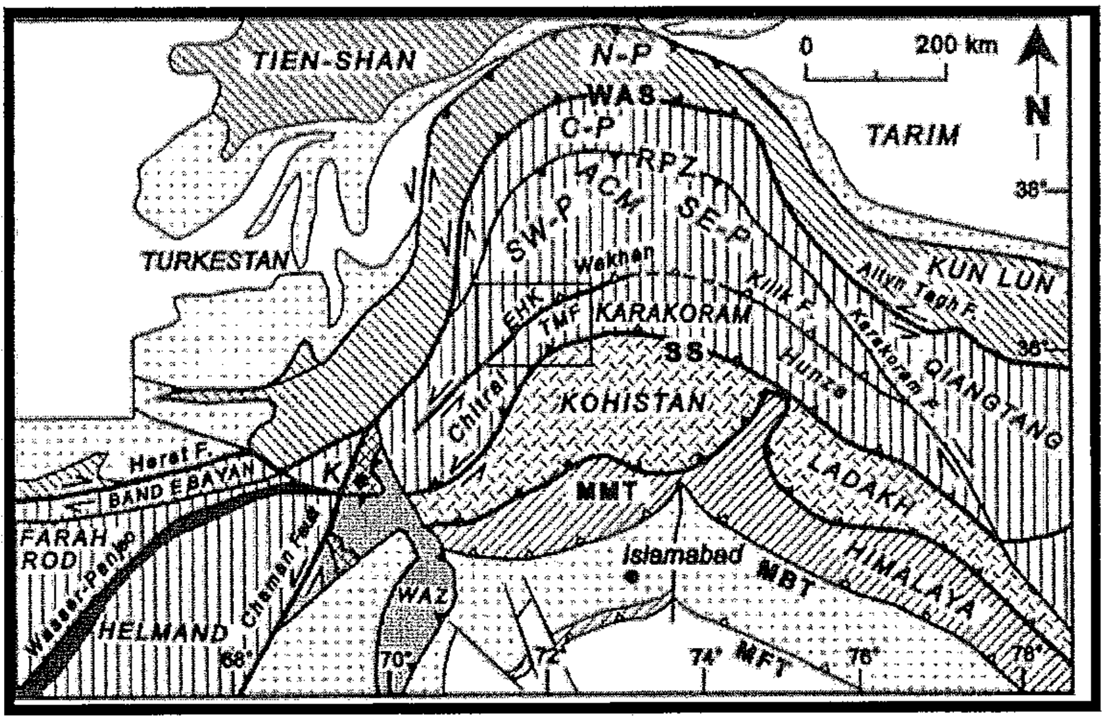
The Hindu Kush Range, along with the Himalayan Range to its south and the Karakoram Range to its east, form the southern part of the Pamir Knot, which is amongst the few regions in the world with average altitude in excess of 3000 m. These mountain ranges are continent – continent collision by origin, where the associated deformation is active even today. Because of this tectonic setting, the Chitral District is subject to a long history of tectonics, which is present to date, and is responsible for recent seismicity. With this background Chitral District has been placed in highest zone of seismicity (Zone-4), the highest potential seismic hazard, in the Seismic Hazard Zonation by Building code of Pakistan, Seismic Provision 2007.

Further details about regional-seismo-tectonic aspects related to our site of interest are provided in the Geological Investigation Report. The project area of Arkari HPP is situated in Chitral district of KPK, located at the NW corner of Pakistan and is a part of the Eastern Hindu Kush Range.(See Fig. 6-3)

Keeping this in mind, the objective of this study was to fully understand/determine the tectonic setting of the Chitral region, with emphasis on faults of the region, in relation to the powerhouse project site and to ultimately determine the MCE and OBE and their PGA.

The tectonic setting characterization of the important faults of the area of interest leads to determination of seismic potential of the faults, their distance from our project area and ultimately the MCE and OBE of each location of structure for the project, design of these structures to resist the impact of relevant earthquake on the components of the HPP.

Figure 6-3: Regional tectonic map of South-Central Asia showing position of the Karakoram-Hindu Kush block



6.1.2 Neotectonics Studies

The neotectonic studies were carried out based on field observations and geological studies. These studies determined the level of seismicity as stated in earlier section, for design of ArkariGol Hydropower project structures. The detail of these field studies is discussed at length in Geological Investigation/Survey Report.

6.1.2.1 Fault Structure

The input parameters in Seismic Hazard Analysis of Critical sites like Nuclear Plants and hydropower projects (including dam sites) include seismic sources, which are primarily the fault structures as well as the seismicity within the a radius of 50 – 150 km from the area of interest. It depends, upon the size of project (Dam etc.), its potential hazard, to ascertain the radius. The fault structures with neotectonic potential are critical as seismic hazard input parameters. Almost all the fault structures which lie in comparatively young orogenic belts of Himalayas, Karakorum and Hindu Kush carry enough neotectonic potential. The recent enhanced seismic activity seen in northern region of Pakistan is an evidence of neotectonic potential of the region.

6.2 Seismic Record

6.2.1 Historicalrecord

The historical data for the Hindu Kush region has been compiled by Amraseys and Biham (2003; 2009) which forms the basis of defining the historical seismicity of the Chitral Region.

The historical data suggests that Kunar Fault and its NE splays like Upper Swat (Kalam) Fault Zone and the MKT have been a focus of several past earthquakes some approaching M 7.5. There are historical records of extensive damage along the Kunar River as far as Drosh, suggesting that MKT did rupture in these earthquakes. In comparison, the Tirich Mir and Reshun Faults have no historical earthquakes associated with them, except for one at 1842 centered on Chitral-Wakhan border. This apparently indicates lack of seismic activity associated with these faults. However, considering that continued convergence in the Hindu Kush is to the order of 5 cm/yr, the Tirich Mir and Reshun Faults may be more vulnerable in terms of seismic hazard potential as they must be storing strain for the past several hundred years.

Both historical/non instrumental (Oldham, 1983; Ambraseys et al, 1975 and Quittmeyer et al, 1979) and instrumental data exist in the area. The instrumentally recorded earthquake data are available only since 1904.

6.2.2 Instrumental Seismicity

The seismometer recording of earthquakes began by the early 20th century, but in South Asia such recordings have only taken place since the 1960s. Until 2005, when the major earthquake occurred in Balakot-Muzafarabad are, the seismometers in Northern Pakistan were at the most up to the Hazara region, and none was installed in the Higher Himalayas, Karakorum and Hindu Kush regions of Northern Pakistan. Nonetheless, the international catalogues such as those of International Seismological Centre (ISC), England and National Earthquake Information Centre (NEIC) of the U.S. Geological Survey have been used for compilation of a catalogue for earthquake events within 150km radius of chitral. Additional data from Pakistani networks are incorporated from the Geophysical Centre, Quetta and MSSP, Atomic Energy Commission Pakistan.

The catalogue compiled for this study comprises over 7000 earthquakes from Northern Pakistan and the surrounding region with magnitudes >3. A great majority of earthquakes are under M_b5, where 289 are in the range of M_b 5-5.9 and 30 in the range of M_b 6-6.9. Only one earthquake is greater than 7 that is Kashmir earthquake M_b 7.6.

6.3 Methodology

A number of tasks and sub-tasks which were performed for the Seismic Hazard Evaluation of the Hydropower project area were based on international standard procedures for such studies. These tasks, along with their sub-tasks are outlined below:

- Data collection and study of literature on regional and local geology.
- Data collection and study of geomorphology and tectonics.
- In-depth laboratory studies on satellite image, analysis using com mercial standard image processing system to study the linea ments/splays and faults on regional as well as local basis.
- Compilation of geological and tectonic maps integrating information and data collected from literature and those deducted from satellite images.
- Field investigations of selected areas for characterization of the fault truncture.
- Development of fault-source map indicating various parameters of each fault and disposition with respect to the dam and power house sites in each hydropower project.
- Compilation of historical and instrumental earthquake data in a comprehensive catalogue. Refinement of the catalogue using standard methods in practice.
- Carryout Seismic Hazard Analysis in accordance with modern in dustry practices, including:
- ICOLD Guidelines for selecting the seismic design parameters
- ER 1110-1806-Earthquake Design and Evaluation for Civil Work Projects.
- EM 1110-2-6050-Response Spectra and Seismic Analysis for con crete hydraulic structures. (to be developed at the final design stage only).
- EM 1110-2-6051 – Time-History Dynamic Analysis of concrete hy draulic structures.(To be carried out at the final Design stage).

6.3.1 Seismic Hazard Analysis

Man-made facilities constructed in seismic regions are subjected to earthquake hazards that are not under the control of human beings. If the facilities are seismically vulnerable due to their design and construction, then the facilities are at a risk.

On the other hand, if these facilities are intentionally made less vulnerable or they are inherently not vulnerable, then they will be little affected by earthquakes and the seismic risk will be low even if the earthquake hazard is high, which means that while seismic hazard must be accepted as given by nature, seismic risk can be controlled and reduced by means of correct application of earthquake engineering techniques.

The seismic hazard analysis of a site is intended to identify the existing natural level of exposure in order that correct earthquake engineering measures can be implemented to keep the seismic risk at a reasonably low level in spite of the seismic hazard being moderate or high. The degree of protection of a facility can be relaxed or increased as a function of the actual seismic hazard level. Thus, the importance of correct identification and appreciation of the potential seismic risk needs to be appreciated.

As far as seismic hazard analysis is concerned, as stated earlier an extensive catalogue of seismicity data was compiled. The composite list of earthquakes, recorded from 1904 to 2010 within 100 km radios of the project site were prepared from International Seismological Center (ISC), U.K earthquake catalogue. The catalogue prepared by ISC includes locally recorded seismic data (e.g., Pakistan Met Office, Pakistan Atomic Energy Commission) for the purpose of location since 1984. It is preferred over the United States National Oceanic Atmospheric Administration (NOAA) catalogue as it has more reliable locations than NOAA for this area. Therefore, ISC catalogue is used as the database for the determination of recurrence relationship. Combined with geological information obtained from field studies, this catalogue serves formulation of source parameters for seismic hazard analysis, both the probabilistic as well as deterministic seismic hazard analysis for determination of 'g' values for the weir sites and Powerhouse locations.

6.3.2 Seismic Design Parameters

Seismic hazard assessments yield two types of results: general qualitative statements about the seismic exposure and specific quantitative parameters called Seismic Design Parameters.

The most important relevant Seismic Design Parameters are described below.

6.3.2.1 Peak Ground Acceleration (PGA)

This parameter represents the highest pulse of ground acceleration during an earthquake. Although it has some theoretical shortcomings as a statistically representative measurement of the intensity of an earthquake, it has been, and still is, the most widely used numerical assessment of the "punch" of an earthquake. Dozens of statistical relationships describing specific characteristics of an earthquake have been derived on the basis of PGA. These range from structural design parameters to damage statistics.

6.3.2.2 Peak Ground Velocity (PGV)

This parameter is less widely used than the PGA; however, it has been gaining importance as a supposedly more stable statistical descriptor of the damaging capabilities or "punch" of an earthquake. Lately it has been used to scale empirical seismic velocity spectra which are then converted to acceleration spectra which, in turn, are used to evaluate seismic stresses in structural analysis.

6.3.2.3 Design Spectra

These are used to calculate the seismic loading on structures. They can be used for the final structural design of all facilities in hydropower projects. Only very critical facilities (such as large dams) require more comprehensive ground motion descriptors. The response spectra would be adequate information at the feasibility stage for virtually all above ground facilities expected to be built on the analyzed sites. Once appropriately reviewed, response spectra would be one of the main tools for a final structural design.

6.3.2.4 Design Earthquake

The specification of a design earthquake implies a level of determination in the seismic hazard analysis; that is, after the design earthquake is characterized deterministically or probabilistically, its effects at the site of interest are computed deterministically. Historically, design earthquakes have been associated with two levels of design, in which structure or facility is required both to remain operational at one level of motion (OBE) and to avoid catastrophic failure at another, more severe level (MCE).

Both of these values are determined based on field study and relevant existing data. These values will be used in Engineering Design of the hydropower project.

6.3.2.5 Hazard Assessment of the Site

As per international practice and guidelines for seismic hazard evaluation and seismic hazard mapping, two procedures are followed in complementary to each other.

1. Probabilistic Seismic Hazard Assessment (PSHA)
2. Deterministic Seismic Hazard Assessment(DSHA)

Seismic Hazard Analysis involves the quantitative estimation of ground motion characteristics at a particular site and conducted by **probabilistic** or/and **deterministic** methods. In recent years a good deal of work has been carried out throughout the world to study the seismicity of various areas to estimate the earthquake hazard potential for establishing design criteria for the construction of massive structures like dams, high rise buildings, etc. Probabilistic techniques for estimation of seismic risk can be used when ample seismic data is available but in case when earthquake data is small, in spite of the presence of a number of active faults, the probabilistic estimates cannot normally be expected to yield realistic results as is the case of **ArkariGol HPP**.

In such case, Deterministic Seismic Hazard Assessment is more heavily relied upon and design parameters are finalized by utilizing this assessment technique for various sites of interest. Anyhow PSHA has its advantages and is also used whenever, seismic data is available. In our case, PSHA based zoning map of Pakistan, developed by the Government of Pakistan was studied for understanding of the PGA's of the area. Although as stated above if ample data is not available, probabilistic analysis cannot normally be expected to yield realistic results. Even in France and Japan, Deterministic Seismic Assessments are used for dams and nuclear plants. Both types of hazard analysis are investigated and discussed in next sections.

6.3.3 Probabilistic Seismic Hazard Analysis

As discussed above, PSHA requires availability of ample seismic data and strong motion earthquake data of the faults in question. In the absence of these, probabilistic estimate don't yield realistic results.

Therefore Pakistan's PGA (g) contour map with 10% probability of exceeding in 50 years was utilized for the project where PGA contour level of 0.02g had been provided. The map shown hereunder was prepared and based on PSHA Methodology (**Figure-6-4**).

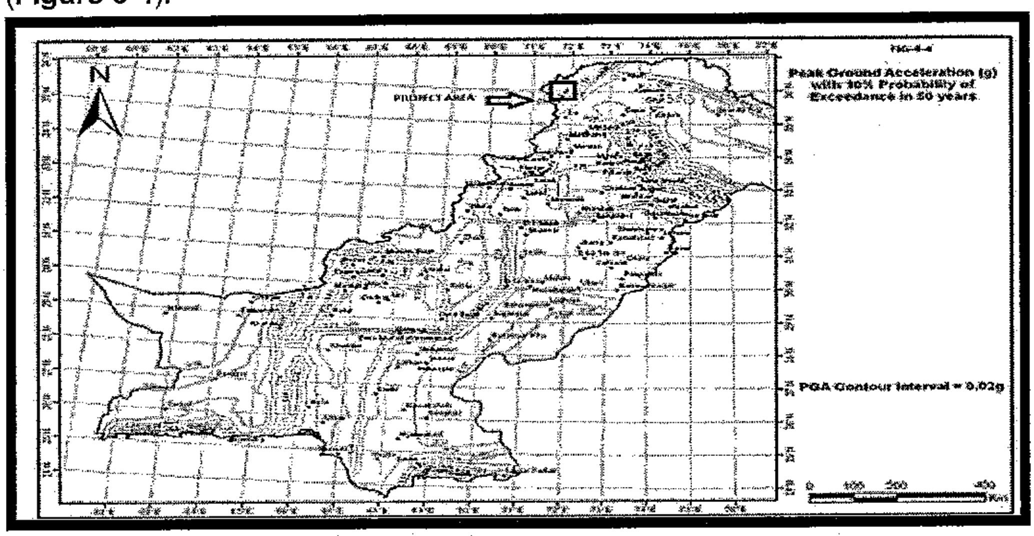


Figure 6-4: Probabilistic Seismic Hazard Analysis

In any case the Probabilistic Seismic Hazard Analysis is discussed at length here for an understanding of the issue. PSHA is based on modeling and analyzing the level of ground motion parameters (peak ground acceleration) in relation to its exceedance during a specified time interval. The principles of analysis to evaluate sites of interest for engineering projects were first developed by Cornell (1968) and later refined by various researchers. This approach combines the probability of exceedance of the earthquake size (recurrence relationship) and probability on the distance from the epicenter to the site.

Because of lack of strong motion data, attenuation law could not be developed for the project area. Various predictive relationships developed for near source and for hard rock have been considered for the estimation of ground motion.

The total Seismic Hazard is finally obtained by adding the interference of various sources. The results are expressed in terms of a ground motion parameter associated with a return period (return period is the inverse of the annual frequency of exceedance of a given level of ground motion). It requires the following:

- All potential sources of seismic activity that could produce significant ground motions at the site of interest are identified and characterized.
  These sources are identified on the basis of geologic, tectonic, historical and instrumental evidences. It allows and quantifies the uncertainties in size, location, rate of recurrence and effects of earthquakes to be explicitly considered in the evaluation of seismic hazard.

- The Gutenberg–Richter recurrence law which assumes an exponential distribution of magnitude is commonly used with modifications to account for minimum and maximum magnitudes.

- Predictive relationships, where the level of shaking produced by an earth quake of a given size occurring at a given source distance to site are determined.

- The probabilities of exceedance of estimated ground motion over the lifetime of the structure.

6.3.3.1 Identification And Characterization Of Earthquake Source

All earthquake sources that are capable of producing significant ground motion at the site are to be identified and characterized. Source characterization includes definition of geometry (the source zone / fault), earthquake potential and its probability distribution of potential rupture locations within source and earthquake distribution with time. Each of these characteristics involves some degree of uncertainties such as spatial uncertainty and size uncertainty.

6.3.3.2 Recurrence Relationship

A general equation that describes earthquake recurrence may be expressed as follows:

$$N(M) = f(M, t) \qquad (1)$$

Where N (M) is the number of earthquakes with magnitude equal to or greater than M and t is time period. The simplest form of equation (1) that has been used in most engineering applications is the well known Richter's law which states that the cumulated number of earthquakes occurring in a given period of time can be approximated by the relationship;

$$\log N(M) = a - b\,M \quad (2)$$

Equation (2) assumes spatial and temporal independence of all earthquakes, i.e. it has the properties of a Poisson model. The coefficients 'a' and 'b' can be derived from seismic data representing the characteristics of the region, which are dominated by Tirich Mir Fault and the Reshun Fault. Coefficient 'a' is related to the total number of events that occurred in the source zone and depends on its area, while coefficient 'b' represents the coefficient of proportionality between log N (M) and the magnitude.

6.3.3.3 Estimation of Ground Accelerations

Using probabilistic method originally developed by Cornell (1968), the estimation of ground accelerations is made. This method assumes occurrence of earthquakes in a Poisson process with equal probability of occurrence at any point within 100 km of the project site. The following parameters are required for the analysis:

- The recurrence law for the project area;
- The predictive ground motion relationship;
- A probabilistic model describing earthquake occurrence;

The typical predictive relationship for the analysis based on the strong motion data and other available information is used. The various predictive relationships developed for near source and for hard rock (Campbell, 1981; Idriss, 1985 and Boore et.al. 1993, 1997) have been considered for the estimation of ground motion.

6.3.4 Deterministic Seismic Hazard Analysis

As discussed earlier in preceding sections Deterministic Seismic Hazard Analysis is suitable for final values of PGA as available data for all the faults in the area are not ample enough for probabilistic analysis. The DSHA involves the development of particular seismic scenarios upon which a ground motion hazard evaluation is based. The scenario consists of the postulated occurrence of an earthquake of a specified size occurring at a specified location. A typical DSHA can be described as a four-step process (Reiter, 1990) consisting of:

- All earthquake sources which are capable of producing significant ground motion at the site of interest are to be identified and characterized.
- The shortest distance for each source zone to the site of interest is determined.
- Determination of the controlling earthquake, expressed in terms of ground accelerations at the site.
- The hazard at the site is formally defined, usually in terms of the ground motion produced at the site by the controlling earthquake.

These four steps are described in further detail in the following sections.

6.3.5 Regional Tectonic Setting

As indicated in the section on geological region, Chitral region is generally known to be part of the Eurasian Plate, to the north of the Kohistan Island arch, from which it is separated by the well establishedKohistan-Karakuram Suture zone (also known as Main Karakorum Thrust, MKT).

The Chitral region is divisible into three tectonic blocks, which from north to south include Wakhan Block, Braghil Block and Yar Khan Blocks, and are mutually separated by major boundary faults including the Tirich Mir and Reshun Faults. The Karakoram-Kohistan safer zone (popularly termed Main Karakurram Thrust – MKT) separates the Chitral tectonic zone from Kohistan Island to its south. The major orogeny in the Chitral region took place, when all three regional faults (Tirich Mir, Reshun and MKT) were reactivated. In not very far of past, the Chitral region suffered seismicity and records show that at-least MKT and possibly Tirich Mir and Reshun faults have reactivated in the recent past during moderately large earthquakes.

Based on the recent studies on Chitral region, three tectonic blocks are recognizable in the region, which include (from north to south). See **Figure 6-5.**

i) Wakhan Block
ii) Braghil Block
iii) Yar Khan

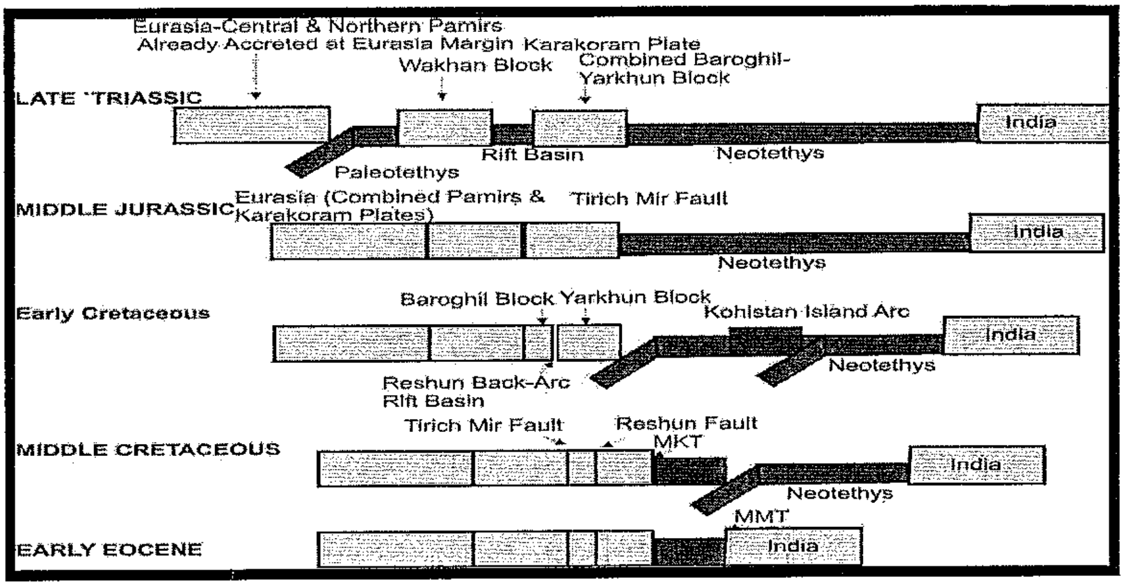


Figure 6-5: Tectonic Model Explaining The Various Stages In The Development Of Major Boundary Faults In Chitral

The above discussed following major faults of the region are as shown in **Figure 6-6**.

1) Reshun Fault
2) Tirich Mir Fault
3) MKT
4) Chitral Fault
5) (ShyokSture Zone) (Bomb Barat Fault)

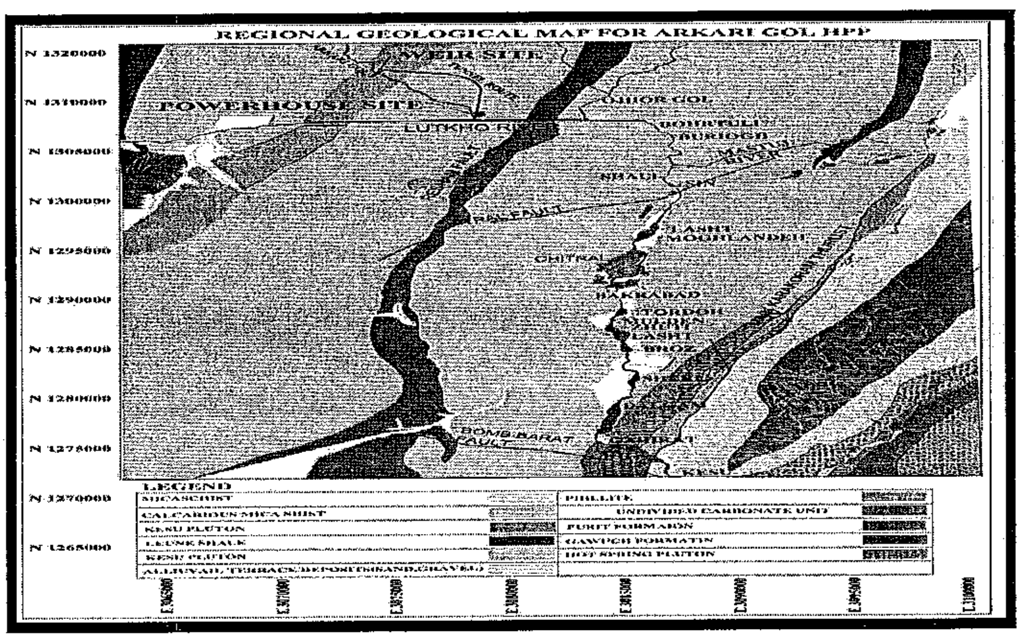


Fig 6-6 Regional Geological Map For Arkari Gol HPP

Figure 6-6 depitcts Tectonic subdivision of the Chitral region into three tectonic blocks 1) Wakhan Block, 2) Baroghil Block, 3) Yarkhun Block. Tirich Mir Fault Zone separates the blocks 1 and 2, and the Reshun Fault separates Blocks 2 and 3. The Chitral region is separated to the south from the Kohistan Island Arc Terrane by the Kohistan-Karakoram Suture (MKT). Location of the ArkariGol Hydropower Project shown as box

6.3.6 Potential Earthquake Sources

The seismic sources and their potential, either line (i.e. fault) or area sources can be used for modeling in DSHA. Although project area lies in the Himalaya fold and thrust belt, it also contains geological faults as seismic sources. Presently, several methods are available for assigning a maximum magnitude to a given fault. These methods are based on empirical correlations between magnitude and key fault parameters, such as, fault rupture length, fault displacement, and fault area. Geological and seismological studies can define these fault parameters. The results of field studies of tectonic features in the project area were evaluated for fault rupture length, and fault displacement.

The important faults already named in Regional Tectonic setting and Geological Report are described in more detail here:

6.3.6.1 Reshun Fault

Originally, the Reshun Fault was the only regional fault recognized in the region. The Reshun Fault separates the northern sedimentary belt of the Baroghil Block from southern metamorphic belt included in the Yar Khan Block in this study. The fault runs almost the entire length of Chitral district, merging with the Tirich Mir Fault near Baroghil. The Fault is divisible in two segments. A SW segment between Bamborit and Parsan is south-southwest oriented with steep dips. From Partsan eastward the fault attains an easterly trend and is a typical thrust fault. .Chitral fault is approximately 12.5 km from weir site and 5.5 km from powerhouse and its rupture length is approximately 28 km.

6.3.6.2 Tirich Mir Fault

Which is a recent discovery by Gaetani and his Co-workers (Gaetani, 1997: Zanchi et al (1997: 2000), within the North-Western unit of Pudsay et al (1985). Unlike the Reshun Fault, this regional Fault structure was noticed to incorporate metabasalts as well as ultramatic rocks of mantle origin, which formed the basis of recognition of this fault as a suture zone.

As shown in Figure 4-5, it runs parallel to Reshun Fault, separating the Wakhan Block from Baroghil Block and their mutual distance reduces in our area of interest. . Tirich Mir fault is approximately 4 km from weir site and 5 km from powerhouse and its rupture length is approximately 500 km.

6.3.6.3 Main Karakorum Thrust (MKT)

The Chitral region is generally considered to be part of the Eurasian Plate, to the north of the Kohistan Island Arc from which it is separated by the well established Main Karakorum Thrust (MKT) also known as Kohistan –Karakorum suture, it runs parallel to Reshun Fault. It divides Yar Khan Block and Kohistan Island Arc Terrane and is another major fault of the region, which subdivides tectonically the Chitral region into three blocks. This fault zone in the Chitral region is 125 Km long, with a SW-NE trending segment between Arandu and Laspur. MKT along this stretch is a 1-7 km. wide fault zone. The other names are Karakoram-Kohistan suture zone (KKSZ), Northern suture..MKT fault is approximately 30 km from weir site and 23.5 km from powerhouse and its rupture length is approximately 700 km.

6.3.6.4 Chitral Fault

Chitral fault is in southwest to southeast of project area. It passes across to various formations such as phyllites, lune shale, calcareous mica schist and Kesu Plutonic (magmatic) granodiorite, gneiss and marble.Chitral fault is approximately 44 km from weir site and 37 km from powerhouse and its rupture length is approximately 15 km.

6.3.6.5 Bomb Barat Fault

Bomb Barat fault is located in south of the project area approximately 31 km from weir site and 32 km from powerhouse site. Bomb Barat fault across to various formations such as lune shale, calcarious mica schist, Kesu Plutonic (magmatic) granodiorite, gneiss and marble, phyllites and alluvial terrace deposit (sand and gravel) near Kesu.

Bomb Barat fault extend from southwest of Gahirat and Kesu to southeast of Gahirat and Kesu with the rupture of approximately 12 km. Bomb Barat fault is approximately 21.5 km from weir site and 13.5 km from powerhouse.

6.3.6.6 Panjal Thrust

Panjal Fault is thrust fault, which runs parallel to MBT on the eastern limb of the Hazara-Kashmir Syntaxis and on the western side it lies over the Sangargali Fault with the nearest segment passing about 1.61kms from Muzaffarabad(Fig.1). Panjal Thrust curves around the apex of the syntaxis then bend southward (Kaazmi and Jan, 1997). On both eastern and western limb of the syntaxis this fault has different tectonic and startigraphic setting. Due to this Greco, 1991, has named the Punjal Thrust as Mansehra Thrust on the western side of the syntaxis. Further westward it apparently links up with Khairabad Thrust (Yeats and Hussain, 1987).

The macro-instrumental seismic record since 1904 shows that the earthquakes with magnitude ranging between 4-5.5Mw have occurred along these faults. On January 04, 1984 an event of magnitude 4.7 was located by MSSP, Nilore along the Panjal Thrust with its epicenter west of Haripur. The seismic data of Tarbela micro-seismic network since 1973 also show a lot of seismic activity along the Panjal fault.

6.3.6.7 Ayun Fault

The Ayun fault extends northeastward from Drosh past Koghozi and separates the Cretaceous rocks of the Chitral syncline on the west from granite and Devonian to Jurassic rocks on the east. This fault has been extended northeastward to join the Holojut fault of Matsushita and Huzita (1965, p. 10, 11, 21). At Darkot, the Ayun fault separates the large granite mass on the north from the Darkot Group (Devonian to Jurassic rocks of pi. 2) on the south (Matshushita and Huzita, 1965, p. 21). The Ayun fault was clearly verified only at one place: namely, on the left (southeast) bank of the Chitral River 1 mile (1.6 km) southeast of Gahirat, where it forms a narrow shear zone dipping 45° W. In GolenGol, 2 miles (3.2 km) east of Koghozi, a well-defined shear zone is not present. The only evidence for faulting is several cataclastic layers found in the granite at and near the contact with the Reshun Formation. The contact at this place appears to be more of the nature of an intrusive contact. Similarly, in JingeretGol, 2 miles (3.2 km) southwest of Drosh, thinly banded cataclastic layers in the Koghozi granite are the only indication of faulting. As marked shearing is absent in two of the three places observed, it is possible that the Ayun fault may not be as important a fault as is implied on the geologic maps of plates 1 and 2. Possibly the junction between the Koghozi granite and the Reshun Formation is basically an intrusive contact, largely or partly obscured by shearing.

6.3.6.8 Naz Bar Fault

The Naz Bar fault, so named by Matsushita and Huzita (1965, p. 76, 77, 78, 80), after Naz Bar (creek) at Yasin, (pi. 2) separates the granite and Devonian to Jurassic rocks on the northwest from the narrow belt of Cretaceous rocks on the southeast. It extends from Drosh in a northeasterly direction and continues along the west side of the Shishi River to the edge of the area of plate 1. It is well exposed at JingeretGol, 3 miles (4.8 km) south of Drosh; on the west bank of the Chitral River, 1 mile (1.6 km) north of Drosh; at both abutments of the bridge across the Shishi River; at Tar on the Shishi River 7 miles (11 km) from Drosh; and in the vicinity of Kalas on the Shishi River, 14 miles (23 km) from Drosh. This fault is inferred to continue north- eastward to connect with the Naz Bar fault of Matsushita, which he has traced from the south of Mastuj to the north of Yasin, a distance of about 50 miles (80 km) (pi. 2). As in the area of plate 1 of this report, Matsushita (Matsushita and Huzita, 1965, p. 85) found that the Naz Bar fault separates the Darkot Group i (Devonian to Jurassic rocks of this report) on the north from the Yasin Group and Green Series (Cretaceous rocks of this report) on the south. In the Drosh-Shishi Valley area, the fault dips steeply to the west and is marked by a shear zone 80 to 200 ft (24-61 m) wide, made up mainly of sheared serpentine and smaller amounts of brecciated greenstone, sheared and altered talcose schist, black brecciated limestone, and other rock types.

6.3.6.9 Shishi Fault

The Shishi fault lies east of the Naz Bar fault and separates Cretaceous rocks on the west from Devonian to Jurassic rocks on the east. It extends northeastward from east of Drosh to the east edge of the mapped area (pi. 1). The Shishi fault is inferred to join the Naz Bar fault a few miles northeast of the mapped area, and to extend southwestward beyond the mapped area of plate 1 as far as the Pakistan-Afghan border, as shown on < plate 2. The fault was observed in DroshGol, Kal-damGol, PuritGol, and at the eastern edge of the mapped area. The fault is marked by a shear zone that dips 75° W. to vertical. In DroshGol, the fault zone, which is about 80 ft (24 m) wide, consists of sheared serpentine (30 ft) (9 m) and brown-weathering silica-carbonate brec- cia (50 ft) (15 m). In PuritGol and Gawu-chGol, only nar- row shear zones, 3 to 10 ft (0.9-3 m) wide, are evident.

In the light of available data and observations by the experts, last three faults are minor faults so these are not critical for the project.

6.3.7 The Shortest Distance of the Source From Site of Interest

In this step, the shortest distance of each site of interest from the source of earthquake is determined. The maximum potential having already been deter-mined in the first step, the shortest distance is evaluated so that it is then applied to the predictive relationships. The peak ground accelerations are very heteroge-neous and display no significant attenuation with distance within a radius of a few kilometers from the fault trace. Accordingly, recent attenuation laws flatter in the near field range, a constant term has been included in the distance expression to account for the fact that focus lies at several kilometers below the surface. Based on the field studies of the faults and interpretation of local seismicity, the shortest distances are assigned to the causative sources for the evaluation of peak ground accelerations.

The following table gives the results of Deterministic Seismic Hazard Assess-ment for ArkariGol Hydropower project area, District Chitral, Khyber Pakh-tunkhwa, which lies in Eastern Hindu Kush Range.

Table 4-1: Results of Deterministic Seismic Hazard Assessment for Site							
Controlling Faults	Fault type	Maximum Magnitude potential*	Repture Length (km)	Distance (km) Weir Site	PGA**/ *** Weir Site	Distance (km) Power House	PGA**/ *** Power House
Reshun Fault	Fault	7.8	28	12.5	0.50	5.5	0.60
Tirich Mir Fault	Fault	7.7	500	4	0.61	5	0.59
MKT Chitral	Thrust	7.7	700	30	0.37	23.5	0.40
Chitral Fault	Fault	6.4	15.0	44	0.24	37	0.26
Bomb Barat Fault	Fault	6.2	13.0	21.5	0.29	14.5	0.33

* Maximum Magnitude Potential has been taken from the Building Code of Pakistan (2007).

** PGA values have been determined using Attenuation Rela tionship of Booreet. al (1993),(1997) and (2005) for site class B soil (360m/s<Vs30 <750 m/s).

*** Campbell, Kenneth W. (Empirical Near Source Attenuation Re lationships for Horizontal and Vertical Components of Peak Ground Acceleration - 1997).

6.3.8 Determination of Maximum Accelerations

As stated above, once maximum potential magnitude of the seismic source and shortest distance from the site of interest are known, the horizontal acceleration at the site can be determined using the attenuation laws developed for the region. As no attenuation law could be developed due to absence of strong motion data for project area, the attenuation laws developed for other regions of similar geology were used.

6.3.9 Determination of Maximum Velocities

Based on the values of $\mathbf{v_{max}}$and $\mathbf{a_{max}}$ for Loma Prieta Earthquake of 1989 (California, USA), having Magnitude 7.1 recorded at a distance of 21.8 km from the epicenter at Gilroy, the ratio of vmax and amax was estimated at 0.078 sec (Kramer, 1996). The ratio v_{max}/a_{max} is related to the earthquake's magnitude and distance as a measure of the frequency content of ground motion. Several investigators have studied this dependence. McGuire (1978) has provided the summary of his results. He suggested the following magnitude and distance dependence where the ratio vmax/amax is proportional to these relationships.

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Site Condition	Magnitude Dependence	Distance Dependence
Rock sites	$e^{0.4M}$	$R^{0.12}$
Soil Sites	$e^{0.15M}$	$R^{0.23}$

Using rock site relationship and earthquake strong motion data, v_{max} was estimated.

6.3.10 Seismic Design Parameters

Due to the nature of the seismic loading, no facility can be made absolutely earthquake proof. Modern technology offers "earthquake resistance", meaning that the facility is intended to survive a strong earthquake while undergoing a certain degree of damage. In fact, the very process of undergoing controlled damage and post-elastic deformations is one of the main sources of seismic energy dissipation, preventing the need of having to provide oversized members capable of handling the seismic energy in the elastic range of the structural materials.

This means that there is a range of possible solutions to counter earthquake resistance. There is a tradeoff between having to build a larger structure, able to delay the onset of damage and accepting a lower threshold of damage (provided the structure is ductile enough as to dissipate the excess of seismic energy). In the latter case, although a well designed facility does not collapse, the damage incurred may put it out of commission temporarily or even permanently in case of extreme ground shakings.

Hence, how low to accept the onset of damage is an economic and functional decision. It depends on the importance of the hydroelectric project and also on the importance of individual facilities within the project. This also means that not all facilities need to be designed for the same level of earthquake resistance.

Earthquake resistant design of new structures and evaluation of the safety of the existing structures require analysis of their response to earthquake shaking. Evaluation of geotechnical hazards, such as liquefaction and slope failure, also requires analysis with respect to same level of shaking. The level of shaking for which satisfactory performance is expected is often referred to a design level of shaking and is described by a design ground motion. The parameters most commonly used to specify design ground motion are peak horizontal acceleration, peak horizontal velocity, predominant period (frequency), response spectrum ordinates and duration.

6.3.11 Design Earthquake

The specification of a design earthquake implies a level of determination in the seismic hazard analysis; that is, after the design earthquake is characterized deterministically or probabilistically, its effects at the site of interest are computed deterministically. Historically, design earthquakes have been associated with two levels of design, in which structure or facility is required both to remain operational at one level of motion (OBE) and to avoid catastrophic failure at another, more severe level (MCE).

6.3.11.1 Operating Basis Earthquake (OBE)

This is a seismic loading that a facility must withstand without loss of operating capabilities of the plant and it represents the level of ground motion at the project site at which only minor damage is acceptable. The powerhouse, intake, related structures and equipment should remain functional and damage easily repairable from the occurrence of earthquakeshaking not exceeding the OBE.

6.3.12 Maximum Credible Earthquake Acceleration

The Maximum Credible Earthquake (MCE) is usually defined as the largest earthquake that can reasonably be expected from a particular source or within a geographically defined tectonic province, under the presently known or presumed tectonic framework. The maximum credible earthquake magnitude for identified sources of earthquakes in the project area are calculated by regression relations given by experts, the probabilistic analysis for MCE in terms of expected accelerations against 2%, 5% and 10% probabilities of exceedance for project life of 50, 100 and 250 years shall be finalized.

A deterministic approach was followed to assess Maximum Credible Earthquake (MCE) for critical structures. All the potential sources of extreme earthquakes near the sites were considered, as indicated in the relevant section earlier. Intensity parameters in terms of Peak Ground Acceleration (PGA) and Peak Ground Velocity (PGV) were determined.

In other words MCE is the worst predicted earthquake while OBE is maximum earthquake expected during the life of the project.

The DBE is OBE, and factor of 2 with respect to MCE is as per different codes (USNRC, Indian Code), otherwise OBE is mostly based on probability analysis, which again depends on availability of large strong motion earthquake data of the area.

So OBE can be taken as ½ of MCE for a fair assessment and is recommended international codes as well as other relevant codes for such projects.

6.3.12.1 Attenuation Equations

The relationships used for predicting Strong Ground motion in this study are provided below;

1. Campbell (1997)

$$in\ (A_H) = -3.512 + 0.904\ M$$

$$- 1.328\ ln\ [\sqrt{R^2 SEIS + [0.149\ exp\ (0.647\ M)^2}$$

$$+ [1.125 - 0.112\ ln\ (R_{SEIS}) - 0.0957\ M]\ F$$

$$+ [0.440 - 0.17\ ln\ (R_{SEIS})\ S_{SR}$$

$$+ [0.40$$

$$5 - 0.222\ ln\ (R_{SEIS})\ S_{HR} + \epsilon$$

Where A_H has units of g (g – 981 cm/sec^2), ϵ is a random error term with a mean of zero and a standard deviation equal to the standard error of estimate of ln (A_H), and all other parameters are defined in the below:

Where,

Y = Peak Horizontal Ground acceleration (g)

M = local or surface wave magnitude for magnitude less than 6 or greater than 6 respectively.

R = Shortest distance to the fault rupture

2. Idriss (1985)
ln (y) = ln (a) +d ln (r+20)

Where,

y = Peak Ground Acceleration (g)
a and d parameters for different magnitudes and rock or stiff soil are:

M	a	d	s.d
6.0	282	-2.07	0.42
6.5	164	-1.85	0.38
7.0	91.7	-1.63	0.33
7.5	49.8	-1.41	0.35

3. Broore et al (1993),(1997) & (2005)

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$$b_1 + b_2(M-6) + b_3(M-6)^2 + b_4 r + b_5 \log r + b_6 G_B + b_7 G_C = \log Y$$

Where

$$r = (d^2 + \square^2)^{1/2}$$

d is the closest distance to the surface projection of the fault in kilometers and h = 5.57

The coefficients and constants are for site class Bwhere average shear wave velocity in upper 30m is 400m/sec as per experts' recommendations.

The equation can be used for magnitudes of 5.5 to 7.5 and for distances not greater than 80 km.

6.4 Design Earthquake For The Project

Any structure designed for OBE level can withstand some damage with MCE, considering the factors of safety and stress levels taken in design. Taking into account that OBE of 0.305g has probability of 10% of being exceeded in 50 years (life span of powerhouse), then for MCE the probability is reduced to 5%, which corresponds to a return period of 975 or 1000 years.

For Powerhouse the design peak ground acceleration is 0.305g, but for ordinary buildings the hazard level is reduced, which means the probability of 20% exceeded in 50 years. This corresponds to a return period of approximately 225 years.
Therefore, It is recommended that the Peak Horizontal Ground Accelerations (PHGA) of 0.61g may be adopted as the Maximum Credible Earthquake. In many codes, a reduction factor of 2 with respect to Maximum Credible Earthquake is recommended to obtain the Design Basis Earthquake which works out to 0.305 g.

Major researchers, however, consider that the Design Basis Earthquake should be an earthquake which is most likely to occur during the life span of the project. If it is assumed that the Reshun Fault source is the one which could generate an event of magnitude 6.5 to 7.8 during the life span of the project, for powerhouse site and Tirich Mir Fault could generate an event of almost same magnitude for weir site, then the projected Maximum Credible Earthquake values for these would be between 0.60 to 0.61 respectively. It is, therefore, suggested that a mean value of 0.305 g may be adopted conservatively for power house as the Design Basis Earthquake, while the Maximum Conceivable Earthquake can be 0.61 g. Similarly the OBE for weir should be 0.305, also MCE is 0.61g.

6.5 Final Recommendations for OBE

According to DSHA it is observed that the OBE is 0.305 while Building Code of Pakistan has probabilistic map of PGA's Fig-6-4 which has contours of 0.32 g and 0.34 g for the project area. These values are slightly more than the observed value. All three values are safe but to comply with the Building Code of Pakistan, it is suggested that for final design, OBE of 0.34 g can be adopted conservatively.

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CHAPTER – 7

ALTERNATIVE STUDY AND SELECTION OF PLANT LAYOUT AND OPTIMIZATION

7.1 PROJECT LAYOUT STUDIES

7.1.1 General

To harness the hydropower potential of 10 km lower stretch of Arkari Gol, GTZ, (German Agency for Technical Collaboration) identified a project layout on the right bank of Arkari River with powerhouse near Lutkho River. Arkari Gol is the left tributary of Lutkho River with confluence 25 km north east of Chitral town in District Chitral of Khyber Pakhtunkhwa Province.

The potential river stretch was studied two times to harness the indigenous resources. First under the study: "Regional Power Development of Lower Chitral" in 1988 to identify a scheme with firm capacity to meet the local power demand of Chitral valley. Then under the study "High Head power projects in Chitral" in 2001, the same river stretch was considered with a different project layout to utilize the summer flows for higher installed capacity. The identified potential project was studied along with other medium size projects for a probable interconnection with National grid.

Alternative project layouts have been considered in this study to plan a scheme for optimum utilization of potential resources with technically sound and economically viable project layout. The average gradient of River in the project area is about 4.5%. The identified layout involves a diversion weir with daily peaking storage, 6.0 km long low pressure tunnel and surface powerhouse near Lutkho River, 390 km from Peshawar and 520 km from Islamabad. The project layout identified by GTZ in two studies is presented on Drawing No. ARKF-01, presented in appendix 7 of this report.

With high electric prices in Pakistan, medium to large size hydropower project projects identified even in remote area with probability of its inter connection to National grid have now become attractive for development. Arkari hydropower project has the facility to provide peaking power during low flow months and to deliver the optimized capacity during summer months.

Alternative project layouts have been framed with weir and powerhouse sites already identified in the previous studied. With preliminary field investigations, preferred layouts have been screened out for further economic evaluation of project optimization and for detailed investigations and studies.

7.1.2 Previous Studies

Arkari Gol in its lower 10 km stretch has steep river gradient of 44 m/km. To harness the hydropower potential of Arkari Gol, the potential site was studied twice by German Agency for Technical Collaboration (GTZ).

In 1988, Regional Power Development study was carried out with SHYDO on tributaries in Chitral valley to identify hydropower schemes to meet regional power demand of local load centres. All schemes identified in Upper and Lower Chitral was based on winter flows available 90% time of the year.

With interconnection of Chitral valley with National grid in mid 90's, further studies exploitation of medium to large size potential schemes were carried out during 1999 to 2001. The previously identified nullah stretches were reviewed and new potential stretches on main rivers were identified for proper utilization of flows during summer months. Arkari Gol project was included in both studies and the details of identified layouts are described in the following paragraphs.

7.1.3 Arkari Gol Hydropower Project in 1988

The project layout was identified to in the study "Regional Power Development Study Lower Chitral" in 1988, prepared by Sarhad Hydel Development Organization SHYDO, Government of NWFP in collaboration with GTZ, the German Agency for Technical Cooperation.

Two alternative layouts were studied with one weir axis and two location of powerhouse and listed as scheme no. 7 and 8 of that study. Both alternative layouts have a common weir intake 1 km upstream of Uchhatur village, 9 km from Arkari confluence with Lutkho River.

Scheme no. 8 has powerhouse within Arkari Gol valley upstream on Momi village. The elevation difference from intake to powerhouse has been checked with topographic has been found as 270 m against the gross head of 335 m mentioned in that study. Scheme no. is not found attractive as to utilize the potential of shorter river stretch.

Scheme no.7 has powerhouse on the left bank of Lutkho River near Shoghar Ghari village, 3.5 km upstream of Arkari Gol confluence.

Project Design Parameters	
Installed Capacity	24 MW
Design Discharge	9.60 m^3/s
Gross Head	305 m
Mean Annual Energy	105 GWh
Plant Factor	50%
Headrace Tunnel Length	6.2 km
Penstock Length	450 m

The intake and upper tunnel part will be situated in Devonian to Jurassic phyllites in the middle part of the tunnel will cross amphibolites and the Tirich Mir Granite. At powerhouse site, Granite rocks were observed.

The project layout that is the weir, headrace tunnel, penstock, powerhouse location was identified for a low design discharge. The project layout is to be reviewed for higher design discharge to utilize the optimum potential resources of the identified stretch of the river.

7.1.4 Uchhatur-Andakht Hydropower Project in 2001

The main weir as diversion structure is proposed on Arkari river near Uchatur village at Latitude 36-03'-57" and Longitude 71- 41'- 37" about 8 km upstream of its confluence with Lukhto river at Andakhat village. The weir site is located on Arkari River, near Uchhatar Village. At the weir site, rock is exposed on either side and the river width is more than the requirement for flood release. The rock in the river bed is assumed at more than 30 m. The river flows along the left bank and jeepable road is located along the right bank. The slope on either side varies from 60° to 70°.

The bed elevation at weir site was assumed at El. 2200 m.a.s.l. A lateral weir of 20 m high and 80 m long was proposed. The diversion weir was proposed with 4 bottom outlets to release 1000 year flood discharge. The size of bottom outlet would be 8 m high and 12 m wide. The right side of valley will be filled with rock fill weir. Due to non-availability of rock near the River bed, sealing measures would be required.

The Powerhouse was proposed near Andakht village as an external slope type at a location to avoid resettlement issue of the local community without comprising the gross head. The existing access road from Chitral town has to be improved. The surface elevation, on road in Arkari valley near powerhouse, is approximately 1940 m.a.s.l.

Salient feature of the project are as follows:

Project Features	
Design Discharge	32.0 m^3/s
Gross Head	318 m
Design Capacity	79 MW
Mean Annual Energy	341.9 GWh
Plant Factor	49.2 %
Type of Weir	Weir with lateral intake
Height of Weir	20 m
Crest Length of Weir	80 m
Number of Flood Gates	4
Tunnel Length	6000 m
Diameter Of Tunnel	4.40 m
Type of Powerhouse	External Type
Type of Turbines	Vertical Francis Type
Number of Turbines	2
Tailrace Length	100 m

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7.1.5 Alternative Project Layouts

At inception stage, the Consultants team visited project area to check topographic and geological features of the sites of main components of previously identified layout. Two weir sites and two powerhouse sites identified in previous studies have been considered to be evaluated as Alternative project layouts.

W1: Weir site identified near Uchhtaur village included in the study of 2001.

W2: Weir site identified 1.5 km upstream of W1 as in the study of 1988.

P1: Powerhouse site identified near Andakht village in the study of 2001.

P2: Powerhouse site identified near Shogore Gram in the study of 1988.

For the previously identified weir and powerhouse sites, three alternative project layouts have been framed to be evaluated for the preferred layout.

Alternative-I: W1-P1	Project Layout "Uchhatur Andakht" identified in 2001 Study.
Alternative-II: W2-P1	Modified Project layout Scheme no. 8 identified in 1988 study.
Alternative-III: W2-P2	Project layout Scheme no. 7 identified in 1988 study.

Topographic survey has been carried out along Arkari River covering two Weir sites W2, W1 and powerhouse site P1. Both weir sites have relatively wide valley section. Sediment load in Arkari Gol necessitate having some minimum dead storage upstream of weir. Wide valley section provide the facility for daily peaking, therefore weir height is to be taken to take care the sediment load and to have minimum live storage for daily peaking. Proper sediment flushing facilities are to be providing in the weir design. Geological investigations are important to determine the river alluvium for type of weir to be proposed.

Based on surface geological features and topographic survey, details of three project layout have been elaborated and compared to select the preferred project layout. The alternative project layouts are indicated on Drawing no. ARKF-01.

7.1.6 Alternative-I : Project Layout W1-P1

Alternative-I utilize the river potential with weir site at W1 and reservoir 1.5 km upstream to powerhouse at P1. The project layout is indicated on Drawing no. ARKF-02. The weir site W1 is located on Arkari Gol just downstream of Uchhatur village where valley section is wide and rock is available on either side. The valley near the river level is relatively wide and is considered as suitable for storage. From power intake to powerhouse, the structures are to be located on the right bank. At weir site bed elevation is 2164 m and a minimum weir height of 30 m is proposed to have normal reservoir level of 2190 m. The preliminary layout plan of W1 Weir area is indicated on drawing no. ARKF-03.

Power site P1 is proposed on the left bank of Lutkho River at its confluence with Arkari Gol near Andakht village. As per topographic survey, elevation of terraces for powerhouse varies from 1841 to 1845 m. The preliminary layout plan for P1 powerhouse area is indicated on drawing no. ARKF-05.

The project layout would provide a gross head of 345 m with about 6.5 km long water way from intake to powerhouse. A tentative design discharge of 32 m^3/s is taken for estimation of power and energy and its comparison with other Alternatives.

Salient Features Alternative-I: W1-P1

ALTERNATIVE-I: W1-P1	
Project Layout	On the Right Bank
Weir Location	8.0 km upstream of Andakht Village
Catchment Area	995 km^2
Powerhouse Location	Left Bank of Lutkho River near Andakht Village
Weir Height Above River Bed	30 m
Normal Reservoir Level	2190 m
Minimum Reservoir Level	2186 m
Turbine Axis Level	1854.3 m
Live Storage	0.674 million m^3
Length Of The Crest	168 m
Mean Annual Flow	17.02 m^3/s
Design Discharge	32.0 m^3/s
Maximum Gross Head	335.7 m
Net Head	318.0 m
Connecting Channel	120 m
Sandtrap Length	90 m
Headrace Tunnel	5800 m
Headrace Tunnel Diameter	4.0 m
Pressure Shaft Length	840 m
Pressure Shaft Diameter	3.0 m
Type of Turbines	Pelton Type Turbines
Number of Turbines	3
Installed Capacity	88 MW
Annual Energy Generated	367.7 GWh
Plant Factor	47.7 %

The project layout identified in 2001 study has been reviewed. Topographic survey indicates that the available gross head is 335 m against the gross head of 305 m as mentioned in the identification report. The increased head for the project layout is useful to propose higher capacity and to improve the economic viability of the scheme.

7.1.7 Alternative-II: Project Layout W2-P1

Alternative-I utilize the river potential with weir site at W2 with 1.5 km long reservoir to powerhouse at P1. The project layout is indicated on Drawing no. ARKF-02. The weir site W2 is located on Arkari Gol, 1 km upstream of Uchhatur village where the rock is available on either side. The valley is wide and river slope is mild to be considered for storage for daily peaking. From power intake to powerhouse, the low pressure tunnel would be located on the right bank. Sand trap is to be located underground as topographic do not allow for surface structure. At weir site bed elevation is 2194 m and with weir height of 30 m, the reservoir level will be 2220 m. The preliminary layout plan for W2 weir area is indicated on drawing no. ARKF-04.

Powerhouse site P1 is same as proposed for Alternative-I. The project layout would provide a gross head of 365 m with about 8.0 km long water way from intake to powerhouse. Like Alternative-I, the design discharge is taken as 32 m^3/s.

Salient Features Alternative-I: W2-P1

ALTERNATIVE-II: W2 – P1	
Project Layout on the Right Bank	On the Right Bank
Weir Location	9.5 km upstream of Andakht village
Catchment Area	980 km^2
Powerhouse Location	Left bank of Lutkho river near Andakht village
Weir Height above River Bed	30 m
Normal Reservoir Level	2220 m
Minimum Reservoir Level	2216 m
Turbine Axis Level	1854.7 m
Live Storage	0.671 million m^3
Length of Crest	150 m
Mean Annual Flow	16.17 m^3/s
Design Discharge	32.0 m^3/s
Maximum Gross Head	365.3 m
Net Head	347.8 m
Connecting Tunnel	80 m
Sandtrap Length	90 m
Headrace Tunnel	7200 m
Headrace Tunnel Diameter	4.0 m
Pressure Shaft Length	840 m
Pressure Shaft Diameter	3.0 m

ALTERNATIVE-II: W2 – P1	
Type of Turbine	Pelton Type
Number of Turbines	3
Installed Capacity	99 MW
Annual Energy Generated	381.6 GWh
Plant Factor	45.3 %

Due to upstream weir location and power intake, the project layout W2-P1 provides more head and power. At W2 site, valley is relatively narrow as compared with W1 site. The project layout identified in 1988 as scheme no. 8 and is included as Alternative layout with modified location of Powerhouse P1 near Andakht village. The gross head and corresponding capacity is more than that of Alternative-I and is required to be evaluated on the basis of cost and benefit comparison.

7.1.8 Alternative-III : Project Layout W2-P2

The weir site W2 is same as described for Alternative-II. Powerhouse site P2 is proposed on the left bank of Lutkho River near Shogor Gram village, 3.5 km upstream of Arkari Gol confluence with Lutkho River. The surface elevation at Powerhouse site is assumed as 1915 m. The project layout would provide a gross head of 305 m with about 6.9 km long water way from intake to powerhouse. Like Alternative-II, the design discharge is taken as 32 m^3/s.

ALTERNATIVE-III: W2-P2	
Project Layout	On the Right Bank
Weir Location	9.5 km upstream of Andakht village
Catchment Area	980 km^2
Powerhouse Location	Left bank of Lutkho River near Andakht village
Weir Height Above River Bed	30 m
Normal Reservoir Level	2220 m
Minimum Reservoir Level	2216 m
Turbine Axis Level	1915 m
Live Storage	0.671 million m^3
Length Of The Crest	150 m
Mean Annual Flow	15.83 m^3/s
Design Discharge	32.0 m^3/s
Maximum Gross Head	305 m
Net Head	287.0 m
Connecting Tunnel	80 m
Sandtrap Length	90 m
Headrace Tunnel	6000 m
Headrace Tunnel Diameter	4.0 m

ALTERNATIVE-III: W2-P2	
Pressure Shaft Length	800 m
Pressure Shaft Diameter	3.0 m
Type of Turbine	Pelton Type
Number of Turbines	3
Installed Capacity	80 MW
Annual Energy Generated	312.5 GWh
Plant Factor	44.6 %

With powerhouse location P2, on Lutkho River, the gross head is reduced as compared with other two project layouts. The cost of developing W2-P2 would be same as that of W1-P1 as length of headrace tunnel is same. With relatively 13% less power potential as compared with W1-P1, Alternative-III cannot be preferred over Alternative-I.

Alternative-I and II are to be compared by estimating the costs and benefits.

7.1.9 Comparison of Alternative Layouts

The three conceived alternative layouts have been compared on the basis of estimated cost and power/energy. The geological conditions, environmental impacts and accessibility conditions for all three layouts are considered in the same range.

7.1.10 Cost Estimates

The cost estimates for three alternative project layouts have been made by a computer program. The input to the computer program is the data of main structures conceived from available topographic survey, geological mapping and hydrological estimates. The updated unit price list of various civil works and equipment is given to the program.

The output of the program is the project base cost that includes the cost of preliminary works, weir and reservoir, river diversion, sand trap, headrace tunnel, surge tank, pressure shaft, powerhouse, mechanical and electrical equipments etc. Costs of main components of the three project layouts are listed in following tables.

Table 7.1 : ESTIMATED PROJECT BASE COST

Project Component	Alternative-I W1-P1 (Million US$)	Alternative-II W2-P1 (Million US$)	Alternative-III W2-P2 (Million US$)
Preliminary Works	6.7	6.7	6.7
Weir and Diversion Works	31.4	31.2	31.2
Sand trap	2.6	4.7	4.7

Table 7.1 : ESTIMATED PROJECT BASE COST			
Project Component	Alternative-I W1-P1 (Million US$)	Alternative-II W2-P1 (Million US$)	Alternative-III W2-P2 (Million US$)
Headrace Tunnel	27.8	36.2	31.7
Surge and Pressure Shaft	7.2	7.7	9.5
Powerhouse and Tailrace	4.2	4.4	4.5
Hydro Mechanical Equipment	15.1	15.4	10.8
Electrical Equipment	16.2	17.6	16.9
Others	23.6	25.4	30.6
TOTAL	134.8	149.3	141.2

Table below gives a comparison of the three alternatives in terms of Base Project Cost, Power Generation and Unit Cost of the energy produced.

Table 7.2 :COMPARISON OF ALTERNATIVES			
Project Components	Alternative-I W1-P1	Alternative-II W2-P1	Alternative-III W2-P2
Project Base Cost	134.8	149.3	141.2
Power	88	99	80
Energy	367.7	358.6	312.5
Energy Cost1_/ (USc/kWh)	6.37	7.58	8.23

1_/ capital recovery factor= 0.14 (12% discount rate, 30 years and O&M 2%of capital cost), IDC is approx 30%.

The comparison of three alternatives layout indicates that Alternative I and II have energy cost in the similar range, while Alternative-III have higher energy cost as compared with others.

Alternative-III W2-P2 with less power output and high energy cost is not selected for further studies. Alternative-I and II have economic benefits in the same range, therefore both layouts i.e. W1-P1 and W2-P1 are considered as preferred layouts to be studied for optimization of project layout studies.

7.2 Preliminary Optimization: Installed Capacity & Weir Height

7.2.1 Introduction

The analysis compares various options related to weir height and project sizing. The ideal analysis would be to optimize the project size for both of the following:

- Weir Height
- Design Discharge or Installed Capacity

This analysis looks at optimization of design discharge or installed capacity and weir height. Optimization of turbine specifications and other components is a separate exercise that will be performed later at engineering and design stage.

7.2.2. Methodology

The sizing analysis comprises of determination of:

- Increase, in relatively small steps, in project cost for a range of installed capacities) and between different dam heights
- Increase in project benefits for the same increment.

The decision criterion is the option that results in the maximum NPV or in other words, the project size is increased to a point where ***Incremental Benefits equal Incremental Costs.***

7.2.3 Benefits

The project power benefits have been quantified on basis of Long Run Marginal Cost (LRMC) of Capacity, Peak Energy and Off Peak Energy at 132 kV level.

7.2.4 Broad Overview

The aim of project optimization is to have an optimum capacity of the plant by utilizing the full potential of the site. The project is to be developed for its interconnection to National Grid. For the two preferred alternative layouts, project sizing has been carried out by selecting various design discharges. Both project layouts are located on the right bank of Arkari Gol with low pressure headrace tunnels and powerhouse at the confluence of Arkari and Lutkho River.

Alternative-I has weir at W1 axis at bed El. 2164 m, power intake on the right bank, followed by 200 m channel, open sand trap and 6.0 km long low pressure headrace tunnel . Alternative-II has weir at W2 axis at bed El. 2194 m, power intake on the right bank, connecting tunnel to underground sand trap and low pressure headrace tunnel. The surge tank, pressure shaft and powerhouse for both alternatives is at same location El. 1845 m. The recorded and estimated flows at weir site indicates that the mean monthly flows vary from 5.8 m^3/s to 52.7 m^3/s. The capacity optimization has been carried out by considering various design discharges ranging from 24 m^3/s to 46 m^3/s with an incremental discharge of 2 m^3/s. The benefits and cost have been estimated for various design discharges and the plant has been optimized on the basis of marginal cost and average cost of generated unit.

7.2.5 Economic Parameters

In order to determine the optimal layout for a specific design discharge and project capacity, the Net Present Value (NPV) was computed for the studied scenarios.

The following assumptions were made for the calculation of Standard Conversion Factor (SCF) and economic parameters:

Calculation of SCF & Economic Parameters	
Analysis Period	30 years
Project implementation	3 years
O&M costs	2.0 % of project cost
Discount Rate	10% and 12 %

7.2.6 Long Run Marginal Cost (LRMC) Analysis

Power projects are capital intensive and therefore increased efficiency is of some importance to a developing country. The relationship between per capita energy consumption and per capita income is well understood. Investments in generation expansion need to be optimized. Classical supply and demand curves for electricity would indicate the price at which demand equals supply. Demand however is growing (usually at a healthy rate) over time and supply needs to match the increased demand. High growth rates mean that the investment decisions need to be based upon a forward looking approach rather than upon an historical approach. The marginal increment in price to meet the marginal increment in demand is the marginal price of electricity.

Marginal cost of power supply is defined as the change in total cost of service resulting from small change in demand. This price, usually, does change from time and place of use. Prices set on the marginal basis provide the correct signals to decision makers and results in market equilibrium at a volume of supply that optimizes economic efficiency.

The main components of the Long Run Marginal Cost (LRMC) structure are :

- Marginal capacity cost at generation level
- Marginal energy cost at generation level
- Marginal capacity and energy costs at other voltage levels (500 kV, 220 kV, 132 kV etc.)

Marginal capacity costs are defined as expenses that need to be incurred to maintain reliability of supply. Marginal energy costs are the incremental running cost of the plant best suited to meet demand variations.

7.3 Development of LRMC without use of WASP

7.3.1 Methodology

The capacity LRMC at generation level is based on this assumption that the plant at the margin will be an Open Cycle Gas Turbine (OCGT). The least cost response to demand increment can be summarized as follow:

- Capital cost of the plant at the margin, which is believed to be an OCGT.
- Cost incurred due to enhanced un-served energy due to the fact that in early plan periods new generation cannot be installed due to lead time.
- Benefit of decrease in energy cost due to advancement of base load thermals and hydels in response to demand increment.

The capacity LRMC of the generation level is estimated to be about 80% of the capital cost of the OCGT.

The peak and off-peak energy costs of thermal equivalents are used as proxies for LRMC energy peak and off-peak.

The development of a thermal equivalent plant to a hydroelectric power plant or facility is not a clear-cut simple exercise. This is mainly due to the fact that each hydroelectric facility is unique and the contribution at peak and off peak periods of each hydroelectric power facility is different. Thus the economic value to the system, of output from each hydroelectric plant, as different and furthermore this output is aimed at different portion of the power mix. The capacity (available 4 hours/day for 90% of time) contributions of the hydroelectric plant result in avoided thermal peaking feasibility (usually an open cycle gas turbine – OCGT). The peak energy contributions avoid the operating cost of this OCGT. Whereas the off-peak contribution of a hydroelectric power facility results in avoided operating cost of equivalent or equal generation of a base load thermal power generation power facility (combined cycle gas turbines, cool fired plant etc.). The hydropower facility therefore contributes to both the peak and off peak segment of the power mix. Ex-WAPDA's power mix and full availability situation suggests that:

- The peaking thermal facility is likely to be an OCGT.
- The base load facility is likely to be a CCGT

Thermal equivalent costs therefore will be based upon; the capital and operating cost of a OCGT; and the operating cost of CCGT.

7.3.2 Economic Peak Fuel (gas) Prices

The development of economic gas prices can follow different paths. Gas prices can be derived on basis of the economic opportunity cost. This for Pakistan would be the price of furnace oil which gas substitutes.

Gas reserves are presently at level that the current consumption cannot be sustained. Gas at the margin will surely be imported gas or LNG. There are currently three gas pipelines under consideration. Gas from Qatar, Iran and Central

Asia are under discussion. Liquid Natural Gas (LNG) import options are also under active consideration.

Gas supplies have dwindled, aging fields, failure to accelerate drilling, delay in infill options etc. have all resulted in diminishing gas supplies. The plan to address this includes: additional domestic supplies; imported Iran and Turkmenistan gas pipelines; LNG from Oman and elsewhere; decreased losses; infrastructure improvements, is implemented only in parts and has resulted in continued gas shortages. The near future is therefore expected to be one of dwindling gas supplies. Natural gas is currently the country's largest energy source, making up 48 percent of Pakistan's energy mix in FY 2009/2010.Pakistan's produces about 60,000 barrels of oil per day which only meets approximately one sixth of the country's current oil requirement. The balance amount is imported at a staggering cost of US$2.5 Billion. In view of the increasing demand and the current decline in production this cost is going to increase substantially over the next couple of years. During 2008-9 unnerved energy needs were met with 18.5 MTOE oil imports plus 3 MTOE coal imports at a cost of about 1 Billion US$, This gap is likely to jump up to 56MTOE costing 38Billion Dollars of imported fuel. The gap between supply and demand is widening. Pakistan's average production of about 3753 MMcfd and reserves of about 33 trillion cubic feet (Tcf) are equal to 24 years of current production .The rapid , medium term decline in production of the seven large fields that produce 65% of the total annual gas , their long term projected decline suggest that gas supplies will further fall short of demand . Studies forecasted in that Pakistan is going to witness gas shortage starting in 2007, and the imbalance will grow every year to cripple the economy by 2025, when shortage will be 11,092 MMCFD against total 13,259 MMCFD productions. Pakistan's gas shortage would get much worse in the next two decades if it did not manage any alternative sources. Demand for natural gas in Pakistan increased by almost 10 percent annually from 2000-01 to 2007-08, reaching around 3,200m cubic feet per day (MMCFD) last year, against the total production of 3,774 MMCFD, according to Pakistani official sources. But, during 2008-2009, the demand for natural gas exceeded the available 7 supply, with production of 4528 MMCFD gas against demand for 4731 MMCFD, indicating a shortfall of 203 MMCFD. Gas shortage is presented as Figure 7.1 follows.

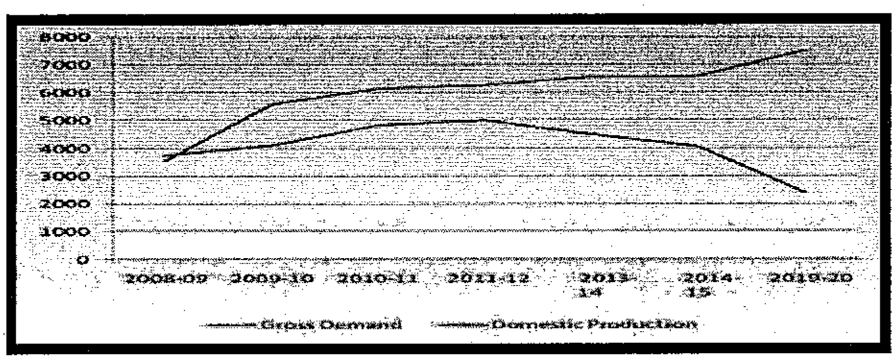

Figure 7.1: Gap between Supply & Demand of Gas (Million cf/d) under do nothing scenario

Pricing of imported gas is as per pricing agreements signed for the Pakistan Iran gas pipeline. Gas prices to be used are as follows:

Imported Gas	=	16 $/mm Btu
Imported LNG	=	18 $/mm Btu

7.3.3 Economic Off Peak Fuel (coal) Prices

The fuel at the margin for base load plants is imported coal. Base load plant fuel may well be coal which is currently priced at 6 $/mmBTU. Fuel prices in the past are presented in the following Figure 7.2.

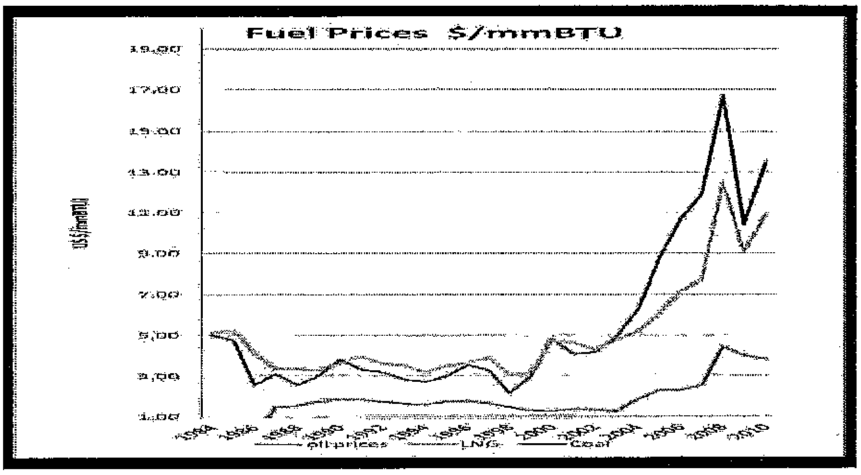

Figure 7.2: Fuel Prices

Coal prices have been relatively stable compared to oil prices. Part of the reason is technological. Electric furnaces are being used to make progressively more steel from scrap, and pulverized coal injection allows expensive coal to be substituted by cheaper steam coal thereby reducing price pressure upon prices. The coal industry has also cut costs dramatically; efficient firms can mine all year round compared to 240 days 10 years ago. Labor productivity in coal mining has increased at a significant rate. The global demand for coal as percentage of primary energy had been steadily declined – it comprised 42.5% of primary energy in 1900 and only 22% in 2000. Coal prices are only weakly connected to oil prices and, having less price volatility than oil, could be attractive for some uses. High oil prices have triggered some shift of energy demand to coal. Several countries have and are reducing subsidies on coal mining.

On the other hand, new materials and technologies are becoming commercially available and will result in dramatic improvement in conversion efficiencies. Efficiencies of 50% in coal fired power generating plants is likely to be possible compared to about 30% for yesterday's technology. World coal usage as percent of total energy will slightly decrease from 2008 to 2018 but will perhaps attain the 2008 levels by 2035. Electricity usage of coal will increase from 2018 to 2035. Coal usage will be about 40% of the total energy consumption. World Coal consumption is forecasted to increase from 139 quad trillion Btu to 209 quad trillion Btu in 2035 at an average annual growth rate of 1.5% per annum. China and India are forecasted to account for 95% of this increase. Most of China's growth came from burning more coal: in 2000 China accounted for just under a third of world coal use; in 2010 it was 48.2%. This expansion will be repeated on a smaller scale for a number of other countries which is why coal is going up in the global mix. Historical coal prices are presented as follows as Figure 7.3 :

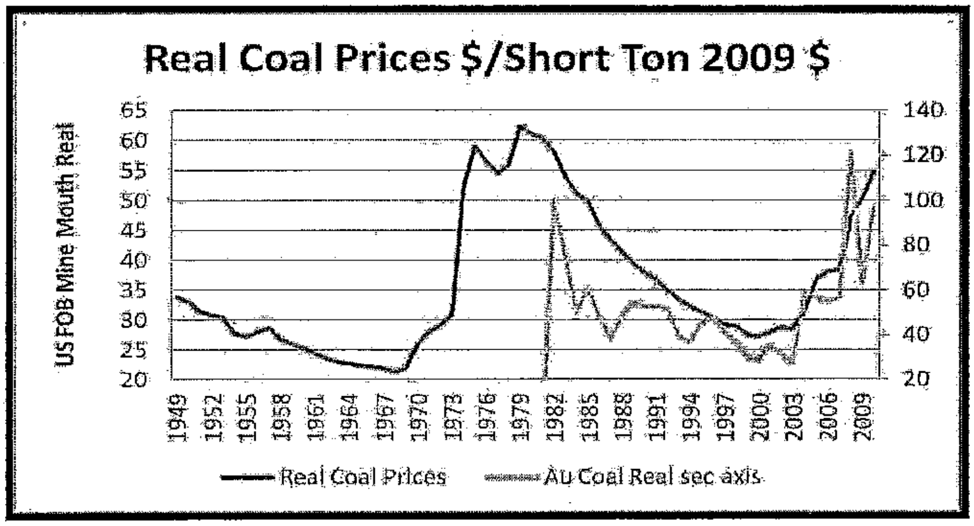

Figure 7.3: Historical Coal Prices

7.3.4 Capacity LRMC

The capacity LRMC at generation level is based on this assumption that the plant at the margin will be an Open Cycle Gas Turbine (OCGT). The least cost response to demand increment can be summarized as follow:

- Capital cost of the plant at the margin, which is believed to be an OCGT.
- Cost incurred due to enhanced un-served energy due to the fact that in early plan periods new generation cannot be installed due to lead time.
- Benefit of decrease in energy cost due to advancement of base load thermals and hydels in response to demand increment.

The capacity LRMC of the generation level is estimated to be about 80% of the capital cost of the OCGT. This assumption has been verified by detailed Wein Automatic System Planning (WASP) runs that capture the marginal capacity price .

7.3.5 Energy LRMC

The peak and off-peak energy costs of thermal equivalents are used as proxies for LRMC energy peak and off-peak.

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Variable operating cost, of an OCGT, excluding fuel is taken of US$ 1.5/MWh. Fixed O&M cost is taken to be 19 $/kW-a .The cost of high Btu gas delivered at load centre has been estimated to be 14.18 (at 80$/barrel parity) $/mm Btu, which given an efficiency of 9100 Btu/kWh translates into a total operating cost of 15.76/kWh.

Secondary energy generated at the hydro station is considered to replace the generating cost of an imported coal fired steam consuming imported gas. The fixed O&M cost is taken to be 35 $/kW-a. The variable O&M cost is taken to be 3.6 $/MWh. The heat rate for a sub critical coal fired power plant is taken to be 9100 Btu/kWh, delivered price of coal to plant is taken to be 6.06 $/mmBtu . The variable cost of the coal fired plant works out to be 9.83 c/kWh (all data used in this analysis has been derived from the NTDC Report – System Expansion Plan 2011-2030) .

The LRMC estimates are therefore presented as Table 7.3 as follows:

Table 7.3 : LRMC ESTIMATES (Based on oil price of US$80)

Voltage	Capacity	Peak Energy	Off Peak Energy
Voltage Level	$/kW	c/kWh	c/kWh
Gen	417	15.76	9.83
500 kV	506	16.02	10.02
220 kV	540	16.29	10.12
132 kV	623	16.78	10.37

7.4 Estimation of Benefits

7.4.1 Estimation of Energy

Andakht project as a run-off river scheme is foreseen with limited reservoir volume. The various cases were analysed for the energy producion (firm energy and secondary energy) to be computed under consideration of the production pattern. For the hydropower scheme with location of main structures, reservoir operating levels, tail water levels and hydraulic losses has been used as inputs for energy simulation for the estimated flows period of 49 years.

Energy Generation in the hydropower plants are estimated with the following aspects:

- Mean monthly flows (m^3/s)
- Compensation Release (m^3/s)
- Target design discharge

- Gross and net head for Turbines
- Waterways Hydraulic Loss Coefficients.
- E&M plant efficiencies

7.4.2 Availability of flows

The observed flows for Arkari Gol are available for a year. The flows of Arkari Gol has been extended to 49 years by establishing a correlation with long term gauging station of Chitral river at Chitral, Lutkho river at Shogore and Ojhor Gol. The estimated flows of Arkari Gol at both weir sites are presented in following **Table 7.4**

Table 7.4 : Flow at Weir Sites (cu.m/sec)

Month	Weir I	Weir II
Jan	6.45	6.00
Feb	5.79	5.39
Mar	5.68	5.28
Apr	7.67	7.13
May	14.73	13.70
Jun	30.19	28.08
Jul	39.48	36.71
Aug	38.85	36.13
Sep	25.38	23.61
Oct	13.25	12.32
Nov	9.24	8.59
Dec	7.52	7.00
Mean	**17.02**	**15.83**

The mean monthly flow varies from 5.7 m^3/s to 39.5 m^3/s with mean annual flows as 17.02 m^3/s at Weir site W1. Considering the updated hydrological data, the range of design discharge varies from 24 m^3/s to 46 m^3/s. The monthly flows at the Weir sites are presented in the following Figure 7.4.

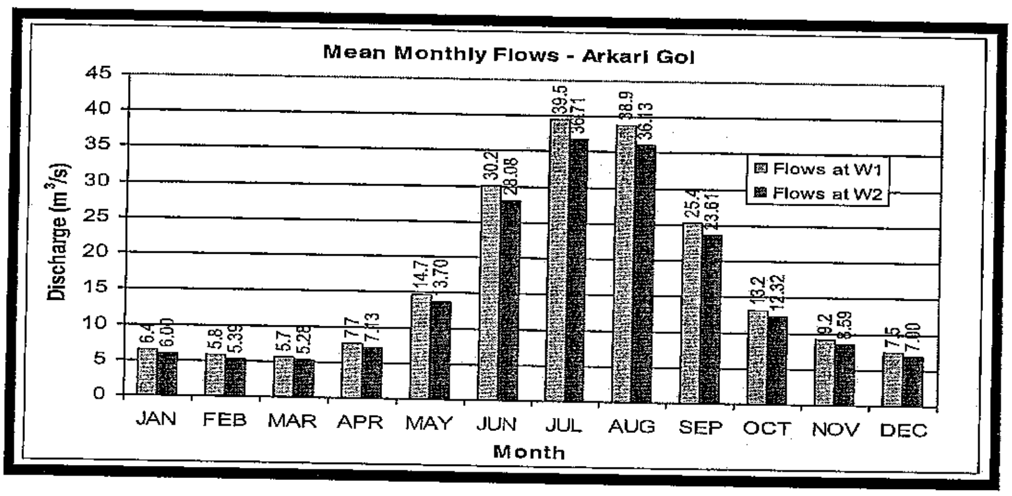


Figure 7.4: Mean Monthly Flows - Arkari Gol at Weir site

7.4.3 Compensation Releases

For Arkari Gol as well as Thauti nullah, necessary releases have been assumed which varies 0.8 m^3/s to 2.0 m^3/s from winter month to summer months. The power and energy are estimated on the basis of mean monthly discharges for average year. For sediment flushing, it has been assumed that power station may have to be shut down for a few days during summer months. Compensation flows from 0.8 m^3/s in winter six months and 2.0 m^3/s in summer months have been considered to be released from the weir as residual flows from Arkari Gol downstream of weir. The compensation flows would be released considering the downstream ecological and biological use and downstream water uses.

7.4.4 Head Losses

The hydraulic loss coefficients have estimated based on empirical values at various locations of important structures. For Intake, entrance, headrace low pressure tunnel, pressure shaft, tailrace and exit losses have been computed for the design discharge through the water ways. The optimal velocities for the concrete lined headrace tunnel is assumed as 2.5 to 3.0 m/s and for the steel lined pressure shaft as 5.5 to 6 m/s. Head losses have been estimated based on the monthly flows through water ways. The maximum losses from intake to turbine axis have been estimated as 17.25 m. The losses are more in summer flows and are reduced to minimum in winter months, as presented in the Table 7.5 below.

Table 7.5 : Estimated Losses in Hydraulic System

No.	Structure	Losses (m)
1	Trash rack	0.12
2	Entrance at intake	0.15
3	Connecting Channel	0.29
4	Sandtrap	0.25
5	Headrace tunnel	10.97
6	Pressure Shaft	4.20
7	Bend	0.27
8	Miscellaneous	1.00
Total	From Intake to Turbine	17.25

7.4.5 Efficiencies of E&M Equipment

The variations in the efficiencies of generating units due to change of net heads have not been considered. For design discharge available to powerhouse, an efficiency of 91.0%, 97.0% and 99% have been used for the turbine, generator and transformers, respectively.

7.4.6 Summary Energy and Capacity Outputs

The energy and capacity outputs for the base case Alternative I are presented as Table 7.6 as follows:

Table 7.6 : Energy Calculations: Andakht HPP – Alternative 1							
S.No	Design Discharge	Installed Capacity	Peak Energy	Off Peak Energy	Total Energy	Plant Factor	Firm Capacity
	m^3/s	MW	GWh/a	GWh/a	GWh/a	%	MW
1	24.00	67.14	96.17	223.86	320.03	54.41	66.13
2	26.00	72.73	104.18	228.69	332.87	52.24	71.65
3	28.00	78.33	112.19	232.77	344.96	50.27	77.16
4	30.00	83.65	119.93	233.55	353.48	48.24	81.83
5	32.00	88.63	126.64	234.99	361.63	46.58	81.83
6	34.00	93.83	133.30	236.47	369.77	44.99	81.83
7	36.00	99.20	139.32	238.60	377.92	43.49	81.83
8	38.00	104.71	145.34	237.32	382.66	41.72	81.83
9	40.00	110.22	151.36	231.30	382.66	39.63	81.83
10	42.00	115.73	156.16	226.49	382.66	37.74	81.83
11	44.00	121.25	160.85	221.81	382.66	36.03	81.83
12	46.00	126.76	165.54	217.12	382.66	34.46	81.83

7.5 Preliminary Estimated Costs

The cost estimates have been based on market prices of June 2013. For the purpose of revision different multiplying factors for different items shall be calculated and applied accordingly for proper cost and tariff estimation.

Cost estimates have been made for the 12 design discharges, from 24 to 46 m^3/s with an interval of 2 m^3/s. The cost estimates cover all structures of the Project such as the weir, diversion works, intake structure, headrace tunnel, surge tank, pressure shaft, powerhouse and tailrace, and E&M equipment. Transportation of equipment, erection and supervision charges, contingencies, engineering supervision, import charges and owner costs have been added to prepare the Project base cost. Interest during construction and the transmission line cost have been added to give a total Project cost.

The cost estimates for all main structures and equipment have been estimated by using a computer programme Hydro Power Costing which was especially prepared for medium size hydropower projects in Pakistan by GTZ-WAPDA during 90's. The programme is useful for costing of various alternative layouts for feasibility study and identification of schemes.

The computer programme estimates the quantities of all main components of the project and with unit price list; it provides the cost of each of main Civil structures, mechanical and electrical equipment. Unit price list is updated with the market rates taken from similar projects in remote area. The cost estimates were computed for the 12 scenarios using cost curves. The operation and maintenance costs of 2 % of the total project costs were assumed. A comparison of cost estimates for various design discharges is presented in the following Table 7.7.

Table 7.7 : Cost Estimates – Alternative I

S.No	Design Discharge	Installed Capacity	Plant Factor	HPP Cost	TL Cost	Total Cost	Cost per kw
	m3/s	MW	%	M US$	M US$	M US$	US$ / kW
1	24	67	54.41	117	18.00	135	2011
2	26	73	52.24	121	19.35	141	1933
3	28	78	50.27	126	20.80	146	1869
4	30	84	48.24	130	22.36	152	1823
5	32	89	46.58	135	24.04	159	1792
6	34	94	44.99	140	25.84	165	1764
7	36	99	43.49	145	27.78	172	1738
8	38	105	41.72	150	29.86	180	1716
9	40	110	39.63	155	32.10	187	1700
10	42	116	37.74	161	34.51	195	1688
11	44	121	36.03	167	37.10	204	1680
12	46	127	34.46	173	39.88	213	1677

7.6 Capacity Optimization and Conclusion

This section focuses on capacity optimization of competing project alternatives with a view to facilitating the decision making process for the adoption of best alternative for detailed design and subsequent implementation of the project.

7.6.1 Capacity Optimization of Alternatives

With power and energy values for various design discharges, benefits are estimated. Total project costs including transmission cost to regional grid have been estimated for corresponding capacity. Net Present Value (NPV) for various design discharge are computed for both Alternatives.

For Alternative-I, power, NPV is presented in following Table 7.8. Similarly for Alternative-II, NPV for various design discharges are indicated in following Table 7.9.

Table 7.8 : Economic Evaluation – Alternative I

S.No	Design Discharge	Installed Capacity	Plant Factor	Total Cost	NPV at 10%	NPV at 12%
	m3/s	MW	%	M US$	M US$	M US$
1	24	67	54.41	135	112.01	77.54
2	26	73	52.24	141	118.87	82.69
3	28	78	50.27	146	125.08	87.26

Table 7.8 : Economic Evaluation – Alternative I						
S.No	Design Discharge	Installed Capacity	Plant Factor	Total Cost	NPV at 10%	NPV at 12%
	m3/s	MW	%	M US$	M US$	M US$
4	30	84	48.24	152	128.63	89.62
5	32	89	46.58	159	129.59	89.63
6	34	94	44.99	165	130.27	89.37
7	36	99	43.49	172	130.44	88.66
8	38	105	41.72	180	128.39	86.11
9	40	110	39.63	187	123.37	81.10
10	42	116	37.74	195	117.59	75.42
11	44	121	36.03	204	111.41	69.38
12	46	127	34.46	213	104.86	62.99

The above table indicates that NPV at discount rates of 10% and 12% is maximum for design discharge range of 36.0 and 34.0 m^3/s respectively. Based on average year flows, the corresponding capacity of 100 MW is considered as the optimal capacity.

Table 7.9 : Economic Evaluation – Alternative II						
S.No	Design Discharge	Installed Capacity	Plant Factor	Total Cost	NPV at 10%	NPV at 12%
	m3/s	MW	%	M US$	M US$	M US$
1	24	71	51.92	147	105.86	71.17
2	26	80	48.22	154	112.43	76.01
3	28	82	47.91	160	115.33	77.76
4	30	88	45.83	167	116.17	77.59
5	32	93	44.57	175	116.59	77.06
6	34	99	42.94	182	115.90	75.58
7	36	105	40.75	190	111.75	71.24
8	38	110	38.61	198	105.99	65.55
9	40	116	36.68	207	99.62	59.31
10	42	122	34.93	216	92.86	52.71
11	44	128	33.34	226	85.69	45.72
12	46	134	31.89	236	78.09	38.33

The above indicates that the Alternative 2 has the optimized capacity at 32.0 m^3/s and 99 MW Installed capacity. NPV for various design discharges has been calculated at 12 % and 10% and the comparison of two Alternatives is made graphically in the following Figure 7.5. (Annexure 1 and 2 present the economic analysis of each design discharge for the two alternatives)

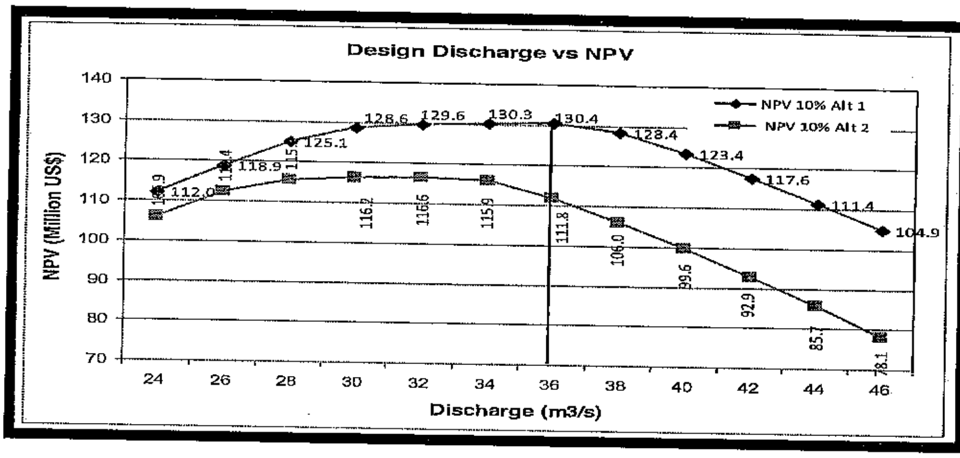


Figure 7.5 NPV for Different Design Discharges

7.6.2 Conclusions

Alternative I, has weir at W1 axis at bed El. 2164 m, power intake on the right bank, connecting tunnel to surface sand trap and low pressure headrace tunnel. The surge tank, pressure shaft and powerhouse for both alternatives is at same location El. 1854.7 m. Alternative 1 has a higher NPV (at 10% discount rate and also at 12% discount rate, discussion presented in the Inception Report recommends that 10% be used as the discount rate for capacity optimization whereas 12% be used as discount rate for economic analysis to conform to the Planning Commission and Provincial Planning departments instructions)) and is therefore the selected option. The selected option has the highest NPV at design discharge of 36 m^3/s and 105 MW installed capacity.

7.7 Optimization of Reservoir Level

7.7.1 General

Reservoir level has been optimized considering the live storage for 4 hours peaking during low flow in winter months. The range of reservoir level operation from minimum to maximum improves the net benefits of the project in terms of increased power in peaking hours. The availability of maximum power in peaking hours justifies the higher reservoir level upstream of weir intake. The increased weir cost, area inundated and realignment of road restrict the net benefits. Upto certain water level, the net benefits increase and then decrease.

The operating range of reservoir level to be utilized within a day depends on the geological conditions of reservoir periphery. Geotechnical expert can provide a better option about the rate of reservoir draw down. In this optimization process, the operating range has been optimized on the basis of maximum NPV. The river bed at weir axis W1 is 2164 m. the intake for power tunnel would be located from elevation 2183 to 2186 m.

7.7.2 Reservoir Volume

Reservoir volume has been estimated from topographic surveyed maps prepared with contour interval of 2 m. Live storage has been estimated for various water levels from 2170 to 2210 m with interval of 2 m. Live storage would be used for daily 4 hours peaking. To have a design of 34 m^3/s during 4 hours peaking, a live storage of about 489,600 m^3 would be required. At minimum operating level of 2186 m, the storage has been estimated as 1,481,814 m^3. At normal reservoir level of 2190 m, the gross storage is 2,155,608 m^3. The live storage from 2186 to 2190 m is 673,794 m^3. The volume-elevation curve is presented in the following Figure 7.6.

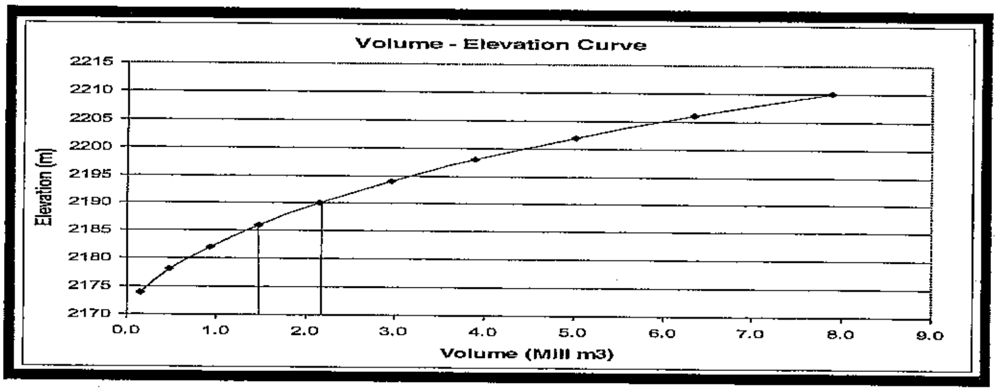


Figure 7.6: Volume-Elevation Curve for Reservoir at Uchhatur

Flows during 20 off peak hours would be stored which will be used as additional flows during 4 hours peak. For various reservoir elevations, the additional discharge from live storage have been estimated and presented in following Table 7.10.

Table 7.10 : Live Storage for Peaking at Different Reservoir Levels

Weir Height (m)	Elevation (m)	Area (m2)	Gross Volume (Million m3)	Live Storage (Million m3)
10	2170	16542		
14	2174	59493	0.15207	
18	2178	102486	0.47603	0.011500
22	2182	124679	0.93036	0.023000
26	2186	151049	1.48181	0.551456
30	**2190**	**185848**	**2.15561**	**0.673794**
34	2194	212515	2.95233	0.796726
38	2198	257428	3.89222	0.939886

Table 7.10 : Live Storage for Peaking at Different Reservoir Levels				
Weir Height	Elevation	Area	Gross Volume	Live Storage
(m)	(m)	(m2)	(Million m3)	(Million m3)
42	2202	308153	5.02338	1.131162
46	2206	355414	6.35052	1.327134
50	2210	405104	7.87155	1.521036

Note: Live storage for different reservoir levels are developed from rating Curves. The reservoir length would vary from 1300 m to 1500 m for reservoir elevation from 2186 m to 2190 m respectively.

7.7.3 Estimation of Benefits

Benefits are derived from power, peak and off peak energy available during each month of average flow year. The design discharge for estimation of power is taken as 34 m^3/s. The minimum head water is taken as 2186 m and turbine level is assumed as 1854.3 m. Long run marginal cost values have been used to have power and energy benefits. The monthly benefits are added to have annual benefits for each reservoir level. The incremental benefits are due to increased head and increased energy during peak hours.

7.7.4 Estimation of Cost

The project cost is estimated with the help of computer program especially designed for costing of medium size Hydropower Projects. Input data about design discharge, water levels, design flood, reservoir, and access road, dimensions of weir, headrace, sand trap, surge, pressure shaft, powerhouse and tailrace are provided. For each reservoir level, separate cost estimate is prepared. The cost is annualized to estimate the net annual benefits. With annuity factor, net present value for each reservoir level has been derived.

7.7.5 Optimized Reservoir Level

Net Present values for various reservoir levels have been estimated and are presented in following Table 7.11. NPV values increases from reservoir level of 2175 to 2190 m and then decreases above 2190 m reservoir level as the cost of weir increases substantially with increase in height.

Table 7.11 : Estimated NPV at Different Reservoir Levels							
Weir Height	Reservoir Level	Power	Annual Energy	Plant Factor	Total Cost	NPV 10%	NPV 12%
M	m.a.s.l	MW	GWh	(%)	M.US	M US$	M US$
15	2175	94.5	362.7	43.80	138.510	108.98	72.67

Table 7.11 : Estimated NPV at Different Reservoir Levels							
Weir Height	Reservoir Level	Power	Annual Energy	Plant Factor	Total Cost	NPV 10%	NPV 12%
20	2180	98.0	367.5	42.82	143.933	125.41	86.30
25	2185	97.6	372.7	43.58	150.230	136.74	95.51
30	2190	99.2	377.8	43.48	157.502	146.61	103.30
35	2195	100.8	383.7	43.47	165.872	143.39	99.72
40	2200	102.3	389.6	43.47	175.484	139.02	95.05
45	2205	103.9	395.5	43.46	186.508	133.33	89.13
50	2210	105.4	401.4	43.45	199.146	126.14	81.80

NPV values at discount rate of 10% and 12% are graphically presented in following Figure 7.7. With increase in discount rate, NPV remains highest at reservoir level of 2190 m for which weir height above river bed is 30 m.

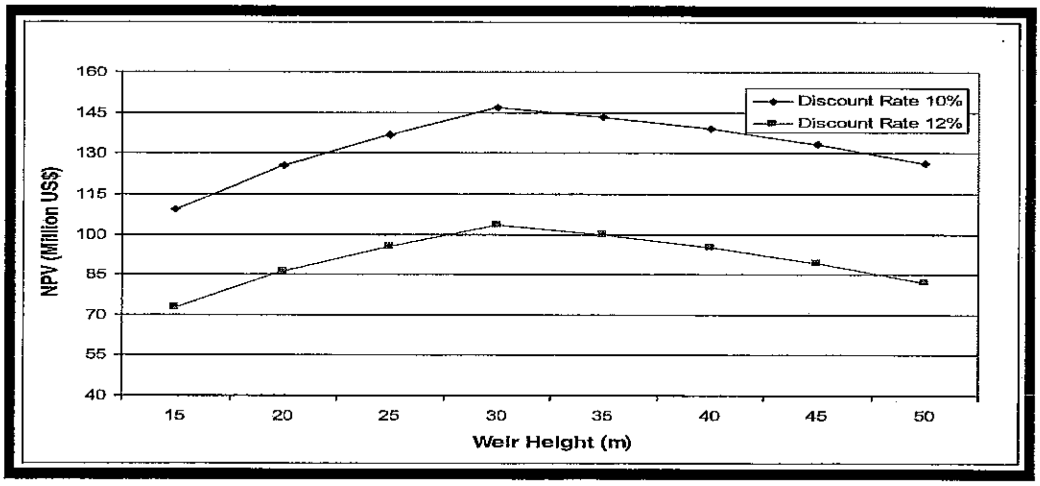


Figure 7.7: Weir Heights Comparison

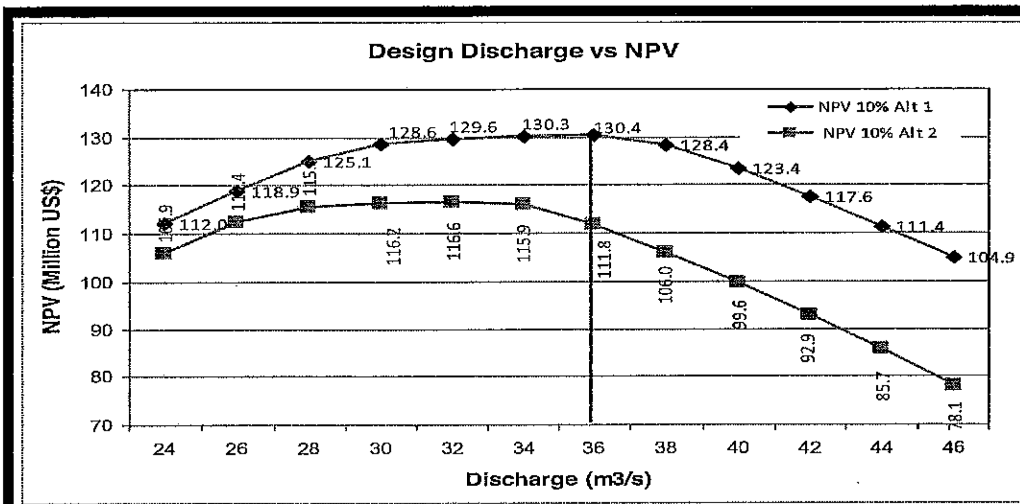
The above table and graph indicates that NPV is highest at reservoir level of 2190 m. It is therefore recommended that 2190 m elevation may be taken as maximum reservoir level. The minimum operating level would be 2186 m. A 4 m reservoir variation would provide a live storage of 673,794 m^3. With this live storage, the design discharge of 36 m^3/s would be available during 4 hours of daily peaking even in winter months.

7.8 Final Conclusions

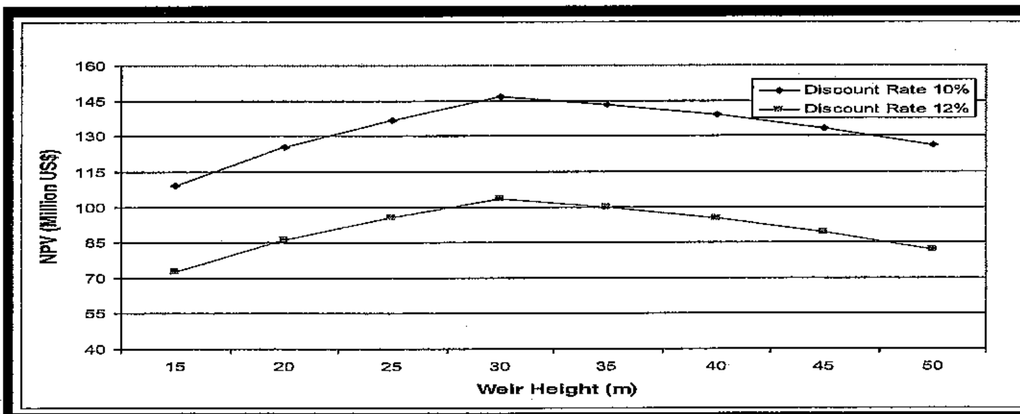
The study looks at various variants and alternatives. Three alternatives were studied. This resulted in the conclusion that alternatives 1 and 2 were comparable. This is presented in the table on that follows.

Table 7.12 :COMPARISON OF ALTERNATIVES			
Project Components	Alternative-I W1-P1	Alternative-II W2-P1	Alternative-III W2-P2
Project Base Cost	134.8	149.3	141.2
Power	88	99	80
Energy	367.7	358.6	312.5
Energy Cost1_/ (USc/kWh)	6.37	7.58	8.23

The detailed analysis of the two alternatives resulted in the conclusion that alternative 1 had a higher NPV and is therefore the recommended solution. The optimized capacity is 99 MW, design discharge 36 m³/s, and plant factor 43.6 % this is presented as follows:



Weir height was optimized for the two alternatives and it as concluded those 30 meters is the optimized weir height for the chosen alternative. This is presented as follows:



The finally optimized project that is to be studied at the next feasibility level is summarized as follows:

TABLE 7.13	SELECTED AND OPTIMIZED OPTION
Project Layout	On the Right Bank
Weir Location	8.0 km upstream of Andakht Village
Catchment Area	995 km^2
Powerhouse Location	Left Bank of Lutkho River near Andakht Village
Weir Height Above River Bed	30 m
Normal Reservoir Level	2190 m
Minimum Reservoir Level	2186 m
Turbine Axis Level	1854.7 m
Live Storage	0.674 million m^3
Length Of The Crest	168 m
Mean Annual Flow	17.02 m^3/s
Design Discharge	36.0 m^3/s
Maximum Gross Head	335.3 m
Net Head	318.05 m
Connecting Channel	240 m
Sand trap Length	90 m
Headrace Tunnel Diameter	4.1 m
Pressure Shaft Length	840 m
Pressure Shaft Diameter	3.0 m
Installed Capacity	**99 MW**
Annual Energy Generated	**377.92 GWh**
Plant Factor	43.6 %

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VOLUME 1 MAIN REPORT- Part I

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8.0 Civil Design

Feasibility stage design of the Arkari Gol Hydropower project is based on the alternative finalized in Chapter No-8 of Interim Report-A of the Arkari Gol Hydropower project. Accordingly, project components have been designed according to the parameters defined earlier during the topographic, geological, hydrological and power generation studies.

This chapter presents Civil Design of project components as follows.

8.1 Reservoir

8.2 Engineering Geological Aspects

8.3 Dam Structure

8.4 Headrace Tunnel from Intake to Surge Tank

8.5 Surge Tank

8.6 Pressure Tunnel

8.7 Powerhouse

8.8 Tailrace

8.1 Reservoir

8.1.1 Storage Requirements

The task from the economist to the engineer was to create a reservoir as a peak storage facility to be used for four hours daily peak operation.

The required storage capacity was defined on the basis of 5.56m^3/sec low flow and the rated discharge of 36m^3/s of the three Pelton wheel turbines.

$$V_L = (Q_{design} - Q_{low\ flow}) \times 4 \times 3600$$

$$V_L = (36 - 5.56) \times 4 \times 3600 = 438{,}336 m^3$$

Live Storage 450,000

8.1.2 Optimization of Reservoir Levels

The dam axis is located at 36^0 03' 57"N,71^0 41' 37"E where there is rock visible on the right abutment with the river bed level at the dam axis at 2172 m.a.s.l and its crest level at 2192 m.a.s.l the reservoir volume was determined with the help of 1:1000 topographic map. Also a reservoir rating curve was drawn based on the topography of the reservoir area.

In order to avoid inflow of bed level sedimentation into the headrace channel and to enable flushing of any sediment accumulation in front of the intake bottom outlets have been designed at an elevation of 2173.84m.a.s.l which is about 2 meters above the river bed.

The top of the trash racks is at an elevation of 2187 m.a.s.l. To avoid air entrance 2 meter free board is considered.
Theoretically storage of 450,000 m^3 will be available with top water level of 2190 m.a.s.l.

Since the dam/weirs will result in a peaking storage facility the flushing of sediments will be carried out routinely as normal operational exercise during the period when flows are in excess of these required for the proposed generation.

Based on economic and technical consideration, the determination of the maximum Reservoir level respectively maximum operation level was based on following parameters;

- Location of the Dam Structure
- Reservoir Volume Curve
- Optimization of Dam Height
- Requirements of Intake Structure
- Resettlement
- Sedimentation

The dam structure is located in a gorge of Arkari Gol River near Uchhatur village.

Based on the survey map 1:1000 the reservoir volume and surface curve were evaluated.

For the determination of the emergency draw down level at an elevation of 2185.00m.a.s.l, mainly the setting of the intake structure was authoritative.

To avoid inflow of bed-load into the headrace tunnel during times when the bottom cutlets at the dam structure are open, the lowest setting of the intake was determined at an elevation of 2181m.a.s.l., i.e. approximately 9m above river-bed.

The top of the trash racks is at an elevation of 2187 m.a.s.l. To avoid air entrance, 2 m freeboard was considered up to the emergency draw down level of 2185 m.a.s.l. Since spilling of sediments during times with full reservoir is not effective, a buffer volume for silting up at the upper reach and on terraces will be necessary to guarantee the required live storage volume.

The resulting cost increase of the darn structure due to the required higher maximum operation level has to be taken into account.

Based on all these economic and technical considerations, the reservoir characteristics have been established for Feasibility Design as follows:

Reservoir levels	m a.s.l.	Volume (m^3)	
Maximum operation level	2190	Storage capacity	1.061Mm^3
Minimum Operation Level	2186.00	Dead Storage	0.656 Mm^2
Maximum Operation Level	2190.00	Live Storage	0.489 Mm^3

The length of the reservoir along the riverbed line is approximately 1.30 km^2. The surface at maximum operation level was determined 0.121Mm^2.

8.2 Engineering Geological Aspects

8.2.1 Geology of Weir Site

The weir is located in the granitic outcrop. The granite body is intruded along the strike of the Wakhan formation which consists of slate, gneiss and quartzite. The contact of granite is with Amphibolites and slates. The contact with granite is considered to be faulted but it could be a normal igneous contact as all the granite in Chitral has igneous normal contact in the Karakorum and Hindu Kush range and Tirich Mir granite is one having similar origin may have normal igneous contact with the Wakhan formation in the Project area.

8.2.1.1 Granite

The rocks at both the bank of Arkari Gol at weir site are granitoids of Tirich Mir granite. The granite is white color; phenol crystalline, large crystals up to 2 inches (pl.6) are common. It is dominantly composed of quartz, plagioclase, feldspar, biotite and muscovite. Albite twining gives mirror shine throughout the granitic body. It is very hard, well jointed and weathered with spheroidal weathering/exfoliation (pl.4).It is highest range form of rock and resistant to weathering and erosion. Sample no: A-8 collected for the petrographic studies give results and details.

8.2.1.2 Amphibolites

It is medium to high grade metamorphic rocks formed by the metamorphism of green schist and composed of garnet, hornblende and plagioclase. It is course grained. This rock is exposed upstream of weir. It is also a hard rock, resistant to weathering and erosional agencies. A number of granite intrusions from Tirich Mir granite have been intruded in the form of dykes (pl.5). The petrographic study of sample no. A-11 gives the petrographic study details.

8.2.1.3 Scanline Survey

Scanline survey conducted at the weir site. Rock properties recorded from the right and left bank exposure. Rocks on the proposed weir site are igneous intrusion. The survey was conducted following the same procedure i-e by using Brunton compass and tape. Different joints sets recorded and their properties were obtained.

Joints dipping in different directions, dip ranging from 45^0-74^0, and dip direction ranging from 12^0-355^0. Joints are very close to widely spaced, 20-2000 mm. Persistence of the joints range from 3-10 m, while some joints have more than 15 m persistence. Surface is slightly rough planer to very rough non planner. Joint aperture is extremely close to medium <2mm-200mm. Most of the joints have no filling material but some joints have soft filling i-e inactive clay. Water condition is dry. The data is plotted on stereonet and rose diagram (RD-W) shown in Appendix-I.

8.2.1.4 Technical Requirements to Control Silting Up of the Reservoir

As already pointed out by the Geologist, sedimentation is a sensitive boundary condition for peak operation of the hydropower project.

According to chapter 2-Hydrology, the total sediment load is estimated to be approximately U.86x106 Tons/year with a distribution of approximately 0.77x106 Tons/year suspended sediment discharge and approximately 0.09x106 Tons/year bed load.

There is no doubt, that the reservoir of a total storage volume of approximately 1 mio m^3 would silt up within approximately 4 years completely without a sediment flushing in an systematic way.

A bed-load delta builds up first at the upper reaches of the backwater pond, thus diminishing the cross-section and enhancing the flow velocity. The bed-load, consequently, is picked up and transported further. Thus the bed-load delta moves and sooner or later arrives at the intake and the dam, respectively. In the meantime, naturally, also the larger particles of the suspended load deposit, since in deeper water they behave as bed-load grains.

However in case of Arkari HPP the reservoir for only peak hours ponding capacity therefore during the period of excess discharge in the river than the design discharge flushing will take place every day which will make it quiet effective.
The flushing effect on the entire deposit will be insignificant.

In other words, a significant flushing of the sediments deposited in the entire basin can only be accomplished if natural (or almost original) flowing of high discharges across the bottom of the reservoir can be rendered possible.

Masses of sediments at flat areas (terraces) trend to remain when flood is running through the empty reservoir.

Therefore besides flushing at some areas, dredging (various methods) for removal of sediment deposits will be necessary.

To avoid silting up of the reservoir,

- Bottom outlets in a sufficient number and size have to be provided at the dam structure of a total capacity of approximately300 m^3/s at lower flow level.

- An operation manual has to be elaborated and continuously adopted in the first years according to operation experiences.

8.3 Dam Structure

8.3.1 Location

Based on previous studies of alternative dam- or weir locations it was recommended by engineering and engineering geological aspects to select.

8.3.2 Dam Site Alternative I

The most suitable location for fitting the dam into the gorge has been found at near Uchhatur Village.

The dam axis coordinates are as follows.

N	E
36^0 03' 57"	71^0 41' 37"

The width of the original riverbed (elevation approximately 2172 m.a.s.l.) varies between 140 to 160 m. The natural descent of Arkari Gol is approximately3.4 percent.

Study of Alternative Dam Types

For completeness of the study, in a first step different dam types for the maximum operation level 2190 m a.s.l. were subjected to comparison:

- Concrete Gravity Dam
- RCC-Roller Compact Concrete Dam
- Rock-Fill Dam

The evaluation method for comparison considered the following criteria.

- Topography
- Geology
- Reservoir flushing requirements
- Flood control

Main component for a comparison is governed by the flushing requirements for the reservoir to avoid silting up of reservoir.

Roller compacted- and the rock fill dams normally are chosen for wide valley sections, combined with concrete structures for spillway and bottom outlets. The gorge of Arkari Gol is sufficient for such types.

The comparatively low dam height of approximately 22 m above riverbed according the maximum operation level at 2190 m.a.s.l. and the perforations for the flood control and bottom outlets do not request for an arch gravity or arch type. The soil investigations of the dam site show that the rock is about 100m deep. Therefore a Rock fill type dam was recommended as basis for the Feasibility Design.

8.3.3 Dam Design

Rock fill type as dam structure have been selected, the design criteria for the following aspects should be examined.

- River diversion
- Application of diversion tunnels for flood of 10 years return period
- Flood control through R.C.C. spillway
- Sediment flushing (bottom outlets)

Topography, geology foundation conditions, the shape and size of the valley dictate the selection of type of the dam i.e. concrete gravity dam or an earth/rock fill dam. Availability of construction material within a reasonable distance from the site, particularly those which would be used in large quantities, also influences the choice of type of dam. Both concrete gravity dam and rock fill dams can be built over competent rock foundations, whereas the later can be built even over gravel foundations, however special precautions have to be taken to provide effective water cut offs and seals. Rock-fill dams are particularly more suitable when any of the following conditions exit:

- Large quantities of rock are readily available or will be excavated in connection with the project components such as weir, de-sanders, and tunnel.
- Restricted construction seasons due to extreme weather condition.
- Ability to place rock-fill throughout winters and carryout grouting simultaneously.

Existence of deep-over burden at the location of Arkari HPP embankment weir, ranging between 160 to180 meters decidedly favors the construction of a rock-fill dam since the option of building concrete gravity dam can only be exercised when competent rock foundation is available.

For Arkari Hydropower project, rock-fill dam with upstream RCC membrane has been proposed due to non-availability of impervious material for the provision of central core.

Axis of weir/diversion embankment has been selected on the basis of prevailing hydrological, topographical, geological and environmental conditions.

A rock fill dam as its name implies is a dam that relies on rock, either dumped in lifts or compacted in layers as a major structural element. It is economical because cheap and local materials are used in its construction and suitable and for location where foundation conditions are not good. Its construction can be continued even in harsh climate. An impervious membrane is used as water barrier and can be placed either within the embankment core or on the upstream slope. Upstream membranes are usually constructed in concrete, asphalt or steel and have the following advantages.

- Readily available for inspection and repair
- Can be constructed after completion of rock fill section.
- Foundation grouting can be performed simultaneously with rock placement.
- A larger section of the dam is available for stability against sliding.

8.3.4 Embankment Section

For building a rock-fill dam, rock material should preferably be hard, durable to withstand disintegration due to weathering and excessive break down due to quarrying etc.

The upstream and downstream slopes of the dam depend upon the type of impervious membrane and its location. For decked rock fill dam the downstream zone of the embankment employs the use of largest and best quality rock available. Rocks in this zone should be well graded in size approximating 0.03 m^3 to one m^3. The upstream zone shall provide a smooth bearing for the facing, yet be graded to retard the water loss shall the facing crack during post completion period. The zone in between upstream and downstream zones should be well graded with rock varying 75 mm. to 300 mm. In size In general, rock material in all the three zones shall be well graded from fine rock upstream to coarse rock downstream.

Embankment slopes normally conform to angle of repose of rock material and on the type of imperious membrane and its location with upstream membrane slopes from 1.6: 1.0 to 1.8 to 1.0 are adopted. Concrete face rock fill dams are normally built with 1.3:1 to 1.4:1 slopes however both upstream and downstream embankment slopes are flattened for safety in earthquake prone areas. Arkari embankment dam shall be built with upstream slope of 1.6:1 and downstream slope of 1.8:1 slope approximating the natural slope of the rock.

8.3.5 Foundation

Foundation requirements for rock fill dams are less severe than for a concrete gravity dam. Rock-fill dams over river gravels or rock fragments can be successfully built as compared to gravity dams which require sound rock footings. Critical importance in functioning of rock fill dam is the prevention of seepage beneath the dam and the erection of a water tight seal between the membrane and the foundation. To prevent seepage, foundations of proposed concrete face rock fill dam (CFRD) shall be grouted beneath the cutoff and its extent has been decided after careful study of site geology, visual examination of drill cores and drill hole water loss values. Plastic concrete cutoff walls are provided to various depths to facilitate grouting operations, to provide a watertight seal with the membrane and to take the downward thrust of the membrane. A minimum width of 3'-0 (0.9m) is recommended in the literature however, depth depends on the foundation strata. Moreover, impervious blanketing is provided to a reasonable distance upstream of the dam to control seepage across the structure.

8.3.6 Top Width

Top width/crest width is determined by the type of membrane used and by its use after construction. It should however, be of sufficient width to accommodate construction of upstream membrane. A minimum of 4.5 m. to 6.0 m. is generally recommended. However Japanese Code 1957 specifies top width (W) in terms of height of the dam as;

$$W = 3.6\,H^{1/3} - 3\ \text{(m)}$$

Where:

W = Top Width
H = Height of Dam

Therefore:

$$W = 3.67\,(22)^{1/3} - 3$$
$$= 10.08 - 3$$
$$= 7.08\ \text{m}$$

Crest camber is determined by the amount of foundation and embankment settlement anticipated since this is difficult to determine a camber of 1.0% of the embankment height is recommended which takes care of anticipated settlement during post completion period.

In earthquake prone areas downstream slopes are flattened to 1.8:1.0. Upstream slope of embankment should also be flattened if additional conservative measures are warranted. RCC concrete membrane upstream of the embankment is preferred due to its better performance durability and ease of construction. Usually 0.2 m thick concrete membrane is provided, however, in earthquake zones like Arkari, it is advised to increase the thickness to 0.3 m. The amount of reinforcing steel to be placed both horizontally and vertically should be 0.5 percent of concrete area.

8.3.7 Location of Joints in RCC Facing

In low height dams like the one for Arkari HPP, horizontal or vertical joints are not normally provided in reinforced concrete facings. Vertical joints may be required to compensate for horizontal expansion on low dams. PVC or rubber waterstops are usually provided to insure impermeability along the joint. The joints are filled with compressive materials to keep out the dirt.

Since concrete facings provide little resistance to wave run up, an increased free board is required to prevent wave run up and over splash. Placement of concrete facing (membrane) should not commence until entire embankment has been placed. This allows for maximum settlement during construction and reduces the possibility of cracking and excess leakage after completion.

8.3.8 Free Board

To ensure safety of embankment dam against wind setup, wave action, uncertainties in analytical procedures and satisfactory operation of the dam etc., free board is provided. This is the vertical distance between the top of the dam and reservoir water surface. For arriving at minimum value of free board, consideration is given to design flood level, the wave run up and wind set up. These values are added as an extra allowance for contingent requirement as factor of safety (FOS) free board is normally governed by wave height.

8.3.9 Wave Height

The wave characteristics depend on the extent and configuration of wind and depth of water in the reservoir however minimum free board above the maximum reservoir level recommended by some author is 4 to 5% of the dam height. Wave height can be determined by using Molitor Formula:

$$H_W = 0.0322\ (FV+0.763-0.27\ (F)^{3/4})^{1/2}$$

Where:
H_W = Wave height in meters (m)
F = Fetch of the reservoir (km)
V = Wind speed in (km/hr)

Free board is normally governed by the following relationship:

Free Board = 1.5 hw

Let V = Wind Velocity = 160 km/hr

F = 0.85 km.

$$\begin{aligned} H_W &= 0.0322\ (0.85 \times 160 + 0.763 - 0.27\ (0.85)^{0.75})^{1/2} \\ &= 0.0322\ (136 + 0.763 - 0.24)^{1/2} \\ &= 0.322 \times 11.68 \\ &= 0.376 \text{ m.} \end{aligned}$$

There is another formula known as Molitor – Stevenson Formula for determining the wave height.

$$H_s = 0.76 + 0.032\ (VF)^{0.5} - 0.26\ (F)^{0.25}$$

With inputs of wind velocity and fetch of the reservoir

$$H_s = 0.76 + 0.032\,(160 \times 0.85)^{0.5} - 0.26 \times (0.85)^{0.25}$$
$$= 0.76 + 0.373 - 0.25$$
$$= 0.883 \text{ m.}$$

The higher value of the two i.e. 0.883 m shall be adopted.

8.3.10 Wind Setup

Wind setup is defined as tilting of water surface in an impounded reservoir caused by wind shear stress.

It is calculated by:

$$S = V^2 F/(1400D)$$

Where:
S = Wind Setup
V = Velocity in miles/hr
F = Fetch in miles
D = Mean reservoir depth along the fetch = 40 ft

$$S = 100^2 \times 0.85 / 1400 \times 36$$
$$= 8500 / 1400 \times 36$$
$$= 0.17 \text{ ft.}$$
$$= 0.052 \text{ m.}$$

Calculations for Wave Run up

Wave run-up is rising of wave up to a height above the still water, on its strike to a barrier.

For smooth vertical face weirs:

$$R = 1.5 \times H_s$$

This gives:
$$R = 1.5 \times 0.883$$
$$= 1.32 \text{ m.}$$

Calculations for Free Board

Free board (FB) = S+R+E

Where:
FB = Free Board
R = Wave Run-up
S = Wind Setup
E = Extra Allowance

Therefore:
$$FB = 0.052 + 1.32 + 0.5$$
$$= 1.875$$

Therefore 2.0 m. free board has been provided.

A hydraulic model test for the dam structure including flood control, bottom outlets, reservoir flushing and intake is required at least up to the stage of Tender Design.

8.3.11 River Diversion during construction

The river diversion facilities have been designed for a flood according to 10-years return period of 284m^3/s. The flood value has been determined in the Hydrological Report.

In case of floods with higher frequency, the cofferdams would be over spilled and flushed downstream. The safety of completed concrete blocks in such an event depends on the stage of actual construction progress (bottom outlets).

Design floods of higher frequency results in increasing cost for the temporary river diversion.

The tunnel axis was determined in a way, that the outflow will follow the downstream flow direction of Arkari Gol.

As the rough excavation would cause considerable friction losses, which in turn would necessitate a much higher cofferdam, at the bottom and side walls of the diversion tunnels a concrete lining has been selected, while the roof will be covered with shotcrete only.

The diversion facilities will presumably be in service for approximately three construction years. Then, before the end of the low-flow period, the tunnel will be closed by a concrete plug located in the area of the grout curtain. The rock around the plug will be grouted so as to connect with the grout curtain.

8.3.12 Application of Diversion Tunnel for Flood Control and Bottom Outlets

It should be examined whether the temporary diversion tunnels could be adapted as permanent structure to serve as flood control and bottom outlets for spilling purposes.

It is certain, that structures (intake, tunnel lining, and outlet) for the only temporary use may be partly damaged during the course of the river diversion during construction.

The required structural conversion for flood control or bottom outlets will be as follows:

- Intake structure steel armored with stop logs and trash-racks.
- Lining of the tunnel with reinforced concrete, steel armor in the lower part for these as bottom outlets (sediment flushing).
- Gate chambers with vertical transport shaft.
- Additional stilling basin at the outlet structures of the diversion tunnels.

For completeness of the model study, the application of the diversion tunnel for reservoir flushing should be considered.

8.3.13 Flood Control and Bottom Outlets

The design flood was selected according to a 1000 years return period. The peak discharge is $HQ_{1000} = 562\ m^3/s$.

The 1000-years frequency is used internationally for rock fill dams.
Four bottom outlets of a size of 6 x 6 m are necessary for a cross-flow of together 562 m^3/s at low reservoir level as a minimum.

There are several possibilities for the arrangement of flood control gates under consideration of bottom outlets for flushing purposes.

Excavation and Foundation

Before the beginning of excavation works, realignment of Arkari Road at a new higher rout has to be completed.

The required valley-width for placement of the dam structure will need extensive excavation at both flanks of Arkari Gol. According to the engineering geological studies granitoids of Tirich Mir granite will ensure general good stability. The final inclinations are proposed to be approximately 5:1, anchorage and shotcrete may be necessary at some parts of un-favorable bedding joints.

8.3.14 Grout Curtain

The, dimensions of the grout curtain were derived from the results of the geological investigations, in particular from the permeability and groundwater conditions in the dam area. Due to the favourable geological conditions, the grout curtain can be designed as follows.

- The boreholes will be drilled vertical;
- The curtain will consist of one row of boreholes;
- There will be three borehole series with a final distance of 1 m between boreholes;
- The depth of curtain will be approximately 30 m only.

A drilling and grouting works will be carried out from a gallery in the dam; this guarantees an execution of the injection works independently from any other construction works and weather condition. The gallery can be used for control purposes (piezometer) and may be utilized for possible supplementary injections, if necessary.

All details about the grouting works proper will be defined after excavation and possible preliminary test injections. The consecutive results of the grouting have to be considered each time for the following works anyway. The details concerning the grouting procedure include quantity of series and boreholes, depth of boreholes, final distance of drilling, grouting pressure according to hydraulic fracture behavior, downwards or upwards grouting procedure, contact injection, length of grout stages, type of grouting material, composition of mixes, additives, mix ratio and water pressure tests (WPT according to LUGEON). Considering the results, the control system, such as control boreholes with core recovery, piezometer, drainage devices and wells, have to be defined as well.

8.3.15 Measuring Installations at Dam Structure

The purpose of the measuring installations is the continuous surveillance and recording of the behavior of the dam and its foundation during all the operation conditions of the reservoir as well as under dynamic loads resulting from earthquakes.

The most important task is consequently the measurement of dam deflections as well as deformations in the foundation. It is necessary to install observation equipment to measure uplift pressures at the foundation, the water levels in the rock abutments as well as the seepage water through the dam and the grout curtain.
The observation program must be supplemented by geodetic measurements such as triangulation of the surroundings of the dam, alignments from bench marks, precision traverse measurements in the inspection gallery as well as leveling of the dam crest.

8.3.16 Conduit System

The conduit system of Arkari Gol Hydropower Project from the reservoir to the powerhouse consists of following structures:

- Intake system and sand-traps
- Approach channel
- Headrace tunnel
- Surge-tank
- Pressure shaft
- Penstock

8.3.17 Power Tunnel Intake Structure

Intake structure would comprise two bays fitted with vertical gates to regulate the inflow from the reservoir. The intake gates shall be operated in such a manner as to ensure the required flow to the turbines is conveyed within acceptable limits of head losses in accordance with the capacity requirements of water conveyance system. The intakes shall be capable of discharging the total design discharge for the turbines plus 20% of the design discharge for flushing of the sediments settled in the de-sanding chambers. Total design discharge of the intakes would be around 36 cumecs.

On each bay, a trash rack shall be provided upstream of the gates to check the entry of floating debris into the power waterway. The intake structure shall also have the provision of stop logs upstream of the gates for maintenance and inspection. Trash rack cleaning machine shall be installed for removal of the floating debris from the trash racks. Removal and placement of stop logs shall be accomplished with a gantry installed at the intake structure.

8.3.18 Siting and Orientation

The intake has been proposed along the right bank of the river as close to embankment dam as possible to facilitate flushing of sedimentation and maintenance of maximum submergence.

The invert of the intake is placed at elevation 2181m.a.s.l. keeping in view the sediment control and submergence considerations. Deck and operating platform levels have been kept at 2185m.a.s.l. and 2196.67m.a.s.l. so that the intake can function over a range of operating water levels in the reservoir.

8.3.19 Intake Geometry

A lateral intake structure proposed for Arkari HPP has been designed so that head losses are minimum and flow accelerates uniformly for trash rack to the gate and downstream.

8.3.20 Hydraulic Design of Intake

Design Criteria

Briefly, the criteria for the design of intake are;

- Sustained hydraulic performance
- Efficient hydraulic in-flow with bell-mouthed intake.
- Entrance losses to be accounted for in the design
- Formation of vortices to be ruled out through model studies
- Head losses in the water way to be accounted for in the design for all normal operating conditions
- Velocity in the tunnel to be non-sitting

8.3.21 Intake Submergence

Vortices can seriously affect the efficiency and safety of intake structure and their intensity is a function of the geometry of the intake. Gordon curve for un-asymmetrical flow is used for the design.

Gordon's relationship for asymmetrical flow is:

$$S_{min} = 2.3DFr$$

Where:	Fr	=	Froude number
	D	=	Diameter of the conduit
	S_{min}	=	Required submergence from the soffit of the opening
	F_r	=	V

The power intakes should have sufficient submergence to prevent air entrainment by vortex formation. The intakes shall be designed for a discharge of 36 cumecs plus 20% for flushing the sediments depositing in the de-sanding Chambers.

8.3.22 Power Intake Settings

Maximum Operating Level	=	2190.00	masl
Minimum Operating Level	=	2186.00	masl
Deck Elevation	=	2185.00	masl
Invert Elevation	=	2181.00	masl
Design Flow	=	36	cumecs

Since vortex formation depends on a multiple factors including its orientation to flow and submergences, hydraulic model studies would be imperative to confirm that vortices are not formed at the intake.

8.3.23 Trash Rack Cross Sectional Area

The gross cross sectional area of the trash rack shall be selected for a flow velocity of 1.0m/sec through the rack. For design discharge of $36m^3$/sec, the required maximum trash rack area would be 36 m^2.

8.3.24 De-Sander Chambers

Suspended sediments in the water fed to the turbines, can severely erode the turbine runners and damage the gate seals and valves leading to decline in efficiency. The de-sander s are incorporated in water conveyance system to reduce the amount of sediments entering the headrace tunnels to substantially reduce the incidence of abrasion and extend the life of the turbine runners and hydro mechanical equipment.

8.3.25 Siting

De-sanders are proposed to be located on surface at the right bank of the river. The location has been selected keeping in view the topographical and geological conditions and fulfillment of the requirement to be as close to the river as possible

to shorten the length of flushing conduit/tunnel. De-sanders comprise of four Chambers of 24 m W x 7.3 m H x 70 m L

8.3.26 Hydraulic Design

Criteria

- Removal of sediments of grain size 0.2 mm or larger
- To maintain flow velocity of approximately 0.3 m/sec
- To build two chambers for staggering operation to provide silt free water to the power tunnel

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- To provide hopper shaped trench at the bottom of de-sanding chambers
- Provision of gated outlets from flushing conduits
- Sizing of flushing conduits for achieving velocity of at least 3.0 m/s

Procedure for Design

Hydraulic design of de-sander s shall cover the following;

Fall Velocity:

Fall velocity of soil particles is dependent on particle size (diameter) specific gravity and kinematic viscosity of water.

$$Ws = (S - 1)\, gd^2 / (18/v)$$

Where:	Ws	=	Fall Velocity of particle
	S	=	Specific Gravity
	G	=	Acceleration due to gravity
	V	=	Kinematic Viscosity of water

Turbulent Flow:

The settling process retards in turbulent flows. Reduction in settling velocity due to turbulence is computed with the following relationship.

$$Ws = 0.132\, V / (h)^{.25}$$

Where:	V	=	Actual Flow Velocity
	H	=	Depth of Water

Removal Ratio of Sediments (R %)

Velikanov defines a variable "λ" as foundation of removal ratio and has given the relationship, an outcome of his investigations;

$$L = \frac{\lambda 2\ V2\ (\sqrt{h} - 0.2)\ 2}{7.51 w2} \quad m$$

Where:	L	=	Settling Length
	V	=	Flow through Velocity
	H	=	Depth of Basin
	W	=	Settling Velocity

His curves drawn between settling velocity in still water and density of silty water and particle diameter given here under;

8.4. Headrace Tunnel from Intake to Surge Tank

8.4.1 Alignment - Longitudinal Profile

The alignment of the headrace tunnel from the intake at Arkari Gol reservoir to the surge tank is a traverse, running from the intake to the surge structure.

According to the elevations 2181m a.s.l. at the intake and 2151.51 m a.s.l at the surge structure the gradient of the tunnel is approximately 0.5 percent.

An approximately 300m long access tunnel will connect the access road with the SurgeTank. The tunnel will have an uphill gradient of about 1 percent.
The headrace tunnel diameter is 4.5.

The access tunnel will thus serve as an exploration adit at the same time.

A new road of approximately1.5 km length has to be constructed from Arkari Road along the Arkari valley to provide access to the tunnel portal.

The maximum gradient should be less than 10%.

Excavating the road, steep rock walls, smaller talus cones, and screes will have to be crossed, resulting in partly difficult excavations, retaining walls and other protection measures.

8.4.2 Cross-section (Internal diameter)

Several optimization analyses were carried out to determine the most economical tunnel cross-section. The annual cost of energy losses in the power tunnel corresponding to different diameters were compared against the annual cost of the tunnel evaluated with 3 capital recovery factor. The tunnel diameter would be most economical when the sum total of the annual cost of the tunnel plus the cost of the energy losses is smallest. This would result in an optimal internal tunnel diameter of 4.4 m to given a rated discharge of 36 m^3/s for the 3 Pelton Turbines.

The resulting flow velocity of approximately 3.00 m/s is within the range allowed for concrete lined tunnels.

8.4.3 General Engineering Geological Aspects: Geology of Tunnel Route Tunnel Corridor:

The tunnel corridor from Power house to Weir passes through various lithological units. As description of the same follows

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Gneiss: It is a type of schist but the foliation is interrupted by the granular minerals like quartz, feldspar and garnet. These rocks are formed from the pre-existing sedimentary and igneous rocks due to increased temperature, pressure and shearing forces at considerable depth in the earth crust. These rocks are exposed in the area of Power house, surge tank and tailrace area showing breaking along the joint and foliation planes. The strike is N45E and dip toward 54NW i-e upstream.

Phyllitic Slates: slates are dark color, exceedingly fine grained, low grade metamorphic rocks. It has remarkable slaty cleavages which permit them to be split into thin broad sheets. These have the tendency to split easily along the bedding plane. The rocks are exposed as a thick unit in the way of tunnel. The slate unit has a number of white and grey color quartzite and two mapable beds of quartzite have been marked on the geological map Quartzite is metamorphic rocks formed by the metamorphism of sandstone. It is very hard, cliff forming, thin to thick bedded, fine to medium grained, well bedded, well jointed, fractured.

Granite: Granite is acidic plutonic and light color rocks, essentially composed of potash-feldspar and quartz, common accessory minerals are mica and hornblende. Texture varies from fine to very course grained and sometime porphyritic. It occurs as major intrusive bodies such as batholith and blocks.

More than 50% of the tunnel length from the weir is passing through granite body which the extension of Tirich Mir Granite. It is white color, very course grained and very phenocrystalline. The pheno crystals are of plagioclase with albite twining having mirror shine (pl.6). The crystals are up to 2 inches long. It is very hard and form the highest range in Chitral with peak of 7708 m. being igneous rocks there is no bedding but will joint.

8.4.4 Conventional Heading Method

In the following most of the discussions concerning engineering geology apply to the conventional method, but will be also significant for TBM-driving.

The main concept of modern tunneling (New Austrian Tunneling Method - NATM) is to activate a zone of the rock mass, surrounding the excavated cavity, by putting it into the position as a "bearing ring" becoming thereby part of the construction system rock + lining. In doing so, four vital principles have to be observed:
Consideration of the geological rock mass behavior;

- Evidence of unfavourable status of stress and strain by applying appropriate support measures in due time;
- Optimization of the support resistance in relation to tolerable deformations; and
- Supervision by measurements concerning deformations.

The heading of a tunnel, therefore, has to be understood as a composite construction consisting of rock mass on the one hand and support elements on the other. The relaxation of the rock necessarily results in an increasing convergence of the tunnel, i.e. movements towards the cavity. This deformation process needs time to develop, the length of which depends on the rock quality ("bridging time" according to Lauffer).

Therefore, any support measures have to be carried out in direct relationship to very rock properties and in such a way that their support becomes active, before critical movements can happen. Support measures have to be carried out in due time and in consideration of the relaxation behaviour of the rock.

Heading will be done in accordance with the fundamental principles of shotcrete methods, viz to maintain the natural rock bearing capacity as far and as soon as possible. To avoid too strong loosening, to reduce the damage of the surrounding rock mass, badly needed as part of the "bearing ring", and to minimize over break, the excavation has to be carried out by parallel bore-hole drilling and mini-second blasting. A larger hole in the centre of 10 to 15 m length in advance would render both a cut for blasting and exploration of the geological conditions as to petrography, faults, and water. The "smooth" excavation method proposed has got many parameters as to length of rounds, pre-splitting, number and pattern of boreholes, muck size, abrasion of core bits, and over break; all of them depend on the rock type and its stability, i.e. the classification of the actual rock conditions (standard cross sections will be discussed in connection with the Supports). In other words, the type of heading is directly depending on the rock class.

For calculation purposes, it is assumed that necessary support measures are applied immediately after excavation in correspondence to the rock class. The explosives correspond in type and quality strictly to the demand of careful rock mass excavation. As driving method and lining measures depend on the type of rock and on the rock classification, respectively, both may have to be changed every now and then.

After mucking has finished, the tunnel floor has to be leveled, possible water occurrences have to be drained and ventilation has to be installed, if necessary. The floor concrete can be placed weekly in order not to interrupt the heading works more than necessary, but not in too long intervals to prevent the floor from too large damages. The floor concrete, if necessary, conic* be placed in longer time-sequences.

During heading, the rock mass has to be classified in order to define the quality of heading and the quantity of supports, respectively.
Although large quantities of water are not expected, drainage measures should not be excluded. While drilling, water always has to be drained, natural groundwater, pouring in through joints, is expected only in the vicinity of the portals, where the rock cover is limited to some deca-metres.

Theoretically, also water pockets and inflows are possible, particularly in the neighborhood of fault zones (impermeable layers) or in sections with small rock cover. Independently from its source, the water must be collected as near to its occurrence as possible to avoid softening of the rock, especially in the tunnel floor. The collected water is drained by a ditch along the bench, if heading is done from bottom to top. In case of falling heading, dewatering requires pump sumps and pumping by means of sewage pumps, regulated by the water level automatically.

Low inflows or dropping water can be sealed by shotcrete layers of 3 to 5 cm only (grain size up to 4 mm, 400 to 500 kg/m^3 of cement, 5 to 10 % accelerator agent). Static water pressure behind shotcrete layers can be avoided by installing water tubes and/or drain holes; the latter ones allow an exact and restricted drainage in whatever distance from the portal. In case of large water quantities, fore-poling drill holes are essential. To stop permanent large inflows, cement grouting would become necessary, the type and quantity of which cannot be defined yet, as it is so much depending on local conditions.

What the chemical properties of the water are concerned, it is expected that no harmful effect will occur to the structures by solution. For purpose of safeguarding evidence, water analyses have to be carried out in the design stage.

The immediate **"outer-shell-support"** is strictly based on the NATM and consists of shotcrete, steel wire mesh, rock bolts, and - in extreme case only - steel arches. During heading through extreme unstable rock masses, lances, grouted pipe bolts, and fore-poling plates may become necessary.

The main support of the excavated opening is made of shotcrete in combination with steel wire mesh and rock bolts. The thickness of the shotcrete, the number of rock bolts, and the number of mesh layers may be altered and combined in such a way that at least five rock classes A to E may be covered by this system. The rock mechanical function of the shotcrete can be seen in the limitation of rock loosening, i.e. a relative high strength of the shotcrete can be quickly achieved. Moreover, the shotcrete seals the rock surface and simply prevents it from weathering. The shotcrete can be reinforced by steel wire mesh in less stable tunnel sections. A second steel wire mesh and a third shotcrete layer may be installed in case of Rock Class D or E. In case of less unstable conditions, for instance Rock Class C, "chicken wire" can be used which is much weaker, better to place onto the rock wall, and much cheaper.

Rock bolts maintain a bearing ring, built-in systematically in the tunnel roof and walls; by this the surrounding rock changes its load function into a support one. Additionally, anchoring prevents the rock mass from loosening, as unfavourable shear planes (joints, bedding, faults) may be crossed by rock bolts. The number of rock bolts varies from nil to a systematically anchoring with 12 or more pieces of different lengths.

Steel arches are a heavy support, difficult to handle, and expensive; their installation is time-consuming. Therefore, they should generally be avoided: if at all necessary, they should be foreseen only in tunnel sections, where the outer lining (rock bolts, shotcrete, wire mesh) seems to be insufficient (i.e. in fault zones or in portal areas). Steel arches increase the bearing capacity of the outer lining and load to a steady

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force distribution. The arches have to be embedded into the applied shotcrete. Steel arches facilitate the exact excavation up to the payline in various cross sections.

8.4.5 ROCK CLASSIFICATION ACCORDING TO LAUFFER

ROCK CLASS A7B (approximately 70 to 75 percent of the total length)	Stable to slightly friable
Rock mass behaviour:	No or single overbreak in the TBM area Bridging time more than 3 weeks (A) Bridging time 4 days to 3 weeks (d)
Location of the support measures:	At any distance behind TBM
Support measures:	Shotcrete local (A) and on the roof (B) and single rock bolts to seal joints or support single rock wedges if required
Influence on the drivage	No influence
ROCK CLASS C (approximately 15 % of the total length)	Friable
Rock mass behavior	Overbreak within and behind the TBM area Bridging time approximately 10 hours to 4 days
Location of the support measures:	Some support (shotcrete and local rock-bolts) is required in the TBM-area. Main support can be completed from the tail.
Support measures:	5 to 7.5 circumferential reinforced shotcrete, rock bolts with a length of 1.5 - 2.0 m mainly in the roof-section.
Influence on the drivage:	Occasional hindrance
ROCK CLASS D (approximately 5 -10 % of the total length)	Intense friable
Rock mass behaviour:	Intense overbreak within the TBM-area. Bridging time 2 to 10 hours
Location of the support measures:	Initial support in the TBM-area with steel arches on the roof shotcrete and rock bolts. Finalization of the support system from the tail.
Support measures:	7.5 to 10 cm circumferential reinforced shotcrete. Steel arches on the roof. Rock bolts with a length of 2.0 - 2.5 m.
Influence on the drivage:	Hindrance of drivage caused by support works.
ROCK CLASS E (approximately 3 - 4 % of the total length)	Swelling

Rock mass behaviour:	Swelling behaviour of the rock mass Bridging time 10 hours to 2 days.
Location of the support measures:	Immediate support behind the cutter-head with steel arches, shotcrete and rock bolts. Systematic completion of the support from the tail.
Support measures:	Steel arches, 10 -15 cm reinforced shotcrete and rock bolts 2.5 - 3.0 m.
Influence on the drivage	Frequent stand still caused by the support works.
ROCK CLASS F (up to 1 % of the total length)	Strong swelling
Rock mass behaviour:	Strong swelling behaviour of the rock mass Bridging time 2 to 5 hours.
Location of the support measures:	Immediate support in the cutter head area with steel arches, shotcrete and circumferential bolting. Completion of the support from the tail.
Support measures:	Steel arches, as minimum 15 cm (2 layers) reinforced shotcrete and bolting system with rock bolts 2.5 - 3.5 m.
Influence on the drivage:	Frequent stand still caused by the support works

8.4.6 Support

The initial lining must maintain the inherent strength of the rock mass, acting as a thin membrane inseparable from the surrounding material to prevent its loss of strength which, if permitted to occur, would require additional support installation. Once installed to a closed ring the initial lining must maintain the stability of the whole structure without further assistance of supplementary supports. The detailed quantity of support elements is dictated by the rock class.

8.4.7 Monitoring

Five different characteristics of the ground/lining response to the excavation and load redistribution must be observed by use of special monitoring devices. These are:

- Deformation of the initial lining
- Deformation of the surrounding rock mass
- Axial stresses acting within the initial lining
- Radial stresses acting as "ground load" upon the initial lining
- Stress acting to the rock bolt system

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8.4.8 Water Pressure Measurements

The design of the inner lining shall take account of the measured quantity and pressure of the ground water ingress, in order to avoid misleading results caused by the dewatering influence of the tunnel drivage the pressure shall be measured at 3 distance of about 15m from the excavation line by using either s standpipe piezometer or electrical pressure measuring device. Where an electric device is used it shall be confirmed, that the plug-in-contacts are properly protected against damp and water and that no water seepage is possible while it is plugged in.

8.4.9 Probe Drilling

Due to the fact that a continuous investigation of the entire tunnel alignment was not undertaken and the complex geological and tectonic conditions do not allow an accurate prediction of the ground conditions which are likely to be met during tunnel drivage, the use of continuous probe drilling must be seriously considered This probe drilling shall extend approximately 20 m ahead the excavation and shall has an overlap of minimum 4m, in order to avoid misleading results due to deviation.

8.4.10 Installation of IBM-Equipment

As the beginning, heading of the access tunnel to the surge structure will be necessary by conventional method. Geotechnical investigations are recommended in this part for determination the final location of the surge tank. IBM-equipment will be installed in the finalized access tunnel.

8.4.11 Mucking

The excavated material will be transported by rail to the tunnel portal and further by trucks to a stockpiling area to be used as construction material or disposed in Arkari Valley.

8.4.12 Lining Alternatives

The maximum internal dynamic pressure in the headrace tunnel will reach approximately 5 bars near the surge tank.

In headrace pressure tunnels, various types of lining are used, which are described in the following paragraph.

Unlined Pressure Tunnels:

Pressure tunnels can be left unlined where the rock is stable and nearly impervious and primary stress is adequate. A lining is not essential where the rock is stable but permeable as long as the groundwater level is higher than operating water level (pressure line), so that no leakage occurs. In Pakistan's Karakorum mountains, unlined power tunnels will be rare for two reasons:

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First, there are no areas in the complex tectonics that offer unfolded and impermeable rock positions. Second, an unlined tunnel has to be excavated with an approximately 30 to 40 percent larger diameter to compensate for the higher friction losses caused by the rough rock.

Even the smooth excavation techniques (IBM) will require in sections with tectonic influenced rock a lining of the tunnel.

Concrete linings

Concrete linings are common for pressure tunnels.

The load cases for dimensioning the thickness of the lining are:

- the external water pressure against the empty tunnel.
- the maximum internal water pressure without considering any external water pressure.

External Water Pressure

In many cases the external water pressure is the load case for the pre-dimensioning of the lining thickness.

It is usual to do this pre-dimensioning according to a very low safety factor due to the following facts:

- It was measured that the external water pressure is a bit lower around the tunnel than it should be theoretically. The reason for that phenomenon may be a long term remaining drainage effect around the consolidated zone of the tunnel.
- The load case is a special load case during emptying the tunnel. Especially for long tunnels with a big water volume it takes a long time to empty the tunnel and the load improves very carefully.
- Normally the external water pressure is reduced by the internal water pressure.
- The geometry of TBM driven tunnels is very accurate which ensures a central pressure
  of the lining created by the external water pressure.

In case of very high external water pressures the installation of vents may be provided to keep the thickness of lining within limits. The vents equalize the external pressure to the internal pressure.

The disadvantage of such vent installation is the necessity of its maintenance.
Due to the narrow mountain ridge between Arkari Gol Valley and Lutkho River the maximal external water pressure was assumed with 400 m = 40 bar above the headrace tunnel. The required lining thickness in case of the internal diameter 3.80 m

was computed to be 17 cm. For reasons of added security, the lining thickness was selected to be 20 cm.

Internal Water Pressure

It is recommended to use the formulas of KASTNER for the stress calculations (tensile stresses in the lining) because results are confirmed by measurements in a high number of pressure tunnels.

For the headrace tunnel the maximal internal pressure is according to the maximum level in the surge tank in case of emergency stop of the turbines. The computed circumferential tensile stresses are lower as the limited value.
In weaker rock classes D, E and F circumferential consolidation grouting is required to improve the rock mass around the tunnel.

Other Lining Systems

As pre-stressed concrete lining, concrete lining plus plastic sheeting, pre-stressed concrete lining with seal or steel lining are not necessary for the headrace tunnel and will be discussed in the sections Surge Tank, pressure shaft and pressure tunnel.

8.5 Surge Tank

Modern peak storage schemes are expected to operate flexibly throughout the whole power range. But this is only possible if the surge tank is designed appropriately. Different systems are possible to meet the demand for full flexibility of operation.

Typical Surge Tank Systems

Type of Surge Tank	Border conditions
Surge shaft without chambers	• Huge dimensions of diameter and height • Heavy oscillations during operation • Limited operation flexibility • Useful for small discharges only
Surge shaft with lower chamber	• Lower chamber is advantageous for regulated startup of turbines • Closing at full load will require larger diameter of the shaft respectively will lead to higher oscillations
Two chamber surge tank	• Conventions type of surge tank without operational restrictions • Reasonable volumes of the chambers

Type of Surge Tank	Border conditions
Two chamber surge tank with a reserve flow control throttle	• Reduced space requirement for the surge chambers • Difficult system of the reserve flow control throttle • Advantageous for high discharge rates

For the Feasibility Design the conventional type of a three-chamber surge tank was selected due to its simplicity.

8.5.1 Structural Design

The surge structure has been designed in connection with the hydraulic analysis as follows:

The surge structure branches at an elevation of 2165.96 m a.s.l & 2209.6 m.a.s.l. The surge shaft is of an internal diameter of 4.5 m and is of 71.18 m high.

- The Lower Chamber-A has a horseshoe section and a length of 96 m.
- The Lower Chamber-B has a horse shoe section and a length of 96 m.
- The end of the lower chambers will be connected again over a horizontal / vertical connection tunnel with the headrace tunnel.
- The upper chamber will be excavated from the working platform at an elevation of 74.5 m long horseshoe section. The chamber has to be closed by a concrete wall with sufficient freeboard to the maximum surge level.
- Ventilation for the surge tank is proposed by an opening at the portal top.

8.5.2 Hydraulic Calculation

The assumptions of plant operation guidelines for the hydraulic design of the surge tank have been determined as follows:

- Startup time of Pelton turbines 9 s/unit
- Closing time of Pelton turbines 7 s/unit

There are two main load cases for the hydraulic calculation:

- Start up at maximum reservoir level, decisive for the maximum surge level.
- Break down at minimum reservoir level, to determine the minimum surge level.

It's not usual to start up all units at the same time,. when simultaneous breakdown of the units has to be considered in the hydraulic dimensioning of the surge structure.

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In the hydraulic calculation the most unfavourable frequency of turbine-operation as basis for determination of the maximum possible surge level in the upper chamber is considered as follow:

- Startup of first unit in 9 s
- Startup of second unit at minimum flow velocity in the headrace tunnel after approximately 5 min.
- Break down of both units at maximum flow velocity in the headrace tunnel after approximately 8 min.
- Second startup of first unit at minimum flow velocity in the headrace tunnel after approximately 12 min.
- Second startup of second unit at lowest flow velocity in the headrace tunnel after approximately 17 min.
- Break down of both units at the highest tunnel flow after approximately 20 min.

Continuation of start- and break down cases will not change the maximum surge level to higher values. The minimum surge level in the lower chamber was computed on the basis of the minimum reservoir level with similar sequences.

The calculation results concerning the extreme surge levels are:

- Maximum Surge Level(upper chamber) 2209.60 m.a.s.l.
- Minimum Surge Level (lower chamber) 2165.96 m.a.s.l.

The safety factor for system stability, according to Thoma, was computed to be 5.

The final dimensioning of the surge structures will need the detail of basic requirements of the manufacturers for the hydro mechanical equipment.

8.5.3 Pressure Shaft

Raise-boring is for the time being the most economical method of shaft sinking. This method involves two steps:

- Pilot drilling (from the top to the bottom)
- Raise boring (from the bottom to the top)

The raise-boring diameter was selected preliminary to be 3.45 m to achieve a net diameter of 3.2m, depending on a thickness of concrete lining of 20 cm and a seal and shotcrete thickness of 10 cm.

In case of higher support requirements, the raise-boring diameter has to be increased according to the shotcrete thickness.
Referring to the time schedule, sinking of the shaft is possibly earliest after completion of the excavation works along the horizontal pressure tunnel due to mucking requirements.

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8.5.4 Lining

The internal water pressure is not so high to prefer at first a costly steel-lining system. Considering the increasing rock cover of the vertical pressure shaft to the surface, the geological conditions can be expected to become better with depth. This assumption must be confirmed by geotechnical investigations during shaft sinking. In good rock quality a concrete lining would be possible.

The required thickness of the concrete lining has been calculated to be 20 cm. To avoid leakages in case of some cracks due to shrinkage and creeping, a seal between the rock and lining is recommended.

This economical method has already been applied for the surge structure.

The rock surface produced by-raise-boring is quite smooth due to which the danger of damage of the plastic seal will be in case of careful working nothing whatever.

Concluding, the lining requirements will depend on geotechnical parameters, which are not yet in hand.

8.6 Pressure Tunnel

8.6.1 Alignment, Longitudinal Profile, Excavation

The powerhouse and the pressure shaft will be connected by a pressure tunnel over a length of 296 m.

The gallery must be driven early enough to enable the determination of geotechnical parameters. The access tunnel thus will serve as an exploration adit at the same time.

Excavation method and support are similar as already described for the headrace tunnel under engineering geological aspects.

At the branching of the penstock from the steel lined pressure tunnel a concrete plug is necessary.

For the purpose of maintenance, a tunnel door is proposed within the concrete plug.

8.6.2 Lining

8.6.2.1 Concrete Lining

Because of the high cost, there is the intention to keep the portion of steel lining as short as possible. Therefore determination of the point, which renders possible transition of the steel lining to the concrete lining with seal as for the pressure shaft, will be necessary.

Based on pre-calculations, in sections with rock cover less than 150 m steel lining is required. The corresponding length of concrete lining with plastic foil is approximately 140 m downwards of the pressure shaft toe.

The required thickness of the concrete lining was evaluated to be 20 cm.

8.6.2.2 Steel Lining

The design of the steel lining for the pressure shaft was based on the following assumptions:

Taking into account the head-bearing action of the rock, considerable savings can be made in the steel lining. The modules are still unknown and have to be determined by rock mechanics tests.

Based on the "Steeber" diagram, as minimum wall thickness 16 mm are required, taking into account a rock module of 25000 MN/m2 and steel with a tensile strength of 600 N/cm^2.

The steel-lined horizontal section must be backfilled with chuted concrete.
For grouting the gap between the steel lining and the concrete, injections are necessary. Grouting will be performed through injection pipes placed on the surface of the steel lining.

8.7 Powerhouse

Previous studies conducted for the Feasibility Design have shown a clear superiority of an external type, with the powerhouse located at right bank of Arkari Gol near Andakht Village at confluence of Arkari and Lutkho Rivers.

The choice of the location has been governed by the favourable topography and the satisfying result of geotechnical investigations. Further priorities dictating the location have been the existing access from Chitral Garam Chashma Road.

- The power station comprises following main structures:
- Turbine shaft for installation of 3 Pelton Wheel Turbine
- Surface machine hall and operation building
- Tailrace channel

8.7.1 Engineering Geological Aspects

The rocks at Power house area are gneissic type and phyllite, well bedded, medium to thick bedded, medium to hard, splintery. The general strike is in NE-SW direction and dipping toward NW with 40^0 to 60^0 angle of dip, well jointed, large numbers of big and rectangular big blocks are lying at the site due to the gravitational falling and many others are inclined to fall from the ridge (Pl.1A).

As powerhouse is located at confluence of Arkari Gol and Lutkho river the quaternary deposits like scree and alluvium are present. The whole terrace is covered by cultivated land. The bed rock is covered under these deposits. The thickness of overburden material is confirmed by drilling boreholes. Bed rock encountered at 48m depth. Overburden material composed of boulder, gravel and cobbles bounded in silt clay matrix. Rock samples collected from the site give and useful information about composition and texture

8.7.1.1 Scanline Survey

It is generally accepted in the engineering geological community that discontinuities play a major role in projects that involve discontinuous rock masses. Particularly the characterization of the discontinuities (orientation, number offsets, spacing, persistence, roughness) is very important in the design and construction phase for tunnels, foundations, excavations and slope stability analysis. Traditionally, a structured recording of discontinuity properties of a rock mass is achieved by conducting a scanline survey or cell mapping (Priest & Hudson, 1981; Priest, 1993). The measurement of discontinuity orientation and position at exposed rock faces is carried out using hand-held equipment such as a geological compass-clinometer device and measuring tape.

Scanline survey was performed at powerhouse site to record the characteristics of discontinuities. Survey was conducted by using Brunton compass and measuring tape. The survey was started from Andakht road just crossing the bridge on Lutkho River toward the powerhouse near Andakht turn. Total 180 m of scanline conducted at powerhouse, section was divided into 30 m sections. Foliations and joints were observed during the survey. Foliation shows the dip ranging from 40^0-60^0, while the dip direction ranging from 010^0-070^0. Foliation is very narrowly spaced, 6-20mm and 200mm. Persistence is >10m, the surface of the foliation is smooth planer to slightly rough planer. Aperture is extremely narrow <2mm. overall water condition is dry no water observed.

The rock is well jointed. Joints dipping in different directions, dip ranging from 30^0-80^0, and dip direction ranging from 020^0-$325^{0.}$ Joint spacing is medium to very close i-e, 20-600 mm. Persistence of the joints range from 3-10 m, while some joints have >10 persistence. Surface is slightly rough planer <1mm to medium rough planer. Aperture is very narrow 2-6mm and extremely narrow <2mm. Water condition is almost dry. The data is plotted on stereonet and rose diagram is prepared.

8.7.1.2 Overview of Subsurface Conditions

An overview of subsurface conditions at the weir site, tunnel route, and powerhouse site is provided below. Appendix-V of factual report presents the borehole logs, results of the ins-situ tests, and results of the laboratory testing.

The stratigraphic boundaries shown the borehole logs and on the interpreted stratigraphic sections and profiles are inferred from non-continuous sampling and therefore represents transitions between types of geo materials rather than exact planes of geological change. The subsurface condition will vary beyond the locations of investigations such as boreholes, ERS, and test pits.

8.7.2 Structural Design

The main power plant structures are the underground turbine shaft, the tailrace channel, the surface machine hall and operation building.

The turbine shaft accommodates the 3 vertical power units as well as their upstream valves and downstream gates including their mechanical and electrical auxiliary equipment. The size of power house 56x30 corresponds to an area of 1680 m^2.

Zones with week geology are to be protected with shotcrete and rock bolts. This phase of construction will start concurrently soon after the pre-construction activities have been completed. Items following under this stage are listed here under and are likely to take about 3 years for completion.

- Excavation of power house pit
- Installation of dewatering system and putting it into operation.
- Concreting of turbine pits and structure forming the lower level of the power house.
- Building of structure above the main floor hall.
- Start of 2nd stage concreting with installation of embedded parts of turbines and hydraulic steel components.
- Placing of spiral casing in position.
- Concreting of space around spiral casing in stages by filling the voids between steel and rock faces.
- Building of powerhouse walls and roof Installation and commissioning of overhead crane.
- Completion of powerhouse superstructure and all other related works.
- Erectionof turbines and generators.
- Testing and commissioning of turbines and generators.

Once the rock excavation in an open area at the location of power house is completed, the construction activities can be started. Excavation shall be deepest at the location of draft tube. The structure forming the lower level of the powerhouse and turbine pits will need to be concreted first. At the same time, the structure above the main floor will be built. The spiral casing will then be placed and its sections welded together. This will be followed by concreting the space around spiral case in stages by filling the voids between steel and rock faces. The walls surrounding the spiral case and generator will be built at the same time. Thereafter, the powerhouse walls and roofs will be constructed with specified type of concrete after erecting the formwork. Installation of powerhouse overhead crane will have to be taken before the installation of the stators. Overhead crane shall also be used for un-loading of power house equipment and its installation. In the meanwhile, concreting and installation of transformers in a separate building shall be accomplished. Tailrace area will be completed concurrently.

The total time for placing of concrete in the powerhouse and installation of the turbines, generators and other appurtenants is estimated to be about 30 months.

From the foregoing, it is concluded that construction of power house embankment dam/weir, Intake Structure and de-sanders shall be carried out concurrently with the excavation of the power tunnel which shall be on the critical path.

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The setting of the turbine axis will be at 1854.70 m.a.s.l. A trifurcation pipe connects the steel-lining of the pressure tunnel with the valves. The forces acting on the valves during closure are transferred from the bifurcation to the rock mass by means of an anchor system. At the end of the draft tubes the tailrace gates are arranged, which are accessible from the turbine floor. A manhole-shaft is provided into the draft tube, assessable after closure of the tailrace gate and emptying the tube.

Between elevation 1854.7 m.a.s.l (turbine floor) and 1862 m.a.s.l. an assembly storey is provided in order to allow dismounting of cover, runner and guide vanes of the turbines. Thus inspection and maintenance is possible without removal of the generator. The assembly storey accommodates an auxiliary crane by means of which the machine Darts can be raised into the assembly shaft situated above the valves. Above the assembly Storey the generators are arranged with generator floor at elevation 1862 m.a.s.l.

8.8 Tailrace

The alignment of the tailrace tunnel from the draft tubes of the power units had to take into account heading in rock formations and the optimum location of the outlet structure. The total length of the tailrace channel to the outlet structure is 100 m.

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10.1 Electrical Equipment

This chapter summarizes the feasibility design considerations for the electrical installations of the Powerhouse. Project Layouts presented in this chapter provide basis for cost estimates and post-feasibility project design.

The electrical equipment consists mainly of:

- Three vertical shaft generators of 39.4 MVA, each connected via 11 kV cable
  to the respective 40 MVA 11/132 kV Block Transformers located in a 132 kV outdoor Switchyard for connection to one outgoing transmission line and space in reserve for two more incoming/outgoing transmission lines to facilitate future power generation upstream on Lutkho River basin.

- Auxiliary supply for all power need of the Powerhouse and intake area designed to give maximum reliability

- One 6.3 MVA 132/11kV Grid Station Transformer for local supply,

- Control and protection devices for all functions of the plant including the132 kV Switchyard.

10.1.1 Boundary Conditions

10.1.1.1 Codes and Standards

All electrical equipment shall comply with the IEC (International Electro-technical Commission) standards. In case of non-existence of relevant IEC standards, BS or VDE/DW standards shall apply. Where available, relevant Pakistani standards and codes shall be respected.

10.1.1.2 Site Conditions

- **Altitudes**

Powerhouse:	1,860 m a.s.l.
Weir:	2,190 m a.s.l.

- **Temperature**

Air (max.)	36.4° C
Air (min.)	6.4° C
Water (max.)	20° C
Water (min.)	3° C

- **Air-Conditioned Rooms**

Temperature	22° C
Humidity	Max. 50%

- **Humidity**

Max.	44%
Min.	24%
Mean	36%

- **Insulation Co-ordination**

WAPDA standards require an Impulse Withstand Voltage of 650 kV for the 132 kV system. This value corresponds to the higher alternative of IEC Standard No.71 which offers two options namely 550 kV and 650 kV. Thus, a high lightning intensity has been taken into consideration.

For the 11kV system, 95 kV has been taken for Impulse Withstand Voltage.

- **Short Circuit Withstand**

A power system analysis has been undertaken in several studies within the region. These studies also considered projects that were planned to be undertaken in future.

As a result, a short circuit level of 4000 MVA has to be established at 132kV level at Andakht Powerhouse. According to WAPDA's standards, minimum short circuit on the 132 kV system is a current of 20 kA. The corresponding values for 11kV equipment are 250MVA and 12.5 kA.

See Drawings:
No. 4.1.01 (No.36) Electrical Power-, Auxiliary-, Measurement-, Control and Protection System
No. 4.1.02 (No.37) General Layout Electrical Power- and Main Services

10.1.2 Generator

10.1.2. Design

The design of the generator is mainly determined by the layout of the turbine.
The rated output of 38.82 MVA corresponds to a nominal turbine power of about 33.0 MW and a power factor of 0.85 which are considered as sufficient for satisfying the reactive power demand of the system.

The voltage was chosen to be 11 kV, appropriate for this size and standard in WAPDA system.

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10.1.2.2 Rotor

Rotor dimensions are functions of the speed n in sec^{-1}, the capacity S_n in MVA, the desired GD^2 (WR^2) in tm^2 and constructive factors.

The optimal dimensions are:

Rotor Diameter: 3.55 m

Length of Rotor: 2.09 m

Flywheel effect: 491 tm^2

For this bore diameter, the most appropriate design comprises of solid forging with thick steel plates welded together to a solid body.The poles shall be laminated and shall be provided with a damper winding for the required operational stability.

10.1.2.3 Stator

The stator shall be framed by welded steel rings on both sides which will transmit all dynamic and static forces through supporting feet to the base plates into the foundations. For proper and effective cooling, the generator core shall be divided by radial air gaps for air flow through the generator core. The winding shall be designed so that a generated wave form is as close to sine wave as possible.

The stator winding shall be made of bar or coil winding system, with an insulation of continuous tape, impregnated with synthetic resin in vacuum which is subsequently cured. The coils must be provided with a necessary anti corona protection at the end of the slot sections. The generator shall be able to run at 10% overload without exceeding the temperature limits.

10.1.2.4 Bearings

The generator will be of conventional design with an upper combined thrust and guide bearing and a lower guide bearing. The thrust bearing should therefore be designed to carry the combined weight of the generator's rotor shaft and the turbine runner, as well as the hydraulic thrust during operation. To allow the unit to be operated with frequent starts and stops, the thrust bearing will be equipped with a high pressure lubrication system. This provides the initial oil film at starting and running out and thus virtually eliminates the break-away torque.

10.1.2.5 Cooling

The generator will be air cooled and self-ventilated by axial or radial ventilation through the rotor itself acting as a fan. The air will be re-cooled by air/water heat exchangers situated outside the stator housing. With this design, a closed air loop system is performed inside the generator pit thus avoiding pollution by atmospheric impurities.

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10.1.2.6 Excitation System

Two types of excitation system have been considered for generator excitation:

A) Static Excitation B) Rotary Excitation

Static excitation has the advantage of giving quick response, delivery full reversible excitation voltage and as the static system can be inserted in the control panels, reducing the height of the generator pit.

Rotary excitation consists of an AC exciter machine together with a converter bridge mounted on the shaft. This system does not require slip rings and carbon brushes and maintenance is considerably reduced. Field flashing to initiate voltage build-up is also eliminated, thus considerably reducing the size of the station battery.

Since the disadvantage of low regulation speed has no significance on a 375 rpm speed generator, the advantages of the Rotary Excitation System by far outweigh those of a Static Excitation System. It is therefore proposed to install a Thyristor-controlled rotating exciter system which constitutes a fast, maintenance free system with well defined frequency characteristics.

10.1.2.7 Voltage Regulation

The voltage regulator forms part of the excitation system. Its primary task is to maintain the voltage of the power system and the transient stability in the network. An additional task is to protect the generator against thermal strain in winding and iron.

The regulator will have the following functions

- Voltage regulation
- Field current regulation
- Field current limitation
- Reaction compensation
- Supervision and Logic Circuits
- Following of line-voltage during synchronizing
- Under excitation limiter
- Stator current limiter
- Power system stabilizer
- Power factor regulator
- Active compensation

The equipment will be powered from the 110 V DC station battery via a DC/DC converter if needed.

10.1.2.8 Generator Summary

Number:	3
Capacity:	38.82 MVA
Speed:	375 rpm
Runaway speed:	675 rpm
Voltage:	11 kV
Power factor:	0.85
Efficiency:	97%
Bore:	3.55 m
Length of Rotor:	2.09 m
Weight of Rotor:	85.42 t
Weight of Stator:	48.05 t
Total Weight:	156.33 t
Moment of Inertia (WD^2):	491.44 tm^2
Winding Insulation:	Class F
Utilization:	Class B
Cooling:	Air/Water
Excitation:	Rotary

10.1.3 Transformers

A total of 9 transformers will be installed, including 3 Block Transformers, 1 Grid Station Transformer and 5 Auxiliary Transformers (3 Unit Transformers, 1 Powerhouse Service Transformer and 1 Intake Service transformer).

10.1.3.1 Block Transformers

The generators are directly connected to the block transformers which step up the generating voltage of 11 kV to the transmission voltage of 132 kV. The Block Transformers are installed in the open air Switchyard outside the Powerhouse and linked by cable to the generators.

See Drawings:
No.41 General Electrical Layout
No.42 Electrical Layout Power and Station Auxiliary Services
No.43 Main Single Line Diagram 132kV/ 11 kV

- **Design**

The transformers shall comply with the system requirements and be built for

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solidly earthed neutral on 132 kV side. Cooling shall be performed by water which can be easily obtained from the generator water re-cooling system (ONWF).

The delta connected winding on the low voltage side will provide a closed circuit for possible third harmonics originated by the generator. The high voltage winding will be Y connected with the neutral taken out on a separate terminal for connection to earth.

- **Rating and Data**

Capacity:	40 MVA
Primary Voltage:	11 kV
Secondary Voltage:	132 kV ± 5% ± 10%
Frequency:	50 Hz
Temperature Rise:	55° C
Power Factor:	0.8
Vector Group:	YNd 11
Impedance:	12%
Cooling:	ONWF

- **Weight**

Total	57 t
Transport	40 t
Oil	12 t

- **Dimensions**

Installed:

Height	5.8 m
Width	3.1 m
Length	6.6 m

For Transport:

Height	3.2 m
Width	2.0 m
Length	5.7 m

10.1.3.2 Grid Station Transformer

In the hydropower station and Switchyard, one grid station transformer will be installed. This transformer shall also supply the local demand for the villages around Arkari Gol.

The transformer will be a typical WAPDA grid station transformer with the following main data:

Capacity	6.3 MVA		
Voltage	Primary =	132 kV±2.5%±5%	Secondary = 11kV
Frequency	50 Hz		
Vector group	Dyn 11		
Type	ONAN		
Impedance	8%		
Dimensions	Length	3.3 m	
	Width	2.5 m	
	Height	3.9 m	
	Weight	15 t	

10.1.3.3 Auxiliary Transformers

Auxiliary transformers will be installed for the power supply of the units, the Powerhouse and the intake area. The transformers for Powerhouse and intake area will be outdoor installed and consequently, conventional oil immersed hermetically sealed distribution transformers. The unit service transformers will be of indoor, dry cast resin insulated type, installed in the corresponding panels.

Transformer Item Function	1 Unit Transformer	2 Powerhouse Transformer	3 Intake Transformer	4 Public Service Transformer
Number [-]	3	1	1	2
Capacity [kVA]	100	400	100	100
Voltage [kV] Primary Secondary	 11±2.5/5% 0.4	 11±2.5/5% 0.4	 11±2.5/5% 0.4	 11±2.5/5% 0.4
BIL [kV]	95	95	95	95
Frequency [Hz]	50	50	50	50
Vector Group	Dny 11	Dny 11	Dny 11	Dny 11
Type	Dry	Oil	Oil	Oil
Cooling	An	ONAN	ONAN	ONAN
Impedance [%]	6	6	6	6
Dimensions [mm] Length Width Height	 1175 600 895	 1470 990 1700	 1030 780 1600	 1030 780 1600
Weight [kg]	640	1460	660	660

See drawings:

No.41 General Electrical Layout

No.42 Electrical Layout Power and Station Auxiliary Services
No.43 Main Single Line Diagram 132kV/ 11 kV

10.1.4 132 kV Switchgear

10.1.4.1 Selection of Switchgear Arrangement

For Andakht Powerhouse, which is designed as an open powerhouse with no lack of space around, an outdoor Switchyard is the most cost effective design.

Basically there is a choice from large number of different alternative layouts for such power station-grid interconnecting Switchyard designs such as single bus-bar, double bus-bar, single circuit breaker system, bypass system, double breaker system and so on.

The variants differ basically in cost and reliability. Main power plants whose loss will seriously affect the main grid or have comparatively high production capabilities for long periods of time will usually go for high reliability designs even at disproportionately high costs.

The power station is located at the far end of the grid and only one transmission line is connecting through two power plants located nearer to the central 132 KV/ 220/500 kV station planned to be installed near Chitral Town. There is no requirement for bearing increased cost for the different multi circuit and breaker systems.

Based on the above considerations, the best alternative is a Single Busbar with a Single Circuit Breaker System.

Maintenance of the breakers can be done during winter months with only one machine running. Nevertheless, to avoid longer production interruptions in the case of an unexpected failure, a set of sufficient spare parts should be available at the plant.

However, configuration of the grid system for export of power from this remote area of Chitral Valley to the National Grid is presently under discussion between PHYDO / GoKP and NTDC. Provision of sufficient additional space will be made in the Switchyard to accommodate more complex grid system equipment that may be larger in size and numbers than the presently envisaged ones.

10.1.4.2 Layout

The switch-gear is assumed to be the conventional outdoor type with modern SF_6 circuit breakers. The design consists of six bays: three for the main block transformers, one for the outgoing line, one for the grid station transformer and one for bus-bar voltage transformers and earthing switch. Furthermore, there is space for one extra bay for future interconnection with power station(s) planned in upstream areas of Lutkho River valley. The following design criteria would apply:

▪	Installation of equipment	Out Door
▪	Highest Voltage for Equipment	145kV

Rated short circuit current (1s) 23kA

Rated impulse withstand voltage (1.2/50µ speak value) 650kV (to earth)

IEC 815/85 recommends creepage distance values ranging from 16 mm/kV (phase to earth voltage) to 31 mm/kV. In Pakistan, a very long dry season is often followed by a very sudden and strong start of the winter season. These conditions could cause considerable build-up of dust on the insulators and hence the creepage distance should not be underestimated. It is proposed that a minimum distance of 3620 mm corresponding to 25 mm/kV should be adopted. The IEC characterizes this distance as being suitable to cover conditions in industrial areas with relatively severe pollution. Since the dust is probably not intensively polluted, it will maintain a comparatively loose consistency and will be washed away by the first showers.

The size of the bus conductors will be 600 mm^2 ACSR cable, mounted between steel structures at a distance of 48 meters.

The distance between different phases should be 3.5 m, as per practice in WAPDA Switchyards. In case of a short circuit, the bus cables are attracted, but because of the short distance of 48 m between the steel structures, the displacement is negligible. For outdoor installations, the minimum distance for 145 kV systems should be 115 cm (as per VDE 0101). The insulation of the bus will be done by a double insulator chain of 12 discs each, type 146/254 mm or similar.

See Drawings:
No.43 Main Single Line Diagram 132 kV/ 11 kV
No.44 132kV Switchyard – Plan View
No.45 132 kV Switchyard – Section View

10.1.4.3 Circuit Breakers

Each feeder will require for 132 kV switch-gear, a power circuit breaker with a nominal rating of 1.250 A and 145 kV. The interrupting capacity should be above 5,000 MVA, which corresponds to an impulse current of 31.5 kA asymmetrically.

It is recommended to install SF6 gas breakers.

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The proposed three phase breakers will allow fast 02 operation at line fault. A motor driven spring charging mechanism is proposed, as it requires less maintenance than a hydraulic mechanism.

The basic dimensions are approximately:

- basic size 0.65 x 0.65 m
- height about 3.6 m
- distance between centre lines 1.8 - 2.0 m

The three poles should be mounted together on a common base. The auxiliary energy will be supplied by 400 V AC from the station service of the power plant.

10.1.4.4 Isolators

The isolators will be electrically group operated. Electrically, they will withstand more than 310 kV between open contacts and a short circuit impulse current of at least 31.5 kA when closed. The nominal rating in closed position will be 800A and 145 kV.

The dimensions are approximately:

Total Height	1.90m
Total Length	1.85m
Length of moving arm	0.85m

All isolators will be mounted on steel structures to reach the necessary height of terminals for electrical connections. The distance will be 3.0 m between the centerlines of disconnecting switches.

For the Transmission Line Feeders, an additional earthing switch will be required. It consists of a blade mounted on the base at the bottom of the column that is orientated to the line side. The specifications will be as per IEC for short circuit conditions.

10.1.4.5 Measuring Equipment

Each unit will be equipped with current and voltage transformers between the main transformer and the main circuit breaker. As enough space will be made available, there is no need of bushing CTs. It is proposed to install independent current transformers which give a higher flexibility.

On the outgoing lines, combinations of current and potential transformers are required for metering and synchronizing. An area of 60 cm x 60 cm is needed for mounting one transformer in each phase. It is proposed to install a capacitive voltage transformer on one phase for the purpose of Power Line Carrier (PLC) connections and for eventual synchronization needs.

All measuring transformers are assumed to be in the accuracy class 0.5 ±, in accordance with normal practice. During detailed design, more precise ratings for current and voltage transformers may be specified as per specific requirements.

10.1.4.6 Surge Arresters

On the incoming lines, Surge Arresters (SA) will be connected to each phase. Additionally, one group of three SA will be included on each transformer bushing as shown in the general layout of the Switchyard.

Metal-oxide arresters are proposed. The magnitude and duration of temporary power frequency over voltages are important design criteria and, accordingly, they must be defined during the detailed design phase.

10.1.5 Medium and Low Voltage Installations

- **Powerhouse**

The medium and low voltage installations are designed to guarantee a reliable power supply for all functions of the hydropower station.

The 11 kV main bus-bar is fed by the 132/11 kV 6.3 MVA grid station transformer.

In case of failure of the grid and / or operational stop of the power turbines or other operational reasons, one 400 kVA transformer will feed the 0.4 kV station service bus-bar which is divided into an essential and a non-essential section. The essential section can be fed by a 250 kW emergency diesel set.

The 0.4 kV unit service is connected via a 100 kVA 11/0.4 kV transformer directly to the generator terminals. This bus can alternatively be supplied by a unit bus inter-link or by a link to the 0.4 kV essential station auxiliary bus.

See Drawings:
No.41 General Electrical Layout
No.43 Main Single Line Diagram 132kV/ 11kV

This arrangement guarantees enough reliability to secure all essential power needs for security, protection and a black start-up.

- **Intake/Dam Area**

Two options were considered for establishing a power supply to the in take area:

- by a tunnel cable;
- by one overhead line, besides those planned for rural electrification within Arkari valley.

Due to its simpler technology and the considerably lower price, preference was given to the overhead line solution. The line will pass alongside the pressure shaft to the surge tank and will then surmount the hill and descend along the slope to the intake area. The length of the line is about 7 km. A communication cable will be mounted on the same poles.

See drawing:
No.46 Service Interconnection with Intake Area

- **Public service Facility**

  Provision will be made for two outgoing 11kV feeder lines for electrification of surrounding rural areas

10.1.5.1 Medium voltage

The primary purpose of the 11 kV switch-gear is to supply auxiliary power for the power plant and also support the rural areas.

The switch-gear shall be located in a separate room in the Powerhouse.

For the auxiliary supply and the generator circuit breakers, these systems shall be equipped with modern fuse disconnect switches and circuit breakers of SF_6 or vacuum type enclosed in cubicles thus providing high personnel safety.

Design Voltage:	12kV
Type of cubicles:	Metal clad, breakers with draw able
Rated Short Circuit Current (1s):	30kV
Rated lightning impulse withstand voltage:	95kV
Fuse Isolator Switches:	The tripping of a fuse shall open the isolator automatically

The connections between the generators and the main transformers will be realized by 12 kV single phase cables. For the rating of 2200 A, this design will offer the most economic solution. Salient characteristics of this design are:

Type:	XPE, 300 mm^2 Copper, Single Core

Length: 80m

Disposition: 3 cables per phase, laid in 3 bundles of 3 cables installed in cable ducts

See drawings:

No.43 Main Single Line Diagram 132kV

No.44 132kV Switchyard – Plan View

No.45 132 kV Switchyard – Section View

10.1.5.2 Low Voltage

The low voltage A.C. distribution system will be designed as a 400 V, 3 phase four wire plus protective (earth) conductor system.

Normally the station service bus will be supplied by the station supply transformer connected to the 11 kV grid bus.

If this supply is not available (of which there is very low probability), a standby diesel generating set shall start automatically and provide power for supply to essential equipment.

See drawing:
No.41 General Electrical Layout

Design of intake as well as Powerhouse distribution systems will include a main switch- gear for normal operation and an essential load switch-gear, interlocked with bus-breaker for automatic separation in case of failure situations. If a black-out occurs in the main system, the feeder connected to the essential load bus-bar will feed all essential loads from the standby diesel generator.

During normal operation, the AC-switch-gear with double bus-bars will be operated with closed bus-breaker. In other words, the essential load distribution system will be continuously energized during normal operation to ensure the system's availability. The distribution system will supply low voltage power to all plant service systems, lighting and battery chargers, including all power cables, local control cabinets with necessary motor starters and sub-distribution panels. From the battery banks, DC/AC power converters will provide uninterrupted power to essential control functions.

All motors shall be powered and controlled through motor starter units assembled in motor control centers (MCCs). The starters are assumed to be of withdraw-able design where each unit may consist of more than one starter. The number of MCCs would be determined by their lengths and availability to the localization motors.
The unit service bus is directly supplied from the respective generator terminals

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via a unit service transformer. In case of any failure, the unit service bus will automatically switch over to the unit bus of the other generator or, if not energized, to the essential bus of the station service bus.

10.1.5.3 DC Supply Design

The purpose of the battery system is to provide a safe and reliable supply of power and control voltage to all primary functions. The system is independent of all other power systems and ensures reliable execution of control functions, both for normal operation and during possible fault conditions.

For the Powerhouse, the recommended direct current supply is based on a duplicated supply design. The two independent 110V battery systems, each with a separate main distribution switch-gear, will both feed each of the local DC distribution bus-bars.

See drawing:
No.47 110V DC Supply System for Power House

The double battery system will mainly provide power to the complete Plant Control System, the Local Control System, the control voltage for the hardwired part of this system and DC-equipment such as motors for black-start procedures.

Some instruments, protections devices or computer interfaces will need 24V or 48V DC supply. In this case AC/DC converters should be used. The use of separate 24V or 48V batteries should be availed.

The battery system for the intake area will provide power mainly to the local control system and the control voltage for the hardwired part of this system. It will also make power available for particular functions performed in the intake area, such as water level monitoring and gate control.

See drawing:
No.48 110V DC Supply System Intake Area

Dimensioning:

The Powerhouse battery shall guarantee the function of all vital elements to bridge a timely limited power failure and to shut down and restart the plant safely.

The capacity will be established as follows:

	Power	Duration	Capacity
Emergency Lighting	W	h	kWh
5 spots on 5 floors 25 x 40 W	1000	6	60
Plant Control System (PCS)	1000	24	24

Unit Control System (UCS) 6x200	1200	24	28.8
Protection System	2000	1	2
Auxiliary Power 11 kV	1000	0.5	0.5
Auxiliary Power 132 kV	1000	1	1
Lubrication pumps	100	0.6	0.06
Hydraulic punps gates + valves			4
Hydraulic pumps governers			1
Telecom/Telecontrol/others			10
Say 80 kWh			**77.9**

Voltage 110V

Capacity $\frac{80,000}{110}$ = 727 Ah

Efficiency and aging factor = 0.7

Battery capacity 727Ah/ 0.7 = 1,038 Ah

Say = 1,100 Ah

The batteries will be installed in a separate, specially ventilated battery room on racks. The net space requirement will be 3 m^2 if arranged in 4 levels.

The battery charger will be dimensioned to recharge the batteries in 5 hours time. Its capacity will be

$\frac{1100Ahx110V}{5h \times 0.8}$ = 30kW

At the intake another emergency battery pack will be installed with the following capacity:

	Power	Duration	Capacity
Use	kW	H	kWh
Lighting	200	6	1.2
Control	150	48	7.2
Telecom	50	48	2.4
Hydraulic			4
Others			2

16.8 kWh
Say: 18kWh

Voltage = 110V

$$\text{Capacity} = \frac{18000}{110 \times 0.7} = 233 \text{ Ah} \quad \underline{\text{Say : 250 Ah}}$$

The Battery charge will have a capacity of

$$\frac{250 \text{ Ah} \times 110 \text{ V}}{5\text{h} \times 0.8} = 7\text{kW}$$

The space requirement of the complete set (battery and charger) will be 1 m^2 if arranged on racks with at least 4 levels.

10.1.6 Control and Alarm System

The plant will be equipped with a state of the art computerized control system. The main advantage of this type of control over the traditional hardwired type is the replacement of the large number of cables and wires for communication between the different plant control points with a single fiber optical wire. All switching, alarm and control conditions are fixed in a computer program which is easier to install, diagnose and maintain. The risk of faulty connections is reduced considerably. The installation also provides a higher level of transparency thereby facilitating fast and simple error diagnostics, Furthermore, future modifications can easily be introduced without disturbing plant operations.

The system consists of the following elements:

- One Plant Control System
- Six Unit Control Systems
- Data Communication System

10.1.6.1 The Plant Control System (PCS)

The Plant Control System (PCS), installed in the Control Room, will be equipped with:

- An elevated floor for cable distribution
- Air conditioning
- A galvanic isolated power supply equipped with overvoltage devices

The Plant Control System will allow the overall control and monitoring of the plant. The operation of the entire system will be carried out from the Plant Control System.

Process control, like command procedures, interlocking routines etc. are handled by the Unit Control Systems so that no failure in the PCS will disturb the operation of individual units.

The Control System Software shall include all state of the art functions. Basically three modes of operation of the power plant will be needed:

A) Load controlled operation with time-dependent function: Used for standard operation of ponding and peaking.

B) Water level controlled operation: Aimed at keeping the water level in the intake reservoir at a constant defined level.

C) Operation on an isolated grid: Used in case of interruption to the national grid (combinations of alternative control modes will be required for project operations)

In any case, the Plant Control System will distribute the load between the units to maintain optimum power production or to meet other specified criteria.

10.1.6.2 The Unit Control Systems (UCS)

Unit Control Systems will be employed for process control of the following units:

UCS1	Generating Unit 1
UCS2	Generating Unit 2
UCS3	Generating Unit 3
UCS4	Auxiliary System
UCS5	132/11 kV Switchyard
UCS6	Intake Functions

See drawing:
No.49 Plant Control System

The UCSs shall coordinate and perform operational tasks commanded by the PCS.

- The UCSs shall comprise programmable controllers (PLC) based on micro-processor technology, and shall perform all functions for accessing, analyzing and acting on information received from different processes / equipment.

- The UCSs will be connected by optical fibers and an interface with the Plant Control System (PCS).

- In the "Local Control" mode, the manual control panel of the UCS will be in operation. Operation of the devices connected to the UCS must then be performed directly.

- Unit Control Systems for the Generating Units (UCS1, UCS2 and UCS3)

  The UCS for the generating units will be programmed for fully automatic start and stop procedures for the units, including synchronization. However, the operation and functions of the voltage regulators and the turbine governors will be independent. The initiated procedure would carry out all command actions sequentially and the sequence of operations (along with status reports) would be transferred to the PCS.

- Unit Control System for the Power Station auxiliary supply (UCS4)

  The UCS supervises the plant auxiliary power supply system and provides automatic switching to the available power sources according to an agreed priority schedule. In addition to the auxiliary power supply, including the medium voltage equipment, UCS4 supervises the drainage pumps, ventilation system, the cooling water pumps, the chilled water system, light and small power etc. (the fire fighting system will have an independent conventional control system).

- Unit Control System for the HV/MV Switchyard (UCS5)

  This and the protection relays will be located in the Powerhouse Control Room. The UCS is interconnected with the local control panels for the 132 kV and 11 kV switch-gear and the relay protection panels which will actuate independently from the UCS.

- Unit control system for the Intake (UCS6)

  This UCS is located in the intake gate house and it supervises the standby diesel generating unit, the power supply and the gates as well as signals from the intake to the Powerhouse and the water level controller.

  For security reasons, the flushing gates will be manually operated at site but signals for "open/closed" will be recorded in the PCS.

10.1.6.3 Communication between the PCS and the UCS

Communication between the PCS and UCS will consist of a fiber-optical cable system. The communication layout can either be a bus system, a loop system or a star system.

10.1.6.4 Manual Control" Mode

In the "Manual Control" mode, the UCSs are put out of automatic operation. In this mode, each operation is performed locally on each device.

In addition, manual operation can be performed directly on the equipment, i.e. on the generating units, switch-gear panels, motor control cubicles (MCC) etc. In this arrangement, all monitoring and control must be done locally from the UCS mimic panel. The design of the local control panels must include equipment for indicating status and control of major parts such as generator, turbine, breakers, switches, control of alarm level set-points etc.

Start, stop and other control of the generating units must be possible by manual operation. The monitoring and operation are done by means of the control panels for the automatic voltage regulator (AVR) and the turbine governor as well as by manual operation of valves, switches etc. for manual operation together with local instruments. Also, an independent emergency stop function for the generating units must be installed for use in the event of a severe fault e.g. fire or flooding. The emergency stop function is initiated by the emergency buttons which are to be installed at selected locations.

10.1.7 Protection Equipment

Separate relay protection cubicles comprising modem electronic relays will be installed. All relays shall preferably be of the same make (manufacture) to build a uniform modular system.

The functioning of the protection relays shall not depend on the control system. The relays are to be organized in two groups so that one group provides back-up protection for the other group.

Auxiliary power shall be taken from the 110 V DC-system only. Separate circuits shall serve the two groups of relays in order to obtain maximum reliability. The relays should be capable of operating properly with voltage variations of -20% to +10%.

- **Generation Protection**

  The generator is linked to the primary winding of the transformer by underground cables.

  To avoid the built up of dangerous over-voltages in the event of an arcing earth fault, which is possible due to the relatively high capacitance of the system, the generator neutral- point must be earthed through an impedance which will limit the earth fault current to a suitable value.

  It is modern practice to use a distribution transformer in the range of about 5-20 kVA for this purpose. The secondary winding, which is designed for a voltage of 100 - 500 V, is loaded with a resistor of a value, that, when referred through the transformer ratio, will pass a suitable fault current. The resistor is therefore of low ohms-value and can be of rugged construction whilst still presenting a high equivalent value in the generator circuit.

  As a basis of design, the resistive component of fault current should be one to five times the residual capacitive current (that is 3 x I_{co}). It is proposed to install the earth fault relay in the secondary circuit of the earthing/distribution transformer.

The main generator protection shall consist of:

- Over-/under voltage relay.

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- Over/under frequency relay.
- Over current/short circuit relay.
- Reverse power relay.
- Negative sequence current relay.
- Loss of excitation relay (Minimum reactance relay).
- Shaft current relay.
- Rotor (field winding) earth fault relay.
- Three phase generator differential current relay.
- Stator earth fault relay.
- Vibration and shaft movement supervision relay.
- Winding thermal relay.

The 132 kV block transformer protection include:

- Oil temperature and level control.
- Buchholz relay.
- Three phase over current relay as backup device.
- Three phase unit block differential current relay.
- Neutral point earth fault current relay (common for all units).

See drawing:
No.50 Unit Protection - Single Line Diagram

The 132 kV transmission line protection comprises:

- Three-phase minimum impedance relay with fault location facility.
- Three phase over current relay.
- Earth fault relay.
- Synchro-check relay.

The 132 kV/11 kV grid station transformer protection comprises of

- Oil temperature.
- Buchholz relay.
- Three phase over current relay (as backup).
- Three phase differential current relay.

11 kV Distribution Line Protection comprises:

- Three phase over current relay.
- Three-phase re-closure relay.
- Earth fault relay.

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10.1.8 Telecommunication and Watches

10.1.8.1 Powerhouse Communication

Within and outside the area of the Powerhouse, an appropriate communication system is needed. This will make it possible to communicate the operational instructions to concerned sections.

A digital telephone network is to be installed in the Powerhouse to cover the entire plant (Powerhouse, intake and residential camp).

Each generating unit will include at least one telephone per floor. All the cranes should also be connected to this system and the working and lay down areas will be reached through this communication system. The central exchange will be connected to the station battery so that there will be no outage in the case of a complete shutdown of the plant.

The system will include 5 loudspeakers and 20 telephone sets.

10.1.8.2 Powerhouse Intake Communication

To link the Powerhouse with the intake area, several alternatives can be considered, including:

- Power Line Carrier on 11 kV or 132 kV System (Expensive End Stations).
- Fiber Optical Conductor in Headrace Tunnel (Expensive Design of Cable).
- Fiber Optical Conductor on 11 kV Overhead Power Line.
- Conventional Communication Cable on 11 kV Overhead Power Line.
- Radio Link.

As the distance between the two stations is short (about 7 km) and within the reach of a conventional communication cable without intermediate signal amplifier, a copper cable, clamped on the 11 kV Power Overhead Line would be the lowest cost alternative.

Nevertheless, an optional fiber cable also clamped to the 11 kV Power Overhead Line offers advantages in terms of reliability, quantity of information which can be transmitted and most importantly, no problems with electro-magnetic compatibility. All of the aforementioned advantages of a fiber cable by far outweigh the disadvantage of its higher price.

It is therefore recommended to adopt the optical fiber cable clamped to the 11 kV Power Line.

10.1.8.3 External Communication

WAPDA uses a system of power line carriers for its communications between

Powerhouses and Load Dispatch Centres. The coupling is done between one phase and earth which makes it necessary to install for each communication line, one line trap and one coupling capacitor at each terminal.

It is planned to integrate Uchhatur-Andakht HPP via Powerhouses at Shogore and Sin to Central Chitral 132 KV/ 220/500 KV grid station, where line traps and capacitive voltage transformers will be installed.

The location of the equipment will be partially in the Switchyard, and partially in the Control Room. The 48 V supply will be made by DC/DC Converters fed by the 110 V main battery.

This system will give the possibility for voice and signal transmission on the 132 kV line between the Powerhouse and the remote load dispatch centre.

The Control Room is additionally connected to the public telephone system to guarantee communication with the power plant in case of failure of the power line carrier system. Radio communication should be added for additional reliability.

10.1.8.4 Watches

An independent system of watches which can be synchronized with outside systems, if necessary, will be installed for control purposes. Each generating unit will have a digital time indication. The master clock will be installed in the Control Room.

10.1.9 Lighting and Small Power

Adequate indoor and outdoor lighting will be provided in due conformity with recognized illumination level standards. Inside the Powerhouse, an emergency lighting system powered from the station battery shall be installed. The system will become operational the moment normal power supply fails.

AC lighting and 230 V small power socket outlets shall be single-phase, connected between phase and neutral of the 400V-system.

Under normal conditions, both emergency and normal lighting will be in operation. However, these two systems will have totally separate circuits with power supply as follows:

- **Normal lighting:**

  Normal lighting will always be powered from normal switch-gear.

  It is recommended that the normal lighting system should be designed according to the following design criteria:

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Type of Area	Illumination level
Outdoor Areas with common staff traffic Other areas, as dam intake area	50 lux 20 lux
Indoor Offices, Control Rooms, switch-gear rooms Storage Rooms, corridors, etc. Tunnels Equipment Rooms Machine Hall, etc.	400 lux 100 lux 50 lux 50 lux 100 lux

Illumination requirement for emergency lighting shall be at least 1 lux all over the related areas.

Portable battery hand-sets shall be available for additional DC lighting during maintenance works etc., in case of AC failure. They shall be placed at various places in the Powerhouse.

Exit lights shall be installed above doors, staircases etc. During blackouts, these shall be powered from their internal batteries for minimum 15 minutes.

The following outdoor areas have to be illuminated:

- **Intake Area**

  Access road

  Intake gate and trash rack

  Dam crest

  Gates

  Reservoir surface upstream using reflectors

  River surface downstream using reflectors

- **Powerhouse area**

  Access road

  Switchyard

  Tailwater Gates

  River surface using reflectors

Indoor lighting will be installed in all rooms, such as transformer boxes, low voltage switch-gear, regulator area, ventilation equipment, relay racks, office, workshop, sanitary facilities.

On both long walls, the machine hall will have a chain of fluorescent lamps which

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will be used for orientation only. During maintenance and repair jobs on a unit, portable illumination will be used where necessary. The Control Room will have intensity controlled illumination so that illumination levels can be adapted according to operational needs. Special attention shall be paid to avoid reflections on monitor screens.

- **Emergency Lighting**

  In normal operation, it will be directly powered from the 415 V essential switch gear. Power supply in the event of plant supply failure shall, for the first 60 seconds, come from the main batteries through a DC/AC converter. After 60 seconds, the supply shall be obtained from the standby diesel generating unit (essential load switch-gear separated from normal supply).

  Both systems have, as a main concept, commonly distributed "on/off" switches. Emergency lighting will therefore not become operational automatically in rooms where lights are switched off. However, special consideration must be given to areas containing "escape routes".

10.1.10 Emergency Diesel Sets

In case of breakdown of the WAPDA system simultaneously with a failure or standstill in the Main Generators, a Diesel Generator must take over the supply of a certain group of equipment to ensure and facilitate a safe shutdown or block start-up or repair of the plant.

10.1.10.1 Powerhouse Diesel Generator Set

The set will be able to supply the complete station service as well as the three unit services.

Station service	180 kW
Unit Service 1	34 kW
Unit Service 2	34 kW
Unit Service 3	34 kW
Total	**282 kW**

x Simultaneous Factor	0.8	=	226 kW
÷ Divided by Aging Factor	0.8	=	282 kW
x Power factor	0.75	=	376 kVA

The Emergency diesel set will have the following characteristics:

Nominal capacity	300 kW/ 400 kVA

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Nominal speed	1500 rpm
Nominal voltage	440V/50 Hz

The biggest motor being only 20 kW, a brushless exiting system with rotating diodes can be applied. Space required for installation of this unit, including an automatic transfer, will be 6 x 4.5 m. The room should be high enough to lead the hot exhaust gases to the outside atmosphere through the silencer. Besides the automatic control system, there will be an independent start battery of 24 V with its charger. A diesel oil tank with a capacity of 5,000 liters will be provided.

An automatic fuel pump shall keep the day tank of 1000 Liter capacity filled.

Cooling air of the room housing the diesel generator set will be moved by the fans of the motor. Warm air will be expelled and fresh air drawn from outdoors through wall openings.

10.1.10.2 Intake Area Diesel Generator Set

The set will supply sufficient power to operate the gates and to insure emergency lighting, control and communication. The set will have the following characteristics:

Nominal capacity	40 kW/50 kVA
Nominal speed	1500 rpm
Nominal voltage	400V/50 Hz

The set will be installed in an annex to the Control Room. Start and shut down will be automatic in case of power failure. An independent 24 V start battery with charger and a 1000 liter oil tank will be installed.

10.1.11 Earthing System

WAPDA operates its 132 kV system with the neutral solidly grounded. This means that in case of any line to ground fault close to the Switchyard, a fault current will pass through the neutral connection of each transformer in service. This fault current must not produce voltages harmful to men and equipment.

To avoid such voltages, it is recommended to:

- Connect all grounding systems together (High Voltage, Medium Voltage and Low Voltage Service and Protection earth).
- Lower the grounding resistance to a value low enough to limit the earthing voltage to a manageable level by connecting all ground systems together
- HV Switchyard earthing mesh

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- Powerhouse foundation ground
- Shield wire of outgoing lines
- Installation of additional grounding rods
- burying of counterpoise of an appropriate length under the outgoing lines
- control step and contact voltages by an appropriate arrangement of earthing conductors

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VOLUME 4: APPENDICES – Part II

Section 1 Appendix 7: Alternative Study & Selection of Plant Layout & Optimization

Section 2 Appendix 8: Hydropower Design, Civil Design, Construction

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Section 4 Appendix 12: Documentary Basis for Project Evaluation

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10.2 Grid Interconnection Chitral District

10.2.1 Introduction

Government of Khyber Pakthunkhwa (KPK) has embarked upon the development of the significant hydroelectric potential in the Province. PHYDO (Khyber Pakthunkhawa Hydel Development Organization) has been entrusted with the responsibility of managing this development. A number of feasibility studies have been out sourced to consulting firms.

A number of feasibility studies in Chitral District aim to develop the power potential. These potential sites will feed the national grid. There is need to evolve a common strategy for interconnection of these sires to the national grid. A summary if the scope of development is presented as follows:

PHYDO Hydropower Projects under Development					
Sr. No.	Name	Installed Capacity MW	Completion Target	Status	Area
1	SHORT TERM				
1.1	Daral Khwar	36	2015	Under Construction	Swat
1.2	Ranolia	17	2015	Under Construction	Kohistan
1.3	Machai	2.6	2015	Under Construction	Mardan
	Sub Total	55.6			
2	MEDIUM TERM		TENDERING STAGE		
2.1	Matiltan	84	2016	Tendering stage	Swat
2.1	Lawi	69	2017	Tendering stage	Chitral
2.2	Sushgai-Zindhaii	144	2018	PC-1 under approval	Chitral
2.3	Shogo-Sin	132	2018	PC-1 under approval	Chitral
2.4	Sharmai	150	2018	PC-1 under approval	Upper Dir
2.5	Kato	31	31	MC Consultant selection	Lower Dir
2.6	Karora	9.3	2014	MC Consultant selection	Shangla
2.7	Jabori	7	2016	MC Consultant selection	Mansherea
	Sub Total	626.3			
3	LONG TERM		FEASIBILITY STAGE		
3.1	Balakot	190	2014(2019)	Feasibility Study	Kaghan
3.2	Naran	210	2014(2019)	Feasibility Study	Kaghan
3.3	Barikot-Patrak	34	2014(2018)	Feasibility Study	Dir
3.4	Patrak-Shingal	21	2014(2018)	Feasibility Study	Dir
3.5	Shigo-Kach	26	2014(2018)	Feasibility Study	Dir
3.6	Ghorband	14	2013(2016)	Feasibility Study	Sangla
3.7	Nandihar	10	2013(2016)	Feasibility Study	Batagram
3.8	Arkari Gol	110	2013(2017)	Feasibility Study	Chitral
3.9	Mugigaram-Shogore	51	2014(2018)	Feasibility Study	Chitral
3.1	Istaru-Bunni	52	2014(2018)	Feasibility Study	Chitral
3.11	Gahrit Swir Lasht	334	2014(2019)	Feasibility Study	Chitral
3.12	Korgrah Parit	223	2014(2019)	Feasibility Study	Chitral
3.13	Laspur Miragram	133	2014(2018)	Feasibility Study	Chitral

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PHYDO Hydropower Projects under Development					
Sr. No.	Name	Installed Capacity MW	Completion Target	Status	Area
	Sub Total	1328.6			
4	Long Term		Prefeasibility Stage		
4.1	Kari Mushkai	446		Prefeasibility Stage	Chitral
4.2	Torkum Gudubar	409		Prefeasibility Stage	Chitral
4.3	Kalam Gabbral	110		Prefeasibility Stage	Swat
	Sub Total	965			
	Grand Total	2975.5			

10.2.2 Transmission:

10.2.2.1 Existing WAPDA (NTDC) Transmission Lines Arrangement:

Two numbers transmission lines of 132KV and 66KV capacity have been constructed and energized at Timergarah Grid Station duly fed from 132/66 KV Chakdara Grid Station. The 66KV Transmission line is further extended to Dir Grid Station from where 33KV transmission line has been constructed for district Chitral. There are two numbers Grid Station 33/11 KV in Chitral District, provided by WAPDA (NTDC).

The detail of the above mentioned Transmission Lines is given as under:

Name of Grid Station	Capacity of T/L	Total length in KM	Type of Tower	Type of conductor	Loading Capacity	Recorded Load
1.Chakdara	132KV Chakdara Swat	42.00 KM	TBA,TM TYD	LYNX	488/400 A	82%
	66KV Chakdara – Timergara	32.00 KM	GS	Dog	846/260 A	75%
	132KV Chakdara-Timergara	30.00 KM	TBA,TM TYD	LYNX	488/280 A	58%
2. 66 KV Timergarah	66KV Timergara –Wari-Dir	80.00 KM	GS	Dog	346/200 A	71%
3. 66 KV Dir	33KV Dir-Chitral Section	110 KM	STP+ Structure	Dog	345/50 A	16%

10.2.2.2 Existing Power Facilities Provided By PHYDO and NTDC Within Chitral District:

In lower and Upper Chitral electric power generation, transmission and distribution system is being operated by PHYDO. A power house of 1800 KW capacity installed at Shishi Gol which supplies power to Drosh area.

In Central Chitral most of the power generation transmission and distribution is maintained and operated by WAPDA (NTDC). There are two power stations one

Hydel of 1000KW and the other Thermal generation of 960 KW capacity in Chitral city. After the interconnection of Chitral city with the National grid of 33KV Transmission line about 2.1 MW power is being imported from WAPDA (NTDC) source.

Further at Booni and Garam Chasma a diesel power station of 216 KW each are in operation. While hydel power stations of installed capacity 4.2 MW at Reshun Gol and 1000 KW (1MW) capacity at Garam Chashma are being operated by PHYDO

Existing Loading Condition 11 KV Feeder distributed from 66kV Grid station at Dir during the year 2011-2012 Name of Grid Station : 66 KV DIR				
Power transformer code #	Make	Rating [MVA]	Voltage Rating [kV]	Current Rating [A]
T1	Elprom	10/13	66/11	653
T2	Elprom	5/6.3	66/33	121

10.2.2.3 Survey of Transmission Lines

The existing power transmission network in the area consisting of 66 KV Dir and 33 KV across Lowari to Drosh Chitral city Drasan, the details are presented in the table on the following page.

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Sr: No.	Name of 11 KV Feeder	C.T Ratio	Cable size	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12
A	INCOMING-1	800/5	1000MCM	540	440	440	470	565	530	500	460	510	460	480	510
1	Warl	200/5	120MM	190	190	200	200	195	190	180	180	180	170	170	200
2	Dir	200/5	500MCM	180	195	190	170	195	200	180	195	170	-	-	-
3	Barawal	400/5	4/0AWG	90	90	90	80	90	80	80	80	80	80	80	90
4	Sheringal	200/5	500 MCM	80	80	80	240	90	80	70	70	250	220	230	240
--	33KV O/G Chitral(T/I)	150/5	Overhead Bus Bar	30	40	40	40	50	50	40	40	40	50	40	40

Existing Power Transmission Network in the Area

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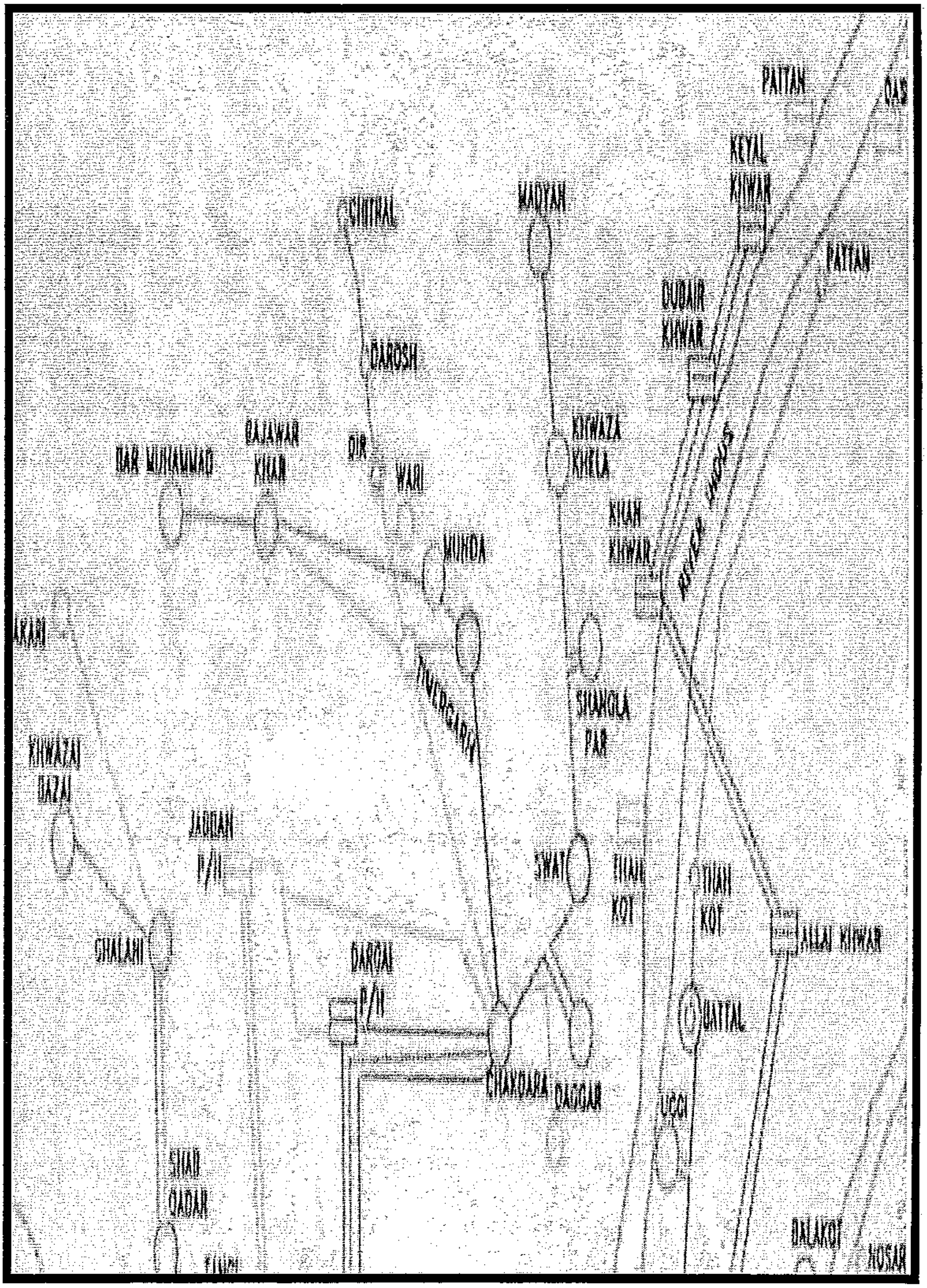
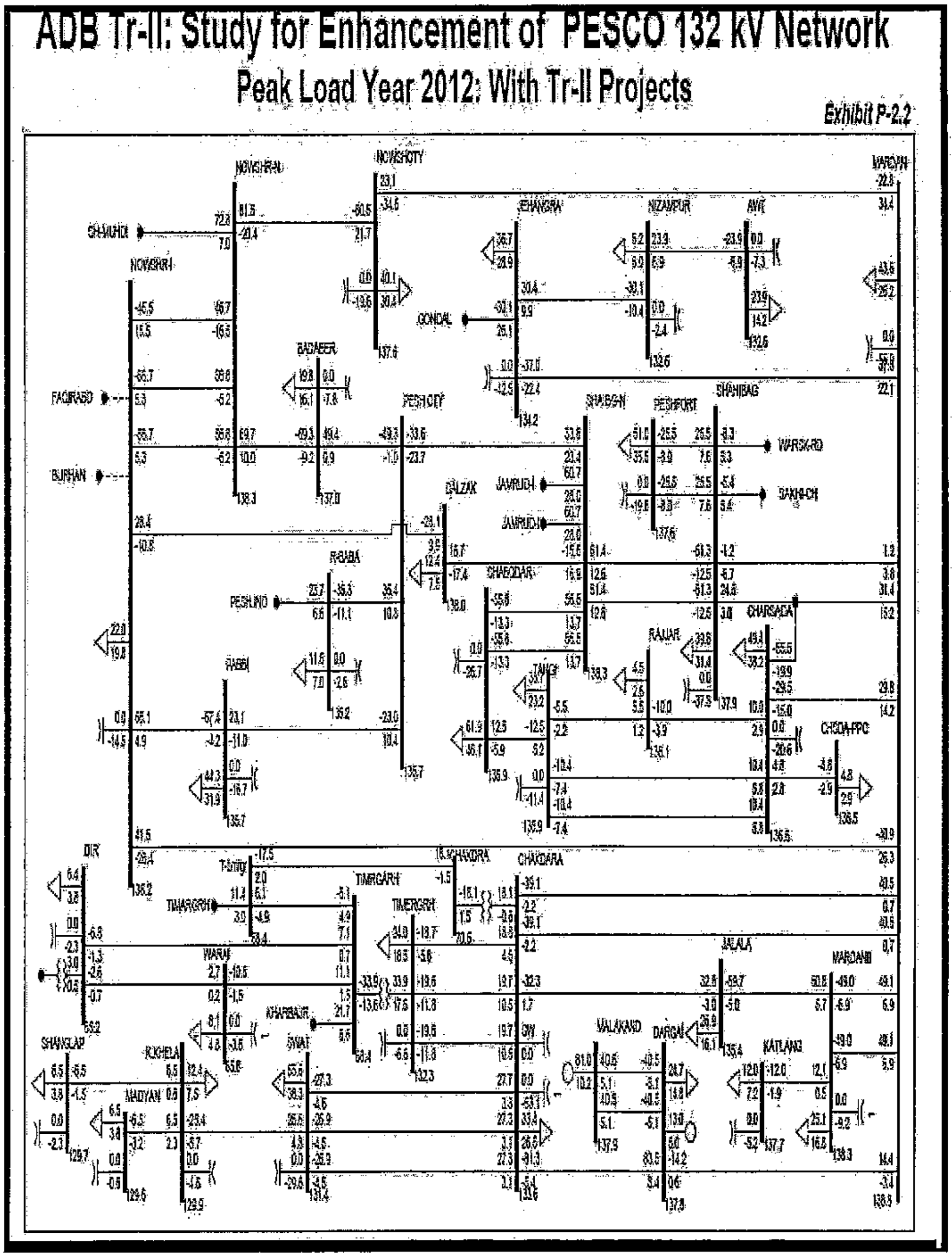
10.2.2.4 Secondary Network Related to Chitral District

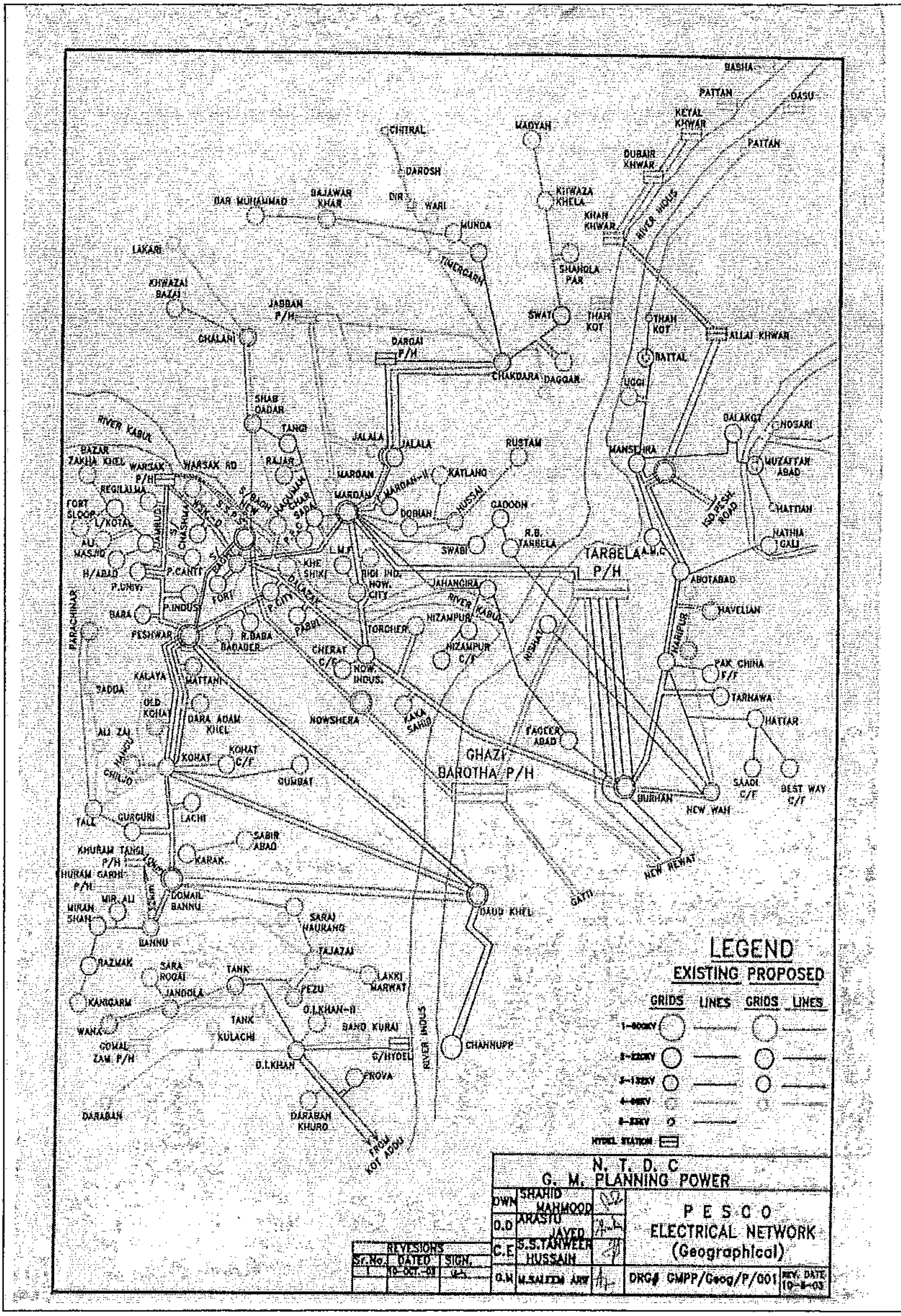
PESCO secondary transmission network is presented as follows



10.2.2.5 Transmission and Distribution Expansion Studies

Asian Development Bank (ADB) has provided with 2 MFF (Multi Financing Facility) to the Government of Pakistan , this has resulted in provision of funds to NTDC (National Transmission and Dispatch Company)and PESCO for expansion of the primary and secondary network , as a part of project preparation load flow studies were carried . These are presented as follows:




LEGEND
EXISTING PROPOSED
GRIDS LINES GRIDS LINES
HYDEL STATION
N. T. D. C
G. M. PLANNING POWER
DWN SHAHID MAHMOOD
D.D ARASTU JAVED
C.E S.S.TANWEER HUSSAIN
G.M M.SALEEM ARIF
PESCO
ELECTRICAL NETWORK
(Geographical)
DRG# GMPP/Geog/P/001
REVISIONS
Sr.No. DATED SIGN.
TARBELA P/H
GHAZI BAROTHA P/H
RIVER INDUS
RIVER KABUL
PESHWAR
MARDAN
KOHAT
BANNU
D.I.KHAN
ABOTABAD
MANSEHRA
SWAT
CHAKDARA
NOWSHERA
DAUD KHEL
CHASHMA
FROM KOT ADDU

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10.2.3 Existing Power Facility provided by WAPDA (NTDC)/PESCO in Chitral District:

Parts of Chitral district is electrified from two (2) numbers 33KV Grid Stations at Drosh and Jutlisht through 33KV transmission line extended from 66 KV of Dir Grid Station. For operation and distribution of power supply a sub-division has been established which controls and maintain whole of the distribution network of Central Chitral District. The detail of customers and energy consumption from June 2007 to June 2012 is given as under:

Number of Customers , Category Wise for PEPCO System							
Customers No	2007	2008	2009	2010	2011	2012	Growth 2007-11
Domestic	9279	9791	9792	10295	10470	10645	2.78
Commercial	1613	1677	1681	1763	1795	1820	2.44
Industrial	50	50	50	50	50	50	0.00
Total	**10942**	**11518**	**11523**	**12108**	**12315**	**12515**	**2.72**

Consumption , Category Wise for PEPCO System kWh/a							
Customers	2007	2008	2009	2010	2011	2012	Growth 2007-11
							Avg. pa.
Domestic	8668804	8553619	8022900	8437247	9510167	10262162	3.43
Commercial	1330797	1355267	1275481	1310353	1371501	1441139	1.61
Industrial	239599	237173	231015	232951	249175	252318	1.04
Total	**10239200**	**10146059**	**9529396**	**9980551**	**11130843**	**11955619**	**3.15**

Per Customer Consumption , Category Wise for PEPCO System kWh/a							
Customers	2007	2008	2009	2010	2011	2012	Growth 2007-11
Domestic	934.24	873.62	819.33	819.55	908.33	964.04	0.63
Commercial	825.04	808.15	758.76	743.25	764.07	791.83	-0.82
Industrial	4791.98	4743.46	4620.30	4659.02	4983.50	5046.36	1.04
Total	**935.77**	**880.89**	**826.99**	**824.29**	**903.84**	**955.30**	**0.41**

There are 4 Nos. 11 kV feeders in Chitral, there are also 4 Nos. Sub Divisions, the WAPDA (NTDC) served area has 2 Nos. 33kV sub stations. Villages/Towns electrified by the WAPDA (NTDC) served area are: Chitral; Drosh; and Garam Chashma .

In central Chitral most of the power generation transmission and distribution is maintained and operated by WAPDA (NTDC). There are two power station one Hydel of 1000 kW and the other Thermal generation of 960 KW capacity in Chitral city. After the interconnection of Chitral city with the National grid of 33KV transmission line about 2.1 MW power is being imported from WAPDA (NTDC) source

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10.2.4 Existing Power Facility Provided by Phydo at Chitral District

In lower and upper Chitral electric power generation, transmission and distribution system is being operated by PHYDO. A power house of 1800 kW capacity is installed at Shishi Gol which supplies power to Drosh area. Further at Booni and Garam Chashma diesel power stations of 216 KW each are in operation, whilst hydel power stations of installed capacity 4.2 MW at Reshun Gol and 1 MW capacity at Garam Chashma are being operated by PHYDO.

Reshun hydroelectric power plant feeds a 33kV regional transmission and distribution System consisting of three main feeders.

FEEDER NO. I

- Length of Transmission Line 73 km
- Transmission Voltage 33 kV

This feeder is interconnected with the existing 33 kV WAPDA (NTDC) Grid Station at Jutilasht. Beside this the villages like Reshun, Greenlasht, Parpish,Riri, Shachar, Jugumi, Jumsheli, Barenis, Prait, Moroy,Mori Lasht, Mori Bala, Mori Payeen, Chumuruk, Shaililasht, Istangol,Koghuzi, Barghozi, Kuju and Ragh.

FEEDER NO. II

- Length of Transmission Line 70 km
- Transmission Voltage 33kV

This feeder is electrifying villages of Lot Oweer, Loon, Gohkir, Kosht Bala, Kosht Payen, Morder, Muzhgol, Khotakan Warijun, Drasun, Authol, Nogram, Shono, Gaht, Samagol, Warzodor, Zainee, Saht, Kushum, Madak,Zezdi, Nishko,Sorwakht, Dru, Tarich, Istaru, Rayeen, Shagram, and Wirkup.

FEEDER NO. III

- Length of Transmission Line 68 km
- Transmission Voltage 33 kV

This feeder electrifies Shogram, Zait, Koragh, Gashtlasht, Charoun, Charounower, Bombagh, Junalikoch, Booni, Driyano Booni, Awi, Awilasht, Miragram, Parwak, Sonoghor, Nisorgol, Sarghoz, Mastuj, Mastuj Chinar, Mastuj Tooq, Chapali, Chuinj, Parkusab and Kargin,

Reshun Power Plant statistics are presented as follow:

Reshun HPP Statistics 2010-2011				
Feeder No.	Energy Generated	Energy Sold	Energy Lost	Energy Lost
	kWh	kWh	kWh	%
Feeder 1	1978520	1585142	393378	19.88
Feeder 2	3734544	3277625	456919	12.23
Feeder 3	3732480	2755902	976578	26.16
Total	9445544	7618669	1826875	19.34
	Installed Capacity	4200	kW	
	Plant Factor	25.67	%	

The customers connected are presented as follow;

Reshun : Number of Customers Served June 2012						
Feeder No.	Domestic No.	Mosque No.	Jamat Khana No.	Commercial No.	Industrial No.	Total No.
1	2848	74	5	71	13	3011
2	6525	277	19	97	38	6956
3	12957	387	76	351	103	13874
Booni						850
3	12957	387	76	351	103	14724
Total	**22330**	**738**	**100**	**519**	**154**	**24691**

10.2.5 Micro Hydels

The Aga Khan Rural Support Program (AKRSP) has installed over 180 micro-hydro power units in Chitral District, KPK Province, Pakistan. So far, AKRSP Chitral has assisted the communities in constructing 171 units (ranging from 20 kW to 100 kW of power generation capacity) of Micro hydels in Chitral District.

10.2.6. Identified Power Potential Chitral District

10.2.6.1 Identification Study

The 1997 identification Study, by GTZ Hydropower Development Program, on behalf of the Ministry of Water and Power (HEPO, Hydroelectric Electric Planning Organization, WAPDA were closely associated with the study), Government of Pakistan, identified 10 sites. The sites were ranked in order of economic merit as well as technical feasibility

The summary of this identification is presented as follow:

Ranking of Identified Sites , Chitral District				
Ranking	Scheme	Installed Capacity	Cost Estimate	Annual Energy
1	Golen Gol 1_/	106	73.68	436
2	Shogo-Sin	127	129.67	586
3	Shusghai-Zhendoli	102	118.22	442
4	Uchhatur-Andokht	79	76.30	339
5	Laspur-Muri Gram	133	193.58	550
6	Loo-Nissar Lawi	65	80.48	275
7	Turtonas-Uzghar	58	67.68	254
8	Istoru-Buni	52	66.49	213
9	Ushan-Ayun	30	44.07	131
10	Darband-Barbuno	40	66.24	167
11	Mujiggram-Shogo	51	92.50	231
12	Nechhchcherdim-Paur	80	139.56	321
	TOTAL	923	1148.47	3945
	1_/ Identified earlier			

10.2.6.2 Subsequent Development

10.2.6.2.1 Golen Gol

The Golen Gol site was identified during the identification of potential for rural electrification and subsequently upgraded for development for grid interconnection. The site is now under construction, which is partially funded by Saudi Fund. The expected commissioning of the site is 2015

10.2.6.2.2 PPIB Studies

Private Power and Infrastructure Board (PPIB) engaged consultants to study two (2) sites; this was funded by the Asian Development Bank (ADB) under the Renewable Energy Resources Multi- Financing Facility Fund (MFF). The result of the two sites studied is summarized as follows:

10.2.6.2.2.1 Shogo-Sin Hydropower Project

Shogo-Sin Hydropower Project was sized with a total installed capacity of 144.01 MW and annual energy generation of about 613.10 GWh/a. The total cost is estimated to be US$ 194 M, this works out to be 1347 $/kW (exclusive of IDC and escalation during construction).

The power and Energy outputs of the plant are summarized in the following table.

SHOGO-SIN HYDROPOWER PROJECT					
Dam Height = 35 m		Surface Area		cu. M	74,340
		Live Storage		cu. M	656,800
Capacity	135	Plant Factor		%	49.4
	Peak Capacity	Off Peak Capacity	Peak Energy	Off Peak Energy	Total Energy
Month	MW	MW	GWh/a	GWh/a	GWh/a
Jan.	131	4	16.28	3.14	19.42
Feb.	131	1	14.70	0.90	15.60
Mar.	125	2	15.97	0.35	16.32
Apr.	129	20	15.70	5.29	20.99
May	132	71	16.42	27.78	44.20
Jun.	134	135	16.15	80.74	96.89
Jul.	134	135	10.76	83.38	94.14
Aug.	134	134	16.67	83.34	100.01
Sep.	133	135	16.06	60.13	76.18
Oct.	132	56	16.41	27.27	43.68
Nov.	132	22	15.80	11.43	27.23
Dec.	131	12	16.30	6.81	23.11
Annual	129	135	187	391	578

10.2.6.2.2.2 Shushghai-Zhendoli Hydro-Power Project

Shushghai-Zhendoli Hydro-Power Project was sized at total installed capacity of 144.01 MW and annual energy generation of about 613.10 MkWh, at a total cost of US $ 179 M (inclusive of IDC and escalation during construction), this works out to be US $ 1246/kW. Estimated Project outputs are given below:

Power and Energy Calculations Shushgai HPP

Capacity 144 MW, Head 615.4 m, Reservoir 453,000 m³

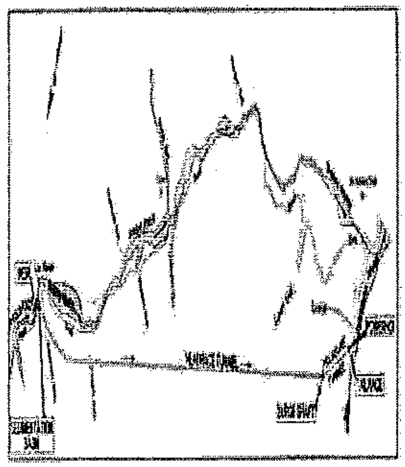
Month	Capacity		Energy		
	Peak Capacity	Off-Peak Capacity	Peak Energy	Off-peak Energy	Total Energy
	MW	MW	GWh/a	GWh/a	GWh/a
Jan	144	4	17.84	1.66	19.50
Feb	137	0	15.40	0.00	15.40
Mar	135	0	17.42	0.00	17.42
Apr	144	24	17.28	7.77	25.04
May	144	44	17.86	17.61	35.48
Jun	145	145	17.36	75.37	92.73
Jul	145	145	17.94	89.72	107.66
Aug	145	145	17.94	89.72	107.66
Sep	145	145	17.35	72.52	89.87

Month	Capacity		Energy		
	Peak Capacity	Off-Peak Capacity	Peak Energy	Off-peak Energy	Total Energy
	MW	MW	GWh/a	GWh/a	GWh/a
Oct	144	59	17.87	25.30	43.18
Nov	144	27	17.28	14.41	31.69
Dec	144	16	17.85	8.39	26.24
Total	**137**	**145**	**209.40**	**402.45**	**611.85**

10.2.6.2.2.3 Lawi Hydropower Project

LOCATION

The project area is located on the right bank of Shishi River, a left tributary of Chitral River. The project involves diversion of Shishi River into Chitral River. The Project is about 350 km from Islamabad.



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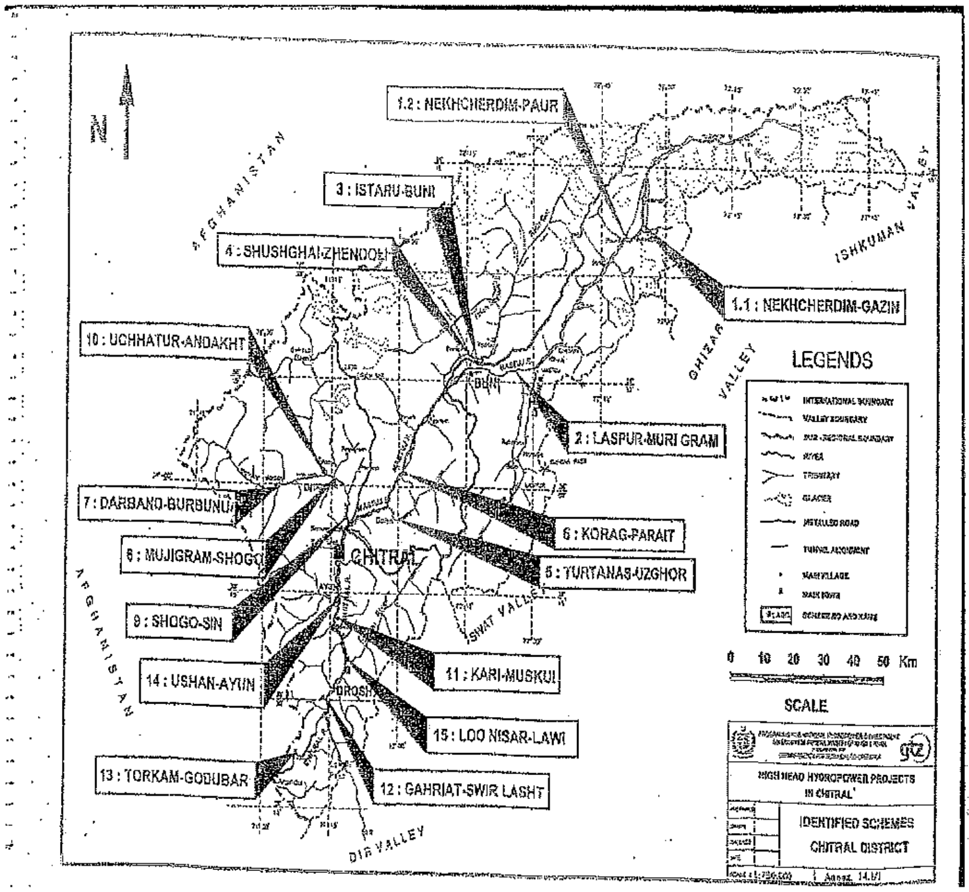
Installed Capacity	70 MW
Gross Head	413 m
Design Discharge	20 m^3/sec
Mean Annual Energy	303 Mil. KWh
No. & Type of Turbine	3 (Pelton)
Project Base Cost	US$ 120 Million
EIRR	18.51%
Implementation Period	4½ Years

The project includes the Interconnection with WAPDA (NTDC) National Grid 132 KV at Timergara (Dir) along-with all interfacing requirement for the system for sale of Power in bulk to WAPDA (NTDC) / NTDC / PESCO .One double Circuit 132 KV Transmission line complete in all respect with an estimated length of 132 km (Length could be varied according to the site requirement.)

10.2.7 Estimates of Power Transfer from Chitral District

The power plants that are proposed are presented as follows:



The power plants that are considered economic are discussed above. The schedule of addition of the plants is presented as follow.

Capacity Addition and Power and Energy Outputs (Chitral District)										
No.	Name of Scheme	Installed Capacity	Annual Energy	July Capacity	Energy	Feb. Cap	Energy	Total Cap	Energy	Year of Addition
		MW	GWh/a	MW	GWh/a	MW	GWh/a	MW	GWh/a	
1	Golen Gol	106	436	106	71	106	12	106	436	2016
2	Lawi	70	303	70	49	70	8	70	303	2018
3	Akrari Gol	79	342	79	56	79	9	79	342	2020
4	Laspur-Muri Gram	133	538	133	88	133	15	133	538	2022
7	Turtonas-Uzghar	58	254	58	41	58	7	58	254	2024
6	Istoru-Buni	52	213	52	35	52	6	52	213	2026
7	Shogo-Khura Lasht	144	578	135	94	131	16	144	578	2028
8	Shusghui-Zhendoli	145	612	145	108	137	15	145	612	2030
9	Ushan-Ayun	30	131	30	21	30	4	30	131	2032
10	Darband-Barbuno	40	167	40	27	40	5	40	167	2034

Capacity Addition and Power and Energy Outputs (Chitral District)										
No.	Name of Scheme	Installed Capacity	Annual Energy	July Capacity	Energy	Feb. Cap	Energy	Total Cap	Energy	Year of Addition
11	Mujiggram-Shogo	51	231	51	38	51	6	51	231	2036
12	Nechhchcherdim-Paur	80	321	80	52	80	9	80	321	2038

The expected power flow from Chitral District to The NTDC system is as follows:

Power Flow Chitral District						
	Jul		Feb.		Total	
	Capacity	Energy	Capacity	Energy	Capacity	Energy
Year	MW	GWh/a	MW	GWh/a	MW	GWh/a
2016	106	71	106	12	106	436
2017	106	71	106	12	106	436
2018	185	150	185	91	185	515
2019	185	150	185	91	185	515
2020	264	206	264	100	264	857
2021	264	206	264	100	264	857
2022	397	293	397	115	397	1395
2023	397	293	397	115	397	1395
2024	455	335	455	121	455	1649
2025	455	335	455	121	455	1649
2026	507	369	507	127	507	1862
2027	507	369	507	127	507	1862
2028	642	463	638	143	651	2440
2029	642	463	638	143	651	2440
2030	787	571	775	158	796	3052
2031	787	571	775	158	796	3052
2032	817	592	805	162	826	3183
2033	817	592	805	162	826	3183
2034	857	620	845	166	866	3350
2035	857	620	845	166	866	3350
2036	908	657	896	172	917	3581
2037	908	657	896	172	917	3581
2038	988	710	976	181	997	3902

10.2.8. Design Considerations

Chitral Valley and District can be accessed by the Lowari Pass, which is approximately 3200m and is closed during the winter due to snow and danger of avalanches. To transmit power produced within the Chitral Valley transmission lines need to cross the Lowari Pass and to connect to existing 66 kV Dir and 132 kV Timergara substations. The recommended line routing is to follow the Chitral River up to Mirkhani and to cross the Lowari Pass reaching Dir and Timergara Substations following the Panjkoora River from Dir Substation onwards.

In 1995 a 33 kV line was constructed from Did substation to Joti Lasht substation in Chitral crossing the Lowari Pass, during the winter of 1995/96 the line collapsed at the pass region due to climatic over loadings .It has been reported that the Lowari Pass, on average, gets 10-12 inches snow every winter , snow fall starts , usually , in December and lasts to March/April . Permanent snows during the winter start at 2000m. Freezing rain is rare and if it does happen it tends to occur at the end of the winter. Some 11 kV structures in Drosh also failed in one winter due to snow.

Lowari Top experiences high winds, the wind direction are from usually form the Chitral side and less frequently it can also be from the Dir side. Minimum temperatures of -25^{0}C accompanied with high winds is reported in the winter; in summer temperatures of up to 30^{0}C are expected. Inspections of the line during winter reveal covering of ice on the conductor (Dog) with an overall diameter of approximately 5cm. estimates (based upon 0.6 kp/dm3 for the ice on the 14.17 dia. Dog conductor results in approximately 1.083 kp weight per meter of conductor) of thickness of ice were approximately 18mm.. Lines in Dir District do not experience ice loading. Detailed specifications, ice loadings, total weight with ice, sag spans, conductor types and routes are presented in the report "132 kV Line Golen Gol –Chakdara- Feasibility Study" by H. Lugschitz ,Verbund , Vienna , and T.N Malik HEPO , Lahore, 19 November 1996 , GTZ-HEPO.

10.2.9 Transmission Interconnection Study

10.2.9.1 Introduction

The intake with the dam is located on Arkari River 8 km upstream its junction into Lutkho River nears the village of Uchhatur. From there, the water is transferred through a desander basin, horizontal low pressure tunnel , surge chamber system and vertical pressure shaft with horizontal pressure tunnel to the surface-type powerhouse situated on right bank of Arkari River near its junction with Lutkho River near the village of Andakht. The output from the Arkari HPP is to be interconnected to the Mujigram-Shoghore HPP.

The Mujigram-Shoghore Hydro Power Project is one of the identified hydel projects in Chitral valley which is under feasibility stage. The Project proposed weir site is located on Lutkho River near Mujigram Village approx. 3 km downstream of Garam Chashma. Lutkho River is a right tributary of Mastuj River and forms together with Chitral River. The confluence is about 5 km upstream of Chitral Town. The project layout is proposed on the right bank of Lutkho River with a powerhouse site near Shoghore village, which is located opposite to Ojhor Gol northwest of Chitral Town at a distance of approx. 26 km.

10.2.9.2 Overview

This feasibility report analyzes the role of Arkari and Mujigram-Shoghore Hydropower Project in meeting the growing power demand of the country and proposes a technically and economically feasible transmission system for dispersal of the power generated to the main Grid. The load demand and power supply analysis has been carried out based on the latest load forecast and generation expansion plan provided by NTDC and also describes the proposed corridor for the transmission line from Mujigram-Shoghore to the grid station to be constructed by NTDC near Chitral town. The output from the Arkari HPP will be fed to the Mugigram –Shoghore HPP.

10.2.9.3 Objectives of Study

The main objectives of the study are:-

- To provide guidance for selecting voltage level for power evacuation, bus bar arrangement for connected switchyard, interconnection with isolated load or grid, selection of necessary protection scheme for the selected grid interconnection.

- Flexibility to deal contingencies with safety and reliability, fulfil the criteria of NTDC Grid Code approved by NEPRA in terms of acceptable transmission parameters for normal (N-0) and contingency (N-1) conditions both under disturbed dynamic/transient conditions and steady state conditions.
- To establish a reliable, economical and viable Inter-connection Scheme for dispersal of power from the Arkari and Mujigram-Shoghore HPP.

- To ensure that the generation of Arkari and Mujigram-Shoghore HPP can be delivered to proposed 220/132 kV Chitral grid station which will be constructed by NTDC.

10.2.9.4 Transmission Corridor General Description

Transmission Corridor is an approachable passage of at least 25 meters width and considerable length between the two terminal stations. It is usually selected to safely accommodate the proposed transmission line taking in to account all the technical, economic, social, environmental and cultural parameters.

10.2.9.4.1 Weather Conditions

The weather conditions in the Project Area are severe and the terrain is snowy in winters thus there is a possibility of landslides and avalanches. To overcome these hazards or to increase the reliability of transmission lines following measures have to be taken care of:

- Installation of stronger conductors with better mechanical properties to carry increased ice and wind loads.
- Installation of stronger towers to withstand snow slide, snow pressure, ice and wind loads and the forces from stronger conductors.
- The towers shall be so spotted that strips with danger of snow slide or avalanches can be avoided to cross or are crossed in long free span.

10.2.9.4.2 Terrain Description

The terrain is mostly dry, rugged and barren, the land uses of the corridor is rural and typical in nature, agricultural-based land uses are seen in small patches scattered in the corridor area. The predominant developed land use throughout the Project Area is slightly developed including semi-rural residential patches with single-family houses. Residential development reaches its highest density in Chitral Town or in its vicinity.

It is anticipated that land uses will remain relatively unchanged during the next few decades. Increase in growth rate is expected, but the overall rural character of the project /corridor area should remain unchanged.

10.2.9.4.3 Transmission Corridor Routes

The transmission line corridor route emerging from Mujigram-Shoghore Hydro Power Project on the right bank of Lutkho River goes down stream towards Shali. Then corridor enters Sin, which has high altitude mountains on the right bank of the river, thus the corridor has to divert to the left bank of the river, which has big terraces and with small agricultural activity. The corridor, before entering Lasht, again diverts to the right bank Before Singur, River Luthkho joins River Mastuj and becomes Chitral River. From Singur, the corridor enters Balach. At Chew Bridge, the corridor on the right bank of the River Chitral enters Chitral Town, from where the corridor cross the river and enters Devashish on the left bank of the river. From this point, the corridor pass through Jughor, The routes then pass through Bakarabad and Chamarkun before entering proposed new Chitral grid station (to be constructed by NTDC) near 33/11 kV Jutilasht grid station.

10.2.9.4.4 Selection of Voltage Level for Dispersal of Power from Project

The system voltage in ehv system very much affect the capital cost of transmission line. The weight of conductor material, the efficiency of the line, the voltage drop in the line and system stability depends upon system voltage. The choice of voltage therefore, is a major factor in the line designs.

While selecting the transmission voltage, the present and future expected voltage of other lines in vicinity of the line under design are taken into account. The selection of highest system voltage to be used at the generating step up substation depends upon the following main consideration.

- Length of transmission line from Arkari to Mujigram-Shoghore and from Mujigram-Shoghore HPP to 220/132 kV Chitral grid station.
- Voltage level available at the receiving substation and suitability of
- connectivity.
- Power System Network of the area for stability and future extension works in the vicinity of the generating stations
- Safety, Reliability, Economy and Simplicity of operation and good technical performance.
- Selection of required voltage level by using standard empirical formulae.

Keeping in view of the existing network and after studying the all factors, capacity and location of proposed power project site and to provide flexible transmission interconnection, the team of experts studied various possible interconnection arrangements / options to connect the proposed power plant with the bus bar of 220/132 kV Chitral grid station. The arrangement should fit in the planning criteria used to design the connected transmission system.

10.2.9.4.5 Interconnection Alternatives

Strategic approach for dispersal of power from large hydropower stations on Chitral River and its tributaries requires a very strong, reliable and stable transmission system. Hydropower projects like Golen-Gol, Shogo-Sin and Shushghai-Zhendoli have completed their feasibility studies and now these projects are under various construction and implementation stages. Their capacities are expected to be 106 MW, 132 MW and 144 MW respectively. **Figure 10.2.1** on the following page shows the conceptual scheme of development of transmission system, as envisaged by National Power Expansion Plan 2011-2030. The concept is to connect hydropower plants at 132 kV level with a collector hub of 220/132 kV at Chitral from where a 220 kV double circuit Chitral-Chakdara (using Greely conductor) would be adequate to evacuate all the collected power to the main grid. However the additional 132 kV circuits in the collector network in Chitral Valley may be required depending on the sequence of additions of hydropower plants in this valley.

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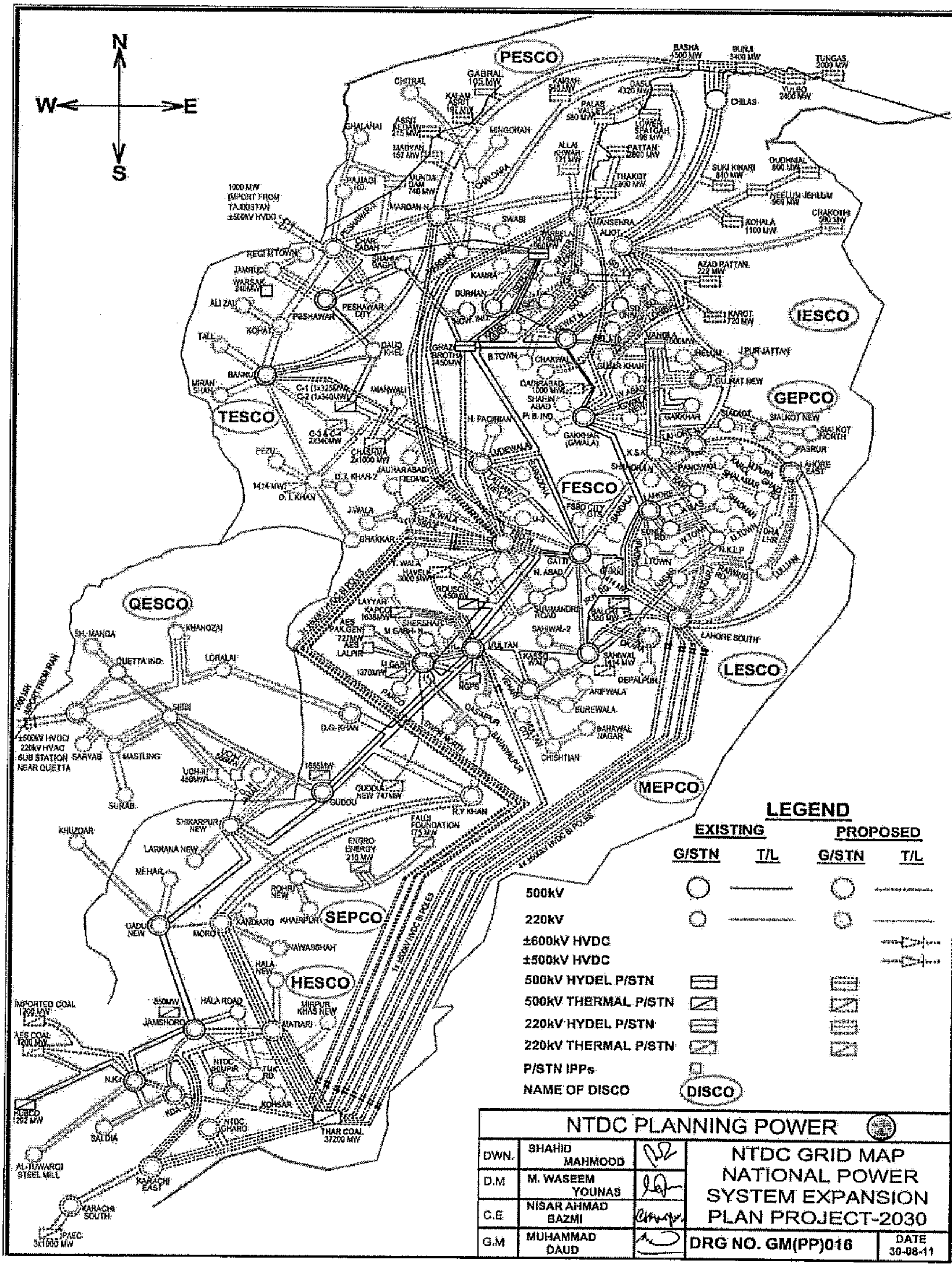
Figure 10.2.1: 500/220 kV System in the Ultimate Year 2030



10.2.9.4.6 Interconnection Options

A comprehensive scheme for dispersal of power from Mujigram-Shoghore Hydro Power Project to load centers has been envisaged for transmitting power emanating from Mujigram-Shoghore Hydro Power Project to the National grid. A set of voltage levels along with the number of circuits have been considered, based on the technical parameters and general load ability indices of HV lines. Presently the expansions of DISCO transmission network are frozen up to 66kV level while it is assumed that the expansion of transmission network up to the 132 kV level will be frozen at the year 2020.

Option – I

In this option, a 132 kV transmission line may originate from the Mujigram-Shoghore HPP and will directly connected to proposed 220/132 kV Chitral grid station.

Option – II

In second option, the evacuation of generation from Mujigram-Shoghore HPP to proposed 220/132 kV Chitral grid station will be carried out through two 132 kV transmission lines. One transmission line will be directly connected with 220/132 kV proposed Chitral grid station and other will be connected with 132 MW Shogo-Sin HPP via an In/Out arrangement.

Option – III

In this option, 132 kV double circuit transmission lines may originate from Mujigram-Shoghore HPP and will be directly connected to the 132 kV bus bar of Shogo-Sin HPP which is about 6 km downstream from Mujigram-Shoghore HPP, from where the combine generation of both hydro power project will be transmitted to 220/132 kV proposed Chitral grid station.

However, details will be provided in the load flow studies which are under preparation. Load flow studies for Arkari to Mugigram interconnection are to be carried out under separate arrangements.

10.2.10. Conclusion

Two power plants, Golen Gol and Lawi are under implementation. There are ten others that are being planned for addition over time. There is need to develop a consolidated , long term plan for the transmission interconnection between Chitral District and The System .The 132 kV double circuit Interconnection presently planned for Golen Gol may need to be changed to 220 kV Double Circuit , so as to cater for the planned schemes.

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It is suggested that NTDC, Office of General Manager Planning (Power) may be requested to undertake load flow studies and develop a long term interconnection for transmission interconnection of Chitral District with the System. Line design will need special considerations related to: spans; ice loading; and conductor types, for portions identified to be prone to heavy winter snow falls.

PHYDO convened a meeting of all consultants engaged in development of feasibility studies IN KPK, on September 17, 2013. The meeting concluded that PHYDO will coordinate with NTDC and if necessary engage a consultant to prepare a transmission interconnection plan for KPK.

Load flow and stability studies to interconnect the Arkari HPP will be carried out under separate arrangements. The analysis is based on the fact that the output from the proposed power plant will be delivered to the NTDC system, since the local demand is already met or is being met with existing and ongoing projects.

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VOLUME 3: APPENDICES – Part I

VOLUME 4: APPENDICES – Part II

12.1 Final Power & Energy Calculations

The layout of Arkari HPP has been selected based on suitable topography, geology and economic evaluation. The project layout has been proposed on the right bank of Arkari Gol along with the diversion weir, low pressure tunnel, surge tank, pressure shaft, surface powerhouse and tailrace channel.

The river bed of Arkari Gol at weir site is 2164 m.a.s.l. and at the tailrace outlet, it is 1845 masl. Capacity optimization has been carried out and optimum discharge of 36 m^3/s has been selected to have the maximum net benefits. Weir height also been selected on the basis of maximum net benefits for daily peaking and environmental considerations in the reservoir area.

The maximum and minimum operating head water levels are proposed as 2190 m and 2186 masl. Tailwater level varies from 1845 to 1848 masl depending upon the flows in the river. Net head for the turbine has been estimated after excluding the losses in the waterways from the gross head. At power intake, power and energy potential have been estimated using monthly discharges, residual flows in Arkari Gol and peaking option

12.1.1 Availability of Flows

The flows at Arkari weir site have been estimated by establishing a correlation between observed flows of Arkari Gol and Chitral river at Chitral. Monthly flows from 1964 to 2011 have been estimated to assess the flow variation over the various years. The mean annual flow series at the dam site is presented in **Figure - 12.1.1**

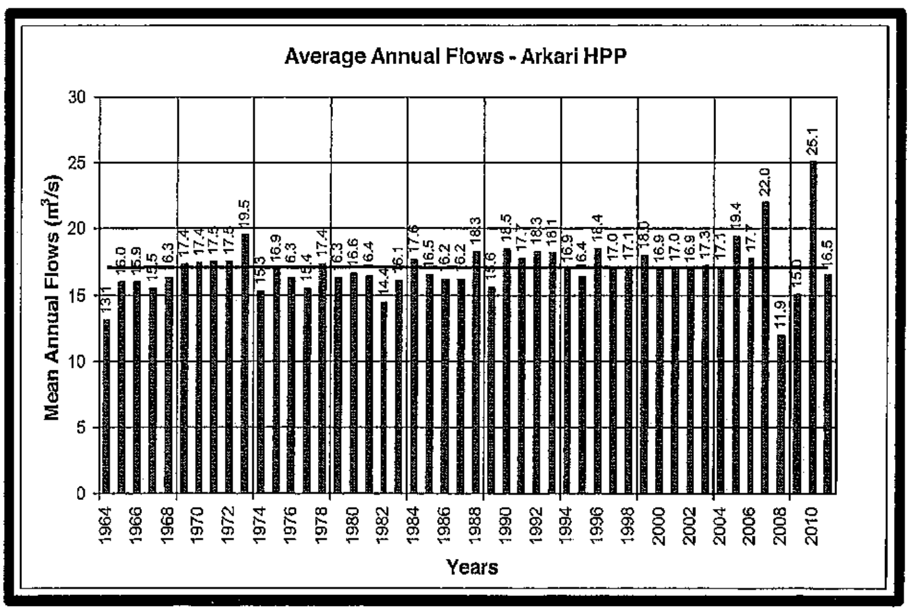

Figure – 12.1.1: Mean Annual Flows – Arkari Gol at Weir site

The mean annual flows vary from 11.93 m^3/s to 25.1 m^3/s with average value of 17.02 m^3/s in the recorded period. Based on the annual volume, wet, average and dry years have been selected as 2008, 2001 and 2010 in the last 48 years. Out of 48, there are 21 years with annual flows below average and 9 years with flows above average and in the remaining years, the mean annual flows are close to average years.

For wet year 2010, the mean annual flow is 25.1 m^3/s and the mean monthly flow varies from 6.8 m^3/s in March to 65.8 m^3/s in August. The availability of design discharge of 36 m^3/s in the year 2010 is for over three months. The mean monthly flows in year 2010 are presented in **Figure 12.1.2.**

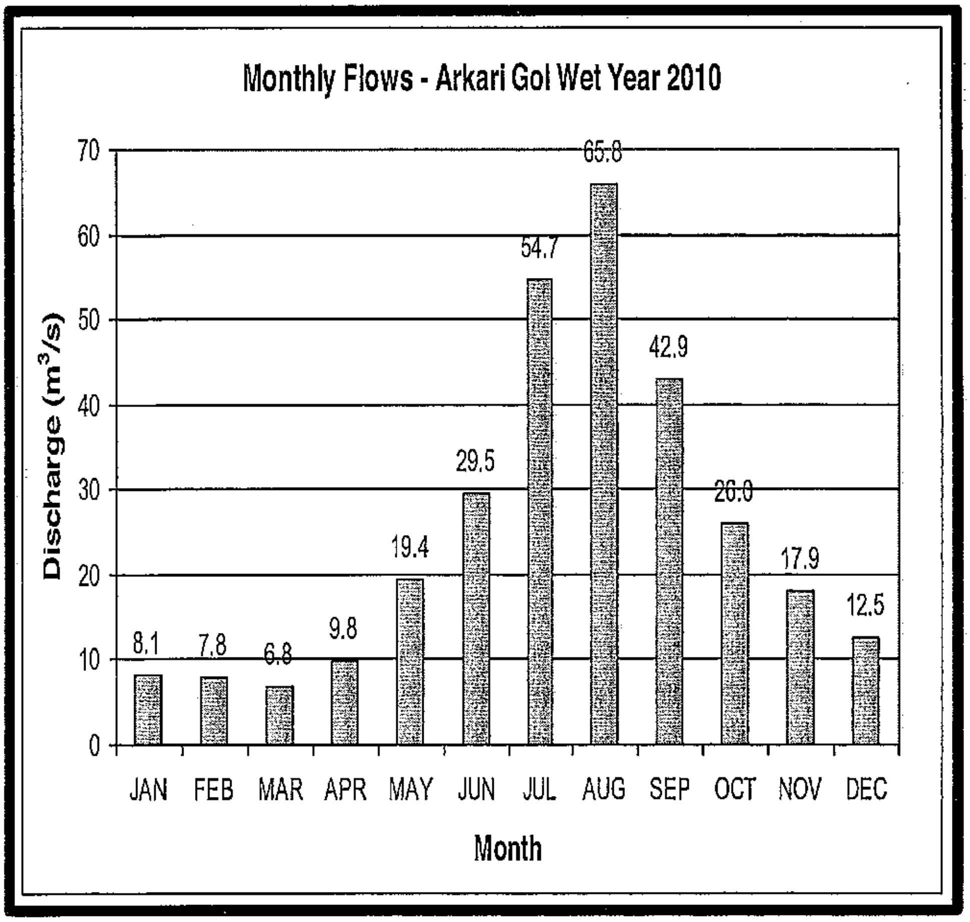

Figure – 12.1.2: Mean Monthly Flows at Weir Site Wet Year 2010

Year 2001 is considered as the average year with mean annual flows as 17.03 m^3/s. The mean monthly flows vary from 5.3 m^3/s in February to 41.8 m^3/s in July. The availability of design discharge of 36.0 m^3/s is about three months. The mean monthly flows in the average year 2001 are presented in **Figure 12.1.3**

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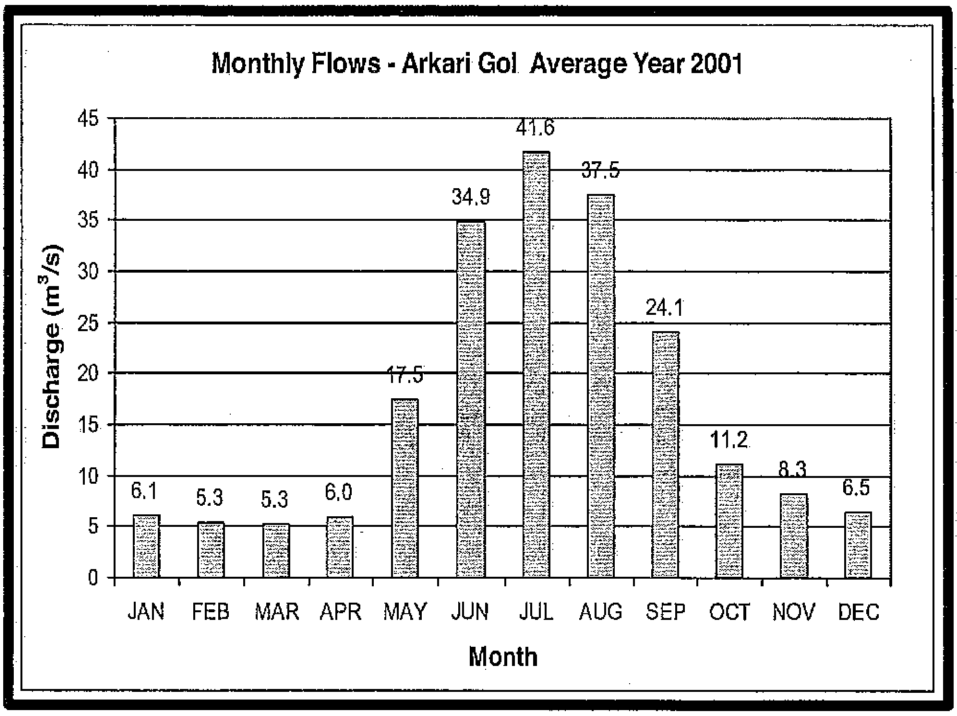

Figure – 12.1.3: Monthly Flows at Weir Site Average Year 2001

The mean annual flow in 2008 is 27.0 m^3/s, which is a dry year. There are minimum flows in the last 48 years. The mean monthly flows vary from 5.7 to 25.3 m^3/s. The 10 daily flows are graphically presented in **Figure 12.1.4**

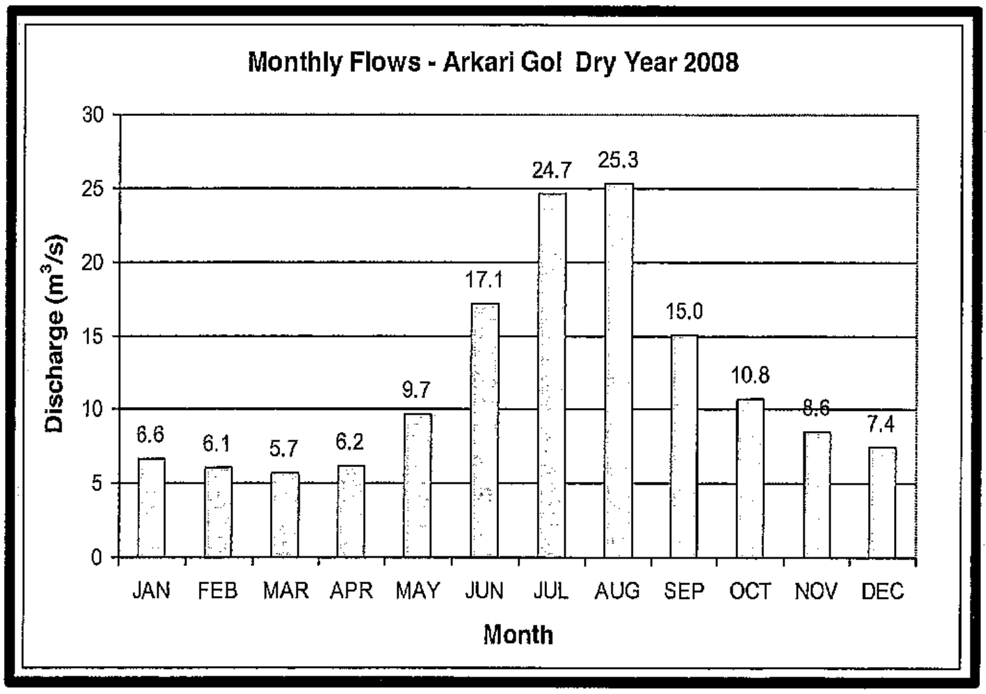

Figure – 12.1.4: Monthly Flows at Arkari Weir Site - Dry Year 2008

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12.1.2 Head and Tail Water Levels

The maximum and minimum operating reservoir levels are 2190 and 2186 m.a.s.l respectively. The reservoir fluctuation of 4 m would provide a live storage of 0.670 MCM and a corresponding discharge of 36.0 m^3/s during the 4 hour peak. The live storage would be utilized as per river inflow at the weir intake. Tail water level would vary from 1845 to 1848 2230 m depending the flows in Arkari Gol. The difference of headwater and tail water provide the gross head. Net head is obtained after deducting the losses in the waterways.

12.1.3 Methodology for Estimation of Power and Energy

Power and energy have been estimated for the design discharge of 36 m^3/s. Power and energy outputs have been calculated for a period of 48 years using monthly estimated flows. For the three years, 2010 as wet year, 2001 as average year and 2008 as dry year, power and energy have been estimated and are presented in **Tables 12.1.2, 12.1.3 and 12.1.4** Monthly power and energy of 48 years from 1964 to 2011 have been estimated and are presented as Appendix 12.1-2.

12.1.3.1 Power

The power and energy have been estimated on the basis of 10-daily flows. The design capacity is computed with the following formula;

$$P = \eta * g * Q * H / 1000$$

where:

a) **P** is capacity (MW) estimated from 10 days discharge and corresponding head.

b) **Q** is the 10 days discharge with maximum value of design discharge Q_d (m^3/s).

c) **H** is net head (m), which is estimated from gross head with deduction of head losses in the power waterway.

d) η is combined efficiencies of turbine, generator, transformer and that of the hydraulic system upstream of the powerhouse.

e) **g** is acceleration due to gravity = 9.81 m/s^2

12.1.3.2 Mean Annual Energy and Plant Factor

The mean annual energy is estimated on the basis of 10-daily flows using the following formula.

$$E = \eta * g * Q * H * t / 10^6$$

where:

a) **E** is mean annual energy in GWh/annum.

b) **Q** is average design discharge (m^3/s).

c) t is time in hours over 10 days.

12.1.3.3 Plant Factor

The plant factor which provides the basis for the installed capacity of the project is calculated as follows:

$$\mathbf{pf} = (E/(P*8.760))*100$$

where:

a) **pf** = Plant factor (%)

b) **E** is mean annual energy (GWh/annum)

c) **P** is Installed capacity (MW)

12.1.4 Basic Assumptions

The following basic assumptions have been made in estimating the power and energy of the project .

a) The residual water in Arkari Gol during the low flow period has been taken as 0.80 m^3/s in the winter months and 2.0 m^3/s in the summer months. It is based on minimum flows required in the river for environmental purpose.

b) The variations in the efficiencies of the generating units due to changes of net heads have not been considered. For the design discharge available to the powerhouse, an efficiency of 91.0%, 97.0% and 99% has been used for the turbine, generator and transformers, respectively.

c) The head loss has been considered as 10.97 m in headrace tunnel, 4.20 m in pressure shaft/pressure tunnel. The total losses including losses at intake, bends, bifurcation pipes, and miscellaneous etc are taken as 17.25 m to estimate the net head for the turbine. The losses would be less for a discharge less than the design.

d) During the low flow periods, when the discharge of Arkari Gol is

less than 36 m^3/s, the live storage is used to store water in off-peak hours to improve the flows for power generation in the peak hours. It has been estimated that 0.67 million m^3, storage would provide additional flows in 4 peak hours.

e) Energy is calculated by multiplying the number of days in a month

and 24 hours in a day. For power and energy during peak and off peak hours, the volume of water available for storage and inflow volume in 24 hours is used to calculate the corresponding discharge. The power during peak and off peak hours is used to calculate the corresponding energy.

12.1.5 Estimated Power and Energy

The selected design discharge is 36 m^3/s, and normal maximum and minimum reservoir operating level are 2190 m and 2186 m.a.s.l. For Pelton turbine, considering the suitable site for surface powerhouse, the turbine axis has been selected as 1854.7 m. The net head varies between 318 to 324 m with an average value of 319.0 m.

For the design discharge of 36 m^3/s and net head of 319 m, the optimum installed capacity would be **99 MW** with average mean annual energy of **377.92 GWh**. The plant factor has been taken as 43.6%.

Power and energy have been estimated using monthly flows of Arkari at Weir site from the year 1964 to 2011. For each year, power during 4 hour daily peak, off peak hours and energy has been estimated and presented as Appendix 12.1-2.2.

For wet year 2010, monthly energy curve is presented in **Figure 12.1.5**.

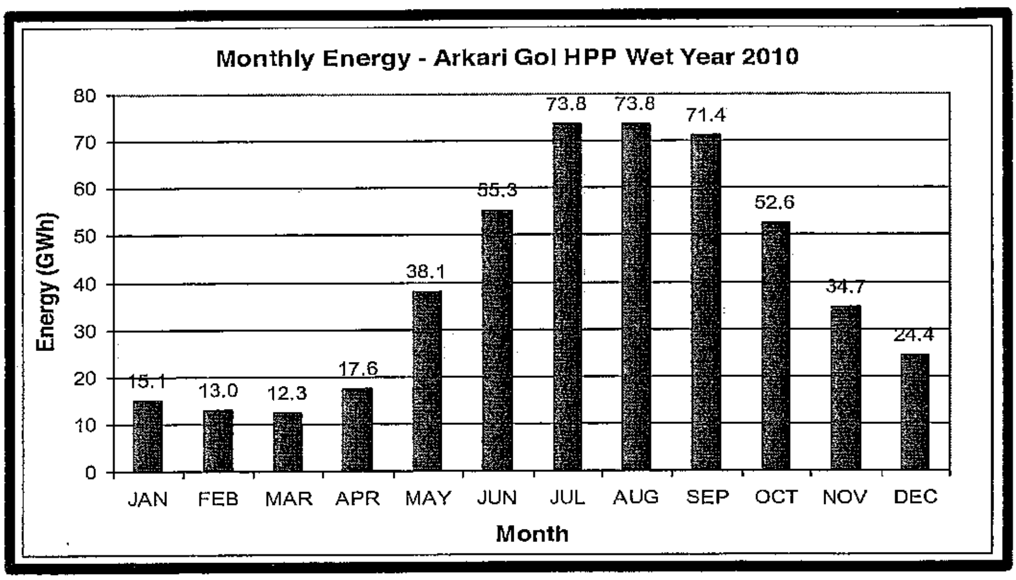

Figure – 12.1.5: Monthly Energy for Wet Year - 2010

The above curves indicate that energy during the low flow months from October to March is low and high energy is available during the summer six months.

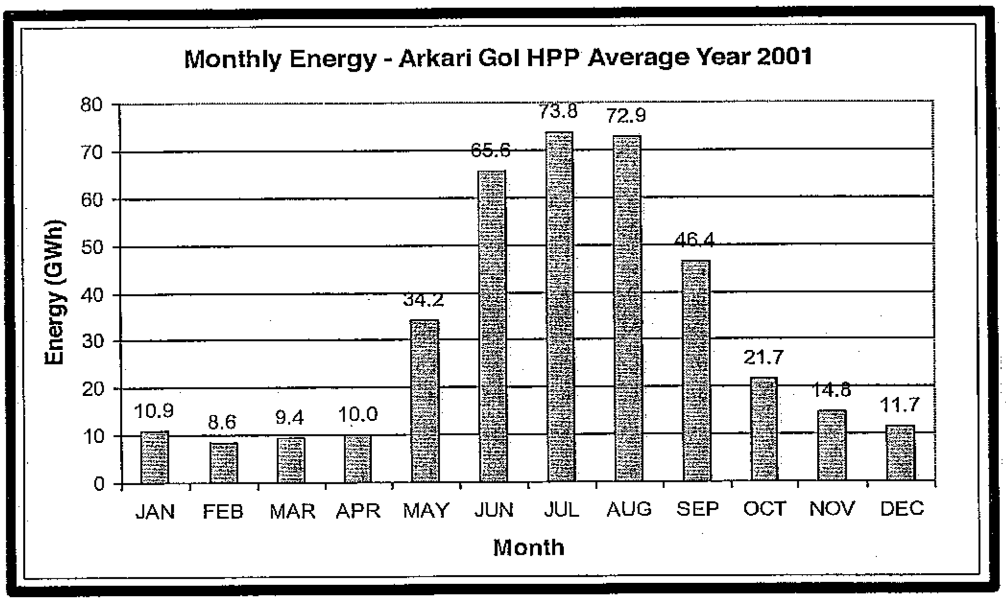

Figure – 12.1.5: Monthly Energy for Average Year - 2001

Monthly daily energy curve for average year 1983 are presented in **Figure 12.1.5**. The low flow months with less energy are from November to January. Similarly energy curve for the dry year 2008 is presented in **Figure 12.1.6**. The energy even during the summer months is less and low energy period is spread over longer period.

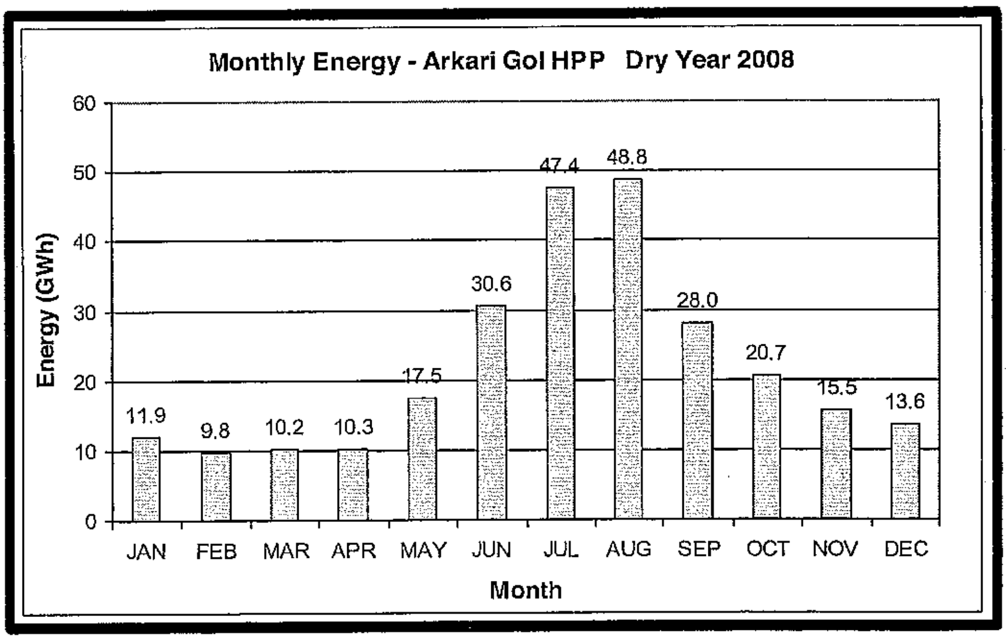

Figure – 12.1.6: Monthly Energy for Dry Year - 2001

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The mean annual energy for the recorded period from 1960 to 2010 has been estimated and presented as Appendix12.2.

The calculated annual energy, for the years 2010 wet year, 2001 average year and 2008 dry year, is 482.0, 379.97 and 264.34 GWh respectively. The energy calculated based on the daily flows for 48 years ranges between 264.34 GWh to 482.0 GWh as presented in **Figure 12.1.7** The average annual energy for the recorded period is 377.92 GWh.

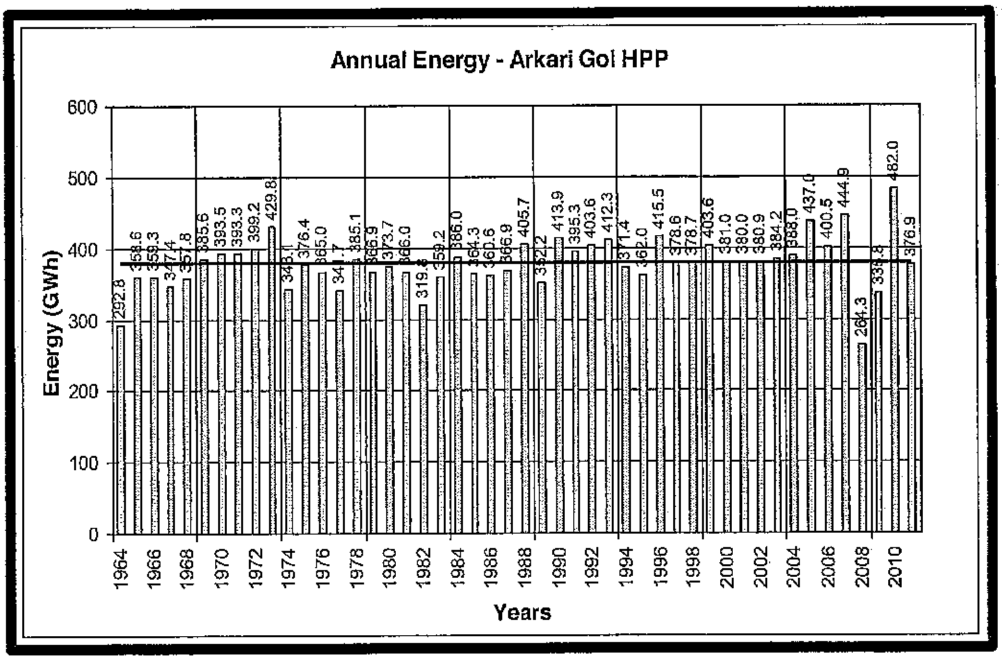

Figure – 12.1.7: Mean Annual Energy from 1964 to 2011

12.1.6 Utilization of Arkari Gol Flows- Arkari Hpp

Arkari HPP has been planned to utilize Arkari Gol potential resources in its lower stretch of 9 km. The project layout has been optimized for installed capacity of 99 MW, firm power of 79.2 MW and to generate 377.92 GWh annually with plant factor of 43.6%. Water utilization factor for Arkari powerhouse has been estimation as 91.0% and the volume of spillage at the weir site is 9.0%. Annual flows, spillage, firm power, peak energy, off-peak energy and plant factor for each of the 48 years from 1964 to 2011 are presented in **Table 12.1.1**.

Table -12.1.1 Annual Flows and Energy								
	Mean Annual Flow			Firm	Annual Energy			Plant
Year	River	Power	Spillage	Power	Peak	Off Pk	Total	Factor
	(m^3/s)	(%)	(%)	(MW)	(GWh)	(GWh)	(GWh)	(%)
1964	13.10	91%	9%	65.25	132.43	160.33	292.76	33.8
1965	16.03	91%	9%	70.46	134.42	224.14	358.55	41.3
1966	15.94	92%	8%	67.41	133.98	225.35	359.33	41.4
1967	15.46	92%	8%	69.45	135.01	212.36	347.37	40.1
1968	16.35	90%	10%	71.25	135.18	222.59	357.77	41.3
1969	17.35	91%	9%	94.38	143.54	242.02	385.56	44.5
1970	17.40	93%	7%	80.05	139.91	253.55	393.46	45.4
1971	17.50	92%	8%	79.84	137.85	255.45	393.30	45.4
1972	17.54	93%	7%	98.77	144.39	254.77	399.16	46.0
1973	19.50	90%	10%	84.85	140.32	289.53	429.84	49.6
1974	15.28	92%	8%	85.29	139.66	203.45	343.10	39.6
1975	16.87	91%	9%	69.34	134.80	241.57	376.37	43.4
1976	16.29	92%	8%	76.06	137.93	227.04	364.97	42.1
1977	15.42	91%	9%	79.52	135.53	206.21	341.74	39.4
1978	17.36	91%	9%	68.19	135.05	250.08	385.13	44.4
1979	16.31	92%	8%	71.79	136.92	229.95	366.87	42.3
1980	16.62	92%	8%	76.18	140.21	233.48	373.69	43.1
1981	16.41	91%	9%	70.40	136.77	229.26	366.02	42.2
1982	14.39	91%	9%	66.24	133.33	186.49	319.83	36.9
1983	16.11	91%	9%	64.32	132.06	227.17	359.23	41.4
1984	17.61	90%	10%	75.76	137.57	248.46	386.03	44.5
1985	16.53	90%	10%	78.92	136.26	228.01	364.27	42.0
1986	16.17	91%	9%	78.69	138.79	221.85	360.64	41.6
1987	16.18	93%	7%	77.74	138.67	228.28	366.94	42.3
1988	18.27	91%	9%	80.98	139.57	266.13	405.70	46.8
1989	15.55	92%	8%	74.13	135.69	216.54	352.23	40.6
1990	18.49	92%	8%	77.10	137.32	276.58	413.90	47.7
1991	17.74	91%	9%	86.61	140.86	254.40	395.26	45.6
1992	18.29	90%	10%	82.91	141.18	262.47	403.65	46.5
1993	18.12	93%	7%	94.10	143.88	268.46	412.34	47.5
1994	16.92	90%	10%	68.48	135.03	236.37	371.39	42.8
1995	16.38	90%	10%	72.90	136.69	225.31	362.00	41.7
1996	18.43	92%	8%	78.85	139.57	275.94	415.51	47.9
1997	16.99	91%	9%	80.31	140.32	238.27	378.59	43.7
1998	17.11	90%	10%	75.13	138.30	240.44	378.74	43.7

Table –12.1.1 Annual Flows and Energy								
	Mean Annual Flow			Firm	Annual Energy			Plant
Year	River	Power	Spillage	Power	Peak	Off Pk	Total	Factor
1999	17.97	92%	8%	80.06	140.38	263.25	403.63	46.5
2000	16.90	92%	8%	81.51	140.57	240.41	380.99	43.9
2001	17.03	91%	9%	75.59	135.24	244.73	379.97	43.8
2002	16.91	92%	8%	74.04	136.93	243.98	380.92	43.9
2003	17.25	91%	9%	76.19	137.87	246.36	384.23	44.3
2004	17.08	93%	7%	77.02	138.32	249.68	388.01	44.7
2005	19.43	92%	8%	87.87	142.62	294.34	436.96	50.4
2006	17.74	92%	8%	98.77	144.39	256.12	400.51	46.2
2007	22.03	83%	17%	87.57	142.06	302.83	444.88	51.3
2008	11.93	90%	10%	81.88	139.08	125.26	264.34	30.5
2009	15.01	91%	9%	92.63	143.32	192.43	335.76	38.7
2010	25.10	79%	21%	98.76	144.46	337.53	481.99	55.6
2011	16.51	93%	7%	96.05	144.04	232.84	376.88	43.5
Mean	**17.02**	**91.0%**	**9.0%**	**79.16**	**138.51**	**239.42**	**377.92**	**43.6**

Table – 12.1.2 Power and Energy - Average Year 2001										
Installed Capacity 99 MW				Firm Power 75.6 MW				Plant Factor 43.8%		
	Discharge				Head			Energy		
MONTH	River	Power	Peak	Off Peak	Head Water	Turbine Level	Net Head	Peak	Off Peak	Total
	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m)	(m)	(m)	(GWh)	(GWh)	(GWh)
JAN	6.07	5.27	32	0	2188.9	1854.7	320.2	10.87	0.00	10.87
FEB	5.35	4.55	27	0	2189.0	1854.7	323.2	8.55	0.00	8.55
MAR	5.30	4.50	27	0	2189.0	1854.7	323.3	9.37	0.00	9.37
APR	5.97	4.97	30	0	2188.9	1854.7	321.5	9.97	0.00	9.97
MAY	17.51	16.31	36	12	2189.2	1854.7	317.2	12.26	21.91	34.18
JUN	34.88	32.88	36	32	2189.9	1854.7	317.9	11.89	53.75	65.65
JUL	41.62	39.62	36	36	2190.0	1854.7	318.1	12.30	61.48	73.78
AUG	37.51	35.51	36	35	2190.0	1854.7	318.0	12.30	60.57	72.86
SEP	24.14	22.94	36	20	2189.4	1854.7	317.5	11.88	34.56	46.44
OCT	11.24	10.44	36	5	2188.9	1854.7	317.0	12.25	9.46	21.71
NOV	8.25	7.45	36	2	2188.8	1854.7	316.8	11.85	2.99	14.85
DEC	6.53	5.73	34	0	2188.8	1854.7	318.1	11.74	0.00	11.74

Table – 12.1.2 Power and Energy - Average Year 2001										
Installed Capacity 99 MW				Firm Power 75.6 MW				Plant Factor 43.8%		
	Discharge				Head			Energy		
MONTH	River	Power	Peak	Off Peak	Head Water	Turbine Level	Net Head	Peak	Off Peak	Total
Mean	17.0	Flow for Power		91.3%	Spillage	8.7%		**135.24**	**244.73**	**379.97**

Table – 12.1.3 Power and Energy – Dry Year 2008										
Installed Capacity		99	MW	Firm Power		81.9	MW	Plant Factor		30.5%
	Discharge				Head			Energy		
MONTH	River	Power	Peak	Off Peak	Head Water	Turbine Level	Net Head	Peak	Off Peak	Total
	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m)	(m)	(m)	(GWh)	(GWh)	(GWh)
JAN	6.62	5.82	35	0	2188.8	1854.7	317.7	11.91	0.00	11.91
FEB	6.08	5.28	32	0	2188.9	1854.7	320.2	9.84	0.00	9.84
MAR	5.70	4.90	29	0	2189.0	1854.7	321.8	10.15	0.00	10.15
APR	6.15	5.15	31	0	2188.9	1854.7	320.7	10.30	0.00	10.30
MAY	9.65	8.45	36	3	2188.8	1854.7	316.9	12.25	5.23	17.48
JUN	17.13	15.13	36	11	2189.1	1854.7	317.2	11.87	18.78	30.65
JUL	24.68	22.68	36	20	2189.4	1854.7	317.5	12.27	35.17	47.44
AUG	25.32	23.32	36	21	2189.5	1854.7	317.5	12.27	36.49	48.76
SEP	15.02	13.82	36	9	2189.1	1854.7	317.1	11.86	16.12	27.98
OCT	10.76	9.96	36	5	2188.9	1854.7	317.0	12.25	8.43	20.69
NOV	8.57	7.77	36	2	2188.8	1854.7	316.9	11.85	3.66	15.51
DEC	7.45	6.65	36	1	2188.7	1854.7	316.8	12.25	1.38	13.63
Mea	11.9	Flow for Power		90.1%	Spillage	9.9%		**139.08**	**125.26**	**264.34**

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Table – 12.1.4 Power and Energy – Wet Year 2010										
Installed Capacity	99	MW	Firm Power		98.8	MW	Plant Factor		55.6%	
	Discharge				Head			Energy		
MONTH	River	Power	Peak	Off Peak	Head Water	Turbine Level	Net Head	Peak	Off Peak	Total
	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)	(m)	(m)	(m)	(GWh)	(GWh)	(GWh)
JAN	8.12	7.32	36	2	2188.8	1854.7	316.8	12.25	2.82	15.07
FEB	7.80	7.00	36	1	2188.8	1854.7	316.8	11.06	1.92	12.98
MAR	6.82	6.02	36	0	2188.7	1854.7	316.8	12.25	0.04	12.29
APR	9.77	8.77	36	3	2188.8	1854.7	316.9	11.86	5.71	17.57
MAY	19.37	18.17	36	15	2189.2	1854.7	317.3	12.27	25.81	38.08
JUN	29.46	27.46	36	26	2189.6	1854.7	317.7	11.89	43.44	55.32
JUL	54.66	52.66	36	36	2190.0	1854.7	318.1	12.30	61.48	73.78
AUG	65.84	63.84	36	36	2190.0	1854.7	318.1	12.30	61.48	73.78
SEP	42.91	41.71	36	36	2190.0	1854.7	318.1	11.90	59.50	71.40
OCT	26.00	25.20	36	23	2189.5	1854.7	317.6	12.28	40.34	52.62
NOV	17.92	17.12	36	13	2189.2	1854.7	317.3	11.87	22.84	34.71
DEC	12.50	11.70	36	7	2189.0	1854.7	317.0	12.26	12.15	24.41
Mean	25.1	Flow for Power		78.6%	Spillage	21.4%		**144.46**	**337.53**	**481.99**

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	ARKARI GOL HYDROPOWER PROJECT	
	PROJECT COST ESTIMATE	
	1 US $ =PKR 105 (AS OF DEC; 2013)	
S. No.	**ITEMS**	**Amount (US $)**
A	**PRELIMINARY WORKS AND ENVIRONMENT**	
a.	GENERAL &PREPARATORY WORKS (TEMPORARY FACILITIES)	1,038,095
b.	LAND ACQUISITION	5,602,035
c.	ACCESS ROADS & BRIDGES	2,376,699
d.	MOBILIZATION / DEMOBILIZATION (2 % Of ITEM C)	868,114
e.	STAFF RESIDENTIAL COLONY	6,526,451
f.	ENVIRONMENTAL MITIGATION AND RESETTLEMENT COST	1,654,620
	SUB TOTAL (A)	**18,066,014**
B.	**CIVIL WORKS**	
a.	COFFER DAM	322,106
b.	WEIR (CFRD) WITH SPILLWAY	23,976,470
c.	DIVERSION TUNNEL	9,346,027
d.	INTAKE STRUCTURE	1,949,091
e.	APPROACH CHANNEL	1,639,257
f.	DESANDER	7,772,138
g.	FLUSHING CHANNEL	133,748
h.	ADIT TUNNEL	12,737,047
i.	HEAD RACE TUNNEL	20,631,700
j.	SURGE TANK & CHAMBERS	2,005,045
k.	PRESSURE SHAFT, PRESSURE TUNNEL & PENSTOCK	1,972,489
l.	POWER HOUSE	2,693,511
m.	TAILRACE DUCT	759,392
n.	PROTECTION & MISCELLENEOUS WORKS	611,880
	SUB TOTAL (B)	**86,549,902**
C.	**E & M**	
a.	COMPLETE E & M EQUIPMENT	39,905,683
b.	TRANSMISSION LINE	1,557,308
c.	SWITCH YARD	1,942,693
	SUB TOTAL (C)	**43,405,684**
	SUB TOTAL (A+B+C)	**148,021,600**
D	**MISCELLENEOUS CHARGES**	
a.	ERECTION,COMMISSIONING& TESTING CHARGES @12% OF ITEM (**C.a**)	4,788,682
b.	DUTIES, LC TAXES@ 5% OF ITEM (**C.a**)	1,995,284
c.	TRANSPORTATION & SHIPMENT CHARGES @7% OF ITEM (**C.a**)	2,793,398
d.	CONTINGENCIES @ 3 % OF ITEM **(A+B+C)**	4,440,648
E	**ENGINEERING SUPERVISION**	
a.	ENGINEERING SUPERVISION @6% OF ITEM (A+B+C)	8,881,296
F	**MANAGEMENT CHARGES**	
a.	ENGINEERING DESIGN @1% OF ITEM (B)	865,499
b.	PROJECT ADMINISTRATION CHARGES @ 4% OF ITEM (A+B+C)	5,920,864
	TOTAL PROJECT INVESTMENT COST	**177,707,270**
	FINANCIAL CHARGES	**641,477**
	TOTAL PROJECT COST	**178,348,747**
	COST PER MW	**1,801,502**

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ARKARI GOL HYDROPOWER PROJECT

COST ESTIMATE

ADIT TUNNEL

1 US $ =PKR 105 (AS OF DECEMBER 2013)

S.No	Description	Quantity	Unit	Rate (PKR)	Rate (US $)	Amount (PKR)	Amount (US $)	U.S $ (Million)
1	Excavation in Hard Rock	27079	m^3	15852	150.97	429,256,308	4,088,155	4.088
2	Excavation in Soft Rock	27079	m^3	9650	91.90	261,312,350	2,488,689	2.489
3	Excavation in Poor Rock	27900	m^3	3726	35.49	103,955,400	990,051	0.990
4	Grouted Bults 3.00 m Long	11731	Nos	4100	39.05	48,097,100	458,068	0.458
5	Steel Ribs (Size 160x80)	5500	Kg	300	2.86	1,650,000	15,714	0.016
6	Pre-cast Laggings	300	m^3	18913	180.12	5,673,900	54,037	0.054
7	Shotcrete With Fiber	2001	m^3	22721	216.39	45,464,721	432,997	0.433
8	R.C.C Tunnel Concrete (21 Mpa)	14232	m^3	17271	164.49	245,800,872	2,340,961	2.341
9	Reinforcement Steel (Grade-40) @96Kg/m^3	1366	Tons	137,000	1304.76	187,179,264	1,782,660	1.783
10	Drain Pipe 400mm Dia	2000	m	4,500	42.86	9,000,000	85,714	0.086
	TOTAL					1,337,389,915	12,737,047	12.737

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ARKARI GOL HYDROPOWER PROJECT

COST ESTIMATE

APPROACH CHANNEL

1 US $ =PKR 105 (AS OF DECEMBER 2013)

S.No	Description	Quantity	Unit	Rate (PKR)	Rate (US $)	Amount (PKR)	Amount (US $)	U.S $ (Million)
1	Excavation in Hard Rock	4050	m^3	15852	150.97	64,200,600	611,434	0.611
2	Excavation in Soft Rock	2430	m^3	9650	91.90	23,449,500	223,329	0.223
3	Excavation in Poor Rock	1620	m^3	3726	35.49	6,036,120	57,487	0.057
4	P.C.C (21 Mpa)	540	m^3	14500	138.10	7,830,000	74,571	0.075
5	R.C.C Tunnel Concrete (21 Mpa)	2295	m^3	17271	164.49	39,636,945	377,495	0.377
6	Expansion Joint	200	m	800	7.62	160,000	1,524	0.002
7	Water Proofing	2500	m^2	250	2.38	625,000	5,952	0.006
8	Reinforcement Steel (Grade-40) @96Kg/m^3	220	Tons	137000	1304.76	30,183,840	287,465	0.287
	TOTAL					172,122,005	1,639,257	1.639

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ARKARI GOL HYDROPOWER PROJECT								
COST ESTIMATE								
COFFER DAM (U/S & D/S)								
1 US $ =PKR 105 (AS OF DECEMBER 2013)								
S.No	**Description**	**Quantity**	**Unit**	**Rate (PKR)**	**Rate (US $)**	**Amount (PKR)**	**Amount (US $)**	**U.S $ (Million)**
1	Filling in Coffer Dam	27500	m^3	880	8.381	24,200,000	230,476	0.230
2	Stone Pitching	966	m^3	5819	55.419	5,621,154	53,535	0.054
3	Removal of Coffer Dam	2	LS	2000000	19047.619	4,000,000	38,095	0.038
	TOTAL					**33,821,154**	**322,106**	**0.322**

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ARKARI GOL HYDROPOWER PROJECT

COST ESTIMATE

STAFF RESIDENTIAL COLONY

1 US $ =PKR 105 (AS OF DECEMBER 2013)

S.No	Category of Building	G/F Area (sft)	No.of Blocks	Gross Area	Cost/sft(PKR)	Amount(PKR)
1	Cat-I Family Flats	4160	3	12481	3600	44,930,916
2	Cat-II(A) Family Flats	3600	4	28802	3600	103,687,200
3	Cat-II(B) Family Flats	3600	7	50404	3600	181,452,600
4	Cat-III	4683	3	28097	3600	101,150,856
5	Guest House	1222	1	1222	3600	4,400,604
6	Officer's Hostel	1335	1	1335	3600	4,807,620
7	School	2824	1	2824	3200	9,035,776
8	Mosque	580	1	580	3200	1,856,000
9	Dispensary/Shops	1728	1	1728	3200	5,529,984
				127473.41		456,851,556
					Cost of Residential & Infrastructure Buildings.	456,851,556
					Add 50% for Roads,Water Supply,Sewerage,Electricity & etc.	228,425,778
					TOTAL PKR	685,277,334
					TOTAL US $	6,526,451

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ARKARI GOL HYDROPOWER PROJECT								
COST ESTIMATE								
DESANDER								
1 US $ =PKR 105 (AS OF DECEMBER 2013)								
S.No	Description	Quantity	Unit	Rate (PKR)	Rate (US $)	Amount (PKR)	Amount (US $)	U.S $ (Million)
1	Excavation In Soft Rock	12893	m^3	9650	91.90	124,418,415	1,184,937	1.185
2	Excavation in Hard Rock	21489	m^3	15852	150.97	340,635,702	3,244,150	3.244
3	Excavation In Poor Rock	8595	m^3	3726	35.49	32,026,460	305,014	0.305
4	Shotcrete With Fiber	449	m^3	22721	216.39	10,201,729	97,159	0.097
5	Supply and Installation of Stop Log	3	Tons	300000	2857.14	960,000	9,143	0.009
6	Supply and Installation of Steel Gate	39	Tons	450000	4285.71	17,550,000	167,143	0.167
7	Supply and Installation of Trash Rack	13	Tons	300000	2857.14	3,810,000	36,286	0.036
8	MS Pipes	32	Tons	450000	4285.71	14,206,867	135,303	0.135
9	Steel Fence	150	m	2500	23.81	375,000	3,571	0.004
10	R.C.C Tunnel Concrete (21 Mpa)	8937	m^3	17271	164.49	154,350,927	1,470,009	1.470
11	Reinforcement Steel (Grade-40) @96Kg/m^3	858	Tons	137,000	1304.76	117,539,424	1,119,423	1.119
	TOTAL					816,074,525	7,772,138	7.772

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ARAKARI GOL HYDROPOWER PROJECT				
COST ESTIMATE				
ELECTROMECHANICAL EQUIPMENT				
1 US $ = PKR 105 (AS OF DEC; 2013)				
DESCRIPTION	**Unit**	**Qty**	**RATE (US $)**	**COST (US $)**
POWER HOUSE EQUIPMENT				
DESCRIPTION	**Unit**	**Qty**	**RATE (US $)**	**COST (US $)**
TURBINES	und	3	2,334,479.17	7,003,437.50
GENERATORS	und	3	2,548,729.50	7,646,188.50
REGULATORS	und	incluido		incluido
OIL REGULATOR	und	incluido		incluido
SPHERICAL VALVE	und	3	820,222.58	2,460,667.75
EXCITATION SYSTEM	und	incluido		incluido
COOLING SYSTEM	und	incluido		incluido
AIR SYSTEM	und	1	103,125.00	103,125.00
WATER AND SEWER SYSTEM	und	1	618,750.00	618,750.00
LIGHTING SYSTEM	und	1	94,157.66	94,157.66
FIRE SYSTEM	und	1	756,250.00	756,250.00
FIRE DETECTION SYSTEM	und	1	62,975.00	62,975.00
EARTH SYSTEM SETTING A	und	1	51,155.91	51,155.91
VENTILATION AND AIR CONDITIONING SYSTEM	und	1	206,250.00	206,250.00
SCADA SYSTEM AUTOMATION AND PROTECTION	und	1	564,945.70	564,945.70
COMMUNICATION SYSTEM	und	1	94,157.66	94,157.66
ELECTRIC AUXILIARY SERVICES	glb	1	763,404.81	763,404.81
13.8 KV EQUIPMENT	glb	1	711,610.35	711,610.35
CONDUCTORS, CABLES AND TRAYS	glb	1	201,915.73	201,915.73
BRIDGE AND GANTRY CRANE	und	1	550,000.00	550,000.00
WORKSHOP TOOLS AND EQUIPMENT	glb	1	68,750.00	68,750.00
				21,957,741.58
ASSEMBLY AND TESTING				
DESCRIPTION	**Unit**	**Qty**	**RATE (US $)**	**COST (US $)**
MECHANICAL SUPERVISION PROVIDER	glb	1	537,370.65	537,370.65
ELECTRIC SUPPLIER MONITORING	glb	1	697,153.20	697,153.20
LABOR (PERSONAL DETAILS, QUALIFICATIONS,	det	1	881,315.25	881,315.25
PRESENCE AT WORK)	glb	1	425,734.95	425,734.95
				2,541,574.05
OPERATION TESTS				
DESCRIPTION	**Unit**	**Qty**	**RATE (US $)**	**COST (US $)**
OTHER EXPENSES OF SUPPLY	glb	1	377,731.12	377,731.12
SHIPPING	glb	1	298,600.64	298,600.64
INLAND	glb	1	703,639.17	703,639.17
				1,379,970.93
DETAILED ENGINEERING				
DESCRIPTION	**Unit**	**Qty**	**RATE (US $)**	**COST (US $)**
GENERAL EXPENSE				5,542,742.64
				5,542,742.64
ELECTROMECHANICAL EQUIPMENT				
DESCRIPTION	**Unit**	**Qty**	**RATE (US $)**	**COST (US $)**
UTILITY				2,396,346.12
				2,396,346.12
SUBTOTAL				**33,818,375.32**
TAXES				6,087,307.56
TOTAL				**39,905,682.87**

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ARKARI GOL HYDROPOWER							
COST ESTIMATE							
ENVIRONMENTAL MITIGATION AND RESETTLEMENT							
1 US $ =PKR 105 (AS OF DECEMBER 2013)							
S.No	Description	Quantity	Unit	Rate (PKR)	Amount(PKR)	Amount(US$)	U.S $ (Million)
1	Stay of Project's Employees Generation of Sewage Places	1	LS	100,000	100,000	952	0.001
2	Number of Fruit Trees	620	Nos	13,500	8,370,000	79,714	0.080
3	Number of Forest Trees	560	Nos	4,300	2,408,000	22,933	0.023
4	Loss of Houses	42471	Sft	3,100	131,660,100	1,253,906	1.254
5	Loss of Houses Land	6	Acres	5,088,362	29,868,688	284,464	0.284
6	Stay of Project's Employees Municipal Solid Waste Generation At The Colony And Work Places	1.00	LS	100,004	100,004	952	0.001
7	Siltation Problem And Inadequate / No Water Might Be Available For Diversion During Peaking Hours.	1	LS	928,350	928,350	8,841	0.009
8	Sensitization Training Program For Project Workers Onenvironmental Sustainability, Health, Safety And Legal Obligationsunder PEPA, 1997 and NEQS etc.	1	LS	200,000	200,000	1,905	0.002
9	Generation of Sewage	1	1.00	100,000	100,000	952	0.001
	TOTAL				173,735,142	1,654,620	1.655

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ARKARI GOL HYDROPOWER PROJECT								
COST ESTIMATE								
FLUSHING CHANNEL								
1 US $ =PKR 105 (AS OF DECEMBER 2013)								
S.No	Description	Quantity	Unit	Rate (PKR)	Rate (US $)	Amount (PKR)	Amount (US $)	U.S $ (Million)
1	Excavation In Hard Rock	242	m^3	15852	151	3,836,184	36,535	0.037
2	Excavation in Soft Rock	145	m^3	9650	92	1,401,180	13,345	0.013
3	Excavation In Poor Rock	97	m^3	3726	35	360,677	3,435	0.003
4	P.C.C (21 Mpa)	73	m^3	14500	138	1,052,700	10,026	0.010
5	Reinforced Cement Concrete (21 Mpa)	243	m^3	17,271.00	164	4,196,853	39,970	0.040
6	Reinforcement Steel (Grade- 40) @96Kg/m^3	23	Tons	137000	1305	3,195,936	30,437	0.030
	TOTAL					14,043,530	133,748	0.134

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ARKARI GOL HYDROPOWER PROJECT							
COST ESTIMATE							
GENERAL & PREPARATORY WORKS							
1 US $ =PKR 105 (AS OF DECEMBER 2013)							
S.No	Description	Quantity	Unit	Rate (PKR)	Amount(PKR)	Amount(US $)	U.S $ (Million)
1	Temporary Facilities,Camps and Plants.	All	LS	46,341,950	46,341,950	441,352	0.441
2	Clearing ,Grubbing and Stripping.	All	LS	6,858,000	6,858,000	65,314	0.065
3	Water Supply and Sewerage Treatment & Solid Waste Disposal	All	LS	55,800,000	55,800,000	531,429	0.531
	TOTAL				108,999,950	1,038,095	1.038

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ARKARI GOL HYDROPOWER PROJECT								
COST ESTIMATE								
HEAD RACE TUNNEL								
1 US $ =PKR 105 (AS OF DECEMBER 2013)								
S.No	Description	Quantity	Unit	Rate (PKR)	Rate (US $)	Amount (PKR)	Amount (US $)	U.S $ (Million)
1	Excavation in Soft Rock	20894	m^3	9650	91.90	201,630,960	1,920,295	1.920
2	Excavation In Hard Rock	52236	m^3	15852	150.97	828,045,072	7,886,144	7.886
3	Excavation In Poor Rock	31342	m^3	3726	35.49	116,778,802	1,112,179	1.112
4	Grouted Bolts 3.0 m Long	31260	Nos	4100	39.05	128,166,000	1,220,629	1.221
5	Steel Ribs (Size 160x80)	30500	Kg	300	2.86	9,150,000	87,143	0.087
6	Pre-Cost Legs	1520	m^3	18913	180.12	28,747,760	273,788	0.274
7	Shotcrete With Fiber	7465	m^3	22721	216.39	169,607,721	1,615,312	1.615
8	P.C.C (21 Mpa)	5224	m^3	14500	138.10	75,742,200	721,354	0.721
9	R.C.C Tunnel Concrete (21 Mpa)	20000	m^3	17271	164.49	345,420,000	3,289,714	3.290
10	Reinforcement Steel (Grade-40) @96Kg/m^3	1920	Tons	137000	1304.76	263,040,000	2,505,143	2.505
	TOTAL					2,166,328,514	20,631,700	20.632

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ARKARI GOL HYDROPOWER PROJECT

COST ESTIMATE

INTAKE STRUCTURE

1 US $ =PKR 105 (AS OF DECEMBER 2013)

S.No	Description	Quantity	Unit	Rate (PKR)	Rate (US $)	Amount (PKR)	Amount (US$)	U.S $ (Million)
1	De-watering	10	Days	10,000	95.24	100,000	952	0.001
2	Excavation in Hard Rock	3106	m^3	15,852	150.97	49,236,312	468,917	0.469
3	Excavation in Soft Rock	1245	m^3	9,650	91.90	12,014,250	114,421	0.114
4	Excavation in Common Material	8074	m^3	8,000	76.19	64,592,000	615,162	0.615
5	Back Filling	863	m^3	800	7.62	690,400	6,575	0.007
6	P.C.C (21 Mpa)	37	m^3	14,500	138.10	536,500	5,110	0.005
7	Shotcrete With Fiber	53	m^3	22,721	216.39	1,204,213	11,469	0.011
8	R.C.C (21 Mpa)	2385	m^3	17,271	164.49	41,191,335	392,298	0.392
9	Reinforcement Steel (Grade-40) @96Kg/m^3	229	Tons	137,000	1,304.76	31,367,520	298,738	0.299
10	Supply of Stop Log Including Installation	6	Tons	300,000	2,857.14	1,800,000	17,143	0.017
11	Supply of Trash Rack Including Installation	2	Tons	300,000	2,857.14	735,000	7,000	0.007
12	Supply of Steel Gate Including Installation	3	Tons	450,000	4,285.71	1,287,000	12,257	0.012
	TOTAL					204,654,530	1,949,091	1.949

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ARKARI GOL HYDROPOWER PROJECT								
COST ESTIMATE								
POWERHOUSE								
1 US $ =PKR 105 (AS OF DECEMBER 2013)								
S.No	Description	Quantity	Unit	Rate (PKR)	Rate (US $)	Amount (PKR)	Amount (US $)	U.S $ (Million)
1	Construction Dewatering	30	Per day	10000	95.24	300,000	2,857	0.003
2	Excavation in Common Material	8454	m^3	8000	76.19	67,632,000	644,114	0.644
3	P.C.C (21 Mpa)	2824	m^3	14500	138.10	40,948,000	389,981	0.390
4	Reinforced cement concrete (21 Mpa)	1745	m^3	17271	164.49	30,137,895	287,028	0.287
5	Reinforced cement concrete (28 Mpa)	1365	m^3	18673	177.84	25,488,645	242,749	0.243
6	Reinforement Steel (Grade-40) @96Kg/m^3	299	Tons	137000	1304.76	40,902,720	389,550	0.390
7	Supply of Structure Steel for Roof Truss	38	Tons	200000	1904.76	7,600,000	72,381	0.072
8	Erection of Structure Steel	38	Tons	80000	761.90	3,040,000	28,952	0.029
9	Supply & Installation Corrugated GI Sheets Roof	1092	m^2	2150	20.48	2,347,800	22,360	0.022
10	Aluminum Doors and Windows &Ventilator	15.00	m^2	9000	85.71	135,000	1,286	0.001
11	Main Gate	44	m^2	7000	66.67	308,000	2,933	0.003
12	Plaster	4100	m^2	430	4.10	1,763,000	16,790	0.017
13	Block Works	403	m^3	7000	66.67	2,821,000	26,867	0.027
14	Flooring	92	m^2	2150	20.48	197,800	1,884	0.002
15	Public Health Works		LS	10%		22,362,186	212,973	0.213
16	Electrical Works		LS	12%		26,834,623	255,568	0.256
17	Miscellanieous Works	1	LS	10000000	95238.10	10,000,000	95,238	0.095
	TOTAL					282,818,669	2,693,511	2.694

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ARKARI GOL HYDROPOWER PROJECT

COST ESTIMATE

PRESSURE SHAFT, PRESSURE TUNNEL & PENSTOCK

1 US $ =PKR 105 (AS OF DECEMBER 2013)

S.No	Description	Quantity	Unit	Rate (PKR)	Rate (US $)	Amount (PKR)	Amount (US $)	U.S $ (Million)
1	Excavation in Hard Rock	3,038	m^3	15852	150.97	48,150,450	458,576	0.459
2	Excavation in Soft Rock	1,823	m^3	9650	91.90	17,587,125	167,496	0.167
3	Excavation in Poor Rock	1,215	m^3	3726	35.49	4,527,090	43,115	0.043
4	Shotcrete With Fiber	1,186	m^3	22721	216.39	26,947,106	256,639	0.257
5	R.C.C (21 Mpa)	862	m^3	17271	164.49	14,887,602	141,787	0.142
6	Penstock Steel Pipe	108	Tons	450000	4285.71	48,600,000	462,857	0.463
7	Reinforcement Steel (Grade-40) @96Kg/m^3	83	Tons	137000	1304.76	11,337,024	107,972	0.108
8	SS Steel Plate	87	Tons	400,000	3809.52	34,800,000	331,429	0.331
9	By Pass Valve	1	No	275,000	2619.05	275,000	2,619	0.003
	TOTAL					207,111,397	1,972,489	1.972

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ARKARI GOL HYDROPOWER PROJECT							
COST ESTIMATE							
ACCESS ROADS & BRIDGES							
1 US $ =PKR 105 (AS OF DECEMBER 2013)							
S.No	**Description**	**Quantity**	**Unit**	**Rate (PKR)**	**Amount (PKR)**	**1 US $ =105 Rs**	**U.S $ (Million)**
1	Excavation In Road	16,000	m^3	8000	128,000,000	1,219,048	1.219
2	Road In Embankment	4,000	m^3	800	3,200,000	30,476	0.030
3	Sub Base	7,808	m^3	1060	8,276,480	78,824	0.079
4	Base	5,856	m^3	2119	12,408,864	118,180	0.118
5	T.S.T	39,040	m^2	960	37,478,400	356,937	0.357
6	Stone Work	720	m^3	5819	4,189,680	39,902	0.040
7	Bridge 30m Span & 4m Wide	1	No	52,500,000	52,500,000	500,000	0.500
8	Bridge 10m Span & 4m Wide	2	No	1,750,000	3,500,000	33,333	0.033
TOTAL					249,553,424	2,376,699	2.377

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ARKARI GOL HYDROPOWER PROJECT								
COST ESTIMATE								
SURGE TANK & CHAMBERS								
1 US $ =PKR 105 (AS OF DECEMBER 2013)								
S.No	Description	Quantity	Unit	Rate (PKR)	Rate (US $)	Amount (PKR)	Amount (US $)	U.S $ (Million)
1	Excavation In Hard Rock	10,442	m^3	15852	151.0	165,526,584	1,576,444	1.576
2	Shotcrete With Fiber	934	m^3	22721	216.4	21,221,414	202,109	0.202
3	Rock Bolts	1,170	Nos	4100	39.0	4,797,000	45,686	0.046
4	Reinforced Cement Concrtet (21 Mpa)	555	m^3	17,271	164.5	9,585,405	91,290	0.091
5	Reinforcement Steel (40 Grade) @96Kg/m^3	53	Tons	137,000	1304.8	7,299,360	69,518	0.070
6	Supply and Installation of Steel Grating	1	Tons	300,000	2857.1	300,000	2,857	0.003
7	Supply and Installation of Trash Rack	2	Tons	300,000	2857.1	600,000	5,714	0.006
8	Supply and Installation of Stop Log	4	Tons	300,000	2857.1	1,200,000	11,429	0.011
	TOTAL					210,529,763	2,005,045	2.005

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ARKARI GOL HYDROPOWER PROJECT								
COST ESTIMATE								
TAIL RACE DUCT								
1 US $ =PKR 105 (AS OF DECEMBER 2013)								
S.No	**Description**	**Quantity**	**Unit**	**Rate (PKR)**	**Rate (US $)**	**Amount (PKR)**	**Amount (US $)**	**U.S $ (Million)**
1	Excavation in Common Material	4224	m^3	8000	76.2	33,792,000	321,829	0.322
2	P.C.C (21 Mpa)	144	m^3	14500	138.1	2,088,000	19,886	0.020
3	Filling Around Structure	1056	m^3	880	8.4	929,280	8,850	0.009
4	Reinforced Cement Concrete (21 Mpa)	1411	m^3	17,271	164.5	24,369,381	232,089	0.232
5	Reinforcement Steel (Grade-40) @96Kg/m^3	135	Tons	137000	1304.8	18,557,472	176,738	0.177
	TOTAL					**79,736,133**	**759,392**	**0.759**

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ARKARI GOL HYDROPOWER PROJECT							
COST ESTIMATE							
TRANSMISSION LINE & SWITCHYARD							
1 US $ =PKR 105 (AS OF DECEMBER 2013)							
S.No	Descaption	No	Weight	Unit	Rate	Amount(PKR)	US $
1	Suspension Tower Made With Galvanised Angle Iron On angle Turn 6 (7741 Kg) On Stright Rot 12 (5523 Kg)	18 pole	113	Ton	200000	22,600,000	215,238
2	Nut.Bolt (3" x1/2") 300 No. P-Pole *18 Pole (ASTM-153)	5400		Nos	50	270,000	2,571
3	GI.Thimble For Earth Wire No.6* 18 Pole	108		Nos	50	5,400	51
4	Length of conducter (Greely Type) No 3*4 KM	12000		m	735	8,820,000	84,000
5	No of Suspension/String	90		Nos	15000	1,350,000	12,857
6	Length of Earth Wire=15m*18pole	270	50	Kg	150	7,500	71
7	Lenrth of shield wire	4	3.7	Ton	150000	555,000	5,286
8	No of Dampers (stock bridge damper)	114		Nos	2000	228,000	2,171
9	Excavation of foundation	8748		m^3	750	6,561,000	62,486
10	P.C.C(1:4:8) in foundation	218.7		m^3	7500	1,640,250	15,621
11	R.C.C(1:2:4) in foundation	4374		m^3	12500	54,675,000	520,714
12	Steel Reinforcement (Grade-60) 96kg/m^3		371	Ton	140000	51,940,000	494,667
		SUB TOTAL				148,652,150	1,415,735
	Contingence	10%				14,865,215	141,573
		GRAND TOTAL				163,517,365	1,557,308
		COST PER KM				46,719,247	444,945
SWITCHYARD							
	SWITCH YARD	COST LS				199,185,525	1,897,005

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ARKARI GOL HYDROPOWER PROJECT								
COST ESTIMATE								
DIVERSION TUNNEL								
1 US $ =PKR 105 (AS OF DECEMBER 2013)								
S.No	Description	Quantity	Unit	Rate (PKR)	Rate (US $)	Amount (PKR)	Amount (US $)	U.S $ (Million)
1	Excavation in Hard Rock	26334	m^3	15852	150.97	417,446,568	3,975,682	3.976
2	Excavation in Soft Rock	26334	m^3	9650	91.90	254,123,100	2,420,220	2.420
3	R.C.C (21 Mpa)	6930	m^3	17271	164.49	119,688,030	1,139,886	1.140
4	Reinforcement Steel (Grade-40) @96Kg/m^3	665	Tons	137000	1304.76	91,143,360	868,032	0.868
5	Grouted Bolts 3 m Long	2772	Nos	4100	39.05	11,365,200	108,240	0.108
6	Steel Ribs (Size 160x80)	42000	Kg	300	2.86	12,600,000	120,000	0.120
7	Pre-Cost Legs	1890	m^3	18913	180.12	35,745,570	340,434	0.340
8	Shotcrete With Fiber	1726	m^3	22721	216.39	39,220,990	373,533	0.374
	TOTAL					981,332,818	9,346,027	9.346

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ARKARI GOL HYDROPOWER PROJECT

COST ESTIMATE

WEIR (CFRD) WITH SPILLWAY

1 US $ =PKR 105 (AS OF DECEMBER 2013)

S.No	Description	Quantity	Unit	Rate (PKR)	Rate (US $)	Amount (PKR)	Amount (US $)	U.S $ (Million)
1	Excavation in Common Material	22939	m^3	8000	76.19	183,512,000	1,747,733	1.748
2	Excavation in Soft Rock	45921	m^3	9560	91.05	439,004,760	4,180,998	4.181
3	Excavation in Rock	51320	m^3	15517	147.78	796,332,440	7,584,118	7.584
4	P.C.C (21 Mpa)	665	m^3	14500	138.10	9,642,500	91,833	0.092
5	R.C.C (21 Mpa)	19322	m^3	17271	164.49	333,710,262	3,178,193	3.178
6	Filling	311673	m^3	880	8.38	274,272,240	2,612,117	2.612
7	Reinforcement Steel (Grade 40) @96Kg/m^3	1855	Ton	137000	1304.76	254,122,944	2,420,219	2.420
8	Stone Pitching	3217	m^3	5819	55.42	18,719,723	178,283	0.178
9	Stone Gabion	3217	m^3	60000	571.43	193,020,000	1,838,286	1.838
10	Wire Mesh	495	m^2	1500	14.29	742,500	7,071	0.007
11	Grouting for Pipe	400	m	3500	33.33	1,400,000	13,333	0.013
12	Supply and Installation of Steel Gates	29	Tons	450000	4285.71	13,050,000	124,286	0.124
	TOTAL					2,517,529,369	23,976,470	23.976

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CASH FLOW ARKARI GOL HPP									
S.No.	Description	Estimated Cost	2,015	2,016	2,017	2,018	2,019	2,020	2,021
		Amount (US $)	Amount (US $)	Amount (US $)	Amount (US $)	Amount (US $)	Amount (US $)	Amount (US $)	Amount (US $)
A	PRELIMINARY WORKS AND ENVIRONMENT								
a)	General & Preparartory Works	1,038,095		1,038,095					
b)	Land Acquisition	5,602,035	5,602,035						
c)	Access Roads and Bridges	2,376,699		2,376,699					
d)	Mobilization / Demobilization	868,114			578,743			289,371	
e)	Staff Residential Colony	6,526,451			4,894,838	1,631,613			
f)	Environmental Mitigation & Resettlement cost	1,654,620		1,654,620					
B (i)	CIVIL WORKS								
a)	Coffer Dam	322,106			322,106				
b)	Weir (CFRD) With Spillway	23,976,470			7,992,157	15,984,313			
c)	Diversion Tunnel	9,346,027			9,346,027				
d)	Intake Structure	1,949,091			487,273	1,461,818			
e)	Approach Channel	1,639,257				1,639,257			
f)	Desander	7,772,538				7,772,138			
g)	Flushing Channel	133,748				44,583	89,165		
h)	Adit Tunnel	12,737,047			12,737,047				
i)	Headrace Tunnel	20,631,700			15,473,775	5,157,925			
j)	Surge Tank & Chambers	2,005,045			1,002,523	1,002,523			
k)	Pressure Shaft, Pressure Tunnel & Penstock	1,972,489				1,972,486			
B (ii)	POWERHOUSE AND TAILRACE								
l)	Power House	2,693,511			299,279	1,197,116	1,197,116		
m)	Tailrace Duct	759,392					759,392		
n)	Protection & Miscellaneous Works	611,880					305,940	305,940	
	SUB TOTAL (A+B)	104,615,916	5,602,035	5,069,414	53,133,768	37,863,772	2,351,613	595,311	0
C	E & M								
a)	Complete E & M Equipment	39,905,683			7,981,137	15,962,273	15,962,273		
b)	Transmission Line.	1,557,308					1,557,308		
c)	Switch Yard	1,942,693					1,942,693		
	SUB TOTAL (A+B+C)	148,021,600	5,602,035	5,069,414	61,114,905	53,826,045	21,813,887	595,311	0
D	MISCELLANEOUS CHARGES								
a)	Erection ,Commissioning & Testing Charges	4,788,682					1,596,227	3,192,455	
b)	Duties, LC Taxes	1,995,284				997,642	997,642		
c)	Transportation & Shipment Charges	2,793,398				1,396,699	1,396,699		
d)	Contingencies 3% of (A+B+C)	4,440,648	168,061	152,082	1,833,447	1,614,781	654,417	17,859	0
E	ENGINEERING SUPERVISION								
a)	Engineering Supervision (6% of A+B+C)	8,881,296	336,122	304,165	3,656,894	3,229,563	1,308,833	35,719	0
F	MANAGEMENT CHARGES								
a)	Engineering Design	865,499		865,499					
b)	Project Administration Charges	5,920,864		1,315,748	1,315,748	1,315,748	1,315,748	657,874	
	TOTAL PROJECT INVESTIMENT COST	177,707,271							
	FINANCIAL CHARGES	641,477	213,826	427,651					
	TOTAL PROJECT COST US $	178,348,748	6,320,044	8,134,559	67,930,994	62,380,478	29,083,452	4,499,214	0

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Brick Work						
Sr No	Discription		Qty	Unit	Rate	Amount (PKR)
A	MATERIAL					
a.	Bricks		1400	No	18	25,200.00
b.	Cement		4.00	Bag	650	2,600.00
c.	Sand		25	Cft	40	1,000.00
d.	Water			LS	200	200.00
				Total		29,000.00
			Add 5% as Wastage			1,450.00
				Total Material		30,450.00
B	LABOUR CHARGES					
	Mason		2	No.	800	1,600.00
	Beldar		4	No.	500	2,000.00
	Mate		1	No.	600	600.00
	Foreman		1	No.	800	800.00
						5,000.00
			1/2 Day Cost			2,500.00
C	Scafolding Charges @ 5% of (A)	5%		PKR		1,522.50
	Total Prime Cost					34,472.50
	Add %					
	Over Head Charges	10%				3,447.25
	Income Tax	6%				2,068.35
	Contractor Profit	20%				6,894.50
	TOTAL RATE Per 2.83 m^3					46,882.60
	TOTAL RATE Per m^3					16,566.29
	TOTAL RATE Per m^3				US $	157.77

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CEMENT CONCRETE (10 mpa)

	Unit:- 2.83 m^3 = 100 Cft			1 US $ =PKR 105 (AS OF DEC;2013)			
Sr No	Discription			Qty	Unit	Rate	Amount (PKR)
A	MATERIAL						
a.	Cement			9.50	Bag	650	6,175.00
b.	Sand			47.4	Cft	40	1,896.00
c.	Coarse Aggregate			94.76	Cft	50	4,738.00
d.	Water			LS		150	150.00
e.	Admixture			LS		200	200.00
						Total	**13,159.00**
					Add 5% as Wastage		657.95
					Total Material		**13,816.95**
B	LABOUR CHARGES						
B.1	Direct Labour	30	m^3				
	Foreman		50000/30	1	No.	1666.67	1,666.67
	Fitter		30000/30	2	No.	1000.00	2,000.00
	Electrician		35000/30	1	No.	1166.67	1,166.67
	Mason		25000/30	2	No.	833.33	1,666.67
	Beldar		20000/30	6	No.	666.67	4,000.00
	Carpenter		25000/30	1	No.	833.33	833.33
	Vibrator operator		20000/30	1	No.	666.67	666.67
							12,000.00
B.1	**In Direct Labour**						
	Towards amenities, construction of camps, transportation, medical facilities & retrenching benefits etc. @ 50 of direct labour charges.		-		PKR	6,000.00	6,000.00
			Total Direct & indirect Charges				**18,000.00**
			Total direct & indirect Charges Per m^3				**600.00**
			Total direct & indirect Charges for 2.83 m^3				**1,698.00**
C	**Concrete Batching, Mixing and laying etc. Rate / m^3**						
C.1	Batching and mixing plant Capacity			80	m^3		
	Cost of Plant (80 m^3)				PKR	30000	
	Assuming job Factor 50%			0.5	PKR	15000	15000
				Cost Per m^3			375.00
				Cost For 2.83 m^3			1,061.25
D	**Transport of Concrete by transit mixer from Batching & Mixing Plant to placement site lead**						
	Capacity of Transit Mixer			3	m^3		
	Expensive of Mixer				PKR	10000	
	Rate Per m^3			1	m^3	3333.33	
	Rate For 2.83 m^3						9,433.33
	Total Prime Cost						26,009.53
	Add %						
	Over Head Charges	10%					2,600.95
	Income Tax	6%					1,560.57
	Contractor Profit	20%					5,201.91
	TOTAL RATE Per 2.83 m^3				PKR		35,372.97
	TOTAL RATE Per m^3				PKR		12,499.28
	TOTAL RATE Per m^3				US $		119.04

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Unit:- 2.83 m^3 = 100 Cft				1 US $ =PKR 105 (AS OF DEC;2013)			
Sr No	Discription			Qty	Unit	Rate	Amount (PKR)
A	MATERIAL						
a.	Cement			17.60	Bag	650	11,440.00
b.	Sand			44	Cft	40	1,760.00
c.	Coarse Aggregate			88	Cft	50	4,400.00
d.	Water			LS		150	150.00
e.	Admixture			LS		200	200.00
						Total	17,950.00
				Add 5% as Wastage			897.50
						Total Material	18,847.50
B	LABOUR CHARGES						
B.1	Direct Labour	30 m^3					
	Foreman		50000/30	1	No.	1666.67	1,666.67
	Fitter		30000/30	2	No.	1000.00	2,000.00
	Electrician		35000/30	1	No.	1166.67	1,166.67
	Mason		25000/30	2	No.	833.33	1,666.67
	Beldar		20000/30	6	No.	666.67	4,000.00
	Carpenter		25000/30	1	No.	833.33	833.33
	Vibrator operator		20000/30	1	No.	666.67	666.67
							12,000.00
B.1	**In Direct Labour**						
	Towards amenities, construction of camps, transportation, medical facilities & retrenching benefits etc. @ 50 of direct labour charges.				PKR	6,000.00	6,000.00
			Total Direct & indirect Charges				18,000.00
			Total direct & indirect Charges Per m^3				600.00
			Total direct & indirect Charges for 2.83 m^3				1,698.00
C	**Concrete Batching, Mixing and laying etc. Rate / m^3**						
C.1	Batching and mixing plant Capacity			80	m^3		
	Cost of Plant (80 m^3)				PKR	30000	
	Assuming job Factor 50%			0.5	PKR	15000	15000
				Cost Per m^3			375.00
				Cost For 2.83 m^3			1,061.25
D	Transport of Concrete by transit mixer from Batching & Mixing Plant to placement site lead						
	Capacity of Transit Mixer			3	m^3		
	Expensive of Mixer				PKR	10000	
	Rate Per m^3			1	m^3	3333.33	
	Rate For 2.83 m^3						9,433.33
		Total Prime Cost					31,040.08

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Sr No	Discription			Qty	Unit	Rate	Amount (PKR)
	Add %						
	Over Head Charges	10%					3,104.01
	Income Tax	6%					1,862.41
	Contractor Profit	20%					6,208.02
	TOTAL RATE Per 2.83 m^3					**PKR**	**42,214.51**
	TOTAL RATE Per m^3					**PKR**	**14,916.79**
	TOTAL RATE Per m^3					**US $**	**142.06**

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EXCAVATION IN TUNNEL (HARD ROCK)

1 US $ =PKR 105 (AS OF DEC;2013)

Sr No	Discription	Length	Width	Hight	Qty	Unit	Rate	Amount(PKR)
1	The Size of tunnel	4.80	6.80	6.60				
	Volume = 19.14 m^3 + Top Half				**37.30**	m^3		
	Quantity of Per 12 Hour	5.36	37.30		**199.93**	m^3	(3 Cycle)	
A	<u>DIRECT LABOUR</u>							
							12 Hours	
	Foreman Special drilling			50000/30	2.00	No	2500.00	5000.00
	Asst. Foreman drilling			30000/30	1.00	No	1500.00	1500.00
	Explosive Inspector			35000/30	1.00	No	1750.00	1750.00
	Electrician			30000/30	1.00	No	1500.00	1500.00
	Explosive (Blaster)			25000/30	1.00	No	1250.00	1250.00
	Hole Cleaner			25000/30	2.00	No	1250.00	2500.00
	Helper Electrician			20000/30	1.00	No	1000.00	1000.00
	Beldar			20000/30	10.00	No	1000.00	10000.00
	Wire man for Blasting			25000/30	1.00	No	1250.00	1250.00
	Explosive Charge Man			40000/30	1.00	No	2000.00	2000.00
							Total	**27750.00**
		In direct charges for labour Towards amenities, construction of camps, transportation, medical facilities & retrenching benefits etc. @ 50% of direct labour charges.						13875.00
					Total Labour Cost for 200 m^3			**41625.00**
					Total Labour Cost Per m^3			**208.13**
B	<u>MACHINERY CHARGES</u>							
		No			2 days		**Rate /h**	
1	Drill Jumbo Machine	1		4 Hour	16	Hour	28000	448000
2	Tippers	6		3 Hour	36	Hour	4000	144000
3	Excavator	1		3 Hour	16	Hour	9000	144000
4	D.B Tractor Dozer	1		3 Hour	16	Hour	13000	208000
5	Loader	1		3 Hour	16	Hour	3500	56000
6	Dump Truck	1		3 Hour	16	Hour	5000	80000
					Total Cost for 200 m^3			**1080000.00**
					Total Cost Per m^3			**5400.00**
C	<u>MATERIAL CHARGES</u>							
	1.5 m progress per cycle,				2	m		
	b) X.Section Area of Each bench				37.3	m^2		
	holes				0.6	m c/c		
	No. of holes required per cycle	103	3		309	No		

Sr No	Discription	Length	Width	Hight	Qty	Unit	Rate	Amount(PKR)
	d) Total Depth of drilling	309		2	618	m		
	Cost of drill steel / m				**600**	**PKR**		
	Total Cost of Drill Steel				**370800**	**PKR**		
	Total Excvated Qty				**200**	m^3		
	Rate per m^3				1854.00	PKR		
C.1	**EXPLOSIVES**							
	a) Gelatine required per m^3	2 x 1.50 Kg	300 Rs/- Per Kg		1	m^3	900	**900**
	b) Detonators and fuse coils							
	1 No. per hole per face				309	No		
	Cost of Detonator				309	No	120	37080
	c) Fuse Coils				309	No	80	24720
	Total Cost of Detonator+Fuse Coil for 200 m^3							**61800.00**
	Total Cost of Detonator+Fuse Coil Per m^3							**309.00**
	Other consumable petty store such as blasting Batteries, galvanimeters and blasting wires etc. @ 50% of item (I)				1	m^3	450	450
	Total Explosive Charges per m^3							**1659.00**
	Total Cost of Drilling and Blasting							**3513.00**
	water for wet drilling per m^3					LS	150	150
	Timber for supports packing per m^3					LS	150	150
	Miscellaneous supplies such as safty hats, gumboots, Rain coat, wire ropes, manila ropes, V-Clamps, rubber gloves, shackels and artficial respirators etc. Per m^3					LS	150	150
	Total Cost of Material Per m^3							**3963.00**
D	**CHARGES FOR VENTILATION BLOWERS**							
	a) Description of Charges							
	accessories such as air ducts						2000000	
	Rated life					Hours	50000	
	Description charges P.hour				1	Hours	40	40

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Sr No	Discription	Length	Width	Hight	Qty	Unit	Rate	Amount(PKR)
					12	Hours	40	**480**
	b) Repair and maintenance Charges							
	100% of depreciation						480	**480**
	c) Pol Charges							
	Horse power of Blower	80	H.P					
	Energy Required	59.68	Kwh/shift		2 Shift			
	Cost of Energy				119.36	KWH	15	1790.4
	Sundries and other item					LS	200	200
								1990.4
	d) Labour Charges				12	Hour	125	1500
	Operator				12	Hour	104.17	1250.04
	Helper							2750.04
	Add for hidden of labour Charges 50%							1375.02
	Total Cost of Labour for 12 Hours							4125.06
	Total Cost of Labour per Hour							**343.755**
	Total Cost (a+b+c+d)							**3294.16**
	per shift				12	Hours		
	Total Charges of Blowers Per Shift				12	Hours	3294.16	39529.86
	Total Quantity of Excavation				200	m^3		
	Total Charges Per m^3				1	m^3	197.65	**197.65**
E	**SHOP CHARGES**							
E.1	Machine Shop i/c foundary and smithy					L/S	100	100
E.2	Structural Shop					L/S	100	100
E.3	Steel metal shop					L/S	100	100
E.4	Air and water pipe shop					L/S	100	100
E.5	Carpentary shop					L/S	100	100
	Total Shop Charges per m^3							**500**
F	Electrical material charges Per m^3					L/S	100	100
G	Jumbo track charges Per m^3					L/S	100	100
H	Compresed air Charges per m^3					L/S	120	120
I	Water Charges Per m^3					L/S	50	50
	ABSTRACT OF CHARGES							
A	Direct Labour Charges				1	m^3	208.13	208.13
B	Machinery Charges				1	m^3	5400.00	5400.00
C	Material Charges				1	m^3	3963.00	3963.00
D	Vantilation Blowers Charges				1	m^3	197.65	197.65
E	Shop Charges				1	m^3	500	500.00
F	Electrical Material				1	m^3	100	100.00
G	Jumbu Track charges				1	m^3	100	100.00
H	Compresed air Charges				1	m^3	120	120.00
I	Water Charges				1	m^3	50	50.00
	Total Charges							**10638.77**

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Sr No	Discription	Length	Width	Hight	Qty	Unit	Rate	Amount(PKR)
	Maintenance of haul roads							531.94
	Add 3% elecricity charges							319.16
	Contractor Profit 20%							2127.75
	Over Head Charges 15%							1595.82
	Income Tax 6%							638.33
	Hence Rate Per m³						**PKR**	**15851.77**
	Hence Rate Per m³						**US $**	**150.97**

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S.No	Discription	Length	Width	Height	Qty	Unit	Rate	Amount (PKR)
	EXCAVATION IN TUNNEL (POOR ROCK)							
	1 US $ =PKR 105 (AS OF DEC;2013)							
1	The Size of tunnel	4.80	6.80	6.60				
	Volume of One Meter (Bottom Volume = 19.14 m^3 + Top Half Circle = 18.14)				**37.30**	m^3		
	Quantity of Per shift	4.00		37.30	**149.20**	m^3	(2 Cycle)	
A	**DIRECT LABOUR**							
	Foreman Special			50000/30	2.00	No	1666.67	3333.33
	Asst. Foreman			30000/30	1.00	No	1000.00	1000.00
	Electrician			30000/30	1.00	No	1000.00	1000.00
	Helper Electrician			20000/30	1.00	No	666.67	666.67
	Beldar			20000/30	10.00	No	666.67	6666.67
							Total	**12666.67**
	In direct charges for labour Towards amenities, construction of camps, transportation, medical facilities & retrenching benefits etc. @ 50% of direct labour charges.							**6333.33**
	Total Labour Cost for 150 m^3							**19000.00**
	Total Labour Cost Per m^3							**126.67**
B	MACHINERY CHARGES							
		No					**Rate /h**	
1	Drill Jumbo Machine	1	4	Hour	6	Hour	28000	168000
3	Excavator	1	3	Hour	5	Hour	9000	45000
5	Loader	1	3	Hour	5	Hour	3500	17500
6	Dump Truck	1	3	Hour	5	Hour	5000	25000
					Total Cost for 150 m^3			**255500.00**
					Total Cost Per m^3			**1703.33**
C	**TIMBER FOR SUPPORTS PACKING PER per Cum**					L/S	100	100
	Miscellaneous supplies such as safty hats, gumboots, Rain coat, wire ropes, manila ropes, V-Clamps, rubber gloves, shackels and artficial respirators etc. Per Cum					L/S	100	100
	Total Cost of Material Per Cum							**200.00**
D	**CHARGES FOR VENTILATION BLOWERS**							
	a) Description of Charges							
	Total Cost of blowers i/c Cost of accessories such as air ducts						2000000	
	Rated life					Hours	50000	
	Description charges P.hour				1	Hours	40	40
					8	Hours	40	**320**
	b) Repair and maintenance Charges							
	100% of depreciation						320	**320**
	c) Pol Charges							
	Horse power of Blower	80	H.P					
	Energy Required	59.68	Kwh/shift					
	Cost of Energy				59.68	KWH	15	895.2
	Sundries and other item					L/S	200	200
								1095.2
	d) Labour Charges							
	Operator				8	Hour	104.25	834
	Helper				8	Hour	75	600
								1434
	Add for hidden of labour Charges 50%							717
	Total Cost of Labour for 8 Hours							2151
	Total Cost of Labour per Hour							**268.875**
	Total Cost (a+b+c+d)							**2004.08**

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S.No	Discription	Length	Width	Height	Qty	Unit	Rate	Amount (PKR)
	No. of Working hours of Blowers per shift				8	Hours		
	Total Charges of Blowers Per Shift				8	Hours	2004.08	16032.6
	Total Quantity of Excavation				150	Cum		
	Total Charges Per Cum				1	Cum	106.88	**106.88**
E	**SHOP CHARGES**							
E.1	Machine Shop i/c foundary and smithy					L/S	50	50
E.2	Structural Shop					L/S	50	50
E.3	Steel metal shop					L/S	50	50
E.4	Air and water pipe shop					L/S	50	50
E.5	Carpentary shop					L/S	50	50
	Total Shop Charges per Cum							**250**
F	Electrical material charges Per Cum					L/S	50	50
G	Jumbo track charges Per Cum					L/S	50	50
H	Compresed air Charges per Cum					L/S	70	70
I	Water Charges Per Cum					L/S	30	30
	ABSTRACT OF CHARGES							
A	Direct Labour Charges				1	Cum	126.67	126.67
B	Machinery Charges				1	Cum	1703.33	1703.33
C	Material Charges				1	Cum	200.00	200.00
D	Vantilation Blowers Charges				1	Cum	106.88	106.88
E	Shop Charges				1	Cum	250	250.00
F	Electrical Material				1	Cum	50	50.00
G	Jumbu Track charges				1	Cum	50	50.00
H	Compresed air Charges				1	Cum	70	70.00
I	Water Charges				1	Cum	30	30.00
	Total Charges							**2586.88**
	Add 5% for the construction and Maintenance of haul roads							129.34
	Add 3% elecricity charges							77.61
	Contractor Profit 20%							517.38
	Over Head Charges 10%							258.69
	Income Tax 6%							155.21
	Hence Rate Per Cum						**PKR**	**3725.11**
	Hence Rate Per Cum						**US $**	**35.48**

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Pre Cast Laggings						
1 US $ =PKR 105 (AS OF DEC;2013)						
Sr No	Discription		Qty	Unit	Rate	Amount (PKR)
A	MATERIAL					
a.	Cement		9.50	Bag	650	6,175.00
b.	Sand		0.45	m^3	1413	635.85
c.	Coarse Aggregate		0.85	m^3	1766	1,501.10
d.	Water			LS	80	80.00
e.	Admixture			LS	150	150.00
					Total	8,541.95
			Add 10% as Wastage			854.20
					Total Material	9,396.15
B	Cost of Steel Reinforcement (15%)		15%	PKR	1,409.42	1,409.42
C	Vibrating Charges (2%)		2%	PKR	187.92	187.92
D	Cleaning, slurry, Curing and finishing Per m^3 (5%)		5%	PKR	469.81	469.81
E	Winches, Gantry and other aids foe lagging Per m^3 (5%)		5%	PKR	469.81	469.81
F	Miscellaneous Supplies such as hose pipes, air and small tolls etc. (3%)		3%	PKR	281.88	281.88
G	Transportaion to Site (8%)		8%	PKR	751.69	751.69
H	Erection on Site (10%)		10%	PKR	939.61	939.61
	Total Prime Cost Per m^3					13,906.29
	Add %					
	Over Head Charges	10%				1,390.63
	Income Tax	6%				834.38
	Contractor Profit	20%				2,781.26
	TOTAL RATE Per m^3					18,912.56
					US $	180.12

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REINFORCED CEMENT CONCRETE (21 mpa)							
	Unit:- 2.83 m^3 = 100 Cft			1 US $ =PKR 105 (AS OF DEC;2013)			
Sr No	Discription			Qty	Unit	Rate	Amount (PKR)
A	MATERIAL						
a.	Cement			17.60	Bag	650	11,440.00
b.	Sand			44	Cft	40	1,760.00
c.	Coarse Aggregate			88	Cft	50	4,400.00
d.	Water			LS		80	80.00
e.	Admixture			LS		100	100.00
					Total		17,780.00
				Add 5% as Wastage			889.00
					Total Material		18,669.00
B	LABOUR CHARGES						
B.1	Direct Labour	30 m^3					
	Foreman	50000/30		1	No.	1666.67	1,666.67
	Fitter	30000/30		2	No.	1000.00	2,000.00
	Electrician	35000/30		1	No.	1166.67	1,166.67
	Mason	25000/30		2	No.	833.33	1,666.67
	Beldar	20000/30		6	No.	666.67	4,000.00
	Carpenter	25000/30		1	No.	833.33	833.33
	Vibrator operator	20000/30		2	No.	666.67	1,333.33
							12,666.67
B.1	In Direct Labour						
	Towards amenities, construction of camps, transportation, medical facilities & retrenching benefits etc. @ 50 of direct labour charges.				PKR	#######	6,333.33
			Total Direct & indirect Charges				19,000.00
			Total direct & indirect Charges Per m^3				633.33
			Total direct & indirect Charges for 2.83 m^3				1,792.33
C	Concrete Batching, Mixing and laying etc. Rate / m^3						
C.1	Batching and mixing plant Capacity			60	m^3		
	Cost of Plant (60 m^3)				PKR	30000	
	Assuming job Factor 50%			0.5	PKR	15000	15000
				Cost Per m^3			500.00
				Cost For 2.83 m^3			1,415.00
D	Transport of Concrete by transit mixer from Batching & Mixing Plant to placement site lead			5	Km		
	Capacity of Transit Mixer			3	m^3		
	Expensive of Mixer				PKR	10000	
	Rate Per m^3			1	m^3	3333.33	
	Rate for 2.83 m^3						9,433.33

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Sr No	Discription			Qty	Unit	Rate	Amount (PKR)
E	Vibrator	1500 Rs/- Per Day		2	No	1500	3000
F	Shuttering Charges	30 Rs/- Per Sft	Rs/- Per Sft	100	Sft	30	3000
	Total Prime Cost						37,309.67
	Add %						
	Over Head Charges	10%					3,730.97
	Income Tax	6%					2,238.58
	Contractor Profit	15%					5,596.45
	TOTAL RATE Per 2.83 m^3					PKR	48,875.66
	TOTAL RATE Per m^3					PKR	17,270.55
	TOTAL RATE Per m^3					US $	164.48

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Sr No	Discription			Qty	Unit	Rate	Amount (PKR)
	REINFORCED CEMENT CONCRETE (28 mpa)						
	Unit:- 2.83 m^3 = 100 Cft			1 US $ =PKR 105 (AS OF DEC;2013)			
A	<u>MATERIAL</u>						
a.	Cement			22.50	Bag	650	14,625.00
b.	Sand			42	Cft	40	1,680.00
c.	Coarse Aggregate			84	Cft	50	4,200.00
d.	Water				LS	100	100.00
e.	Admixture				LS	150	150.00
						Total	**20,755.00**
					Add 5% as Wastage		1,037.75
					Total Material		**21,792.75**
B	<u>LABOUR CHARGES</u>						
B.1	Direct Labour	30 m^3					
	Foreman	50000/30		1	No.	1666.67	1,666.67
	Fitter	30000/30		2	No.	1000.00	2,000.00
	Electrician	35000/30		1	No.	1166.67	1,166.67
	Mason	25000/30		2	No.	833.33	1,666.67
	Beldar	20000/30		6	No.	666.67	4,000.00
	Carpenter	25000/30		1	No.	833.33	833.33
	Vibrator operator	20000/30		1	No.	666.67	666.67
							12,000.00
B.1	**In Direct Labour**						
	Towards amenities, construction of camps, transportation, medical facilities & retrenching benefits etc. @ 50 of direct labour charges.				PKR	6,000.00	6,000.00
			Total Direct & indirect Charges				**18,000.00**
			Total direct & indirect Charges Per m^3				**600.00**
			Total direct & indirect Charges for 2.83 m^3				**1,698.00**
C	**Concrete Batching, Mixing and laying etc. Rate / m^3**						
C.1	Batching and mixing plant Capacity			60	m^3		
	Cost of Plant (60 m^3)				PKR	30000	
	Assuming job Factor 50%			0.5	PKR	15000	15000
				Cost Per m^3			**500.00**
				Cost For 2.83 m^3			**1,415.00**
D	**Transport of Concrete by transit mixer from Batching & Mixing Plant to placement site lead**				**5 Km**		
	Capacity of Transit Mixer			3	m^3		
	Expensive of Mixer				PKR	10000	
	Rate Per m^3			1	m^3	3333.33	
	Rate for 2.83 m^3						**9,433.33**
E	**Vibrator**	1500 Rs/- Per Day		2	No	1500	3000
F	**Shuttering Charges**	30 Rs/- Per Sft	Rs/- Per Sft	100	Sft	30	3000

Sr No	Discription			Qty	Unit	Rate	Amount (PKR)
	Total Prime Cost						40,339.08
	Add %						
	Over Head Charges	10%					4,033.91
	Income Tax	6%					2,420.35
	Contractor Profit	15%					6,050.86
	TOTAL RATE Per 2.83 m^3					US $	52,844.20
	TOTAL RATE Per m^3					US $	18,672.86
	TOTAL RATE Per m^3					US $	177.84

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Rock Bolts (25mm dia)					
1 US $ =PKR 105 (AS OF DEC;2013)					
Sr No	Discription		Qty	Unit	Amount (PKR)
A	**Drilling and Fixing Charges**				
	Drilling for Rock Bolting will be Carried out by Rock Bolter				
	Progress of Rock Bolter per Hour		20	m	
	Hourly use rate of Rock Bolts			**PKR**	**20000**
A.1	Rate of Drilling /m			PKR	1000
A.2	Cost of Drill rods / m Drilling			PKR	300
A.3	Grouting Rock Bolts (LS)			PKR	200
A.4	Miscellaneous (LS)			PKR	200
	SUB TOTAL			**PKR**	**1,700.00**
B	**Material Charges**				
B.1	Supply of Rock Bolts 25mm dia 3 m Long of wt/m. At a rate per Kg	300 Rs/- Per Kg	11.5	m	1150
B.2	Wastage in Cutting 3% of (B.1)				34.5
B.3	Cost of nuts and plates (LS)				80
B.4	Cost of shell type anchors or resin capsules (LS)				60
	Total Prime Cost Per m				**3,024.50**
	Add %				
	Over Head Charges	10%			302.45
	Income Tax	6%			181.47
	Contractor Profit	20%			604.90
	Hence Rate per m			**PKR**	**4,113.32**
	Hence Rate per m			**US $**	**39.17**

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STEEL FIBER REINFORCED (Shortcret)							
1 US $ =PKR 105 (AS OF DEC;2013)							
Sr No	Discription		Qty	Unit	Rate	Amount (PKR)
A	MATERIAL					
a.	Cement		9.00	Bag	650	5,850.00
b.	Sand		0.75	m^3	1413	1,059.75
c.	Coarse Aggregate		0.25	m^3	1766	441.50
d.	Steel Fiber		35	Kg	150	5,250.00
e.	Water		LS		50	50.00
					Total	12,651.25
				Add 10% as Wastage		1,265.13
					Total Material	13,916.38
B	Charges for Mixing of Material and Transportation and batching to site as per Tunnel 10% of (A)			PKR		1,391.64
C	Placement Charges					
1	Rate for Use shortcrete Machine capacity of 30 m^3 in a day			PKR	8000	
2	Efficiency Charges Machine 50% Capacity 15 m^3			PKR	4000	
3	1 m^3 Charges			PKR	266.67	266.67
D	Lightning, Workshop Charges & other misc items @ 10%					1,381.00
	Total Prime Cost					16,955.68
	Add %					
	Over Head Charges	10%				1,695.57
	Income Tax	6%				1,017.34
	Contractor Profit	18%				3,052.02
	TOTAL RATE PER m^3					22,720.61
					US $	216.39

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EXCAVATION IN TUNNEL (SOFT ROCK)								
1 US $ =PKR 105 (AS OF DEC;2013)								
Sr No	Discription	Length	Width	Hight	Qty	Unit	Rate	Amount(PKR)
1	The Size of tunnel	4.80	6.80	6.60				
	19.14 m^3 + Top Half Circle = 18.14)				**37.30**	m^3		
	Quantity of Per shift	4.00		37.30	**149.20**	m^3	(2 Cycle)	
A	DIRECT LABOUR							
	Foreman Special drilling			50000/30	2.00	No	1666.67	3333.33
	Asst. Foreman drilling			30000/30	1.00	No	1000.00	1000.00
	Explosive Inspector			35000/30	1.00	No	1166.67	1166.67
	Electrician			30000/30	1.00	No	1000.00	1000.00
	Explosive (Blaster)			25000/30	1.00	No	833.33	833.33
	Hole Cleaner			25000/30	2.00	No	833.33	1666.67
	Helper Electrician			20000/30	1.00	No	666.67	666.67
	Beldar			20000/30	10.00	No	666.67	6666.67
	Wire man for Blasting			25000/30	1.00	No	833.33	833.33
	Explosive Charge Man			35000/30	1.00	No	1333.33	1333.33
							Total	**18500.00**
		In direct charges for labour Towards amenities, construction of camps, transportation, medical facilities & retrenching benefits etc. @ 50% of direct labour charges.						9250.00
					Total Labour Cost for 150 m^3			**27750.00**
					Total Labour Cost Per m^3			**185.00**
B	MACHINERY CHARGES							
		No					**Rate /h**	
1	Drill Jumbo Machine	1		4 Hour	8	Hour	28000	224000
2	Tippers	6		3 Hour	18	Hour	4000	72000
3	Excavator	1		3 Hour	8	Hour	9000	72000
4	D.B Tractor Dozer	1		3 Hour	8	Hour	13000	104000
5	Loader	1		3 Hour	8	Hour	3500	28000
6	Dump Truck	1		3 Hour	8	Hour	5000	40000
					Total Cost for 150 m^3			**540000.00**
					Total Cost Per m^3			**3600.00**
C	MATERIAL CHARGES							
	progress per cycle, therefore 2 m deep				2	m		
	b) X.Section Area of Each bench				37.3	m^2		

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Sr No	Discription	Length	Width	Hight	Qty	Unit	Rate	Amount(PKR)
	c) Assuming average spacing of holes				0.75	m c/c		
	No. of holes required per cycle	66	2		132	No		
	d) Total Depth of drilling	132		2	264	m		
	Cost of drill steel / m				**550**	**PKR**		
	Total Cost of Drill Steel				**145200**	**PKR**		
	Total Excvated Qty				**150**	**m^3**		
	Rate per m^3				**968.00**	**PKR**		
C.1	**EXPLOSIVES**							
	a) Gelatine required per m^3	1.50 Kg	300 Rs/- Per Kg		1	m^3	450	**450**
	b) Detonators and fuse coils							
	1 No. per hole per face				132	No		
	Cost of Detonator				132	No	120	15840
	c) Fuse Coils				132	No	80	10560
	Total Cost of Detonator+Fuse Coil for 150 m^3							**26400.00**
	Total Cost of Detonator+Fuse Coil Per m^3							**176.00**
	Other consumable petty store such as blasting Batteries, galvanimeters and blasting wires etc. @ 50% of item (I)				1	m^3	225	225
	Total Explosive Charges per m^3							**851.00**
	Total Cost of Drilling and Blasting							**1819.00**
	for wet drilling per m^3					LS	100	100
	Timber for supports packing per m^3					LS	100	100
	Miscellaneous supplies such as safty hats, gumboots, Rain coat, wire ropes, manila ropes, V-Clamps, rubber gloves, shackels and artficial respirators etc. Per m^3					LS	100	100
	Total Cost of Material Per m^3							**2119.00**
D	**CHARGES FOR VENTILATION BLOWERS**							
	a) Description of Charges							
	accessories such as air ducts						2000000	
	Rated life					Hours	50000	
	Description charges P.hour				1	Hours	40	40

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Sr No	Discription	Length	Width	Hight	Qty	Unit	Rate	Amount(PKR)
					8	Hours	40	320
	b) Repair and maintenance Charges							
	100% of depreciation						320	320
	c) Pol Charges							
	Horse power of Blower	80	H.P					
	Energy Required	59.68	Kwh/shift					
	Cost of Energy				59.68	Kwh	15	895.2
	Sundries and other item					LS	200	200
								1095.2
	d) Labour Charges							
	Operator				8	Hour	104.25	834
	Helper				8	Hour	75	600
								1434
	Add for hidden of labour Charges 50%							717
	Total Cost of Labour for 8 Hours							2151
	Total Cost of Labour per Hour							268.875
	Total Cost (a+b+c+d)							**2004.08**
	shift				8	Hours		
	Total Charges of Blowers Per Shift				8	Hours	2004.08	16032.6
	Total Quantity of Excavation				150	m^3		
	Total Charges Per m^3				1	m^3	106.88	106.88
E	**SHOP CHARGES**							
E.1	Machine Shop i/c foundary and smithy					LS	80	80
E.2	Structural Shop					LS	80	80
E.3	Steel metal shop					LS	80	80
E.4	Air and water pipe shop					LS	80	80
E.5	Carpentary shop					LS	80	80
	Total Shop Charges per m^3							400
F	Electrical material charges Per m^3					LS	80	80
G	Jumbo track charges Per m^3					LS	80	80
H	Compresed air Charges per m^3					LS	100	100
I	Water Charges Per m^3					LS	30	30
	ABSTRACT OF CHARGES							
A	Direct Labour Charges				1	m^3	185.00	185.00
B	Machinery Charges				1	m^3	3600.00	3600.00
C	Material Charges				1	m^3	2119.00	2119.00
D	Vantilation Blowers Charges				1	m^3	106.88	106.88
E	Shop Charges				1	m^3	400	400.00
F	Electrical Material				1	m^3	80	80.00
G	Jumbu Track charges				1	m^3	80	80.00
H	Compresed air Charges				1	m^3	100	100.00
I	Water Charges				1	m^3	30	30.00
	Total Charges							**6700.88**

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Sr No	Discription	Length	Width	Hight	Qty	Unit	Rate	Amount(PKR)
	Maintenance of haul roads							335.04
	Add 3% elecricity charges							201.03
	Contractor Profit 20%							1340.18
	Over Head Charges 10%							670.09
	Income Tax 6%							402.05
	Hence Rate Per m^3						**PKR**	**9649.27**
	Hence Rate Per m^3						**US $**	**91.90**

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STEEL REINFORCEMENT						
1 US $ =PKR 105 (AS OF DEC;2013)						
Sr No	Discription		Qty	Unit	Rate	Amount (PKR)
A	MATERIAL					
a.	Cost of Steel at Store		1.00	Ton	80000	80,000.00
					Total	80,000.00
				incidentals to work		4,000.00
					Total Material	84,000.00
B	Handling and Placing					
B.1	Bending & Cutting @ 5%		5%	PKR	4,200.00	4,200.00
B.2	Handling @ 4% of (A)		4%	PKR	3,360.00	3,360.00
B.3	Placing and Welding @ 4% of (A)		4%	PKR	3,360.00	3,360.00
B.4	Binding Wire and other Materials @ 4% of (A)		4%	PKR	3,360.00	3,360.00
B.5	Transportation Charges @ 10% of (A)		10%	PKR	8,400.00	8,400.00
	Total Prime Cost					106,680.00
	Add %					
	Over Head Charges	10%				10,668.00
	Income Tax	6%				6,400.80
	Contractor Profit	12%				12,801.60
	TOTAL RATE Per Tons					136,550.40
	TOTAL RATE Per Tons				US $	1300.48

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Stone Pitching (1:6)							
	Unit: 100 Cft = 2.83 m^3			1 US $ =PKR 105 (AS OF DEC;2013)			
Sr No	Discription			Qty	Unit	Rate	Amount (PKR)
A	MATERIAL						
a.	Rubble Stone			130	Cft	50	6,500.00
b.	Cement			1.50	Bag	650	975.00
c.	Sand			26	Cft	40	1,040.00
d.	Water				LS	200	200.00
						Total	8,715.00
				Add 5% as Wastage			435.75
						Total Material	9,150.75
B	LABOUR CHARGES						
	Mason			2	No.	800	1,600.00
	Mazdoor			4	No.	500	2,000.00
	Mate			1	No.	600	600.00
	Foreman			1	No.	800	800.00
							5,000.00
				1/2 Day Cost			2,500.00
C	T & P Charges @ 5% of (A)	5%			PKR		457.54
	Total Prime Cost						12,108.29
	Add %						
	Over Head Charges	10%					1,210.83
	Income Tax	6%					726.50
	Contractor Profit	20%					2,421.66
	TOTAL RATE Per 2.83 m^3						16,467.27
	TOTAL RATE Per m^3						5,818.82
						US $	55.42

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Stone Work							
1 US $ =PKR 105 (AS OF DEC;2013)							
Sr No	Discription			Qty	Unit	Rate	Amount (PKR)
A	MATERIAL						
a.	Rubble Stone			135	Cft	50	6,750.00
b.	Cement			3.00	Bag	650	1,950.00
c.	Sand			26	Cft	40	1,040.00
d.	Water				LS	200	200.00
						Total	9,940.00
					Add 5% as Wastage		497.00
						Total Material	10,437.00
B	LABOUR CHARGES						
	Mason			2	No.	800	1,600.00
	Mazdoor			4	No.	500	2,000.00
	Mate			1	No.	600	600.00
	Foreman			1	No.	800	800.00
							5,000.00
				1/2 Day Cost			2,500.00
C	Scafolding Charges @ 5% of (A)	5%			PKR		521.85
	Total Prime Cost						13,458.85
	Add %						
	Over Head Charges	10%					1,345.89
	Income Tax	6%					807.53
	Contractor Profit	20%					2,691.77
	TOTAL RATE Per 2.83 m^3						18,304.04
	TOTAL RATE Per m^3						6,467.86
						US $	61.60

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CONSTRUCTION METHODOLOGY & PLANNING

12.3.1 General

This chapter of feasibility study report deals with the project Implementation methodology and planning, which covers a number of the construction activities and assessment of time required for its completion synchronized with the corresponding construction methods and construction equipment. Detailed construction and implementation schedule for the project has been prepared on the basis of implementation of construction methods envisaged.

This work approach has been elaborated under the assumption that the owner would apply EPC contracting for implementation of this project.

However other contracting systems may be applied for the project, depending upon capacities of the owner and policy decisions.

12.3.2 Pre-Construction Activities

Certain preparatory infrastructure works are essentially required well before the actual commencement of launching a project particularly in a remote area and largely contribute to its timely completion. The following tasks would be needed to be performed prior to the commencement of work on main elements of the project.

The activity pertaining to the arrangement of financing from local and international resources need to be taken up as soon as possible, since this process generally takes considerable time.

In order to make an overall assessment of different elements of this Project viz-à-viz their completion timing, the study has been divided under the following sub-heads:

- General characteristics of the Project Area, and its weather conditions
- Up-gradation of approach roads and bridges
- Pre-construction activities
- Procurement modes and contract packaging
- Quantities of major items of civil works
- Construction planning and scheduling
- Agreements for construction supervision

The construction work on various components of the Project is proposed to be under taken round the clock or at least in two shifts. This will, however, be decided by the civil works contractor to meet the targets for timely completion of the project. Different construction activities shall proceed in parallel where practicable. The completion period for the entire project is envisaged as four years excluding the time required for pre-construction activities viz.

- Arrangements for project financing.
- Additional geotechnical investigations if so required supplementing the design inputs already available.
- Planning, analysis & design of structures
- Preparation of EPC documents.
- Contract packaging
- Bidding process
- Selection of EPC contractor
- Award of contract on EPC basis
- Acquisition of land for permanent structures (if required).
- Lease of land for construction camp as well as permanent structures.
- Construction of 11 KV sub-station at the project site to make power available during construction of the project.
- Arrangements of water for construction.

12.3.3 Characteristic of Project Area

12.3.4 General Description

Proposed Arkari Gol Hydropower project is located on Arkari River flowing in the narrow Arkari valley bounded by high mountain ranges along Chitral Garam Chashma Road. Arkari River is a Left Bank Tributary of Lutkho River and joins it about 25km North East of Chitral Town, from where the river is named as Chitral River. The identified dam site is close to Uchatar Village whereas, the powerhouse site is near Andakht Village. The powerhouse is 25 km and the weir is 33km from Chitral Town, respectively. The site is accessible from Islamabad and Peshawar via Chitral by air and by road through Lowari Pass/ Lowari tunnel. Chitral is 365 km from Peshawar & 455 km from Rawalpindi/Islamabad. Both the dam and powerhouse sites are accessible from Chitral Town by a poorly maintained metaled Chitral/Garam Chashma Road and three wooden bridges, which shall be rehabilitated according to the Project Requirements.

To harness the hydropower potential of 8 km lower stretch of Arkari Gol, GTZ, (German Agency for Technical Collaboration) identified this project site on the right bank of Arkari River with powerhouse near Andakht Village.

Arkari Gol is the left tributary of Lutkho River with confluence 25 km north east of Chitral town in District Chitral of Khyber Pakhtunkhwa Province.

On the basis of the recent study conducted by the Consultant, the total head available for generation of power is 318 meters which can produce 101.2 MW with design discharge of 36 m^3/s. The headrace power tunnel is nearly 5.804 kilometers long connecting the intake to the powerhouse.

12.3.5 Climate

The climate of the Project Area is very harsh during winters and pleasant and dry in summers. Mean monthly temperatures and precipitations are reflected in the Table12-1 below. The maximum rainfall occurs during the months of March and April and minimum in the months of July and August each year.

Chitral Town is surrounded by high mountains and, therefore, it does not receive monsoon rains during July & August. The daily precipitation data at Chitral Meteorological Station is available and has been used to compute rainfall. Based on 19 years precipitation record (1992-2010) the maximum daily precipitation, observed on 10th October, 2004, was 109 mm and maximum annual precipitation during the year 1992 was recorded as 719 mm. Mean annual rainfall in Chitral is about 500 mm, occurring mainly during springs and winters. Summer and autumn seasons remain dry with 10-25 mm rainfall per month. In upper Chitral valley, the annual precipitation is as low as 200 mm. It is mostly in the form of snowfall at the higher altitudes.

The mean maximum temperature varies from 35°C to 37°C, which is recorded during the months of June to August. The minimum temperature is usually recorded as 0 to -1°C in January and February. The powerhouse and dam sites are surrounded by high mountains and therefore, it is expected that minimum temperature at the Project will be a few degrees lower than the freezing point in winters. Since the flows in Arkari River largely relate to snow and glacier melts, the intensity of flow is directly dependent on atmospheric air temperature. Temperature therefore, is of vital importance for access to Chitral and availability of water in the rivers for hydropower generation. The table given below provides the climatic data of Chitral Town.

Table 02-1: Climatic Data of Chitral Town

Month	Temperature in °C		Rainfall in mm
	Maximum	Minimum	
January	9	-1	43
February	11	0	60
March	16	5	110

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Table 02-1: Climatic Data of Chitral Town			
Month	Temperature in °C		Rainfall in
April	22	8	84
May	27	12	40
June	35	19	10
July	37	21	4
August	36	20	3
September	32	14	14
October	25	8	32
November	18	3	30
December	12	0	40

Generally maximum humidity is recorded during the month of December with an average value of 43% while in the month of June; it is the minimum with an average value of 24%.

12.3.6 Approach Route to Site

Major electro-mechanical, heavy steel structural components and construction equipment will be imported from abroad by sea. The consignments would be unloaded at Karachi Port. The equipment shall be transported from Karachi to the Project site on long trucks and low bed trailers by traveling a long distance of about 1960 kilometers via Hyderabad, Rahim Yar Khan, Bahawalpur, Khanewal, Lahore, Rawalpindi, Mardan, Dargai, Dir and to Chitral after passing through Lowari Tunnel (presently under construction). The transportation of heavy equipment to the project site would be a monumental task and would require hiring of experienced transporters.

Major construction materials like cement, re-steel bars and structural steel are available from the cities of Nowshera, Islamabad and Peshawar. The transportation of heavy equipment on trailers along the dirt track with sharp turns and steep gradients connecting Lowari Tunnel portals shall require careful planning and meticulous handling. Transportation Study is included in relevant section of the report and provides in-depth review of the selected route.

Chitral Town, the major city close to the project lies in the North-West of the country and is connected with Motorway M1 through metaled road starting from Rakashai Interchange and proceeding along cities/towns of Mardan, Dargai, Malakand, Chakdara, Dir, Drosh and approaches Chitral Town after crossing through Lowari Tunnel. Previously the road passed through Lowari pass at EL 3300 masl. It was a dirt road studded with sharp turns and steep gradients. Transport of goods through trailers was an uphill task however, with the completion of Lowari Tunnel, movement of trucks and trailers would be facilitated to a large extent.

The road from Dir to Chitral used to remain closed for about four months during winters for all types of traffic due to heavy snowfall over Lowari Pass. Hence, it used to be necessary to bring construction materials like cement, reinforcing bars etc. and equipment to Chitral and beyond and stored in proper place during summers for use during winters. However, with the completion of Lowari Tunnel and up-gradation of Dir - Chitral road it would remain open throughout the year except for small periods of heavy snowfall along approaches to the tunnel.

Up-gradation of 25 kilometers of Garam Chashma Road and 8km of Arkari Village Road in any case would be necessary to facilitate the movement of trailers and long trucks from Chitral to project site. This task was identified to be completed much before the start of the project on-ground.

Up-gradation of Approach Road from Chitral Town to Project Site. This Project is located on Arkari River, which is a left bank tributary of Lutkho River. A metalled road, 4 meters wide with one meter shoulders on each side, named Chitral-Garam Chashma road, exists on the right bank of Chitral River up to some distance beyond Shoghore village. The same road continues on the right bank of the Lutkho River upto Ruji Village and then crosses over to the left bank leading to Arkari Village. From Ruji to weir site, the existing road is jeep able but requires to be widened. There are three wooden bridges which shall be replaced by RCC Bridges capable of sustaining AA class loading.

The up-gradation of this road, about 40 kilometers long has been envisaged for safe transportation of machinery and equipment on the trailers up to the weir site and particularly the powerhouse site

Although widening and improvement of Chitral Garam Chashma road has been initiated during 2012 – 2013. PHYDO should emphasize the Provincial Communication and Works Department to plan and complete it well before, work on the project starts i.e. within next two years.

12.3.7 Construction of Permanent Office & Residential Accommodation

Office & residential accommodation of different categories for Employer's operation and maintenance (O&M) staff would be another important requirement which must be met with well before mobilization of the contractors. This accommodation shall be used by client staff and consultants during construction phase of the project. Number of housing units and requirement of utility buildings for the project would need to be worked out according to the strength of the O & M staff envisaged by the Client. Area for the establishment of office and residential accommodation would need to be acquired if state land is not available in the vicinity of the power house.

In the absence of any clear requirements of operation and maintenance staff, the consultant based on his experience of other similar projects has prepared a proposal annexed to this chapter.

12.3.8 Temporary Infrastructure Works

Project is surrounded by high mountains and narrow valley along both banks of the river, therefore limited space is available for construction of temporary accommodation for the labour force and supervisory staff, workshops, construction yard and stores. Since skilled and semi-skilled labour force and supervisory staff would originate from regions other than Chitral from where unskilled labour would be hired, temporary accommodation, therefore, would be essentially required for their presence near the project.

The contractor shall also need the following temporary infrastructure works for the timely and smooth completion of the Project and will construct the same prior to mobilization of construction equipment and manpower.

- Barracks for the labour and bachelor accommodation for supervisory and managerial staff.
- Field offices, laboratory, check posts, fencing etc.
- Temporary access roads connecting the working areas.
- Concrete batching and aggregate processing plant.
- Arrangements for water supply, sewerage and electricity.
- Workshop and stores after completion of the project, these temporary buildings may be taken over by the employer for utilization by Powerhouse O & M staff.

12.3.9 Factors Affecting Progress of Construction Works

The number of days needed for completion of any job has been worked out with respect to the magnitude of different construction activities, and the knowledge of local practices of execution of works and nonproductive days due to weekly holidays, public holidays and religious festivals.

12.3.10 Effective Working Days

Based on the 6 working days a week, the effective working days in a month have been considered to be 25 days. As a result of heavy snowfall in the project area during the winters and temperature falling below freezing point, suspension of the construction activities are expected for about 2 months collectively during months of January & February. Moreover, 12 official holidays as details given below are observed during the remaining 10 working months. Hence, accumulative working days per year will be 10 × 25 = 250 – 13 = 237. The ratio of net working days to elapsed calendar days in a year, as shown on the Project Schedule is 237/365 = 0.70. For the purpose of development of the cost estimate and construction schedule, the required production rates have been calculated based on the effective working time.

Non-productive Days

In order to determine networking periods available for construction, it is necessary to evaluate the time that will not be available due to various reasons. The following will cause reduction in the working period.

Sundays

Sunday is observed as a weekly holiday in Pakistan. It is therefore, assumed that, under normal circumstances, only six days would be available during each week i.e. Monday to Saturday.

Fridays

Although Friday is a working day in Pakistan but the Muslims congregate for offering Jumma prayers. Therefore on Fridays the working period would be less by about 2 hours.

Public Holidays

There are 13 official public holidays in Pakistan, as mentioned below in Table 16-2. The dates of some of these are subject to appearance of moon. Additionally, there are some days of optional holidays relating to particular religion or local occasions.

Table 12-2: Official Public Holidays

Official Public Holidays		
Occasions	Date	No of holidays
Pakistan Day	23 March	1
Kashmir Day	5 February	1
Labour Day	1st May	1
Independence Day	14 August	1

Table 12-2: Official Public Holidays		
Official Public Holidays		
Occasions	Date	No of holidays
Iqbal Day	9 November	1
Eid-ul-Fitr*		2
Birthday of Quaid-e-Azam	25 December	1
Eid-u l-Az ha*		2
9th10th of Muharram*		2
Eid-ul-Milad-un-Nabi (S.A.W.)*		1
Total Official Holidays		13

However, it is traditional to close the site for 7 to 10 days for breaking on Eidul Fitr & Eid ul Azha as most of the labour, who would be hailing from distant places visit their families to celebrate these festivals with them.

Effective working days therefore would be about 240. Normally, weekly holidays are not observed at projects in remote areas, and the labour is allowed to avail more holidays than the official holidays on Eids.

Ramadan

During the month of Ramadan, all followers of Islamic faith are required to fast from dawn until dusk. Therefore, there would be consequential drop in productivity during this month, which has been estimated to a loss of about 10 working days.

Miscellaneous Delays

Landslides and heavy snowfalls during winter seasons may further reduce the number of working days at the project.

12.3.11 Materials Required for Construction

12.3.11.1 Drilling Items and Explosive Materials

Large quantities of drilling bits, rods and other accessories will be necessary due to considerable quantities of rock excavation. The consumption of these imported items is generally difficult to assess. However, a sustainable inventory will have to be maintained at site in view of remote location of the project. Wah - Bofors factory in Wah near Islamabad is capable of supplying all the explosive and blasting items required for the Project.

12.3.11.2 Cement

Cement is abundantly available in Pakistan. During snowfall and rainy season, there is invariably a risk of supply hold-up due to route being frequently interrupted due to snowfall and invasion of hill torrents. To ensure continuity of construction works, storage of adequate quantity of cement at site would be essential.

Mostly, Ordinary Portland Cement will be used. Sufficient production capacity of about 30,000 tons per day is available with the existing cement factories in Pakistan and cement can be transported to the project site using trucks or long trailers/bulk cement carriers. The daily consumption of cement for concrete works at the Project may vary between 150 to 200 tons.

Table 12-3 indicates the present daily production of six factories nearest to the Project. It is evident from production rates of these factories that any of these factories can furnish the requisite quantity of cement for concrete works at the Project site.

Table 02-3: Cement Production Capacities in Various Factories

Factory	Capacity (tones/ day)	Distance from Powerhouse site (Approx. km)
Maple Leaf, Daud Khel	5,000	610
Bestway, Hattar	3,450	400
Askari, Wah	3,300	385
Askari, Nizampur	4,000	344
Fauji, Attock	3,200	345
Saadi, Haripur (Hattar)	2,500	365

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12.3.11.3 Reinforcing Steel

A significant quantity of reinforcing steel is required for this Project. Several factories in the country produce varying quantities of re-steel bars, in the form of plain and deformed bars. There is no factory of re-rolling reinforcing steel bars in the near vicinity of the proposed Project. The nearest station from where the reinforcing steel bars of the desired specifications are available is Islamabad, 475 kilometers and Peshawar 365 km. from the powerhouse site, where both hot and cold rolled reinforcing steel bars are available in the desired quantity.

Steel sheets of various thicknesses are produced at Karachi Steel Mills, which can be used to fabricate steel formwork. These can also be used for fabricating steel liners and other miscellaneous items required in connection with the construction activities. Alternatively, steel items can be imported from abroad in case there is shortfall in the country which would be a remote possibility.

12.3.11.4 Source of Coarse & Fine Aggregates and Fill Materials

The Source (s) of coarse and the fine aggregates as well as other embankment fill materials for construction and their availability close to the site have been described and discussed in the report covering Construction Materials studies.

12.3.12 Project Implementation

It is contemplated that after completion of the Feasibility Study, through International Competitive Bidding (ICB) investors for the project shall be chosen.

This may take about 12 months after which the investor will achieve financial close within next 18 months and finally 4 years will be required for construction of the Project.

The envisaged three phases of implementation of the Project are foreseen as under:

- **Phase I: Pre-Construction Activities and Award of Project to Investors.**

  ICB Process: 12 months

  Financial Close: 18 months

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- **Phase II: Project Construction Works with Detailed Engineering Design of Project Components**

  Completion Period: 48 months will be consumed for completion of all the components of the Project works.

- **Phase III: Testing and Commissioning of Turbines**

  A period of 3 – 4 months will be required for accomplishment of the requisite performance tests which shall be performed simultaneously with in the scheduled period.

12.3.13 Contract Packaging

This project is anticipated to be executed under EPC contracting under which, the contractor manages all engineering design and supervision activities together with series of civil construction and permanent equipment supply, installation and commissioning packages.

It is expected that contracts will be awarded to a number of civil works contractors with capabilities to undertake construction of different elements of civil works.

- River diversion and dam/weir construction, power channel, power tunnel intake and desanders.
- Power tunnel including surge tank and surge shaft, surge chambers, pressure shaft, and pressure tunnel.
- Power house complex and switchyard.
- Widening of Arkari Road and Construction of three Bridges
- Power house equipment, switch yard and hydro-mechanical equipment like gates, hoists, trash racks, steel liners etc.

12.3.14 Contract Award on EPC Basis

International Competitive Bidding (ICB) is proposed for execution of the Project. Award of contract on EPC basis has been foreseen with details given below:

- Detailed engineering design of the Project components.
- Construction of infrastructure works, civil works, procurement and installation of electrical and mechanical equipment including

switchyard, steel structures and its components etc.

12.3.15 Construction Sequencing

It is envisaged that project implementation would take about four years excluding period of detailed design, preparation of tender documents, floating of bids, negotiations, contract awarding and mobilization to the project site, construction of civil works, equipment supply, installation, testing and commissioning of hydro mechanical and electrical equipment and demobilization would form part of implementation periods. It may take another 4 to 6 month for trial run and handing over the project to the client.

12.3.15.1 Mobilization

Mobilization includes:

- Construction of office and residential accommodation for client and consultant staff.
- Living accommodation for Contractor's managerial & supervisory staff.
- Barracks for labour.
- Kitchen and recreation facilities.
- Construction of project workshop equipped with necessary equipment.
- Construction yard for safe keeping of construction equipment.
- Storage of construction materials.
- Re-bars cutting and bending yard.
- Installation of concrete batching plant with cement silos
- Concrete handling equipment.
- Excavation equipment, emergency generators and compressors etc.
- Arrangements for dewatering

Generally, construction of diversion tunnel, embankment dam with spillway, intake structure, headrace tunnel, and power house & tailrace channel would be carried out simultaneously followed by installation of mechanical and electrical equipment. The sequence of activities has been incorporated in the implementation schedule.

12.3.15.2 Pre-construction Stage

In this phase, following works would need to be initiated for completion within 6 months.

- Land acquisition/temporary lease of area for construction camp, construction yard and workshops.
- Establishment of construction camp and mobilization of construction equipment and materials, storage yard, workshops comprising of space for carpentry shop, re-bars cutting and bending shop and construction equipment and transport maintenance shop.
- Availability of construction power, water and communication facilities.
- Labour camp with kitchen dining and recreation facilities,
- Construction of offices, living accommodation for the operational staff (during construction phase, this shall be occupied by the clients and consultant staff).

12.3.15.3 Diversion Tunnel

- Construction of two coffer dams in ring form with crest level higher than floods of 10 years return period for creating working areas to undertake underground excavation of diversion tunnel.
- Excavation of diversion tunnel using conventional drill and blast method/NATM.
- Installation of temporary supports including wire meshing, pattern rock bolting and shotcreting depending upon the quality of rock encountered.
- Provision of concrete lining of suitable thickness.
- Removing the rock plugs and placement of rock boulders at the location of u/s coffer dam to be built for excavation of foundations of embankment dam.
- Diversion of river water to the diversion tunnel.
- Construction of project structure

12.3.15.4 Embankment Dam

- Construction of coffer dams u/s and d/s of embankment dam axis/weir.

- Excavation of foundation strata with suitable heavy construction equipment for the embankment after diversion of river water.
- Striping of abutment areas and excavation of over burden upto the specified levels.
- Filling of depressions with concrete and blanket grouting from surface of entire foundation area to a depth of about 5.0 m.
- Construction of cut off wall to the specified depth along u/s edge of the dam profile.
- Placing in layers and compaction of specified fill material brought from approved borrow areas/quarry sites in specified thickness and compaction with vibratory rollers to required density.
- Concurrent laying of concrete face slab over the u/s face of embankment to check seepage.

12.3.15.5 Spillway

On completion of the excavation up to the specified level, construction of spillway will be commenced in monoliths by erecting formwork. Before erecting formwork, steel reinforcement shall be positioned and concrete hauled in transit mixers from the batching plant. It shall be poured in lifts not exceeding 1.0 m. with concrete pumps. Surface of the freshly poured concrete shall be roughened/chipped with compressed air water jet to provide proper bond between the successive lifts. Copper/PVC water stops shall be provided towards u/s segment of the construction/contraction joints to check seepage through the joints. In this way concreting of the spillway shall be achieved. Block outs/embedment for different installations shall be provided at the required locations. Curtain grouting and pressure relief drains will be provided later.

12.3.15.6 Power Canal Intake Structure

After completion of the excavation, construction of Intake for the power canal, desandars and flushing tunnels shall be undertaken. Concreting of monoliths shall be achieved with concrete produced by batching plant hauled by transit mixers and its placement in lifts not exceeding 1.0 m. with mobile/stationary pumps. After completion of desanders, construction of connecting tunnels will be taken up starting from Desanders towards intake area.

12.3.15.7 Head Race Tunnel

Head Race Tunnel approximately 5.804 km. long shall be excavated in two segments of approximately 2.25 to 2.92 km in length. Access tunnel at the designated location shall be excavated using New Austrian Tunneling Method (NATM) to reach the alignment of head race tunnel. From each access tunnel, excavation of head race tunnel shall be proceeded in both the directions. Muck shall be removed through these access tunnels and dumped at designated locations.

It is estimated that 6 – 8 m. long excavation of head race tunnel shall be achieved by each party by working in two shifts of 10 hrs using conventional drill and blasting techniques. One cycle of operation shall comprise of drilling holes, charging with explosive, de-fuming, blasting, mucking and its transportation to the designated muck disposal areas. Excavation of the tunnel would require a good lighting and efficient ventilation systems for providing safe and comfortable environment to the staff working underground. The rate of excavation is estimated on the stipulation that modern and well maintained equipment will be used and work force will be adequately trained and experienced.

Initial treatment to the excavated tunnel surface shall be provided by rock bolting wire meshing and shotcreting. In weaker sections, steel arches and wire meshing may be required to stabilize the tunnel section before its lining is undertaken.

During excavation of tunnel, seepage of water through crevices and fissures is likely to be encountered. It would require its channelization leading to sumps of adequate capacity excavated for collection of seepage water and its pumping out with submersible pumps. For efficient disposal of seepage water installation of automatic float switches would be desirable. The sections/reaches where seepage of water is experienced will be treated by annulus grouting to stop leakage through the crevices and rock joints/fissures.

Nonetheless, efficient ventilation and proper lighting arrangements for safety of the manpower and equipment would be essentially required. To keep lighting and ventilation systems operative during suspension of power supply from the utility, standby generators would be essentially needed. It is expected that excavation of power tunnel and fore-bay would be accomplished in about 1.25 years' time.

At the power house end, the headrace tunnel will open up into Surge Tank as shown in Drawing no. 19 of Volume --, where steel lined pressure tunnel,

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connected to surge tank via steel lined pressure shaft, shall be connected to convey water to the turbines. It would be held in position over concrete pedestals properly designed and built.

Construction of Power House

This phase of construction will start concurrently soon after the pre-construction activities have been completed. Items following under this stage are listed here under and are likely to take about 3 years for completion.

- Excavation of power house pit
- Installation of dewatering system and putting it into operation.
- Concreting of turbine pits and structure forming the lower level of the power house.
- Building of structure above the main floor hall.
- Start of 2nd stage concreting with installation of embedded parts of turbines and hydraulic steel components.
- Placing of spiral casing in position.
- Concreting of space around spiral casing in stages by filling the voids between steel and rock faces.
- Building of power house walls and roof
- Installation and commissioning of overhead crane,
- Completion of power house superstructure and all other related works.
- Erection of turbines and generators.
- Testing and commissioning of turbines and generators.

Once the rock excavation in an open area at the location of power house is completed, the construction activities can be started. Excavation shall be deepest at the location of draft tube. The structure forming the lower level of the powerhouse and turbine pits will need to be concreted first. At the same time, the structure above the main floor will be built. The walls surrounding the turbines and generator will be built at the same time. Thereafter, the powerhouse walls and roofs will be constructed with specified type of concrete after erecting the formwork. Installation of powerhouse overhead crane will have to be taken before the installation of the stators. Overhead crane shall also be used for un-loading of power house equipment and its installation. In the meanwhile, concreting and installation of transformers in a separate building shall be accomplished. Tailrace area will be completed concurrently.

The total time for placing of concrete in the powerhouse and installation of the turbines, generators and other appurtenants is estimated to be about 30 months.

From the foregoing, it is concluded that construction of Power House Embankment Dam, Intake Structure and Desanders shall be carried out concurrently with the excavation of the power tunnel which shall be on the critical path.

12.3.16 Construction Equipment

Construction equipment shall be selected by the EPC contractor and moved to site for deployment during construction according to the methodology adopted by him for completion of the project within a period of 48 months. Major equipment is listed below

- Stone crushing plant for aggregate production.
- Dozers
- Dump trucks
- Front end loaders
- Jumbo drilling machines
- Rock bolting jumbos
- Pressure grouting equipment
- Shotcreting machines
- Stand by Emergency generators
- Air Compressors
- Axial flow ventilating fans
- Flexible air duct for ventilation.
- Concrete batching plant with cement silos
- Transit mixers
- Concrete pumps
- Rebar bending machines
- Blasting machines
- Vibratory roller/compactor
- Concrete vibrating equipment
- Water pumping equipment
- Road Grader
- Bowsers

- Tractors with trolley
- Transformers, cables, switch boards and lighting equipment.

12.3.17 Implementation Schedule

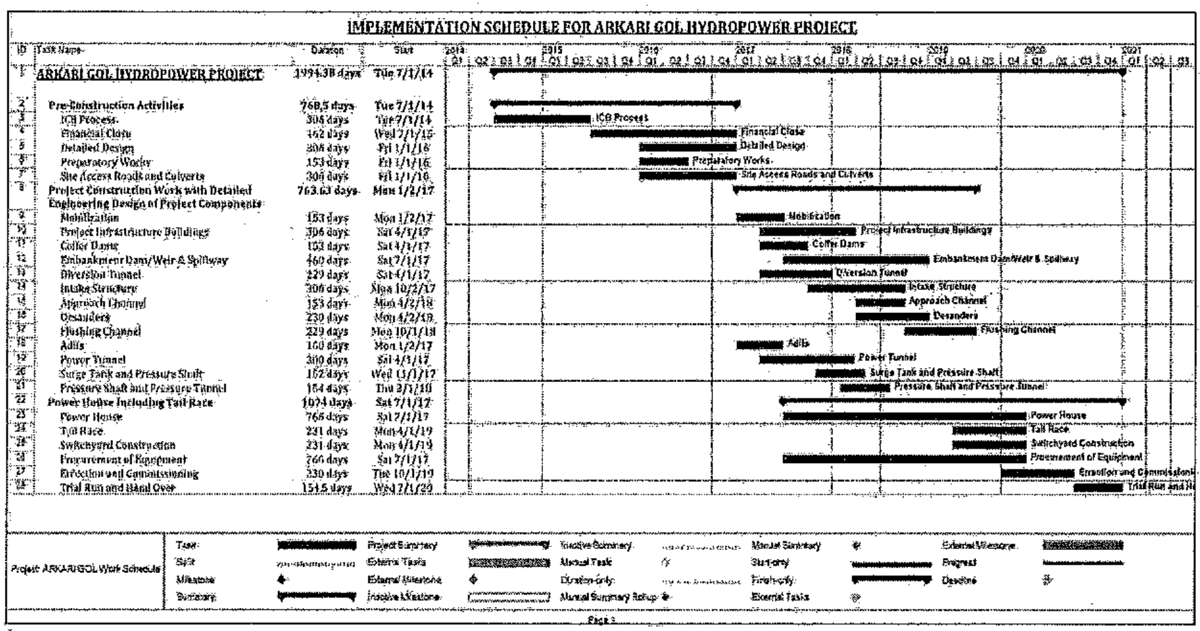
The implementation schedule for the Arkari Gol Hydropower project is shown in Figure 12-1.

12.3.18 Construction Supervision

Implementation of EPC Contracts is ensured by appointment of an experienced and professionally competent organization as Management Consultant by the Employer. (Moreover, top supervision is also made by the International financing organization).The Management Consultant, on behalf of the Employer review all the design and drawings before implementation and holds progress review meetings at site, prepares weekly/monthly progress reports to up-date the Employer on progress and sorts out interface problems where more than one contractor is working.

For construction supervision of Arkari Gol Hydropower project, similar procedure shall be followed.

Figure 12.1: Implementation schedule for Arkari Gol Hydropower Project



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CHAPTER - 12.4
TRANSPORT AND ACCESSIBILITY

12.4. Transportation Study

12.4.1 Introduction

The Arkari Gol hydropower project will entail procurement, transportation and installation of heavy and large sized construction and powerhouse equipment such as cranes, turbines, generators, transformers etc. Most of the equipment will be imported from foreign countries and will first land at the Karachi Port before being subsequently transported to the project site. This will require specialized handling of the equipment during loading, transit and off-loading. This will also need a review of the alternative transport modes and routes and their comparative suitability for the project's transportation needs.

In terms of modes of transport, the following two options were considered:

- Railway
- Road

Rail and road networks of Pakistan have been presented in the network maps of National Highway Authority (NHA) and Pakistan Railways annexed at the end of this chapter. Both road and railway were found to be suitable for the transport of project equipment. The road infrastructure will, however, need rehabilitation / up gradation at certain sections. This may entail adjustments to road and infrastructure dimensions, profiles, cross-sections, curves, slopes, clear heights, axle load capacities etc.

A discussion on alternative approaches follows.

12.4.2 Transport by Railway:

Pakistan's railway network connects Karachi to main cities and cantonments of the country. A map Pakistan Railway's network across the country has been presented below.

In the context of the project location, railway can be used for the transport of project equipment up to Nowshera Cantonment. Onwards, the equipment will need to be transported by road. It is pertinent to mention that different routes can be used for transport of equipment from Karachi to Nowshera by railway. However, from amongst the available options, the Broad Gauge Main Dual Line is considered as the more preferred route for transport of project equipment. Being the main artery of the country's railway network, it offers a more supportive infrastructure vis-à-vis the project's transportation requirements. Project equipment is therefore recommended to be transported from Karachi to Nowshera via the following railway route:

- Karachi – Nawabshah – Khanpur – Sahiwal – Lahore – Gujranwala – Gujrat – Rawalpindi – Attock – Nowshera

From Nowshera onwards, the equipment will be transported to the project site by road. The Nowshera-Mardan road will be used for transport of equipment up to Rashakai Interchange. Details of route to be followed beyond Rashakai Interchange have been given in Sections 12.4.3.4 to 12.4.3.12 of this chapter.

12.4.3 Transport by Road

Transport of project equipment to the project site is also possible by road. Services of local transporters who specialize in the transport of such equipment can be availed for the purpose. These transporters have the necessary experience and equipment for loading, transport and unloading of heavy project equipment. They operate multi-axle low bed trailers for haulage of heavy, odd-sized equipment. Transportation of equipment for the Chashma Nuclear Power project, Ghazi Barotha Hydropower project and large industrial projects in northern areas has contributed to the knowledge and expertise of local transporters in handling of such consignments.

Transport of equipment along different segments of the road en route to project site has been discussed as follows.

12.4.3.1 Karachi Port to Jamshoro

The Karachi Port is adequately equipped for lifting, handling and off-loading of heavy, odd-sized equipment from cargo ships to trailers. With the construction of Karachi Northern by-pass, cargo trucks/trailers now detour the city to enter Karachi – Hyderabad Expressway. From the toll plaza on Super Highway linking Karachi and Jamshoro up to a distance of approx 115 km, the road is built to International Standards with adequate clearances & gradients. There are, therefore, no impediments to smooth flow of all types of vehicular traffic. Bridges and culverts en-route are designed for Class AA loadings. An alternate route from Karachi to Kotri via National Highway (N-5), though available, is not feasible due to relatively poor road condition.

From Jamshoro (Hyderabad), either left bank Indus Road or right bank National Highway can be used for transport of equipment of all sizes and weights. Both the roads are extensively being used by transporters. The right bank road is a bituminous carpeted dual carriageway, all-weather highway.

12.4.3.2 Jamshoro to Lahore

National Highway between Jamshoro and Lahore is now an all-weather bituminous carpeted road with bridges and culverts

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designed for Class AA loadings. This route is being extensively used for transport of all types of goods including heavy and odd-sized equipment on low bed trailers. Most of the cities and towns en-route have been bypassed to avoid traffic congestion. Apparently, there appears to be no hurdle in transportation of equipment on this section of the National Highway.

Right Bank Road passes through Sukkur, Rahim Yar Khan, Multan, Sahiwal, Lahore and Rawalpindi. Road distances between various sections are as under:

Road Section	Distance
Karachi to Hyderabad	178 km
Hyderabad to Rahim Yar Khan	478 km
Rahim Yar Khan to Multan	253 km
Multan to Lahore via Sahiwal	341 km

The Left Bank Road is also an all weather road with bridges and culverts designed for Class AA loadings. This road passes through the towns of Dadu, Larkana, Kashmore, Rajanpur, Jampur, Dera Ghazi Khan, Taunsa, Dera Ismail Khan, Kohat, Peshawar and Mardan.

12.4.3.3 Lahore to Rashakai Interchange (via Motorway M-1)

Lahore is directly connected to Rashakai Interchange through the Motorway (M1, M2). Motorway is normally preferred for its ride quality and easy grades. The only difficult section is through the salt range stretching over approximately 16 kilometers. This section of the motorway can be safely commuted with slow speed and careful negotiation of bends and curves.

12.4.3.4 Lahore to Rashakai Interchange (via G.T.Road)

The G.T.Road is a dual carriage way with adequate infrastructure for convenient transportation of the equipment. Road width is sufficient and bends and slopes are negotiable for large vehicles. The G.T.Road leads to Nowshera via Rawalpindi. En route, trailers will have to pass through congested towns and cities. The Mardan-Nowshera Road then links the G.T.Road to the Rashakai Interchange.

Equipment transport via railway will also have to use the Mardan-Nowshera Road for access to Rashakai Interchange.

12.4.3.5 Rashakai Interchange to Dargai (N-45)

The road between Rashakai Interchange and Dargai is also a dual carriageway all weather road. Bridges and culverts are designed for Class AA loading. However, in view of traffic congestion, it may not be advisable to enter Mardan city during day time. This may entail crossing of Mardan during night time when the traffic volume recedes and businesses close down. A new ring road has recently been constructed which, while bypassing Mardan city, links Mardan-Malakand Road to Mardan-Nowshera Road. This ring road may facilitate transport of project equipment even during day time.

12.4.3.6 Dargai to Chakdara

After its recent upgradation, the road between Dargai and Chakdara is a well-surfaced, good quality bituminous asphalt road with easy grades and curves. The road section has an approximate width of 7.5 meters. There is one short length tunnel with a clearance of 4.8 m. Over-sized equipment can also be transported via a road bypassing the tunnel. The culverts and bridges in this section of the road have the capacity for Class AA loading. Because of its long and crowded bazaar stretching over a distance of approximately 3 km, it may be difficult to transport equipment across Butkehla during day time. This may necessitate transport across this town during night time.

12.4.3.7 Chakdara to Dir

Road distance between Chakdara to Dir is 226 km. This section has a 6.5 m wide, well-surfaced, all-weather road. Section of the road between Chakdara and Timergara is finished with Triple Surface Treatment (TST) and offers good ride quality. The bridge over River Swat at Chakdara was damaged during the 2010 floods and has temporarily been abridged by Bailey bridge. Reconstruction of the damaged portion is in progress. It is expected that the bridge will be rehabilitated much before the start of the project. Section of the road between Timergara and Dir Bala has been widened and upgraded in the recent past. It is a well-finished 7.5 m wide all-weather road. Road curves and gradients are easy except in the vicinity of Dir Town. However these can be conveniently negotiated by multi-axle long trailers at low speed.

12.4.3.8 Dir Bala to Lowari Tunnel

The road is metalled up to approximately 15 km but studded with sharp curves/bends and uneasy gradients. Rest of the road, which is about 25 km in length, is battered and poorly maintained. This section of the road is badly damaged by hill torrents, snow melt and spring waters. Average width of the road is nearly 4.0 m. Movement of long trailers would require vigilance and controlled management of traffic during

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movement of the equipment. In bends, the gradient varies from 1:2 to 1:2.5. Gradient in remaining portion of the road varies from 1:6 to 1:10.

12.4.3.9 Lowari Tunnel

Excavation work of the 8.75 km long and 7.1 m wide Lowari tunnel has been completed but the project remains unfinished as of preparation of this report. Construction activity had been suspended by the Korean contractor on account of some dispute with NHA. However, work was resumed in September 2012. Originally, it was designed to be built and operated as a Railway Tunnel but subsequently it was decided to convert it to a two-lane road tunnel. It is expected to be finished in two years' time.

12.4.3.10 Eastern Portal to Drosh

Section of the road between the eastern portal and Ashrait Village, a stretch of about 7 km, is un-metaled. The road has steep gradients and sharp curves and needs to be widened to meet project transportation needs. From Ashrait to Darosh town, the road is in poor condition due to lack of maintenance and neglect. Because of its narrow width, unsatisfactory surface condition, steep gradients and sharp curves, the road cannot be considered suitable for long heavy trailers unless improved significantly.

12.4.3.11 Drosh to Chitral

This section of the road was upgraded in the recent past and is generally in good condition. Poor maintenance is, however, evident from the erosion of the road surface and berms at few places. This section of the road is 42 km long and is not expected to pose any major problems for transportation of equipment. Due to congestion, over-crowdedness and narrow rights of way, some settlements along the road may have to be got around during night time. Road gradients along the road from Darosh to Chitral town remain well within 5% and all culverts and road bridges are designed for Class AA loading.

Section of the road between Dir Bala and Darosh town will need widening, strengthening and up gradation. Some steep curves along this section of the road will require smoothing and widening. Stone masonry retaining and buttress walls will require repair and strengthening. After widening and improvement, the road will need proper maintenance for convenient transport of construction equipment, plant machinery and construction material to the project site. Various transport routes have been presented in the map showing National Highways Network of Pakistan.

12.4.3.12 Chitral to Arkari River Uchhatur Andakht HPP:

Arkari River is a left tributary of the Lutkho River and joins it near Andakht village about 5 km upstream of Shoghore village. The proposed weir site is about 8 km upstream of its mouth near Uchhatur village. It is located at a distance of 37 km to the north-west of Chitral city. The powerhouse site is about 29 km from Chitral city. The national grid is located at Chakdara at a distance of 240 km from the powerhouse site.

Both weir and powerhouse sites are accessible from Chitral Town through the Chitral-Garam Chashma Road. A jeepable road branches off from Chitral Garam Chashma Road about 2 km upstream of the confluence of Arkari River and Lutkho River. The road leads to Arkari village. The weir site is proposed near Uchhatur whereas the powerhouse site is proposed in Andakht village at the confluence of Arkari River with Lutkho River.

12.4.4 Conclusion & Recommendations

From the foregoing, it is concluded that there are more than one alternative for transportation of project equipment from Karachi to the project site. The two main options for transport of project equipment are:

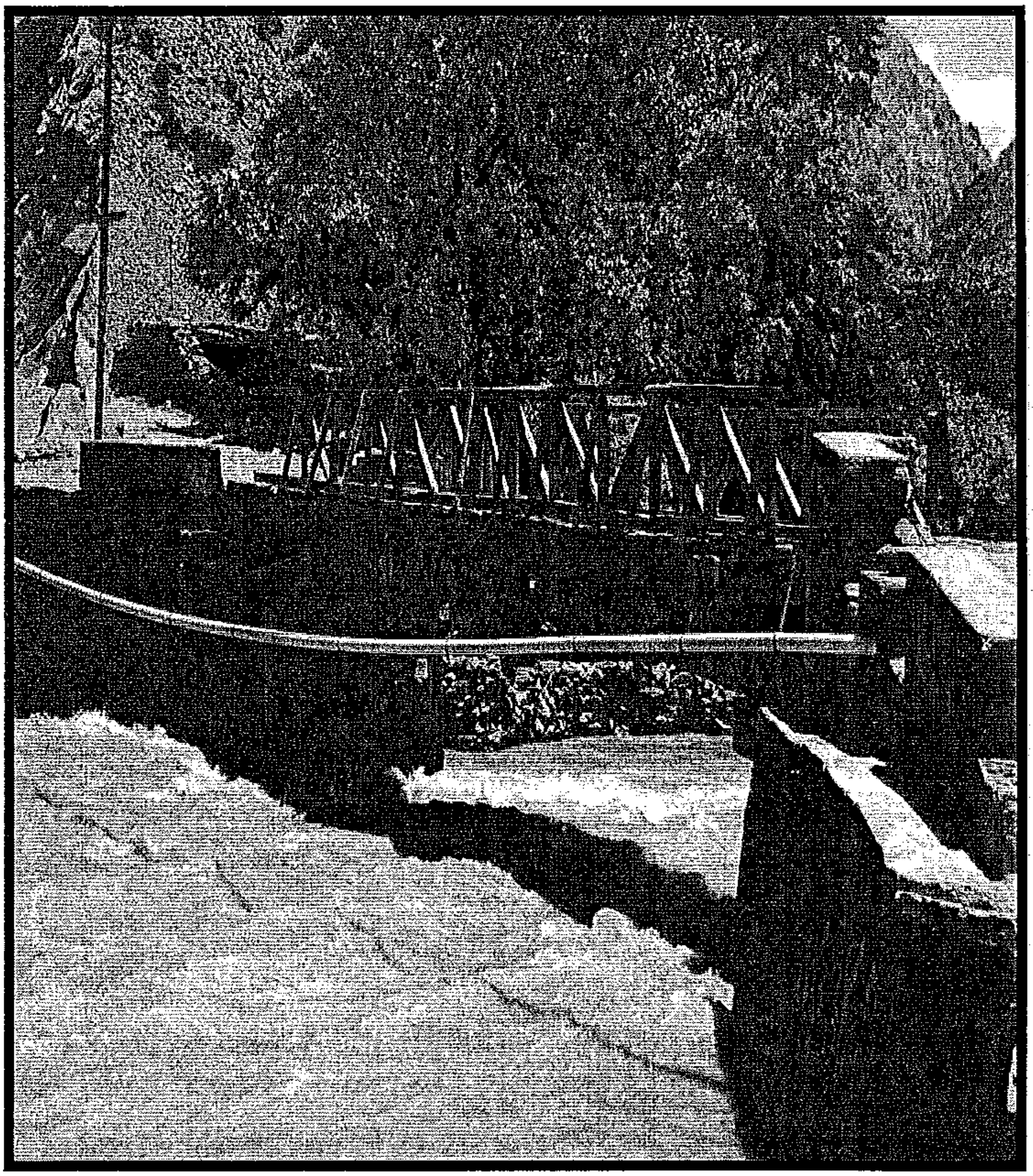
- Entirely by road
- By railway up to Nowshera and then by road.

In view of the availability of satisfactory and supportive infrastructure, both the options are suitable for the transport of project equipment. A final decision with regard to the route and mode of transport will be taken after sufficient data is available for making a comparative analysis of the competing options.

For road transport from Chakdara to Chitral, certain sections of the road will need up gradation / rehabilitation of the road surface and improvement of design features such as gradients, curves, road width, clear heights etc. to make it suitable for transport of project equipment. Likewise, access roads from Chitral Town to the project site will require upgradation. Some curves will need to be smoothened to facilitate movement of trailers.

The proposed infrastructure up gradation / rehabilitation works should be pursued in due coordination with the Construction & Works (C&W) Department of the Government of Khyber Pakhtunkhwa and the National Highway Authority (NHA) and accomplished before the work on the project is commenced.

PHOTOGRAPHS



Roji Bridge at Chitral to Arkari

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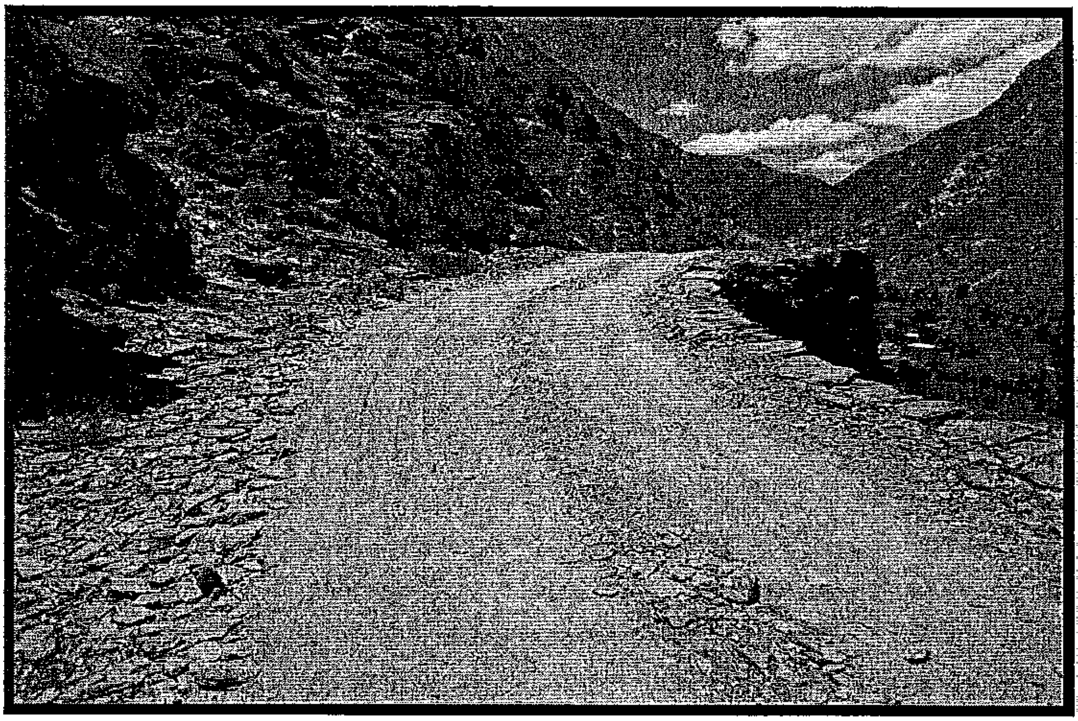

Arkari Road

Road to Weir at Andakht village

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Wooden Bridge on Stream at Road to Arkari Weir

Weir Access Road Condition

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13 ECONOMIC AND FINANCIAL ANALYSIS

13.1 General

Economic and financial analysis of the proposed Arkari hydropower project is presented. The project site is located in Chitral District of Khyber Pakhtunkhwa (KPK), Pakistan, on the Arkari Gol, the left tributary of Lutkho River. The tributary flows into Lutkho River near Andakht village. The weir site is located 6 km upstream of the confluence of Arkari Gol and Lutkho River near village Uchhatur at 36°- 03'- 57" N / 71°- 41°- 37" E.

The Arkari Gol Hydropower Project comprises of a Diversion Weir near Uchhatur village. The weir diverts water into a 6.2 km long Head Race Tunnel which is linked to the Powerhouse through a 580 m long pressure shaft. The Powerhouse is located in Andakht village. With an installed power generation capacity of 99 MW, the project is expected to generate 378 GWh of electricity annually.

13.2 Structure of the Power Sector

There are two integrated public sector power utilities in Pakistan, the Water and Power Development Authority (WAPDA) – which has now been unbundled into a number of separate corporate entities -and the Karachi Electric Supply Corporation (KESC). WAPDA supplies power to the whole of Pakistan, except for the city of Karachi, which is supplied by KESC. The system of WAPDA and KESC are interconnected through one 500 kV and 220 kV double circuit transmission lines. The total installed generating capacity for the entire country in 2012 was 23,538 MW and the (diversified) maximum demand, 17,630 MW. During the financial year 2012-2103, capacity additions were: hydroelectric 97 MW; thermal 189 MW. Thus only 277 MWs were added, which is less than 1% growth over the previous year. The country's installed capacity and ownership of the generating capacity is presented in Table 13.1.

Table - 13.1: Country Generating Capacity

As on 30th June		2008	2009	2010	2011	2012
THERMAL						
GENCOs with PEPCO		4,899	4,900	4,885	4,720	4,720
KESC Own		1,756	1,846	1,946	1,821	2,381
IPPs	Connected with PEPCO	5,773	5,956	7,060	8,325	8,308
	Connected with KESC	262	262	262	252	252
RPPs	Connected with PEPCO	286	286	122	403	0
	Connected with KESC	0	50	50	50	50
CPPs/SPPs connected with KESC		239	239	272	324	324
	Sub-Total	**13,215**	**13,539**	**14,597**	**15,895**	**16,035**
	Percentage share	65.32	65.86	67.53	68.14	68.12
HYDEL						

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Table - 13.1: Country Generating Capacity					
As on 30th June	2008	2009	2010	2011	2012
WAPDA Hydel	6,444	6,444	6,444	6,516	6,587
IPPs Hydel	111	111	111	129	129
Sub-Total	**6,555**	**6,555**	**6,555**	**6,645**	**6,716**
Percentage share	32.4	31.89	30.33	28.49	28.53
NUCLEAR					
CHASNUPP (I&I)	325	325	325	650	650
KANUPP	137	137	137	137	137
Sub-Total	**462**	**462**	**462**	**787**	**787**
Percentage Share	2.28	2.25	2.14	3.37	3.34
Total Installed Generation Capacity of the Country	**20,232**	**20,556**	**21,614**	**23,327**	**23,538**

Ownership of the country's generating capacity is structured as follows:

A. Water & Power Development Authority (WAPDA) 11343 MW
B. Karachi Electric Supply Corporation (KESC) 1756 MW
C. Pakistan Atomic Energy Commission (PAEC) 462 MW
D. Independent Power Producers (IPPs) 6421 MW

The unbundling of WAPDA has not been entirely completed. Old WAPDA has been split into New WAPDA and Pakistan Electric Power Company (PEPCO). WAPDA manages the water sector assets and is engaged in development of water resources. PEPCO has inherited the power sector assets of WAPDA. PEPCO controls 14 corporate bodies, 4 thermal Generation Companies (GENCOs), 9 distribution companies and NTDC. Kot Addu Power Company (KAPCO) and KESC have been privatized. Central Power Purchase Authority (CPPA) has been created to perform the single buyers function. GENCO Holding Company (GHCL) has been formed; PEPCO is also in the process of being dismantled. This process is incomplete both in form and substance; the present structure of the power sector is presented in Figure 13.1.

As a result of the privatization process, WAPDA's distribution network has been divided into nine (9) independent distribution companies (DISCOs), which have succeeded the former Area Electricity Boards (AEBs). At the same time, three generation companies (GENCOs) and a National Transmission and Dispatch Company (NTDC) were created. Presently these entities are incorporated under the management of PEPCO. A single electricity purchasing agency, the Central Power Purchase (CPP), has been established and currently resides within NTDC, but is planned to become a legally separate, independent body. Recent initiatives suggest that GoP intends to dismantle PEPCO. In recent moves, the Government has created a holding company to restructure the four GENCOs and to select private sector operators for the power plants. Recent moves suggest privatization of public sector assets and induction of private sector to the power generation and distribution functions.

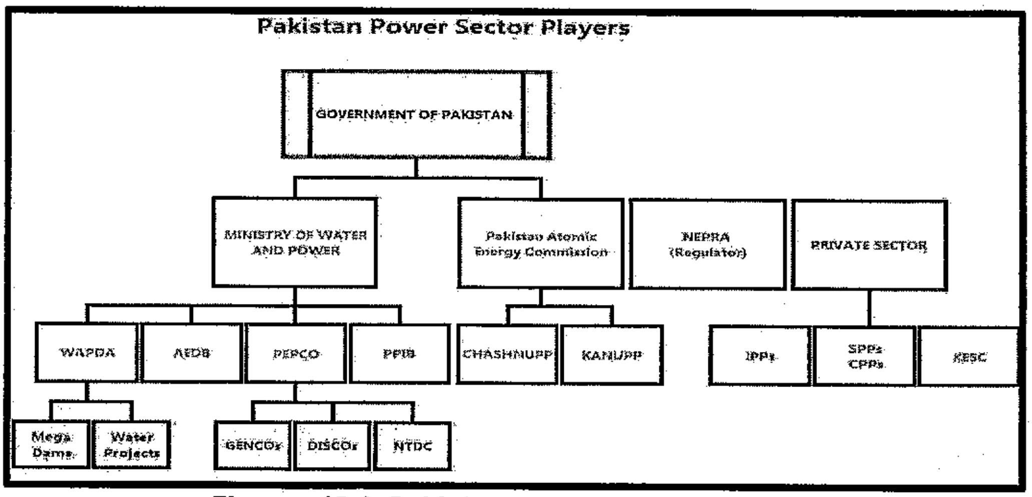

Figure - 13.1: Pakistan Federal Power Sector Players

(In the above figure, AEDB= Alternative Energy Development Board, CHASHNUPP= Chashma Nuclear Power Plant, DISCO= Distribution Company, GENCO= Generating Company, IPP= Independent Power Producer, KANUPP= Karachi Nuclear Power Plant, KESC= Karachi Electricity Supply Company, NEPRA= National Electrical Power Regulatory Authority, NTDC= National Transmission and Dispatch Company, PEPCO= Pakistan Electric Power Company, PPIB= Private Power Infrastructure Board, WAPDA= Water and Power Development Authority.)

The Government of Khyber Pakhtunkhwa (KPK) had established an organization named Small Hydel Development Organization (SHYDO), to identify and develop the small hydel potential in the province. The organization with technical assistance of GTZ: identified, high head small output hydroelectric potential in the province. SHYDO also developed and managed small isolated networks in rural areas fed by small high-head hydroelectric power plants. GTZ assistance resulted in identification of medium to large output high head hydroelectric power potential in the province. The Federal Government at that point in time allowed provinces to develop power plants of less than 50 MW generating capacity. Subsequently this restriction has been withdrawn. SHYDO was later on converted to Sarhad Hydel Development Organization (SHYDO), an autonomous body created under the SHYDO Act 1993. Recent change in the name of the province has again prompted a change in the name from SHYDO to Pakhtunkhwa Hydel Development Organization (PHYDO), an autonomous body under the SHYDO Act 1993, as amended in 2013.

A thirteen member Board of Directors under the chairmanship of the Chief Minister KP governs PHYDO. Members include the Ministers for Power, P&D and Finance departments, the Chief Secretary, Additional Chief Secretary to Govt: of KP, Secretary Energy & Power, Secretary Finance, Secretary Irrigation, Financial Expert from Private Sector, Expert from Hydropower Sector, President KP Chamber of Commerce and Managing Director, PHYDO. The organization head office is situated at Hayatabad, Peshawar and field offices are located at Malakand, Pehur, Chitral, Dir, Swat and Kohistan. The scope of work for the organization has been defined as:

a) Identification of the hydroelectric power potential

b) Development and operation of hydroelectric power plants, and

c) Facilitator for private sector investment in hydropower projects.

PHYDO has prepared a master plan, which consists of an identification study over seven regions of KP. Initially a total potential of about 400 MW, comprising of 67 'small' hydel sites has been identified. These sites are suitable for regional supply to isolated communities in the mountainous areas of the province. The master plan covers the area of Chitral, Dir, Swat, Mansehra and Kohistan districts. Apart from this, PHYDO has also identified five big sites with a total capacity of 5000 MW in the aforesaid areas. The organization has also completed feasibility studies for nine (9) hydropower projects. Besides the small high head potential, identification of medium to large high head hydropower potential was also carried out and more than 4000 MW potential was identified. This potential is being studied by: PHYDO; PPIB; and WAPDA. Feasibility studies at various stages of development seek to convert this identification into projects for implementation. The Federal and provincial Governments have issued power policies for the induction of private sector to the Power Sector. Private Power and Infrastructure Board (PPIB) and PHYDO are respectively responsible for the management of the Federal and Provincial Power Policies respectively .In 1992, the Government approved WAPDAs Strategic Plan for the Privatization of the Pakistan Power Sector. This Plan sought to meet three critical goals:

I. Enhance capital formation,

II. Improve efficiency and rationalize prices, and

III. Move over time towards full competition by providing the greatest possible role for the private sector through privatization.

This major decision was taken to improve the viability of Pakistan's electric power sector, which was characterized by extensive government involvement in management, political interference, and a tariff plagued by gross-subsidies.

A critical element of the Strategic Plan was the creation and establishment of a Regulatory Authority to oversee the restructuring process and to regulate monopolistic services. The existence of an independent and objective regulatory entity reduces the perception of risk to investors in a market. Accordingly, an autonomous regulatory agency is essential for the immediate need and long-term stability of the sector.

Pakistan has been successful in attracting substantial foreign investment in the power sector, but the absence of a transparent regulatory regime led investors to secure their investment through long-term contracts. Consequently, a substantial part of the sector has been carved out for long term contract regulation and the rest of the sector has to carry whatever risk arises from changing circumstances and realities.

The December 16, 1997, issue of the Gazette of Pakistan proclaimed the enactment of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997, which had become effective on 13 December 1997. National Electric Power Regulatory Authority (NEPRA) has been created to introduce transparent and judicious economic regulation, based on sound commercial principles, to the electric power sector of Pakistan. NEPRA reflects the country's resolve to enter the new era as a nation committed to free enterprise and to meet its social objectives with the aim of improving the quality of life for its people and to offer them opportunities for growth and development.

Pakistan is attempting to restructure the electric power sector to catch up and keep pace with the gigantic strides the power utility business has made during the 20th century. A first step to creating a climate conducive to investment and economic development is the need to enunciate a new regime to regulate the utility business of the future. NEPRA is one such name and it proposes to establish a new form of governance in Pakistan through its regulatory regime.

The NEPRA statute reflects the desire of the Government to establish an autonomous regulator body to improve the efficiency and availability of electric power services by protecting the interest of the investor, the operator and the consumers and to do so with a view to promoting competition and to deregulate power sector activities where there is competition.

NEPRA's main responsibilities are to:

i. Issue licenses for generation, transmission and distribution of electric power

ii. Establish and enforce standards to ensure quality and safety of operation and supply of electric power to consumers

iii. Approve investment and power acquisition programs of the utility companies

iv. Determine tariffs for generation, transmission and distribution of electric power.

NEPRA is entrusted to regulate the electric power sector to promote a competitive structure for the industry and to ensure the coordinated, reliable and adequate supply of electric power in the future. By law, NEPRA is mandated to ensure that the interests of the investor and the customer are protected through judicious decisions based on transparent commercial principles and that the sector moves towards a competitive environment.

To promote competition in the electricity market and to protect the rights of customers and market participants, the Government of Pakistan introduced the Generation, Transmission and Distribution of Electric Power Regulation Act, 1997. Under this act, NEPRA performs the three main regulatory functions of

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licensing of generation, transmission and distribution of electric power, tariff determination and setting of market rules and operating standards.

In addition to generation constraints, the nature and location of demand and supply on the existing power system are creating a considerable need for primary network investments. Current peak energy and capacity shortfalls are to some extent the consequence of shortages and bottlenecks in the national network. Primary network constraints cause inefficiencies at the consumer end – such as high levels of un-served energy or investment in costly self or captive generation - which extract a significant economic and financial rent. Export competitiveness is being eroded by high electricity costs and unreliable supplies.

For example, in cotton spinning, where power charges account for about a fifth of total costs and 42 percent of conversion costs, competitiveness and profitability are adversely affected not only by the high electricity tariffs for industrial users, but also by frequent outages - commonly an average of 3 per day - that heighten inefficiency and expense. With funds they could otherwise use to automate some processes, many textile mills install back-up generators, further raising their costs of production.

The recent past has seen large shortfalls in generating capacity, which has resulted in the need for load shedding , causing adverse effects upon economic performance, and also has political repercussions .This gap in supply and demand has many reasons, one of which is the inability to add capacity to the system, the other reason has been the generation mix. Capacity that has been added is based on a number of sources but a significant portion of that capacity is based on furnace oil/diesel. Due to price spikes in oil, the power sectors has been unable to sustain the price shock primarily due to tariffs that do not cover the cost.

13.3 Methodology - Economic Viability

13.3.1 General

The economic viability of the proposed project has been analyzed according to the following methodology: firstly, establishing the need for the project, secondly, establishing that the project represents the least-cost means of achieving the desired objectives, and finally, establishing that the project has a positive economic return – i.e. that its economic internal rate of return (EIRR) exceeds the economic opportunity cost of capital.

The financial viability of the proposed power plant has been determined on the basis of it being a stand-alone privately owned power plant. The NEPRA and PPIB stipulations, as outlined in the 2002 Private Power Policy and NEPRA/PPIB guidelines towards determination of reference tariff have been followed.

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13.3.2 Rationale for Investment

Pakistan is suffering from an acute energy crisis, which is caused by (i) insufficient energy supply (ii) increasing demand (iii) inefficient use of energy (iv) improper pricing. NEPRA in its "State of Industry Report 2012" states " the year continued with miseries to the consumers as there was no respite for them from long , scheduled and unscheduled hours of load shedding resulting in riots and protests by angry crowds storming the streets all over the country. There are technical and financial issues to be resolved. The installed capacity in the country was 23,518 MW whereas at any given time the available capacity remained less than 14,000 MW".

NEPRA in the "State of Industry Report 2012" presents, the impact of load shedding as follows: It resulted in forced shutdown of a large number of industrial units, leading to unemployment of work force, Despite 3000 MW of new generation; there was a large quantum of suppressed demand that outpaced addition to the generation. The present plans, if implemented fully, will not guarantee end of load shedding before FY 2020.It is feared that the gap between supply and demand would continue to widen as the current plans would not be adequate to meet the needs of the sector even by 2020. **Table 13.2** below presents information on the supply-demand position of power generation.

Table - 13.2: Country Supply and Demand Position 2008-2020 (MW)

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Existing Generation	15903	15903	15903	15903	15903	15903	15903	15903	15903	15903	15903	15903	15903
Committed & Proposed Additions	530	4235	7226	10115	10556	13307	13520	14607	16134	18448	18448	18448	18448
Total Existing & Proposed Generation	16433	20138	23129	26018	26459	29210	29423	30510	32037	34351	34351	34351	34351
Expected Available Generation	13146	16110	18508	20814	21167	23368	23538	24408	25630	27481	27481	27481	27481
Demand Summer Peak	16484	17868	19352	20874	22460	24126	25919	28029	30223	35504	34918	37907	41132
Surplus / Deficit	-3338	-1758	-844	-60	-1293	-758	-2381	-3621	-4593	-8023	-7437	-10426	-13651

Source : Private Power and Infrastructure Board (PPIB)

It is claimed that industrial sector alone has lost more than $6 billion over the last year and half due to electricity and gas shortage. Small businessmen are the worst sufferers of financial losses, some up to 50%, with load shedding in shopping centers at peak sale hours. Manufacturing in general has been hard hit by the cuts, with 8-12 hours a day, especially in the Punjab, this has caused 30%-45% rise in the cost of production. Operational costs have risen sharply for small businessmen; small industries affected by this steep rise in operational costs are soap and small steel mills. Some have closed down whereas others have resorted to lay-off of workers.

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It is evident that the high growth of electricity demand in Pakistan is putting the existing infrastructure under stress and the need to invest in additional generation facilities is clear-cut. The proposed strategy for developing generation capacity through this project is consistent with the various energy sector policy initiatives listed below that have been adopted by the Government:

a) Government of Pakistan, 2002/2004 Power Policy

b) Energy Efficiency Multi Finance Facility (MFF)

c) Intec: "Technical Diagnostics of the Thermal Power Plants belonging to Pakistani Public Generation Companies (GENCOs)" report, May 2011

d) Power System Rehabilitation Program (PSRP)

e) Government of Pakistan, 2013 Power Policy

The last decade has seen reduced levels of expenditure on addition of new power generation facilities. This along with depleting gas fields, gap in costs and electricity tariffs, and poor revenue recoveries (resulting in ballooning 'circular debt') has resulted in load shedding and fuel shortages/shedding .The Government has developed short, medium and long term plans to meet the power demand and to make fuel resources available. Chronic energy shortages are one of Pakistan's most serious constraints to economic growth and job creation

The energy sector and power sector (which is a subset of the energy sector) woes stem in part due to the external shock , as oil prices of around 100 US$/barrel have stressed the energy and power sectors. The impact of this oil shock has been worsened by: past inability to add hydropower plants; power mix that favors import of oil products; and high reliance on domestic gas that is depleting. International fuel prices have risen sharply since 2002. Oil prices rose from less than 5 $/mmBtu to about 17 $/mmBtu in 2008. Liquefied natural Gas (LNG) prices rose in sync with oil prices , Coal prices have also risen sharply in the last oil shock period to a maximum of about 4.46 $/mmBtu in 2008 .

PEPCO System has steadily relied more and more upon thermal energy. Hydro energy has grown at an average annual rate of 3.75% over the period 1980-2012 , this growth dampened to 2.67% in the last 10 years and to 0.22% during the last 5 years .Hydro energy as percent of total energy declined from about 72% in 1980 to about 33% in 2010, This heavier reliance upon thermal sources also results in increasing dependence upon imported fuels as Pakistan imports most of its liquid fuels. This in the last few years has reached a level, where half the exports pay for fuel imports. This is presented in **Figure 13.2**.

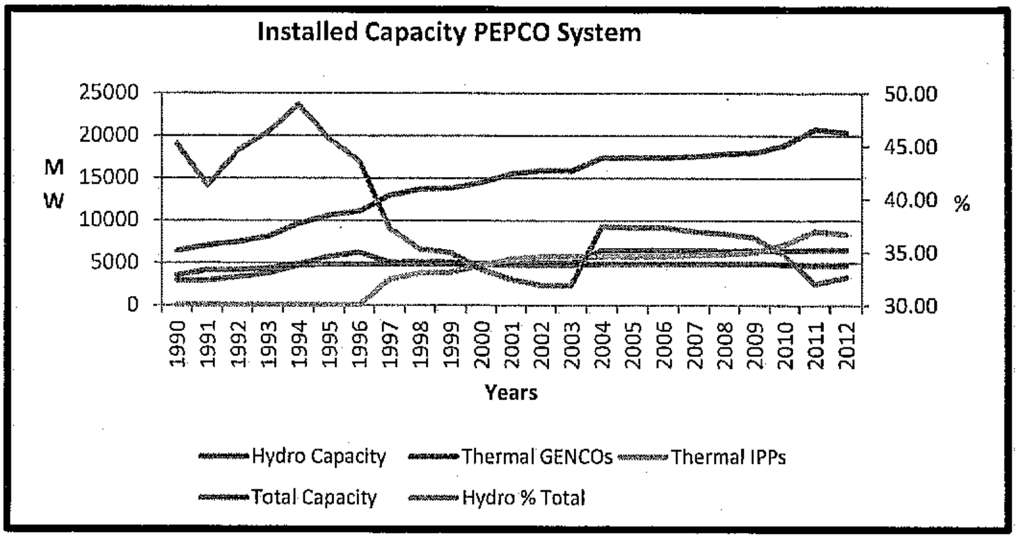

Figure - 13.2: Installed Capacity PEPCO System (Source: Power System Statistics, 35th Issue)

The distribution of energy supplies in Pakistan is very different from the US and other countries in the region. Pakistan depended very heavily upon gas as the main commercial fuel; almost 50% of the demand was met by gas. Coal played an insignificant part in the primary fuel supplies. This model was different from India and China which depended very heavily on local and imported coal to provide over 50% of the primary energy supplies. Distribution of energy supplies in Pakistan is presented in **Figure 13.3.**

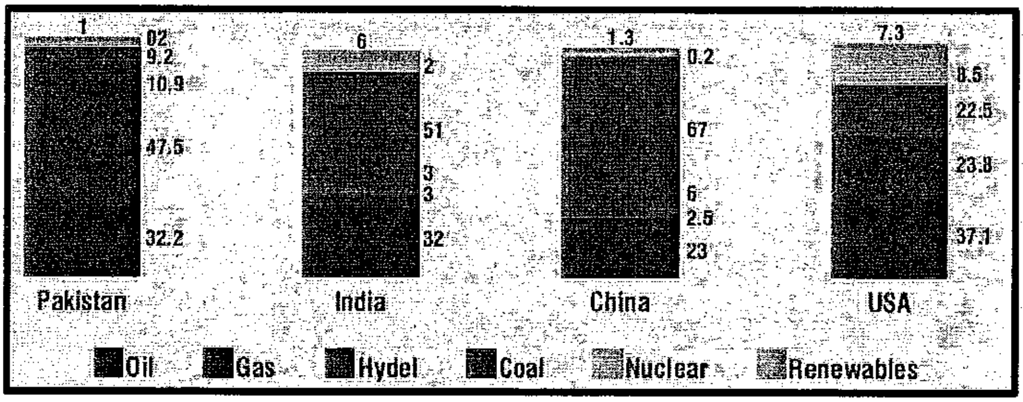

Figure - 13.3: Distribution of Energy Supplies in Pakistan

Source: Various, IEA, Pakistan Year Book

The energy mix in the NTDC system has changed from 65% hydroelectric in 1980 to about 30% at present. The heavily thermal dependent system is in turn heavily dependent on natural gas, With depleting gas supplies, the alternative is costly and imported furnace oil. Fuel mix in the PEPCO system is undergoing change. Gas is still the dominant fuel but its usage has dropped to 51% of total, in 2010, from 70% of total in 2000. Furnace oil and HSD usage has significantly increased. The depleting gas fields contribute to this substitution of gas by furnace oil and HSD. Coal usage is not significant but its use is also decreasing due to the deterioration of the only coal fired power plant on the PEPCO System.

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The fuel consumption for thermal power generation in terms of million tonne of oil equivalent (MTOE) is presented in as follow.

Table - 13.3: Fuel Consumption for Thermal Power Generation (TOE)							
Type of Fuel	2006-7	2007-8	2008-9	2009-10	2010-11	2011-12	Growth
Gas	8640101	8492919	7830065	7106962	6493766	6732876	-4.87
% share of Gas	56.54	54.88	51.3	45.08	44.88	47.45	
Furnace Oil	6521503	6741614	7210211	8339330	7827500	7206839	2.02
% share of Furnace Oil	42.68	43.56	47.24	52.9	54.1	50.79	
Diesel Oil	45125	168449	173847	262499	105160	203072	35.1
% share of Diesel Oil	0.3	1.09	1.14	1.67	0.73	1.43	
Coal	73551	72568	50341	56141	43169	46800	-8.65
% share of Coal	0.48	0.47	0.33	0.36	0.3	0.33	
Total	15280280	15475550	15264464	15764932	14469595	14189587	-1.47
Annual Growth Rate (%)		1.28	-1.36	3.28	-8.22	-1.94	

Source: Pakistan Energy Year Book, 2011-12

Primary commercial energy supplies in Pakistan increased by 1.3% during the FY 2012 and reached 64.73 MTOE. Supplies include: Gas 32.03 MTOE (49.50%); Oil 19.96 MTOE (30.80%); hydro energy 6.81 MTOE (10.50%); Coal 4.29 MTOE (6.60%); Nuclear electricity 1.26 MTOE (9.10%); Liquefied Petroleum Gas (LPG) 0.32 MTOE (0.56%); and Imported electricity 0.07 MTOE (0.10%) shown in as presented in Table 13.4 below.

Table - 13.4: Primary Energy Supplies by Source (MTOE)										
Fiscal Year	Unit	Gas	Oil	LPG	Coal	Hydel	Nuclear	Imported	Total	Annual Growth Rate (%)
2006-07	Million TOE	29.32	18.19	0.47	4.43	7.63	0.55	0.04	60.62	4.42
	% share	48.37	30	0.78	7.3	12.58	0.9	0.07	100	
2007-08	Million TOE	2987	19.21	0.42	5.78	6.85	0.73	0.05	62.92	3.78
	% share	47.48	30.53	0.67	9.19	10.89	1.17	0.08	100	
2008-09	Million TOE	30.25	20.1	0.4	4.73	6.63	0.39	0.05	62.55	-0.58
	% share	48.36	32.13	0.64	7.56	10.6	0.62	0.08	100	
2009-10	Million TOE	30.81	19.81	0.39	4.62	6.7	0.69	0.06	63.08	0.85
	% share	48.84	31.4	0.62	7.32	10.62	1.09	0.1	100	
2010-11	Million TOE	30.68	20.67	0.34	4.35	7.59	0.82	0.06	64.51	2.27
	% share	47.56	32.04	0.53	6.74	11.77	1.27	0.09	100	
2011-12	Million TOE	32.03	19.96	0.32	4.29	6.81	1.26	0.07	64.73	1.3
	% share	49.5	30.8	0.56	6.6	10.5	9.1	0.1	100	

Source: Pakistan Energy Year Book

Pakistan being a large consumer of gas has total resource potential of 282 trillion cubic feet with recoverable reserves as 24 trillion cubic feet and production of almost 4 billion cubic feet per day. During 2012, total production remained 1,559 billion cubic feet that is equivalent to 32 million TOE, which shows a growth of 6 percent when compared to last year in billion cubic feet while in TOE it shows a growth of 4.5 percent. There are 146 non-associated gas fields while 44 associated gas fields are operating under 15 companies. Pakistan's power sector is heavily depended on gas. Reduction of gas has crippled its performance. The

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country is witnessing gas shortage due to which during July-March FY 13, gas supplies remained 1,139,253 million cubic feet as compared to 1,164,915 million cubic feet last year indicating a shortfall of 2.2 per cent. Pakistan's electricity generation is highly dependent on imported oil as almost $ 14.5 billion worth of oil is imported each year, the bulk of which is used for electricity generation. Thus pronounced shift from hydro to thermal generation, and more recently from natural gas to fuel oil as the primary fuel for electricity generation have caused fuel crisis in Pakistan's power sector. Further these trends have contributed to an increase in power supply costs. Thus there is need of immediate shifting of fuel mix from expensive to cheaper. Final energy consumption is presented in **Table 13.5.**

Table - 13.5: Final Energy Consumption by Source (MTOE)

Fiscal Year	Unit	Gas	Oil	LPG	Coal	Electricity	Total	Annual Growth Rate (%)
2006-07	Million TOE	14.7	10.58	0.66	4.15	5.92	36.01	6.07
	% share	40.83	29.37	1.83	11.52	16.45	100	
2007-08	Million TOE	15.88	11.53	0.62	5.4	5.98	39.41	9.46
	% share	40.3	29.25	1.57	13.71	15.17	100	
2008-09	Million TOE	16.31	10.84	0.57	3.89	5.73	37.34	-5.26
	% share	43.68	29.03	1.53	10.42	15.35	100	
2009-10	Million TOE	17.02	10.83	0.58	4.28	6.05	38.76	3.8
	% share	43.91	27.94	1.5	11.04	15.61	100	
2010-11	Million TOE	16.78	11.25	0.5	4.02	6.28	38.83	0.18
	% share	43.21	28.97	1.29	10.35	16.17	100	
2011-12	Million TOE	17.62	11.62	0.48	4.06	6.25	40.03	2.1
	% share	44	29	1.2	10.1	15.6	100	

Source: Pakistan Energy Yearbook

The primary energy mix in Pakistan over the last 11 years has changed in a number of ways , the period saw an even higher dependence upon gas which constituted 50.5% in FY 2012 of the primary energy as compared to 41,7% in FY2001, an average growth of about 1.76% per annum . Oil's share dropped from 43.5% to 30.7% during the same period. This trend, however, is no longer sustainable since depleting gas supplies means that alternatives have to be sought. In the near term, the shift has been towards costly oil products. This has resulted in the oil import bill to increase form M$ 2.1 to M$14.5, an average annual increase of 19.2%. Coal usage has increased from 4.5% to 6.3% during the period. To put that in context, the oil import bill exceeds both the workers' remittances (B$ 11.2) and the textile exports (B$10.2). The energy mix in Pakistan is presented in Table 13.6.

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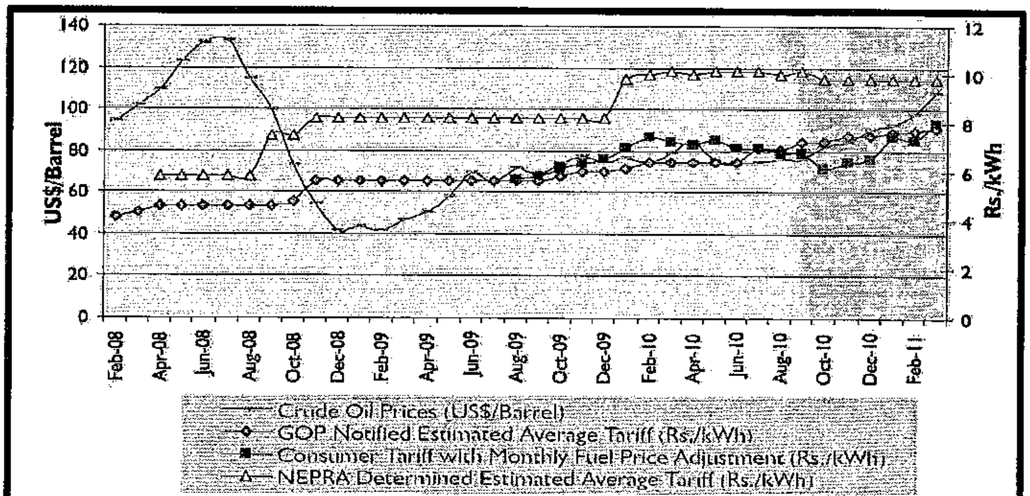
Table - 13.6: Pakistan Energy Mix			
	2001 %	2012 %	Growth (%)
Natural Gas	41.7	50.5	1.76
Coal	4.5	6.3	3.11
Hydro	10.3	12.5	1.78
Oil	43.5	30.7	-3.12
Total	100	100	
M.Toe	44.5	64.9	3.49
Oil Import M$	2.1	14.5	19.2

Source: Economic Survey of Pakistan, 2012

The circular debt issue relates partly due to the differential between the GoP notified tariff and the NEPRA determined tariff. GoP was paying a subsidy to bridge the gap. High oil prices impact was not passed fully to the customers. Circular debt was estimated to be about Rs.220 M. By March 2012, GoP has directed power companies to recover the full cost of supply and this is being implemented in small steps . During the FY 2013, the new government has paid the circular debt, this however gives the government a temporary respite since the underlying causes will need time to be resolved. The underlying issues are presented as **Figure 13.4.**



Source: World Bank

Figure - 13.4: Consumer Tariffs, Fuel Price Adjustments and Crude Oil Prices

The gap between the determined tariff, that covers full cost and the GoP tariff is widening; even with the increases in GoP tariff, this is adding to the subsidy that the GoP is required to pay as high oil prices prevent the satisfactory resolution of the issue. The new government has initiated a series of tariff hikes to bridge the gap. This is an ongoing process .The estimated gap between NEPRA and GoP tariff is presented in **Table 13.7.**

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Table - 13.7: Estimated Gap Between NEPRA and GoP Tariff		
	FY 2010-11	FY 2011-12
NEPRA's Determined Average Sale Rate (Rs./kWh)	9.58	11.89
GOP's Notified Average Sale Rate* (Rs./kWh)	7.78	8.72
Gap in terms of Rs./kWh	1.80	3.17

Note: This may vary with different consumer mix, load factors and does not include the impact of monthly fuel adjustments passed in consumer bills. (Source: NEPRA, State of Industry Report, 2012)

The country's energy mix for the power sector further exacerbates the problem and in fact is partly responsible for the GoP's lack of success in resolution of the issue. Depleting gas supplies mean that increasing reliance has to be made on furnace oil and HSD, which are at high price levels. The resulting bulk tariff for the DISCOs is too high as oil prices are volatile as well as high. The 2012 average cost of supply to the DISCOs reveals that HSD and furnace oil supply about 36% of the energy but are responsible for 81% of the cost. The obvious and intuitive solution seems to be to add more hydroelectric power plants and/or add coal and gas fired thermal power plants. Hydroelectric power plants have a long lead time, whilst gas supplies are dwindling. Imported coal therefore presents the only option for reduction of the bulk tariff in the near term. The average cost of supply for 2012 is presented in Table 13.8.

Table – 13.8: Average Cost of Unit Delivered to DISCOs 2011-2012

	Unit	Hydro	Coal	HSD	RFO	Gas	Nuclear	Import	Mixed	Wind	Total
Energy	GWh	28643	66	1474	30882	23431	4413	296	730	6	89941
Share	%	31.85	0.07	1.64	34.34	26.05	4.91	0.33	0.81	0.01	100
Cost	M.Rs.	4660	206	27848	488617	99340	4078	2662	9331	51	636793
Share	%	0.73	0.03	4.37	76.73	15.60	0.64	0.42	1.47	0.01	100.00
Cost	Rs./kWh	0.16	3.12	18.89	15.82	4.24	0.92	8.99	12.78	8.50	7.08
Share	%	2.30	44.08	266.84	223.47	59.88	13.05	127.02	180.54	120.05	100.00

It is estimated that the country was losing two to three percent of its GDP due to power shortages, which may increase, if the shortages persist. The deepening power crisis has forced many businesses to close down .Energy shortages have also had an adverse economic and social impact upon users. Shortages of LPG and Condensed Natural Gas (CNG) have disrupted the household and manufacturing activities in the urban areas, acute energy shortage has crippled the textile industry, which has reduced its output by about 30%. Textile mills have increasingly relied upon electricity as a substitute, but gas and capacity shortages have also rendered this move ineffective. Exports have declined by 1.3 % during July to November 2012, as compared to the corresponding period last year.

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Energy demand has increased significantly in the last 10 years but supply has failed to match the growth in demand. A supply shortfall of natural gas (which contributes about 50% of the commercial energy supplies) has ranged 10% to 15% of demand. Demand for FY 2012 is around 5,777 Bcf/d, which will grow to 7, 516 Bcf/d by FY 2021. Gas shortfalls are estimated to grow from 1,605 bcf/d in FY 2012 to 5,247 Bcf/d in FY 2021. The gas supply and demand gap is presented in **Table 13.9.**

Table - 13.9: Projected Demand, Supply and Shortfall of Natural Gas (mmcfd)

FY	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Growth (%) 2012-2021
Demand	5777	5995	6358	6531	6681	6823	7007	7147	7333	7516	2.97
Supply	4172	4372	4479	4035	3623	3282	3007	2723	2535	2269	-6.54
Shortfall	1605	1623	1879	2496	3058	3541	4000	4424	4798	5247	14.07

Source: Ministry of Water and Power, GoP

The gas consumption by the power sector in Pakistan has increased from 315 B.Cft in FY 2002 to 345 B.Cft in FY 2013, an average annual increase of 0.83%. This trend , however, has been reversed in the near past as the usage has decreased by average 2.05% during the period FY 2010 to FY 2013 and 3.65% during the period FY 2012 to FY 2013. Gas consumption of power sector as percent of the total gas consumed has decreased by 2.73% during the last 11 years. Gas consumption by power sector is presented as follows in **Table 13.10.**

Table - 13.10: Gas Consumption by Power Sector, Pakistan

B.cft	Power		Power %
FY	Sector	Total	Total %
2002	315	835	37.7
2003	336	872	38.5
2004	470	1051	44.7
2005	507	1161	43.7
2006	492	1223	40.2
2007	434	1222	35.5
2008	430	1275	33.7
2009	404	1269	31.8
2010	367	1278	28.7
2011	337	1271	26.5
2012	358	1288	27.8
2013	345	1240	27.8
Growth	0.83	3.66	-2.73
Growth, 3 yrs	-2.05	-1.00	-1.06
Growth, 2 years	1.17	-1.22	2.42
Growth, 1 years	-3.65	-3.73	0.08

Source: Hydrocarbon Institute of Pakistan

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The objective of this study is to show how a reliable and high quality power supply can be delivered to the rising number of industrial, commercial, agricultural and domestic customers. The plan supports that part of the government's poverty reduction strategy which is targeted at producing an increased level of economic activity. Inability to serve electric demand has been directly linked to poverty. There is a strong relationship between the provision of energy services and global: health; nutrition; education; economic growth; and agriculture. Lack of provision of electricity is strongly correlated to the number of people living under $2 per day. This is presented as follows in **Figure 13.5** on the following page.

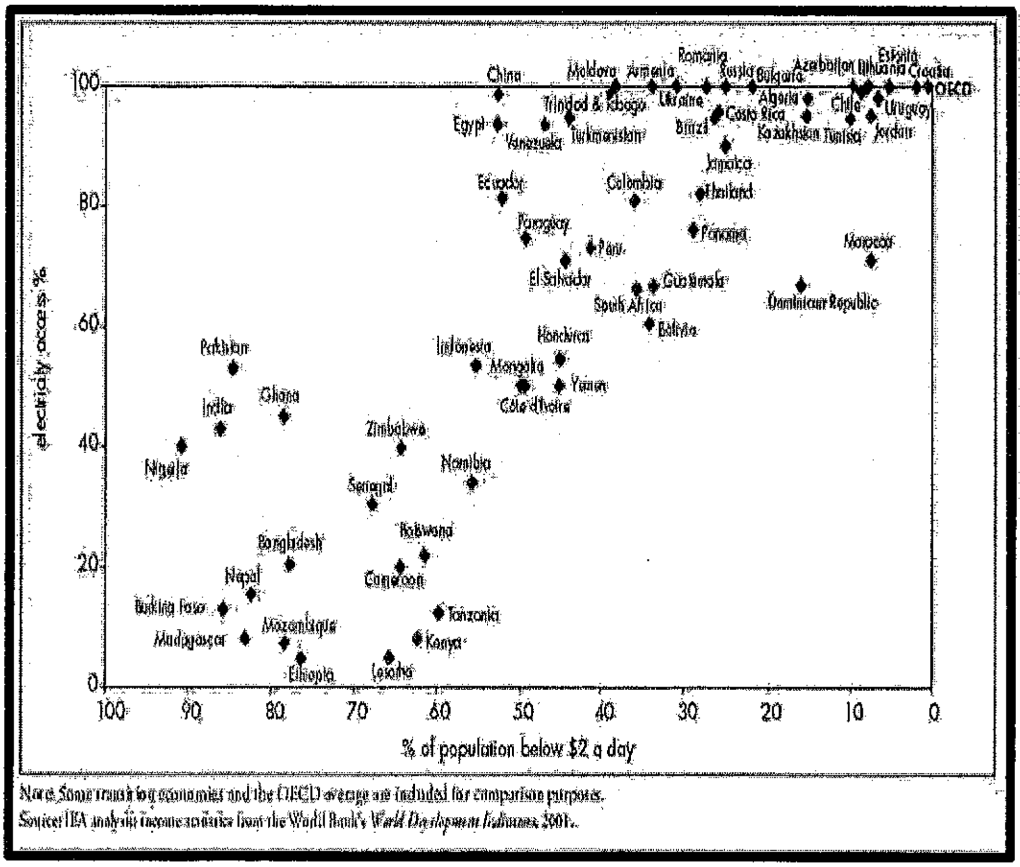

Figure - 13.5: Access to Electricity versus GNP

This study is based on the: Government of KP's plans to add hydroelectric power capacity ; Government of Pakistan (GoP), 2013 Power Policy ; and Government of Pakistan plans towards achieving normalcy in the electricity sector. GoP plans towards revitalization of the power sector include: addition of generating capacity; reduction in transmission and distribution losses; generation rehabilitation; development of small and medium HPPs; construction of large multi-purpose water storage projects; shale gas exploration; thermal efficiency improvement of generating facilities; distribution loss reduction and performance improvement thereof; Thar (and other domestic) coal and imported coal capacity addition; renewable energy, in particular wind power and nuclear energy.

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13.3.3 Electricity Demand

13.3.4 Historical Demand Data

As illustrated in **Error! Reference source not found.** over the last three decades akistani GDP has been growing at an accelerated rate; however, since the end of 2000s, the rate of growth has dampened. Pakistan's economy continued to face challenges like energy shortages, floods and rains, poor law and order situation, and a host of other structural impediments that have held back investment and growth in the country. The economy of Pakistan during the last five years grew on an average at the rate of 2.9 percent per annum. Deterioration in the power sector is the main constraint on growth. Power outages have shaved off annual GDP growth by 2 percent. GDP growth has been stuck at a level, which is half of the level of Pakistan's long-term trend potential of about 6.5 percent per annum. Real GDP growth for 2012-13 has been estimated at 3.6 percent. Commodity producing sector comprising agriculture and industry accounted for 42.3 percent of GDP during the outgoing fiscal year. The commodity producing sector has performed better in the outgoing fiscal year as compared to the last year; its growth rate is 3.4 percent against 3.1 percent last year. Agriculture sector accounted for 21.4 percent of GDP. The performance of the agriculture sector remained weak due to unfavorable weather conditions, which resulted in lower production of cotton and rice. A growth of 3.3 percent is recorded against the growth of 3.5 percent last year. Manufacturing sector has 13.2 percent share in GDP. The growth of the manufacturing sector is estimated at 3.5 percent compared to the growth of 2.1 percent last year. Electricity and gas distribution witnessed a growth of -3.2 percent against the growth of 2.7 percent last year. This is presented in the following **Table 13.11.**

Table - 13.11: Economic Growth: Indicators (% increase p.a.)

Period	GDP	Manufacturing
1990s	4.6	4.8
2000s	4.8	7.0
2000/1	2.0	9.3
2001/2	3.1	4.5
2002/3	4.7	6.9
2003/4	7.5	14.0
2004/5	9.0	15.5
2005/6	5.8	8.7
2006/7	5.5	9.0
2007/8	5.0	6.1
2008/9	0.4	-4.2
2009/10	2.6	1.4
2010/11	3.7	2.0
2011/12	4.4	2.1
2012/13	3.6	3.5

Source: GoP Economic Review, July 2013

Pakistan has sought IMF intervention and obtained approval , the agreement includes replacement of the woefully inadequate revenue base with one that meets the country's requirements ; energy sector reforms ; restructuring of the PSEs and privatization of the State owned enterprises ; improved capital and financial account net inflows . The reforms include restructuring 65 public enterprises and privatization of many of these. These include PIA, Pakistan Railways, and Pakistan Steel Mills. The IMF's Executive Board has approved a $6.6 billion loan for Pakistan to support its program to stabilize the economy and boost growth while expanding its social safety net to protect the poor.

The program aims, first and foremost, at macroeconomic stabilization-that is, bringing the budget deficit down and reversing the balance of payments problems. This will require some tightening on both the fiscal and monetary sides in order to put the fiscal position on a sustainable path and reduce inflation. The program envisages a substantial decline in the budget deficit of the government from nearly 8.5 percent of GDP last year to 5.8 percent of GDP in 2013/2014 and to 3.5 percent of GDP by the end of the program. To achieve this, the authorities will substantially reduce tax loopholes and exemptions, broaden the tax base, and reduce tax evasion. The program includes substantial structural reforms that will help boost the long-term growth potential of the economy. The most important of these is tackling the current energy crisis, which is a substantial drag on economic growth. The government has already launched a comprehensive energy policy, which will address energy supply, distribution, regulation, and pricing. The idea is to encourage more efficient consumption and better use of energy resources by reducing energy subsidies that currently go mainly to the rich. The 36-month program under the IMF's Extended Fund Facility aims at bringing down inflation and reducing the fiscal deficit to more sustainable levels. The program also includes measures to help achieve higher and more inclusive growth, in particular through addressing bottlenecks in the energy sector.

Installed capacity in PEPCO system grew at an average rate of 5.39% during the period 1990-2012, this growth dampened to 2.56% during the period 2002-2012 and to 3.03% during the period 2007-2012. Hydro capacity as % of total capacity has declined over the 22 year period at an average rate of 1.47% p.a. The recent past has seen decline in the rate of growth of both total installed capacity and hydro capacity. The ratio between hydro and total capacity has continued to worsen . During the financial year 2012-2013, capacity additions were: hydroelectric 97 MW; thermal 189 MW. Thus only 277 MWs were added, which is less than 1% growth over the previous year. The development of the PEPCO (System less KESC) system is presented in **Table 13.12.**

Table - 13.12: PEPCO Installed Capacity MW

Year	Hydro MW	GENCOs Thermal MW	IPP Hydro MW	IPP Thermal MW	Nuclear MW	Total MW	Hydro % Total %
1990	2897	3512				6409	45.2
1991	2897	4126				7023	41.25
1992	3329	4134				7463	44.61
1993	3761	4361				8122	46.31

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Table - 13.12: PEPCO Installed Capacity MW							
Year	Hydro MW	GENCOs Thermal MW	IPP Hydro MW	IPP Thermal MW	Nuclear MW	Total MW	Hydro % Total %
1994	4725	4926				9651	48.96
1995	4825	5738				10563	45.68
1996	4825	6238				11063	43.61
1997	4825	5070		3061		12956	37.24
1998	4825	5070		3788		13683	35.26
1999	4825	5070		3905		13800	34.96
2000	4825	4871		4748		14444	33.4
2001	5009	4740	30	5430	325	15534	32.44
2002	5009	4740	30	5715	325	15819	31.85
2003	5009	4740	30	5715	325	15819	31.85
2004	6463	4834	30	5715	325	17367	37.39
2005	6463	4834	30	5743	325	17395	37.33
2006	6463	4834	30	5743	325	17395	37.33
2007	6444	4834	30	5893	325	17526	36.94
2008	6444	4899	111	6048	325	17827	36.77
2009	6444	4900	111	6242	325	18022	36.37
2010	6444	4829	111	7183	325	18892	34.7
2011	6516	4720	129	8728	650	20743	32.03
2012	6516	4720	129	8328	650	20343	32.66
Growth	Avg % pa						
1990-2012	3.75	1.35				5.39	-1.47
2002-2012	2.67	-0.04		3.84		2.55	0.25
2007-2012	0.22	-0.48	33.87	7.16	14.87	3.03	-2.43

The near past has seen failure of the planning process where: firstly the planned additions did not materialize; secondly the increase in demand was erroneously estimated. Increase in world fuel prices and Pakistan's heavy dependency upon imported fuel exacerbated the situation as 25% of the planned capacity did not materialize .In addition to the planning failures , which should also include the failure to diversify fuels notably coal , there has been an implementation failure . WAPDA launched projects which have by now had a cost overrun of US $ 2.29 billion. Neelum Jehulm project has had a cost overrun if 225% and the new cost is US$ 2.75b. The project was to be commissioned in 2013, which has been delayed to 2016. Mangla raising has had a cost overrun of 46.57% and had been delayed by many years , Golen Gol project was to be commissioned by 2009 but is still at the tendering stage , Gomal Zam project's cost has increased to US $ 160 m an increase of 25%, Keyal Khwar ,Allai Khwar ,Duber Khwar and other projects included in the intervention have had large cost increases and have been delayed by significant number of years .The gap between planned and actual additions is presented in **Table - 13.13.**

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Table - 13.13: Lag between Planned and Actually Added Generating Capacity				
	Planned in 2005 (MW)	Actual in 2010 (MW)	Difference MW	Difference %
Hydel	7720	6555	1165	15.09
Thermal	18420	13691	4729	25.67
Alternate Energy	880	5	875	99.43
Nuclear	400	300	100	25.00
Total	27420	20551	6869	25.05

Source: PEPCO, KESC, Planning Commission

13.3.4.1 Demand Forecast

For the purposes of the least-cost analysis, NTDC's base case demand and energy forecast was considered. The forecast, which covers 20 year plan period, was prepared using a regression- based approach. The forecasts are relatively optimistic, resulting in an average load growth over the period of 8% p.a. A comprehensive review of the demand forecasting methodology is beyond the scope of this report, but we understand that historically, this methodology has produced satisfactory forecasts. NTDC has tried to use more sophisticated forecasting techniques in the past, including a detailed econometric approach, but results have not been satisfactory primarily due to the lack of reliable data. The forecast is summarized in **Table - 13.14.**

Table - 13.14: Electricity Demand Forecast (PEPCO) Low Scenario (Base Case Load Forecast)					
FY	Energy Consumption GWh	Losses GWh	Energy Generated GWh	Load Factor %	Demand MW
2011	91079	26449	117528	69.24	19340
2012	96859	26880	123739	68.99	20436
2013	104345	27268	131613	68.9	21766
2014	111890	27586	139476	68.81	23097
2015	119981	27849	147830	68.72	24513
2016	129774	28561	158335	68.63	26290
2017	137777	28698	166475	68.66	27629
2018	147680	29052	176732	68.44	29424
2019	158131	30603	188734	68.35	31464
2020	169047	32775	201822	68.26	33691
2021	180960	35021	215981	68.17	36104
2022	193541	37455	230996	68.07	38666
2023	206785	40019	246804	67.98	41368
2024	220715	42714	263429	67.89	44214
2025	235175	45572	280747	67.8	47180
Growth Avg. p.a. 2011-15	7.01	3.96	6.42	-0.15	6.58

Source : NTDC Demand Forecast , Office GM Planning
Basis: Low growth , GDP growth 4%, 4,5% and 5% , 2011-13 and 2014-15, 2015-25 respectively

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13.3.4.2 Supply / Demand Balance

The system is at present stretched on a number of counts. This sub-optimality is expected to continue in the near future. The near future may see further deterioration in system performance. The system at present is unable to meet the system demand. In 2010, about 23% of the load was unmet . The total country installed capacity in 2011 was 24173 MW, and PEPCO installed capacity was 20986 MW. Total GENCO installed capacity was 4829 MW, de-rated to 3000 MW. NEPRA's 'State of Industry Report 2011" states: the gap between supply and demand crossed 5000 MW , but it also remained around 4000 to 5000 MW mark for the most part of the year. Based on seven to eight hours of daily load shedding, the ratio of energy shed in the PEPCO system to the total energy sold in PEPCO system was 36% ". The quantum of load shedding is presented in **Table 13.15.**

Table - 13.15: Load Shedding Estimates

FY	Annual Sales GWh/a	Load Shed	Total Demand	Load Shedding
		GWh/a	GWh/a	%
2003	52661		52661	
2004	57467	560	58027	0.97
2005	61247	265	61512	0.43
2006	67608	1208	68816	1.76
2007	71947	2040	73987	2.76
2008	72518	12578	85096	14.78
2009	69668	18222	87890	20.73
2010	73595	21821	95416	22.87
Growth Avg. p.a.	4.9	4.13	8.86	69.48

Source: Office GM Planning, NTDC

The load shed at generation, primary transmission and secondary transmission level is estimated to be about 5000 MW. This load shedding figure does not include the "load shed" due to under frequency and low voltage "measures". The impact of load shedding has been estimated at 3% to 4% of GDP, costing about US$ 10b a year .This has rendered about 7.5% of the work force jobless.

13.3.4.3 Least-Cost Analysis

NTDC has undertaken a revision/updating of the National Power Plan. The plan is based upon an expansion of the system over the next 25 years. The expansion plan is based on a load forecast, presented as **Table - 13.16** below:

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Table - 13.16: Load Forecast

	2010	2020	2035	Growth Rate (2010-2035)
Sales (GWh)				
Base Case	106,569	254,105	737,860	8.10%
Base Case with DSM	106,569	254,105	737,860	8.10%
Low Case	106,569	217,348	551,314	6.80%
High Case	106,569	290,299	916,155	9.00%
Generation (GWh)				
Base Case	139,954	306,797	889,583	7.70%
Base Case with DSM	139,954	306,797	889,583	7.70%
Low Case	139,954	262,518	665,210	6.50%
High Case	139,954	338,663	1,106,567	8.60%
Peak Demand MW				
Base Case	22,251	49,824	149,665	7.90%
Base Case with DSM	22,251	49,146	144,779	7.80%
Low Case	22,251	42,612	111,906	6.70%
High Case	22,251	54,998	186,228	8.90%

The expansion plan envisages the addition, during 2011-2015 (short term) of: 3600 MW combined cycle/gas turbine gas based capacity; 176 MW coal (conversion) capacity; 320 MW Nuclear capacity; 950 MW hydroelectric capacity; 150 MW wind capacity; 100 MW bio-mass capacity. The projected expansion has already fallen short of the expectation as some capacity implementation has been delayed whilst preparatory work on other projects has been delayed or not yet initiated. Issues with gas imports and LNG Imports have brought in focus the option of conversion to coal and imported and domestic coal fired generating capacity. This is presented as follows in **Table 13.17.**

Table - 13.17: Least Cost Expansion Plan

Year	Name of Project	Unit Additions			Annual Total (MW)
		Type	Number of Units	Net Capacity (MW)	
	Candidate Wind PP	Wind	8	50	
2015-16	Haveli	GT	12	-153	4,110
	Haveli	CC	6	497	
	Sahiwal	CC	2	689	

Table - 13.17: Least Cost Expansion Plan					
Year	Name of Project	Unit Additions			Annual Total (MW)
		Type	Number of Units	Net Capacity (MW)	
	Neelum-Jhelum	Hydro	4	240	
	Gul Pur, IPP	Hydro	1	99	
	Rajdhani, IPP	Hydro	1	131	
	Candidate Wind PP	Wind	8	50	

Capacity addition over the plan period 2012-2030 include: 1188 MW (1,21%) gas turbine; 100067 MW (10.26%) combined cycle; 450 MW (0.50%) steam on bio-mass (bagass and waste); 37422 MW (38.14$) coal; 6600 MW nuclear; 35000 MW (35.66%) hydro ; and 5400 MW wind (5.5%) . The plan does not address the hydro thermal ratio, which only marginally improves from 34.7 in 2010 to 35.66 in 2030. Addition of hydro and coal (about 73% of total), mostly local coal, will address the dependency on imported fuel concern. This is presented in **Table - 13.18.**

Table - 13.18: Net Capacity Additions										
Year	Load (MW)	Net Capacity Additions								Subtotal (MW)
		Unit								
		GT	CCGT	ST400	ST600*	Nuclear	Hydro	Wind	Interc	
2011-12	22,567		364			320	166	100		950
2012-13	24,295	267	546	452**			249			1,513
2013-14	26,225		658				165			823
2014-15	28,423	1,841					0	400		2,241
2015-16	31,018	-1,841	4,363				1,189	400		4,110
2016-17	33,750				2,835	320	370	500	2,000	6,025
2017-18	36,728				2,268	320	2,136	300		5,024
2018-19	40,149				3,969		1,236	100		5,305
2019-20	43,867				3,969	940	1,435			6,344
2020-21	47,879				2,268	940	4,089			7,297
2021-22	52,147		1,379		567		3,061	400		5,407
2022-23	56,665						5,316	400		5,716
2023-24	61,424				2,268	940	4,768	400		8,376

Table - 13.18: Net Capacity Additions										
Year	Load (MW)	Net Capacity Additions								Subtotal (MW)
		Unit								
		GT	CCGT	ST400	ST600*	Nuclear	Hydro	Wind	Interc	
2024-25	66,418					940	5,544	400		6,884
2025-26	71,610	307			3,402		911	400		5,020
2026-27	77,015		1,379				4,356	400		6,135
2027-28	82,586				5,670	940	0	400		7,010
2028-29	88,324	307			4,536	940	0	400		6,183
2029-30	94,231	307	1,379		5,670		0	400		7,756
	Total	1,188	10,067	452	37,422	6,600	34,991	5,400	2,00	98,120

Note: * Steam turbines using Thar coal.

** Including 76 MW Jamal Din Wali, R. Y. Khan Punjab (Bagass) and 24 MW Bio Waste plant and 352 MW converted from oil to coal in KESC system.

NTDC have updated the least cost expansion program. The expansion program includes the rehabilitation of the existing publically owned thermal power generation facilities and also the new 600 MW super critical coal fired power plant at Jamshoro, which has been shown as completed in FY 2017-2018 in **Table 13.19.**

Table - 13.19: New Capacity Addition								
Sr. No.	Fiscal Year	Name of Project	Agency	Fuel	Capacity	Commissioning Date	Capacity Addition / year	Total Installed Capacity
		Existing Capacity						**20415**
	2012-13						537	20952
1		Allai Khwar HPP	WAPDA	Hydel	121	Dec. 2012		
2		Zorlu wind power	AEDB	Wind	56	Dec. 2012		
3		Jinnah Low Head	WAPDA	Hydel	96	Dec. 2012		
4		Fauji wind power	AEDB	Wind	50	Dec. 2012		
5		Duber Khwar HPP	WAPDA	Hydel	130	Mar. 2013		
6		New Bong Escape	PPIB	Hydel	84	Mar. 2013		
	2013-14						2042	22994
7		Nandipur Power project	GENCO	Oil	425	Oct. 2013		
8		Guddu New CC	GENCO	Gas	747	Dec. 2013		
9		Rehabilitation of GENCOS	GENCO	Gas	245	Dec. 2013		
10		UCH-II	PPIB	Gas	375	Dec. 2013		
11		Three Gorges Wind Farm	AEDB	Wind	50	Dec. 2013		
12		Green Power Ltd	AEDB	Wind	50	Jan. 2014		
13		Beacon Energy Ltd	AEDB	Wind	50	Jan. 2014		
14		Dawood Power (Pvt.) Ltd.	AEDB	Wind	50	Jun. 2014		
15		New Park (Pvt.) Ltd.	AEDB	Wind	50	Jun. 2014		
	2014-15						770	23764

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Table - 13.19: New Capacity Addition

Sr.	Fiscal	Name of Project	Agency	Fuel	Capacity	Commissioning	Capacity	Total
16		Tenaga Generasi Ltd.	AEDB	Wind	50	Sep. 2014		
17		Lucky Energy	AEDB	Wind	50	Sep. 2014		
18		Metro Power Company Ltd.	AEDB	Wind	50	Sep. 2014		
19		Gul Ahmed Wind Energy Ltd.	AEDB	Wind	50	Sep. 2014		
20		Grange Holding	PPIB	RFO	147	Dec. 2014		
21		Saphire Wind power Company	AEDB	Wind	50	Dec. 2014		
22		Master Wind Energy (Pvt.) Ltd.	AEDB	Wind	50	Feb. 2015		
23		Zephyr Power (Pvt.) Ltd.	AEDB	Wind	50	Feb. 2015		
24		Sachal Energy Development	AEDB	Wind	50	Mar. 2015		
25		Jamal Din Wali Co-gen	PPIB	Coal	73	Jun. 2015		
26		Wind Eagle Ltd.	AEDB	Wind	100	Jun. 2015		
27		Abbas Steel Group	AEDB	Wind	50	Jun. 2015		
	2015-16						516	24280
28		Golen Gol HPP	WAPDA	Hydel	106	Aug. 2015		
29		Radian Power Project	PPIB	RFO	150	Dec. 2015		
30		Ramzan Co-gen	PPIB	Bagasse / Coal	100	Dec. 2015		
31		Janpur Co-gen	PPIB	Bagasse / Coal	60	Dec. 2015		
32		Fatima Co-gen	PPIB	Bagasse / Coal	100	Jun. 2016		
	2016-17						4196	28476
33		Iran Pakistan	Import	Imp.	1000	Sep. 2016		
34		CASA	Import	Imp.	1000	Sep. 2016		
35		Neelum Jhelum Hydel	WAPDA	Hydel	969	Nov. 2016		
36		Chishtia co-gen	PPIB	Bagasse / Coal	65	Dec. 2016		
37		CHASUPP-III Punjab	PAEC	Nucl	340	Dec. 2016		
38		Dewan co-gen	PPIB	Bagasse / Coal	120	Dec. 2016		
39		Kandra Power Project	PPIB	Gas	120	Dec. 2016		
40		Kurram Tangi HPP	WAPDA	Hydel	83	Dec. 2016		
41		Patrind HPP	PPIB	Hydel	147	Dec. 2016		
42		Keyal Khwar	WAPDA	Hydel	122	Jan. 2017		
43		Gulpur (Poonch River)	PPIB	Hydel	100	Jun. 2017		
44		Sehra HPP	PPIB	Hydel	130	Jun. 2017		
	2017-18						3802	32278
45		Tarbela 4th ext. Hydro	WAPDA	Hydel	1410	Jul. 2017		
46		Imported Coal	GENCO	Coal	600	Aug. 2017		
47		CHASHNUPP-IV-Punjab	PAEC	Nucl	340	Oct. 2017		
48		Kotli HPP	PPIB	Hydel	100	Dec. 2017		
49		Rajdhani (Poonch River)	PPIB	Hydel	132	Dec. 2017		
50		Karot HPP	PPIB	Hydel	720	Dec. 2017		
51		Chakothi HPP	PPIB	Hydel	500	Dec. 2017		
	2018-19						4112	36390
52		Phandar	WAPDA	Hydel	80	Dec. 2018		
53		Asrit – Kedam HPP	PPIB	Hydel	215	Dec. 2018		
54		Madyan HPP	PPIB	Hydel	157	Dec. 2018		

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Table - 13.19: New Capacity Addition								
Sr.	Fiscal	Name of Project	Agency	Fuel	Capacity	Commissioning	Capacity	Total
55		Azad Pattan HPP	PPIB	Hydel	640	Dec. 2018		
56		Suki Kinari HPP	PPIB	Hydel	840	Dec. 2018		
57		Kohala	PPIB	Hydel	1100	Dec. 2018		
58		Dasu-1	WAPDA	Hydel	1080	Feb. 2019		
	2019-20						1548	37938
59		Chashma Nuclear	PAEC	Nucl	1000	Sep. 2019		
60		Kaigah HPP	PPIB	Hydel	548	Dec. 2019		

Source: Office of GM Planning Power, NTDC

The present Government after taking over in 2012 , undertook a detailed analysis of the power sector and after detailed deliberations reached a policy conclusion which is summarized as follows : The present gap between supply and demand was 4500 to 5500 MWs , resulting in 12 to 16 hours load shedding ; the cost of supply was high at Rs. 12/kWh , due to heavier reliance upon furnace oil and HSD; system losses were 23 to 25 %, which result in a cost of supply of Rs. 14.70/kWh ; collection losses result in the final cost of supply to be Rs. 15.60/kWh. Theft is causing financial losses of Rs. 140 b / annum.

GoPs policy initiative has been reduced to the targets which can be summarized as follows: decrease supply demand gap from 4500-55500 MW at present to zero in 2017; decrease cost of generation form 12 c/kWh at present to less than 10 c/kWh in 2017; decrease system losses form 23-25 % today to less than 16% in 2017; increase collection rate from 85% today to 95% by 2017.

GoP has already paid circular debt, thereby adding 1700 MW to the supply. Other short and medium term measures include: rehabilitation of the publically held GENCO assets, which will add 1447 MW within one year ; Letter of Support (LOS) for 450 MW wind plants have been issued , this along with under study wind plants could add up to 2276 MW by 2016 ; 341 MW solar plants are in feasibility stage, which could be online by 2016 ; bagasse based plants could add 83 MW by 2016 ; 6 No. hydroelectric power plants will add 388 MW by 2015; Gulpur and Patrind could be on line by 2017 adding 247 MW ; ongoing Neelum-Jehulm will add 969 MW possibly by 2016 ; 4th. and 5th. Tarbela extensions could add 1910 MW by 2017; sea shore based coal fired plants could add 6000 to 7000 MW in the next 5 to 7 years. Longer term plans include: 7100 MW Bunji ; 4500 MW Basha ; 2160 MW Dasu ; 2800 MW Patan ; and 2800 MW Thakot .

The KP Provincial Government is already engaged in the systematic development of the hydropower power potential within the province. This province, through PHYDO has already developed: Malakand-111MW, Dargai 81 MW ; Pehur , Swabi 18 MW ; Reshun , Chitral 4.2 MW ; and Sishi Chitral , 1.8 MW .36.5 MW Duberr Khwar, in Swat District is scheduled to be operational in December 2015, 17 MW Ranolia, in Kohistan District, is also due for commissioning by December 2105, 2.6 MW Machai Canal. In Mardan District, is to be commissioned by June 2014, Development of hydropower is one of the

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important initiatives of KPK. Hydroelectric power development activities by KP through PHYDO are summarized in **Table - 13.20**, as follows:

Table - 13.20: PHYDO Hydropower Projects Under Development

Sr. No.	Name	Installed Capacity MW	Completion Target	Status	Area
1	Short Term				
1.1	Daral Khwar	36	2015	Under Construction	Swat
1.2	Ranolia	17	2015	Under Construction	Kohistan
1.3	Machai	2.6	2015	Under Construction	Mardan
	Sub Total	55.6			
2	Medium Term		Tendering Stage		
2.1	Matiltan	84	2016	Tendering stage	Swat
2.1	Lawi	69	2017	Tendering stage	Chitral
2.2	Sushgai-Zindhali	144	2018	PC-1 under approval	Chitral
2.3	Shogo-Sin	132	2018	PC-1 under approval	Chitral
2.4	Sharmai	150	2018	PC-1 under approval	Upper Dir
2.5	Kato	31	31	MC Consultant selection	Lower Dir
2.6	Karora	9.3	2014	MC Consultant selection	Shangla
2.7	Jabori	7	2016	MC Consultant selection	Mansherea
	Sub Total	626.3			
3	Long Term		Feasibility Stage		
3.1	Balakot	190	2014(2019)	Feasibility Study	Kaghan
3.2	Arkari	210	2014(2019)	Feasibility Study	Kaghan
3.3	Barikot-Patrak	34	2014(2018)	Feasibility Study	Dir
3.4	Patrak-Shingal	21	2014(2018)	Feasibility Study	Dir
3.5	Shigo-Kach	26	2014(2018)	Feasibility Study	Dir
3.6	Ghorband	14	2013(2016)	Feasibility Study	Sangla
3.7	Nandihar	10	2013(2016)	Feasibility Study	Batagram
3.8	Arkari Gol	110	2013(2017)	Feasibility Study	Chitral
3.9	Mugigaram-Shogore	51	2014(2018)	Feasibility Study	Chitral
3.1	Istaru-Bunni	52	2014(2018)	Feasibility Study	Chitral
3.11	Gahrit Swir Lasht	334	2014(2019)	Feasibility Study	Chitral
3.12	Korgrah Parit	223	2014(2019)	Feasibility Study	Chitral
3.13	Laspur Miragram	133	2014(2018)	Feasibility Study	Chitral
	Sub Total	1328.6			
4	Long Term		Prefeasibility Stage		
4.1	Kari Mushkai	446		Prefeasiblity Stage	Chitral
4.2	Torkum Gudubar	409		Prefeasiblity Stage	Chitral
4.3	Kalam Gabbral	110		Prefeasiblity Stage	Swat
	Sub Total	965			
	Grand Total	2975.5			

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13.3.5 Analyses Conducted

Economic and financial analyses of the proposed project have been carried out to establish its viability. The need for the project is identified, its inclusion in the least-cost generation expansion path is inferred and thus indirectly verified, and its economic internal rate of return (EIRR) and a reference levelized tariff and financial internal rate of return (FIRR) at a nominal tariff determined. Key assumptions used in the analysis and the results are outlined below. More detailed rationale underpinning key assumptions are contained in Annex 1.

Economic feasibility of the proposed project has been tested by, firstly, establishing the need for the project, secondly, establishing that the project represents the least cost means of achieving its objectives, and finally, establishing that the project has a positive economic return viz. that its EIRR exceeds the economic opportunity cost of capital.

Financial feasibility of the proposed project has been tested by determining the levelized tariff required to allow recovery of the estimated weighted average cost of capital for a typical project sponsor.

13.3.6 Economic Assumptions

Table - 13.21 below contains a summary of the key statistics and basic assumptions used in the economic analysis.

Table - 13.21: Economic Analysis Assumptions

PARAMETER	COMMENT
Prices	All costs and benefits expressed at constant Jun. 2013 prices. The analysis has been undertaken using economic prices Financial prices have been shadow priced to remove distortions caused by taxes/subsidies/shortages or surpluses of labour and materials.
Exchange Rate	Managed floating exchange rate in Pakistan means calculation of a shadow rate is not necessary This does not imply that the Balance of Payment is in equilibrium or that distortions such as import/export taxes do not exist. Correction of these distortions is incorporated by applying an SCF The exchange rate as in Dec. 2013 has been taken as Rs. 107.20 = $1
Discount Rate	Economic discount rate is 12% (recommended by ADB and used by Pakistan's Planning Commission for appraising power sector projects)
Standard Conversion Factor (SCF)	SCF for Pakistan is estimated at 0.9 Based on 1997-2003 data, (Economic Survey of Pakistan - derivation detailed in Annex 2)
Land Values	Where applicable, land is valued at its market price.
Oil Price	Oil price of US$80/bbl used for the base case
Capital Costs & Economic Lives	Economic capital costs and lives used by PHYDO/NTDC for planning considered appropriate and adopted for least cost and economic analysis
LRMC Estimates	LRMC estimates based upon WASP runs (see Basha Dam Feasibility Study Report & TA for Renewable Energy PPTA Report) , LRMC prices have been

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	revised in the light of recent and expected changes in the country's energy mix
Capital Costs & Economic Lives	Economic capital costs and lives used by PHYDO/NTDC/WAPDA for planning considered appropriate and adopted for least cost and economic analysis
Evaluation Period	30 years has been used for economic evaluation
Sources: Various	

13.4 The Project

13.4.1 General

The need to add generating capacity in Pakistan is amply evident. The need, however, is also to bring the cost of generation to affordable levels. Hydroelectric power generation is one option that will fulfill both objectives. Government of KP has taken up the systematic development of hydropower potential within the province, and PHYDO is entrusted with the task of managing this intent .PHYDO plans include a number of hydropower options, the present project being a part of these.

The Arkari Gol Hydropower Project comprises of a Diversion Weir near Uchhatur village. The weir diverts water into a 6.2 km long Head Race Tunnel which is linked to the Powerhouse through a 580 m long pressure shaft. The Powerhouse is located in Andakht village. With an installed power generation capacity of 99 MW, the project is expected to generate 378 GWh of electricity annually. The gross head is 339 m.

The weir site W1 is located on Arkari Gol just downstream of Uchhatur village where valley section is wide and rock is available on either side. The valley near the river level is relatively wide and is considered as suitable for storage. From power intake to powerhouse, the structures are to be located on the right bank. At weir site bed elevation is 2164 m and a minimum weir height of 30 m is proposed to have normal reservoir level of 2190 m.

13.4.2 Cost Estimates

Project costs have been estimated on the feasibility level. The detailed cost estimate is presented in **Table 13.22,** as follows:.

Table 13.22: Economic Cost Estimates (Million US$)

S.No.	Description	Cost	2015	2016	2017	2018	2019	2020	2021
A. PREPARTORY WORKS									
1	Land Acquisition	7.24	7.24						
2	Access Roads and Bridges	2.38		2.38					
3	Infra structure Bridges	6.53		6.53					
4	Mitigation Costs	0.01		0.01					

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Table 13.22: Economic Cost Estimates (Million US$)									
S.No.	Description	Cost	2015	2016	2017	2018	2019	2020	2021
B (i). CIVIL WORKS									
1	Mobilization	0.54		0.54					
2	Coffer Dam	0.32		0	0.32	0	0	0	
3	CFRD	23.98			7.99	15.98			
4	Diversion Tunnel	9.26			9.26				
5	Intake Structure	1.94			0.48	1.45			
6	Approach Tunnel	1.63			0	1.63			
7	Desanders	7.7			0	7.7			
8	Flushing Channel	0.13				0.07	0.07	0	0
9	Adit Tunnels	12.65			12.65	0	0	0	0
10	Headrace Power Tunnel	20.47			15.35	5.12	0	0	0
11	Access Tunnel	4.29				4.29			
12	Surge Tank	1.97			0.99	0.99			
13	Pressure Shaft	1.96			0.98	0.98			
B (ii). POWERHOUSE AND TAILRACE									
14	Power House	1.57			0.31	0.63	0.63		
15	Tailrace	0.76					0.76		
16	Switchyard	0.16					0.16		
17	Miscellaneous Works	0.4					0.2	0.2	
	TOTAL (A+B)	105.9	7.24	9.46	48.34	38.84	1.82	0.2	
C. E & M									
a)	E & M Equipment	39.91		0	7.98	15.96	15.96		
b)	Erection and Commissioning	11.97					3.99	7.98	
c)	Transmission Line	0.05						0.05	
	TOTAL (A+B+C)	157.83	7.24	9.46	56.32	54.8	21.77	8.23	
D. MISCELLANEOUS CHARGES									
a)	Import/Duties	0				0	0		
b)	Transportation & Shipment	1.2				0.6	0.6		
c)	Contingencies (3% of A+B+C)	4.73	0.22	0.28	1.69	1.64	0.65	0.25	
E. ENGINEERING SUPERVISION									
a)	Engineering Supervision Charges (5% of A+B)	5.3	0.36	0.47	2.42	1.94	0.09	0.01	
F. MANAGEMENT CHARGES									
a)	Management Charges (2% of A+B)	2.12	0.14	0.19	0.97	0.78	0.04		
b)	De-Mobilization	0.54							0.54
	Transmission Line	20		2	4	4	4	4	2
	TOTAL PROJECT COST	189.6	7.82	12.22	64.43	62.99	27.11	12.49	2.54

Note: Transmission costs are only applicable to LRMC analysis

13.4.3 Project Outputs

The project size (installed capacity and design discharge) has been optimized. This optimization has been made on the basis of a marginal analysis. The results of this optimization are presented, in **Table - 13.23** as follows:

Table 13.23 : Economic Evaluation – Alternative I

S.No	Design Discharge	Installed Capacity	Plant Factor	Total Cost	NPV at 10%	NPV at 12%
	m3/s	MW	%	M US$	M US$	M US$
1	24	67	54.41	135	112.01	77.54
2	26	73	52.24	141	118.87	82.69
3	28	78	50.27	146	125.08	87.26
4	30	84	48.24	152	128.63	89.62
5	32	89	46.58	159	129.59	89.63
6	34	94	44.99	165	130.27	89.37
7	36	99	43.49	172	130.44	88.66
8	38	105	41.72	180	128.39	86.11
9	40	110	39.63	187	123.37	81.10
10	42	116	37.74	195	117.59	75.42
11	44	121	36.03	204	111.41	69.38
12	46	127	34.46	213	104.86	62.99

Note: Costs for optimization were generated by software, for feasibility detailed cost estimates have been prepared, these are not exactly similar

The optimized installed capacity is 99 MW, 377.92 GWh/a average energy at 43.49% plant factor. Peak energy is estimated to be 138.51 GWh/a. The cost estimates for the 99 MW project are presented in **Table – 13.23** above.

13.4.4 Output of the Optimized Project

The output, installed capacity, and the capacity and the energy outputs of the optimized project are presented, in **Table - 13.24**

Table 13.24: Project Outputs

Year	Mean Annual Flow			Firm Power	Annual Energy			Plant
	River	Power	Spillage		Peak	Off Peak	Total	
	(m^3/s)	(%)	(%)	(MW)	(GWh)	(GWh)	(GWh)	(%)
1964	13.1	91%	9%	65.25	132.43	160.33	292.76	33.8
1965	16.03	91%	9%	70.46	134.42	224.14	358.55	41.3
1966	15.94	92%	8%	67.41	133.98	225.35	359.33	41.4
1967	15.46	92%	8%	69.45	135.01	212.36	347.37	40.1
1968	16.35	90%	10%	71.25	135.18	222.59	357.77	41.3
1969	17.35	91%	9%	94.38	143.54	242.02	385.56	44.5
1970	17.4	93%	7%	80.05	139.91	253.55	393.46	45.4

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Table 13.24: Project Outputs

Year	Mean Annual Flow			Firm Power	Annual Energy			Plant
	River	Power	Spillage		Peak	Off Peak	Total	
1971	17.5	92%	8%	79.84	137.85	255.45	393.3	45.4
1972	17.54	93%	7%	98.77	144.39	254.77	399.16	46
1973	19.5	90%	10%	84.85	140.32	289.53	429.84	49.6
1974	15.28	92%	8%	85.29	139.66	203.45	343.1	39.6
1975	16.87	91%	9%	69.34	134.8	241.57	376.37	43.4
1976	16.29	92%	8%	76.06	137.93	227.04	364.97	42.1
1977	15.42	91%	9%	79.52	135.53	206.21	341.74	39.4
1978	17.36	91%	9%	68.19	135.05	250.08	385.13	44.4
1979	16.31	92%	8%	71.79	136.92	229.95	366.87	42.3
1980	16.62	92%	8%	76.18	140.21	233.48	373.69	43.1
1981	16.41	91%	9%	70.4	136.77	229.26	366.02	42.2
1982	14.39	91%	9%	66.24	133.33	186.49	319.83	36.9
1983	16.11	91%	9%	64.32	132.06	227.17	359.23	41.4
1984	17.61	90%	10%	75.76	137.57	248.46	386.03	44.5
1985	16.53	90%	10%	78.92	136.26	228.01	364.27	42
1986	16.17	91%	9%	78.69	138.79	221.85	360.64	41.6
1987	16.18	93%	7%	77.74	138.67	228.28	366.94	42.3
1988	18.27	91%	9%	80.98	139.57	266.13	405.7	46.8
1989	15.55	92%	8%	74.13	135.69	216.54	352.23	40.6
1990	18.49	92%	8%	77.1	137.32	276.58	413.9	47.7
1991	17.74	91%	9%	86.61	140.86	254.4	395.26	45.6
1992	18.29	90%	10%	82.91	141.18	262.47	403.65	46.5
1993	18.12	93%	7%	94.1	143.88	268.46	412.34	47.5
1994	16.92	90%	10%	68.48	135.03	236.37	371.39	42.8
1995	16.38	90%	10%	72.9	136.69	225.31	362	41.7
1996	18.43	92%	8%	78.85	139.57	275.94	415.51	47.9
1997	16.99	91%	9%	80.31	140.32	238.27	378.59	43.7
1998	17.11	90%	10%	75.13	138.3	240.44	378.74	43.7
1999	17.97	92%	8%	80.06	140.38	263.25	403.63	46.5
2000	16.9	92%	8%	81.51	140.57	240.41	380.99	43.9
2001	17.03	91%	9%	75.59	135.24	244.73	379.97	43.8
2002	16.91	92%	8%	74.04	136.93	243.98	380.92	43.9
2003	17.25	91%	9%	76.19	137.87	246.36	384.23	44.3
2004	17.08	93%	7%	77.02	138.32	249.68	388.01	44.7
2005	19.43	92%	8%	87.87	142.62	294.34	436.96	50.4
2006	17.74	92%	8%	98.77	144.39	256.12	400.51	46.2

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Table 13.24: Project Outputs

Year	Mean Annual Flow			Firm Power	Annual Energy			Plant
	River	Power	Spillage		Peak	Off Peak	Total	
2007	22.03	83%	17%	87.57	142.06	302.83	444.88	51.3
2008	11.93	90%	10%	81.88	139.08	125.26	264.34	30.5
2009	15.01	91%	9%	92.63	143.32	192.43	335.76	38.7
2010	25.1	79%	21%	98.76	144.46	337.53	481.99	55.6
2011	16.51	93%	7%	96.05	144.04	232.84	376.88	43.5
Mean	**17.02**	**91.00%**	**9.00%**	**79.2**	**138.51**	**239.42**	**377.92**	**43.6**

13.4.5 Estimation of Benefits

13.4.5.1 General

The project will deliver both incremental and non-incremental outputs. Incremental output meets increased demand for electricity and has been valued using consumers' estimated willingness-to-pay (WTP) or on consumer surplus basis.

For the incremental part of the output, the benefits of the overall project and of the individual sub-projects have been based on prevailing tariffs, including consumer surplus (assigned to primary transmission) and for the non-incremental part of the output, benefits have been based on resource cost savings. Given the scale of the proposed project, no attempt was made to value environmental or any other external benefits.

The peak firm capacity provided by the project provides the additional benefit of voltage stability during the network peaks. This would be expected to assist in avoiding brown-outs and the need for unscheduled load shedding. As there is no reasonable basis upon which to quantify this benefit; no value has been ascribed to it.

No attempt was made to value external benefits such as environment and health improvements that are likely to accrue from substitution of thermal-based electricity generation with hydro plant.

13.4.5.2 Incremental Consumption Valued at Willingness-to-Pay

Willingness-to-pay (WTP) for incremental consumption was estimated by comparing the current price of electricity with the price of alternative sources of energy. The fundamental concept is that consumers would be willing to pay a proportion of the difference between what they currently have to pay for an alternative source of energy and the amount they would actually have to pay for incremental units of electricity. A semi-log electricity demand function is generally assumed in estimating WTP, but a lack of primary energy consumption data prevents its accurate calculation in this instance. A conservative view has therefore been taken that the consumer surplus is given by 50% of the difference between the electricity tariff and the cost of alternative energy sources.

Due to the fact that the primary and secondary transmission grids are peak-constrained, it has been assumed that the bulk of incremental consumption will be in the residential sector. Residential consumers typically use kerosene lamps for reserve lighting when grid-supplied electricity is unavailable (constrained-off), as these represent the next best viable alternative from an economic perspective. The economic life-cycle cost of kerosene lamps is approximately Rs 37.54/kWh.

In the commercial, industrial and agricultural sectors, diesel generators are typically employed to provide back-up electricity when grid supplied electricity is constrained-off. Thus, diesel generators were assumed to be the next best alternative, at an estimated life-cycle cost of Rs. 34.41/kWh, Rs. 33.26/kWh and Rs. 33.73/kWh for each of the three sectors respectively. The estimates are presented as Table - 13.25 as follows:

Table - 13.25: Willingness-to-Pay Estimates

SECTOR	WTP (Rs/kWh)
Residential	37.54
Agricultural	33.73
Commercial	34.41
Industrial	33.26
Weighted average	35.47

Source: Consultants Estimates

The WTP estimate assigned to generation is 68.83 of the total .The WTP for the energy delivered at the generation level was calculated as 68.3 % of the total cost, which works out as Rs. 24.23 /kWh. This is then split between other and thermal costs. Based on 2012 bulk tariff calculations presented by NEPRA, this works out to be 33.26 Rs./kWh for other (than thermal) generation, presented in Annex 2, The benefit used is the gross consumer surplus allotted to generation i.e. 24.23 Rs./kWh

The economic analysis, based on benefits quantified on consumer surplus basis is presented, in **Table - 13.26**, as follows:

Table 13.26: Economic Feasibility on Consumer Surplus Basis								
Cost Estimates								
MUS$ (1 US$= 107.20 Pak Rupees)								
Year	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Total
Fc	6	6	33	32	13	5	0.3	95
Lc	3	5	27	27	10	4	0.24	76
Total	8	10	60	59	23	8	1	170
SCF	0.9	O&M	2	%				
Station Use	0.50%	Installed Capacity		99	MW			
Energy								
Peak	Off Peak	Total	Consumer Surplus Gross at Generation level					
GWh/a	GWh/a	GWh/a	c/kWh	24.23				
139	378	516	Discount Rate		12			%
losses	1	%	Station Use		1			%
Economic Feasibility on Consumer Surplus Basis-Arkari Hydropower Plant								
Year	Capital Cost	O&M Cost	Total Cost	Total Energy	Net Energy	Total Benefits	Net Benefits	
	M.US$	M.US$	M.US$	GWh/a	GWh/a	M.US$	M.US$	
-7	8		8				-8	
-6	10		10				-10	
-5	57		57				-57	
-4	56		56				-56	
-3	22		22				-22	
-2	8		8				-8	
-1	1		1				-1	
0		3	3	516	506	110	107	
1		3	3	516	506	110	107	
2		3	3	516	506	110	107	
3		3	3	516	506	110	107	
4		3	3	516	506	110	107	
5		3	3	516	506	110	107	
6		3	3	516	506	110	107	
7		3	3	516	506	110	107	
8		3	3	516	506	110	107	
9		3	3	516	506	110	107	
10		3	3	516	506	110	107	
11		3	3	516	506	110	107	
12		3	3	516	506	110	107	
13		3	3	516	506	110	107	
14		3	3	516	506	110	107	

Table 13.26: Economic Feasibility on Consumer Surplus Basis								
15		3	3	516	506	110	107	
16		3	3	516	506	110	107	
17		3	3	516	506	110	107	
18		3	3	516	506	110	107	
19		3	3	516	506	110	107	
20		3	3	516	506	110	107	
21		3	3	516	506	110	107	
22		3	3	516	506	110	107	
23		3	3	516	506	110	107	
24		3	3	516	506	110	107	
25		3	3	516	506	110	107	
26		3	3	516	506	110	107	
27		3	3	516	506	110	107	
28		3	3	516	506	110	107	
29		3	3	516	506	110	107	
30		3	3	516	506	110	107	
				NPV	**at 12 %**	**M.US$**	**407**	
				IRR		**%**	**27.93**	

The proposed investment is feasible as the NPV, at a discount rate of 12%, is 407 M. US$ and the IRR is 27.93% .The uncertainty in costs and benefits is reflected in the sensitivity analysis, which is presented in **Table - 13.27**, as follows:

Table 13.27: Sensitivity Analysis		
Consumer Surplus Basis	**NPV**	**IRR**
	M.US$	**%**
Base Case	407	27.93
Sensitivity		
Costs +10%	394	26.43
Costs +20%	381	25.10
Benefits -10%	354	26.34
Benefits -20%	300	24.56
Cost +20%, Benefit -20%	273	21.87
Switching Value		
Consumer Surplus	c/kWh	5.88
Consumer Surplus	Rs./kWh	5.95

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The project seems to be feasible on certain assumptions, The project also seems to be based on robust parameters as it is feasible on 10% and 20% reduction of benefits and on 10% and 20% increase of costs, and the project is feasible even if costs increase by 20% and benefits reduce by 20% .The switching value at which the project is marginally feasible is when the gross consumer surplus at generation level is 5.88 c/kWh. The average bulk tariff in FY 2012 was about 10.82 c/kWh (2013 bulk tariff was about 12 c/kWh).The project seems robust as it is feasible even with significant changes in benefits or costs.

13.4.6 LRMC Estimates

13.4.6.1 Development of LRMC estimates

The economic analysis on the basis of long run marginal cost (LRMC) evaluates the site at the voltage level at which the power is delivered, which in this case is the 132 kV level. Transmission of 20 M.US dollars is included in the cost estimate and transmission losses have also been included to determine the net output at 500 kV level. The development of the LRMC estimates is presented as follows.

13.4.6.2 Long Run Marginal Cost (LRMC) Analysis

Power projects are capital intensive and therefore increased efficiency is of major importance to a developing country. The relationship between per capita energy consumption and per capita income is well understood. Investments in generation expansion need to be optimized. Classical supply and demand curves for electricity would indicate the price at which demand equals supply. Demand however is growing (usually at a healthy rate) over time and supply needs to match the increased demand. High growth rates mean that the investment decisions need to be based upon a forward looking approach rather than upon a historical approach. The marginal increment in price to meet the marginal increment in demand is the marginal price of electricity.

Marginal cost of power supply is defined as the change in total cost of service resulting from small change in demand. This price, usually, does change from time and place of use. Prices set on the marginal basis provide correct signals to the decision makers and result in market equilibrium at a volume of supply that optimizes economic efficiency.

The main components of the LRMC structure are :

a) Marginal capacity cost at generation level

b) Marginal energy cost at generation level

c) Marginal capacity and energy costs at other voltage levels (500 kV, 220 kV, 132 kV etc.)

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Marginal capacity costs are defined as expenses that need to be incurred to maintain reliability of supply. Marginal energy costs are the incremental running cost of the plant best suited to meet demand variations.

13.4.6.3 Development of LRMC Without Use of WASP

13.4.6.3.1 Methodology

The capacity LRMC at generation level is based on the assumption that the plant at the margin will be an Open Cycle Gas Turbine (OCGT). The capacity LRMC at the generation level is estimated to be about 80% of the capital cost of the OCGT.The peak and off-peak energy costs of thermal equivalents are used as proxies for LRMC energy peak and off-peak.

The development of a thermal equivalent plant to a hydroelectric power plant or facility is not a clear-cut simple exercise. This is mainly due to the fact that each hydroelectric facility is unique and the contribution at peak and off peak periods of each hydroelectric power facility is different. Thus the economic value to the system, of output from each hydroelectric plant, is different and furthermore this output is aimed at different portions of the power mix. The capacity (available 4 hours/day for 90% of time) contributions of the hydroelectric plant result in avoided thermal peaking feasibility (usually an OCGT). The peak energy contributions avoid the operating cost of this OCGT.Whereas the off-peak contribution of a hydroelectric power facility results in avoided operating cost of equivalent or equal generation of a base load thermal power generation power facility (combined cycle gas turbines, cool fired plant etc.). The hydropower facility therefore contributes to both the peak and off peak segment of the power mix. Ex-WAPDA's power mix and full availability situation suggest that:

i. The peaking thermal facility is likely to be an OCGT.

ii. The base load facility is likely to be a combined cycle gas turbine (CCGT)

Thermal equivalent costs therefore will be based upon; the capital and operating cost of an OCGT; and the operating cost of CCGT.

13.4.6.3.2 Economic Peak Fuel (gas) Prices

The development of economic gas prices can follow different paths. Gas prices can be derived on the basis of the economic opportunity cost. This for Pakistan would be the price of furnace oil which the gas substitutes.

Gas reserves are presently at a level that the current consumption cannot be sustained. Gas at the margin will surely be imported gas or LNG. There are currently three gas pipelines under consideration. Gas from Qatar, Iran and Central Asia are under discussion. LNG import options are also under active consideration.

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Gas supplies have dwindled, aging fields, failure to accelerate drilling, delay in infill options etc. have all resulted in diminishing gas supplies. The plan to address this includes: additional domestic supplies; imported Iran and Turkmenistan gas pipelines; LNG from Oman and elsewhere; decreased losses; and infrastructure improvements, which are implemented only in parts and have resulted in continued gas shortages. The near future is therefore expected to be one of dwindling gas supplies. Natural gas is currently the country's largest energy source, making up 48 percent of Pakistan's energy mix in FY 2009/2010.Pakistan produces about 60,000 barrels of oil per day, which only meets approximately one sixth of the country's current oil requirement. The balance amount is imported at a staggering cost of US$2.5 billion. In view of the increasing demand and the current decline in production, this cost is going to increase substantially over the next couple of years. During 2008-9, un-served energy needs were met with 18.5 MTOE oil imports plus 3 MTOE coal imports at a cost of about 1 billion US$, This gap is likely to jump up to 56 MTOE costing 38 billion US Dollars of imported fuel. The gap between supply and demand is widening. Pakistan's average production of about 3753 MMcfd gas and reserves of about 33 trillion cubic feet (Tcf) are equal to 24 years of current production .The rapid , medium term decline in the production of the seven large fields that produce 65% of the total annual gas , their long term projected decline suggest that gas supplies will further fall short of demand . Studies forecasted that Pakistan was going to witness gas shortage starting in 2007, and the imbalance will grow every year to cripple the economy by 2025, when shortage will be 11,092 MMCFD against was total 13,259 MMCFD production. Pakistan's gas shortage would get much worse in the next two decades, if it did not manage any alternative sources. Demand for natural gas in Pakistan increased by almost 10 percent annually from 2000-01 to 2007-08, reaching around 3,200m cubic feet per day (MMCFD) last year, against the total production of 3,774 MMCFD, according to Pakistani official sources. But, during 2008-2009, the demand for natural gas exceeded the available supply, with production of 4528 MMCFD gas against demand for 4731 MMCFD, indicating a shortfall of 203 MMCFD. Gas shortage is presented in **Figure - 13.6** on the following page.

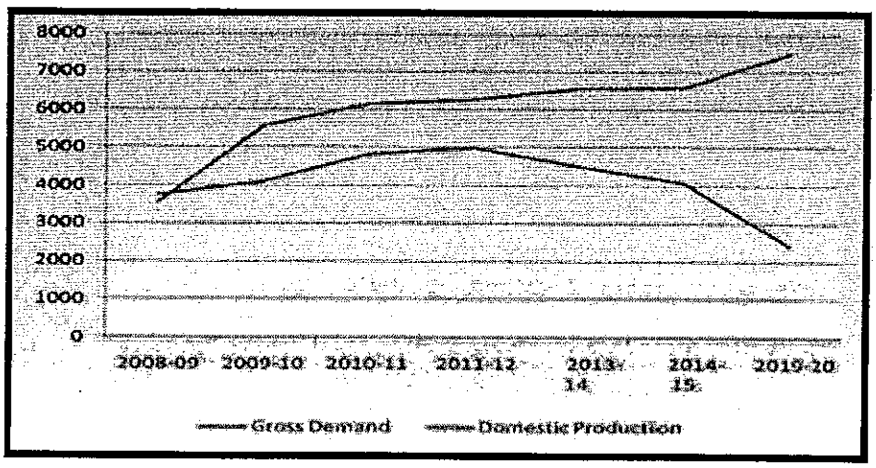

Figure - 13.6: Gap between Supply & Demand of Gas (Million cf/d) Under Do Nothing Scenario

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Pricing of imported gas is as per pricing agreements signed for the Pakistan Iran gas pipeline. Gas prices to be used are as follows:

Imported Gas	=	16 $/mm Btu
Imported LNG	=	18 $/mm Btu

13.4.6.3.3 Economic off Peak Fuel (coal) Prices

The fuel at the margin for base load plants is imported coal. Base load plant fuel may well be coal, which is currently priced at 6 $/mmBTU. Fuel prices in the past are presented in the following **Figure 13.7**.

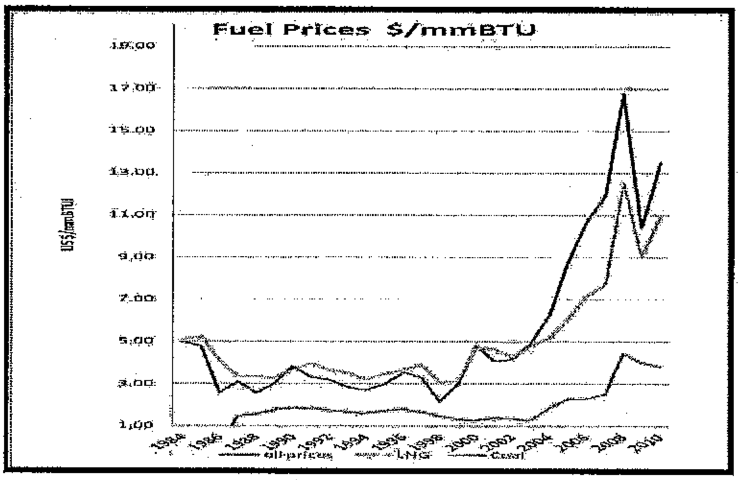

Figure 13-7 Fuel Prices

Coal prices have been relatively stable compared to oil prices. Part of the reason is technological. Electric furnaces are being used to make progressively more steel from scrap, and pulverized coal injection allows expensive coal to be substituted by cheaper steam coal thereby reducing price pressure upon prices. The coal industry has also cut costs dramatically; efficient firms can mine all year round compared to 240 days 10 years ago. Labor productivity in coal mining has increased at a significant rate. The global demand for coal as percentage of primary energy had steadily declined – it comprised 42.5% primary energy in 1900 and only 22% in 2000. Coal prices are only weakly connected to oil prices, and are having less price volatility than oil, which could be attractive for some uses. High oil prices have triggered some shift of energy demand to coal. Several countries have and are reducing subsidies on coal mining.

On the other hand, new materials and technologies are becoming commercially available and will result in dramatic improvement in conversion efficiencies. Efficiencies of 50% in coal fired power generating plants is likely to be possible compared to about 30% for yesterday's technology. World coal usage as percent of total energy will slightly decrease from 2008 to 2018 but will perhaps attain the 2008 levels by 2035. Electricity usage of coal will increase from 2018 to 2035. Coal usage will be about 40% of the total energy consumption. World Coal consumption is forecasted to increase from 139 quad trillion Btu to 209 quad

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trillion Btu in 2035 at an average annual growth rate of 1.5% per annum. China and India are forecasted to account for 95% of this increase. Most of China's growth came from burning more coal: in 2000 China accounted for just under a third of world coal use; in 2010 it was 48.2%. This expansion will be repeated on a smaller scale for a number of other countries, which is why coal is going up in the global mix. Historical coal prices are presented as follows in **Figure - 13.8.**

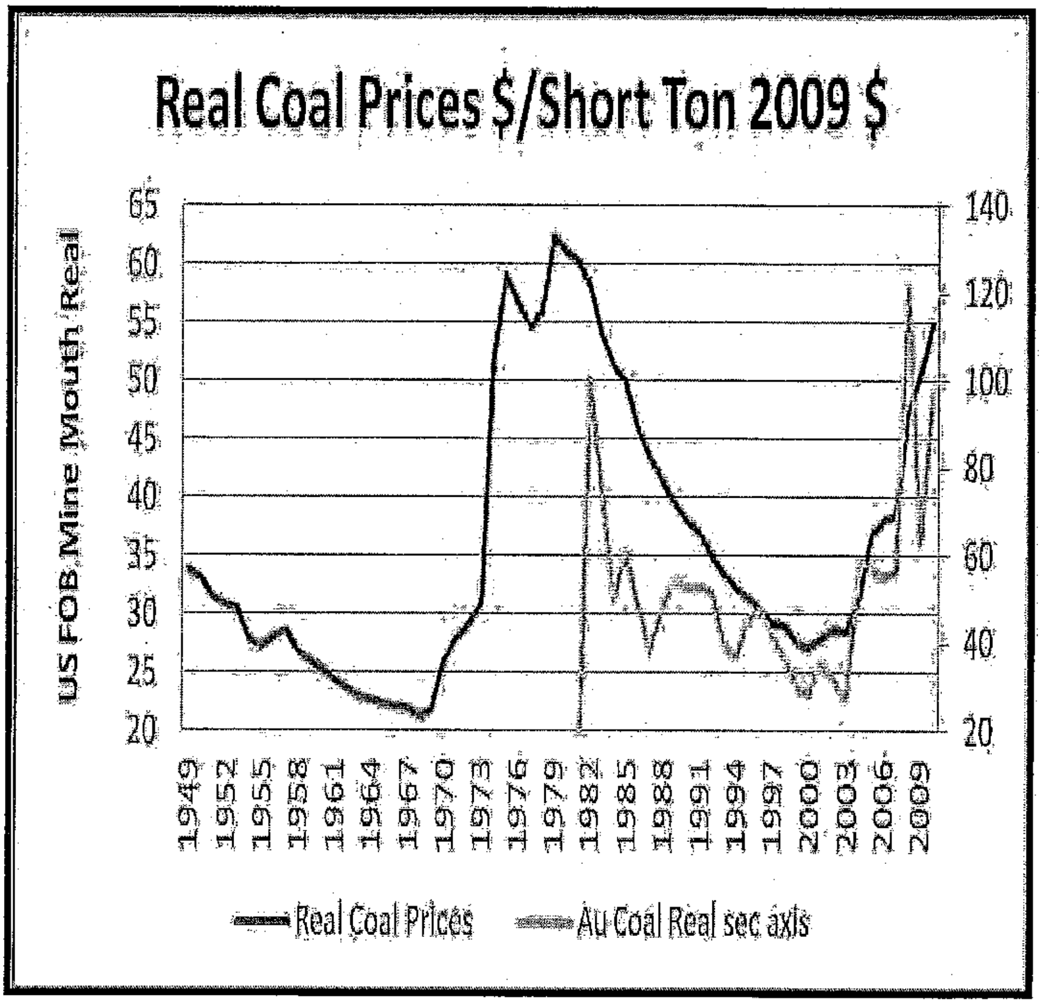

Figure - 13.8: Historical Coal Prices

13.4.6.3.4 Capacity LRMC

The capacity LRMC at generation level is based on the assumption that the plant at the margin will be an OCGT. The least cost response to demand increment can be summarized as follows:

a) Capital cost of the plant at the margin, which is believed to be an OCGT.

b) Cost incurred due to enhanced un-served energy due to the fact that in early plan periods new generation cannot be installed due to lead time.

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c) Benefit of decrease in energy cost due to advancement of base load thermals and hydels in response to demand increment.

The capacity LRMC of the generation level is estimated to be about 80% of the capital cost of the OCGT. This assumption has been verified by detailed Wein Automatic System Planning (WASP) runs that capture the marginal capacity price.

13.4.6.3.5 Energy LRMC

The peak and off-peak energy costs of thermal equivalents are used as proxies for LRMC energy peak and off-peak.

Variable operating cost of an OCGT excluding fuel is taken as US$ 1.5/MWh. Fixed O&M cost is taken as 19 $/kW-a .The cost of high BTU gas delivered at load centre has been estimated as 14.18 (at 80 $/barrel parity) $/mm Btu, which given an efficiency of 9100 Btu/kWh translates into a total operating cost of 15.76/kWh.

Secondary energy generated at the hydro plant is considered to replace the generating cost of an imported coal fired steam consuming plant. The fixed O&M cost is taken to be 35 $/kW-a. The variable O&M cost is taken as 3.6 $/MWh. The heat rate for a sub-critical coal fired power plant is taken to be 9100 Btu/kWh, and delivered price of coal to plant is taken as 6.06 $/mmBtu . The variable cost of the coal fired plant works out to be 9.83 c/kWh (all data used in this analysis has been derived from the NTDC Report – System Expansion Plan 2011-2030) .

The LRMC estimates are therefore presented in **Table - 13.28** as follows:

Table - 13.28: LRMC Estimates
(Based on oil price of US$80)

Voltage Level	Capacity $/kW	Peak Energy c/kWh	Off Peak Energy c/kWh
Gen	417	15.76	9.83
500 kV	506	16.02	10.02
220 kV	540	16.29	10.12
132 kV	623	16.78	10.37

13.4.7 Economic Feasibility on LRMC Basis

The economic feasibility of the proposed project based on LRMC estimates at 132 kV level benefits is presented in Table - **13.29**, as follows:

Table 13.29: Economic Feasibility on LRMC Basis								
Cost Estimates								
MUS$ (1 US$= 107.20 Pak.Rs.)								
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Total
Fc	4	7	35	35	15	7	1	104
Lc	4	5	29	28	12	6	1	85
Total	8	12	64	63	27	12	3	190
SCF	0.9	O&M	2	%				
Station Use	0.50%	Installed Capacity		99	MW	Firm Capacity	79.16	MW
Energy			Benefits	at 132 kV level				
Peak	Off Peak	Total	Capacity		peak Energy		off peak energy	
GWh/a	GWh/a	GWh/a	623	$/kW	16.78	c/kWh	10.37	c/kWh
139	239	378	Discount Rate		12	%		
Losses	1	%	Station Use		1	%		
Economic Feasibility on Consumer Surplus Basis- Arkari Hydropower Plant								
Year	Capital Cost	O&M Cost	Total Cost	Firm (Net) Capacity	peak Energy	Off Peak Energy	Total Benefits	Net Benefits
	M.US$	M.US$	M.US$	MW	GWh/a	GWh/a	M.US$	M.US$
-7	7		7					-7
-6	12		12					-12
-5	61		61					-61
-4	60		60					-60
-3	26		26					-26
-2	8		8					-8
-1	2		2					-2
0		4	4	77.57521	137	237	96	92
1		4	4		137	237	48	44
2		4	4		137	237	48	44
3		4	4		137	237	48	44
4		4	4		137	237	48	44
5		4	4		137	237	48	44
6		4	4		137	237	48	44
7		4	4		137	237	48	44
8		4	4		137	237	48	44
9		4	4		137	237	48	44
10		4	4		137	237	48	44
11		4	4		137	237	48	44
12		4	4		137	237	48	44
13		4	4		137	237	48	44
14		4	4		137	237	48	44
15		4	4		137	237	48	44
16		4	4		137	237	48	44
17		4	4		137	237	48	44
18		4	4		137	237	48	44

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Table 13.29: Economic Feasibility on LRMC Basis

19		4	4		137	237	48	44
20		4	4		137	237	48	44
21		4	4		137	237	48	44
22		4	4		137	237	48	44
23		4	4		137	237	48	44
24		4	4		137	237	48	44
25		4	4		137	237	48	44
26		4	4		137	237	48	44
27		4	4		137	237	48	44
28		4	4		137	237	48	44
					NPV	**at 12 %**	**M.US$**	**110**
					IRR		**%**	**16.88**

The project seems to be feasible when benefits are quantified on the basis of LRMC of capacity, peak energy and off peak energy at 132 kV level. The NPV at 12% discount rate is about 110 M.US$ whereas the IRR is about 17%. The uncertainty in costs and benefits is reflected in the sensitivity analysis, which is presented in **Table - 13.30**, as follows:

Table 13.30: Sensitivity Analysis

Analysis Parameter	**LRMC**	**Basis**
	NPV	**IRR**
	M.US$	**%**
Base Case	110	16.88
Sensitivity	NPV	IRR
Costs +10%	96	15.63
Costs +20%	82	14.53
Benefits -10%	85	15.50
Benefits -20%	60	14.03
Costs +20%, Benefits -20%	32	11.88
Switching Value		
Capacity	$/kW	352
Peak Energy	c/kWh	9.48
Off Peak Energy	c/kWh	5.86

The proposed investment seems to be robust as it is economically viable even when benefits and costs are changed by 20%, even a combined sensitivity with benefits decreased by 20% and costs increased by 20% still results in a feasible project. The switching values (estimates of LRMC which are used as benefit parameters) at which the project is only marginally feasible are: firm capacity 352 $/kW; peak energy 9.48 c/kWh; and off peak energy 5.86 c/kWh

13.4.8 Results and Conclusions

The project seems to be economically feasible both when benefits are valued on willingness to pay (consumer surplus) basis and upon LRMC basis, the economic feasibility is presented in **Table - 13.31** as follows:

Table 13.31: Sensitivity Analysis

Analysis Parameter	LRMC	Basis	Consumer Surplus Basis		
	NPV	IRR	NPV	IRR	
	M.US$	%	M.US$	%	
Base Case	110	16.88	407	27.93	
Sensitivity	NPV	IRR	M.US$	%	
Costs +10%	96	15.63	394	26.43	
Costs +20%	82	14.53	381	25.10	
Benefits -10%	85	15.50	354	26.34	
Benefits -20%	60	14.03	300	24.56	
Costs +20%, Benefits -20%	32	11.88	273	21.87	
Switching Value			Consumer Surplus Estimate		
Capacity	$/kW	352	c/kWh	5.88	
Peak Energy	c/kWh	9.48	Rs./kWh	5.95	
Off Peak Energy	c/kWh	5.86			

13.5 Financial Tariff and Feasibility

13.5.1 Financial Assumptions

The financial analysis of the project is based on the assumption that the project will be developed as a standalone, privately financed project. Interest rates, discount rates and other assumptions used all reflect the point of view or perspective of a private investor and conform to PPIB/NEPRA guidelines on the subject.

Cost estimate of the project has been developed on feasibility level .the detailed cost estimate is presented in Chapter-15; the summary of the cost estimate is presented, in **Table - 13.32**, as follows:

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Table - 13.32: Summary of Financial Cost Estimates (Million US$)									
S.No.	Description	Cost	2015	2016	2017	2018	2019	2020	2021
A.	**PREPARTORY WORKS**								
1	Land Acquisition	7.24	7.24						
2	Access Roads and Bridges	2.38		2.38					
3	Infrastructure Bridges	6.53		6.53					
4	Mitigation Costs	0.01		0.01					
B (i). CIVIL WORKS									
1	Mobilization	0.54		0.54					
2	Coffer Dam	0.32		0.00	0.32	0.00	0.00	0.00	
3	CFRD	23.98			7.99	15.98			
4	Diversion Tunnel	9.26			9.26				
5	Intake Structure	1.94			0.48	1.45			
6	Approach Tunnel	1.63			0.00	1.63			
7	Desanders	7.70			0.00	7.70			
8	Flushing Channel	0.13				0.07	0.07	0.00	0.00
9	Adit Tunnels	12.65			12.65	0.00	0.00	0.00	0.00
10	Headrace Power Tunnel	20.47			15.35	5.12	0.00	0.00	0.00
11	Access Tunnel	4.29				4.29			
12	Surge Tank	1.97			0.99	0.99			
13	Pressure Shaft	1.96			0.98	0.98			
B (ii). POWERHOUSE AND TAILRACE									
14	Power House	1.57			0.31	0.63	0.63		
15	Tailrace	0.76					0.76		
16	Switchyard	0.16					0.16		
17	Miscellaneous Works	0.40					0.20	0.20	
	TOTAL (A+B)	105.90	7.24	9.46	48.34	38.84	1.82	0.20	
C. E & M									
a)	E & M Equipment	39.91		0.00	7.98	15.96	15.96		
b)	Erection and Commissioning	11.97					3.99	7.98	
c)	Transmission Line	0.05						0.05	
	TOTAL (A+B+C)	157.83	7.24	9.46	56.32	54.80	21.77	8.23	
D. MISCELLANEOUS CHARGES									
a)	Import/Duties	5.99				2.99	2.99		
b)	Transportation & Shipment	1.20				0.60	0.60		
c)	Contingencies (3% of A+B+C)	4.73	0.22	0.28	1.69	1.64	0.65	0.25	
E. ENGINEERING SUPERVISION									
a)	Engineering Supervision Charges (5% of A+B)	5.30	0.36	0.47	2.42	1.94	0.09	0.01	
F. MANAGEMENT CHARGES									
a)	Management Charges (2% of A+B)	2.12	0.14	0.19	0.97	0.78	0.04		
b)	De-Mobilization	0.54							0.54
	TOTAL PROJECT COST	175.58	7.82	10.22	60.43	61.98	26.10	8.49	0.54
TOTAL PROJECT COST		**176**		1738	$/kW				

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The above cost estimate does not include financial charges .The capital cost of the project includes civil works, E&M equipment, temporary works, engineering and development cost .The civil works cost has been based on the feasibility level design of the project .Quantities have been derived from the general arrangement and layout drawings of the structures developed as part of the feasibility level design.

Interest rates and interest during construction: KIBOR plus 250 points and LIBOR plus 250 points have been taken as the interest rates for local and foreign capital. This is forecasted to result in interest rate of 3.00% for foreign capital and 14.5 % for local capital at the time of implementation and financial close of the plant. Interest during construction and debt servicing have been calculated at the above mentioned rates .These rates will be adjusted on the basis of actual on COD .

Foreign costs have been indicated in US Dollars only. At the time of EPC or COD stage, foreign prices will be mentioned in actual currencies that will be incurred .Energy purchase price includes variable O&M and water use charges, whereas the capacity price includes debt servicing, equity return and redemption, and fixed O&M costs .

Variable O&M has been calculated on the basis of analysis and includes: cost of services of O&M operator for day to day management of the plant; replacement of spare parts; and cost of maintenance for forced and scheduled outages Eighty (80)% of this cost will be in foreign exchange. The variable O&M cost for the project has been estimated to be 0.81 US$/a.

Water use charges are estimated at Rs. 0.15/kWh based on the energy delivered to the power purchaser at the plant bus bars .This component is subject to indexation to Pak WPI. This charge is payable to the Government of NWFP .The water use charge works out to be US $ 1.13 /a.

Capacity purchase price is based on net capacity available to the power purchaser i.e. less station use .This is a fixed monthly payment payable to the sponsor irrespective of the hydrology and dispatch .Hydrological risk shall be borne by the power purchaser.

Fixed O&M costs have been estimated, which are to be incurred both in foreign and local currency .Total fixed O&M costs are estimated to be US $ 7.50.0 / annum. 20% of these are to be incurred in foreign exchange and the rest in local currency. Fixed O&M foreign costs are incurred on expatriate staff and include maintenance and operation of the plant. Fixed local O&M costs are inclusive of remunerations of the operation and maintenance staff, other administrative costs, rents, utilities, fees for maintaining consent, consultancy fees, environmental monitoring costs, and reporting fees.

Insurance at 1% of the EPC cost has been included in the tariff calculations. This has been shown as a local cost although in fact due to reinsurance this cost has a significant foreign component. Return on equity has been taken to be 15%. The assumptions and inputs to the tariff model are presented as follows:

FINANCIAL MODEL	
INPUT AREA	
Installed Capacity MW	99.00
Project Cost (excl IDC) M.US$	175.58
Energy Output Gwh/a -NET	377.92
Interest % p.a.-Re. Loan	14.50
Interest % p.a.-$ Loan	3.00
Repayment Years-Re Loan.	10.00
Repayment Years-$ Loan.	10.00
Grace period-Re. Loan	0.00
Grace period-$. Loan	0.00
Rate Of Return on Equity %	15.00
Exchange Rate Reference(1 $=Rs.)	107.20
Reference Year	2014
Construction Period Years	7.00
Equity % Total	20.00
Loan % Total	80.00
Foreign Exchange M.US$	96.57
Local Currency	79.01
Fixed O&M US$/a	7.50
Fixed O&M Local US$/a	2.02
Fixed O&M Foreign US $/a	5.48
Variable O&M US $/a	0.26
Variable O&M Foreign US $/a	0.21
Variable O&M Local US$/a	0.05
Water Use Charge US$/a Local	0.32
Discount Rate %	12
Insurance cost 1% EPC cost, M.Rs.	216
CALCULATED VALUES	
Installed Cost $/kW-Incl. IDC.	2033
Total Cost M$(Incl IDC)	201
Plant factor %	43.58

The above inputs were used to establish the reference tariff for the power plant. The results are summarized, in **Table 13.33** as follows:

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Table 13.33: Summary of Tariff Calculations					
		Years			Lev.
Average		1-10	11-20	21-30	at 12 %
CPP	Rs./kW/m	3511	1514	1514	
EPP	Rs./kWh	0.16	0.16	0.16	
Total	Rs./kWh	11.20	4.92	4.92	
Lev.	Rs./kWh			at 12%	9.33

The breakdown of the tariff by components, i.e. CPP and EPP and sub components is also summarizd, in **Table 13.34** as follows:

Table 13.34: Tariff Summary for Components

	CPP Rs./kW/m									EPP Rs./kWh				Total
Year	Fixed O&M Local	Fixed O&M Foreign	Insurance Cost	ROE	ROEDEC	Debt Foreign	Debt Local	With Holding Tax	Total	Variable O&M Local	Variable O&M Foreign	Water Charge	Total	Tariff EPP+CPP Rs./kWh
1	495	182	182	458	152	822	1397	46	3733	0.01	0.06	0.09	0.16	11.9
2	495	182	182	458	152	822	1397	46	3733	0.01	0.06	0.09	0.16	11.9
3	495	182	182	458	152	822	1397	46	3733	0.01	0.06	0.09	0.16	11.9
4	495	182	182	458	152	822	1397	46	3733	0.01	0.06	0.09	0.16	11.9
5	495	182	182	458	152	822	1397	46	3733	0.01	0.06	0.09	0.16	11.9
6	495	182	182	458	152	822	1397	46	3733	0.01	0.06	0.09	0.16	11.9
7	495	182	182	458	152	822	1397	46	3733	0.01	0.06	0.09	0.16	11.9
8	495	182	182	458	152	822	1397	46	3733	0.01	0.06	0.09	0.16	11.9
9	495	182	182	458	152	822	1397	46	3733	0.01	0.06	0.09	0.16	11.9
10	495	182	182	458	152	822	1397	46	3733	0.01	0.06	0.09	0.16	11.9
11	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
12	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
13	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
14	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
15	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
16	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
17	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
18	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
19	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
20	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
21	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
22	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
23	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
24	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
25	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
26	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
27	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
28	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
29	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
30	495	182	182	458	152			46	1514	0.01	0.06	0.09	0.16	4.92
Levelized Tariff at 12 % discount rate Rs./kWh														9.33
c/kWh														8.71

13.5.2 Financial Feasibility

The financial analysis of the proposed hydropower plant has been carried out in accordance with the Asian Development Bank's (ADB) *Financial Management and Analysis of Projects.* All financial costs and benefits have been expressed at early 2013 constant prices. Cost streams used for the purposes of financial internal rate of return (FIRR) determination (i.e., capital investment, operations and maintenance, insurance costs and taxes) reflect costs of delivering the estimated benefits. The NEPRA approved tariff for Suki Kinari, a high head hydroelectric project was used to estimate the financial benefits.

The construction period of 7 years were assumed for this project. Capital costs were estimated in Pakistan rupees based on the latest available local prices. Taxes and duties, and an allowance of 3% physical contingencies were included while price contingencies and interest during construction were excluded.

Financial viability was examined by comparing the incremental costs and benefits of "with" and "without" investment scenarios. The incremental benefits arise through the increased availability of power due to the implementation of the project.. The resultant incremental capacity has been translated into monetary terms using the tariff for Suki Kinari, 5.9412 c/kWh determined by NEPRA. Incremental operating and maintenance costs have been computed as a percentage of the investment. It is assumed that the investment will have a 30-year economic life and no residual value at the end of that life.

To estimate the weighted average cost of capital (WACC), it has been calculated that the foreign exchange loan component of the project is US $ 73.28 million (without IDC) whereas the local loan component is US$ 59.86 million (without IDC). Equity is estimated to be US $ 33.31 million. Local capital cost has been calculated as 14.5%, whereas foreign capital cost has been calculated as 3.00% while the owner expects 15% return on equity. Domestic inflation is to be 10.0% per annum, whereas foreign inflation is taken to be 1.5%. The WACC for the investment program is 6.322%. The estimation of the WACC is presented as follows:

Weighted Average Cost of Capital (WACC)				
		Foreign Loan	Local Loan	Equity
Amount	M$	78	79	44
Weighting	%	39	39	22
Nominal Cost	%	3	14.5	15
Tax Rate	%	0	0	0
Tax-adjusted nominal	%	3	14.5	15
Inflation Rate	%	1.5	10	
Real Cost	%	2.71	5	15
Weighted Component	%	1.05	1.97	3.31
Weighted Average Cost			**6.32**	**%**

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FIRR was calculated at 8.31% for the project. The overall rate compares favorably with the estimated WACC of 6.322%, substantiating the financial viability of the project. The FIRR calculation is presented, in **Table - 13.35**, as follows:

Table 13.35: FINANCIAL ANALYSIS						
Year	Capital Cost	O&M Cost	Total Cost	Net Energy	Total Benefits	Net Benefits
	M.Rs.	M.Rs.	M.Rs.	GWh	M.Rs.	M.Rs.
1	839		839		0.0	-838.6
2	1095		1095		0.0	-1095.1
3	6478		6478		0.0	-6478.2
4	6644		6644		0.0	-6644.3
5	2798		2798		0.0	-2798.4
6	910		910		0.0	-909.9
7	58		58		0.0	-58.2
8		357.1	357	370.4	2511.7	2154.6
9		357.1	357	370.4	2511.7	2154.6
10		357.1	357	370.4	2511.7	2154.6
11		357.1	357	370.4	2511.7	2154.6
12		357.1	357	370.4	2511.7	2154.6
13		357.1	357	370.4	2511.7	2154.6
14		357.1	357	370.4	2511.7	2154.6
15		357.1	357	370.4	2511.7	2154.6
16		357.1	357	370.4	2511.7	2154.6
17		357.1	357	370.4	2511.7	2154.6
18		357.1	357	370.4	2511.7	2154.6
19		357.1	357	370.4	2511.7	2154.6
20		357.1	357	370.4	2511.7	2154.6
21		357.1	357	370.4	2511.7	2154.6
22		357.1	357	370.4	2511.7	2154.6
23		357.1	357	370.4	2511.7	2154.6
24		357.1	357	370.4	2511.7	2154.6
25		357.1	357	370.4	2511.7	2154.6
26		357.1	357	370.4	2511.7	2154.6
27		357.1	357	370.4	2511.7	2154.6
28		357.1	357	370.4	2511.7	2154.6
29		357.1	357	370.4	2511.7	2154.6
30		357.1	357	370.4	2511.7	2154.6
31		357.1	357	370.4	2511.7	2154.6
32		357.1	357	370.4	2511.7	2154.6
33		357.1	357	370.4	2511.7	2154.6
34		357.1	357	370.4	2511.7	2154.6
35		357.1	357	370.4	2511.7	2154.6
36		357.1	357	370.4	2511.7	2154.6
37		357.1	357	370.4	2511.7	2154.6
					FIRR %	7.94

FIRR = Financial Internal Rate of Return, O&M = Operation and Maintenance.

Notes: Capital costs include base costs, physical but not price contingencies. No residual value is assumed. Tariff of 6.3263 c/kWh (NEPRA determined Suki Kinari levelized tariff) is used to estimate avoided cost, which is less than that

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calculated on cost plus basis for the power plant in question . 2% station use and losses are assumed. Costs and benefits are at 2013-14 price levels.

The project seems to be financially feasible as the FIRR is above the WACC of 6.322%; risks are quantified by the sensitivity analysis presented, in **Table 13.36**, below:

Table 13.36: Sensitivity Analysis

		FIRR %
Base Case		7.94
Cost +10%		7.20
O&M +10%		7.81
Cost +10% O&M +10%		7.08
Switching Value		
Tariff	Rs./kWh	5.75
WACC	%	6.32

The project is financially feasible on central assumptions. The project is based on robust parameters and will be able to stand reasonable uncertainties. The tariff at which the project becomes marginally feasible is 5.75 Rs./kWh

13.6 Conclusions

The WASP IV program (and now alternatives) is the primary means by which NTDC undertakes economic least cost planning for electricity generation. Its validity as a least cost planning tool is well established, and is used widely by utilities and planning entities. We have therefore assumed it to be an acceptable means by which to verify that the project is part of the least cost expansion plan.

In the case of distributed generation where a benefit is derived by virtue of location of generation near to consumption (and thereby avoiding primary and secondary transmission costs), WASP IV may produce a sub-optimal result. WASP IV is designed as an integrated system planner, and does not explicitly capture location factors. This is an issue in the case of low head and small high head hydro plants, which often serve local demand as well as providing capacity and energy to the grid, and is particularly relevant in Pakistan where the primary and secondary transmission grids are heavily constrained in some areas.

Although the plant was not run on WASP, the fact that the plant is feasible when benefits were quantified on the basis of LRMC at the voltage level that the plant output is delivered, implies that the plant would form a part of the least cost system expansion program. This implication is based on the fact that LRMC estimates at generation level were derived from multiple WASP runs.

No attempt was made to value environmental impacts that might accrue from the project. Impacts are generally considered to be positive for a hydropower project, particularly where thermal generating sources are being displaced. Moreover, voltage stability benefits that would accrue as a consequence of the peak firm

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capacity provided by the project have not been valued. Therefore, calculated returns can be considered as minimum estimates.

The project seems to be both economically and financially feasible. The project is, however, sensitive to cost overruns of reduction in tariffs .It is recommended that the project be implemented after tariff determination by NEPRA.

13.7 ANNEXURE

- **Annex 1**: Economic Analysis Assumptions
- **Annex 2**: Willingness-to-Pay Calculations
- **Annex 3**: Voltage Level Weights

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Annex 1: Economic Analysis Assumptions

Standard Conversion Factor (SCF)

The standard conversion factor (SCF), used to determine the shadow prices for all non-tradable inputs and outputs, was estimated using the following standard formula:

$$SCF = (eX + nM) / [eX (1 - t_x) + nM (1 + t_m)]$$

Where:

X = f.o.b. value of exports

M = c.i.f. value of imports

e = elasticity of export supply

n = elasticity of import demand

t_x = average tax on exports (negative for subsidy)

t_m = average tax on imports.

Based on 1997 - 2003 data, the SCF is approximately 0.90 as demonstrated in the table below.

	1997-98 (Rs m)	1998-99 (Rs m)	1999-00 (Rs m)	2000-01 (Rs m)	2001-02 (Rs m)	Average (Rs m)
Total Imports	436,338	465,964	533,792	627,000	634,630	539,545
Total Exports	373,160	390,342	443,678	539,070	560,947	461,439
Import Duties	74,496	78,654	61,600	65,000	48,100	65,570
Sales Tax on Imports	26,971	34,340	58,384	76,750	83,150	55,919
Subsidies on Imports	6,268	9,533	14,700	19,700	23,700	14,780
Export Duties	1,464	1,769	1,350	1,048	1,705	1,467
SCF	**0.89**	**0.89**	**0.9**	**0.91**	**0.92**	**0.9**

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Annex 2: Willingness-to-Pay Calculations

1. General

WILLINGNESS TO PAY					
Consumer Type	Units	Residential Kerosene	Agriculture Diesel	Commercial Diesel	Industrial Diesel
Alternative Sources Of Energy		lamp	genset	genset	genset
Ratings and Usage					
Capacity	kW	0.1	10.44	5	12
Daily Use	hours	5	6	5	8.4
Daily Energy Output	kWh	0.5	63	25	101
Annual Use	hours	1825	2190	1825	3066
Annual Energy Output	kwh/yr	183	22872	9125	36792
Design Life	years	5	10	10	10
Annual Load Factor	%	20.83	25.00	20.83	35.00
Investments Costs					
Specific Capital Cost	Rs./kW	9484	44194	44194	44194
Capital Cost	Rs	948	461563	220970	530329
Unit Cost	Rs./kWh	0.27	2.09	2.50	1.49
Operation And Maintenance					
Fixed	Rs./kW/a	0	774	774	774
Variable	Rs./kWh	0.75	0.32	0.32	0.32
Annual Cost	Rs./yr	137	15460	6813	21153
Unit Cost	Rs./kWh	0.75	0.68	0.75	0.57
Fuel Costs					
Efficiency	%	11			
Fuel Consumption	litre/kWh	0.78	0.276	0.276	0.276
Fuel Retail Price	Rs./litre	107.80	116.75	116.75	116.75
Annual Cost	Rs/a	15345	737016	294035	1185549
Unit Cost	Rs./kWh	84.08	32.22	32.22	32.22
Local Losses	%	0	3	3	3
Local Costs	%	100	100	100	100
Alternative Energy Cost	Rs./kWh	85.10	33.93	34.41	33.26
Willingness To Pay Calculation					
Marginal Tariff	Rs./kWh	11.11	14.00	18.00	14.50
Monthly Consumption	kWh/m	120.00	1906.03	760.42	3066.00

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WILLINGNESS TO PAY					
Consumer Type	Units	Residential Kerosene	Agriculture Diesel	Commercial Diesel	Industrial Diesel
Annual Consumption	kWh/a	1440.00	22872.36	9125.00	36792.00
Annual Electricity Cost	Rs./a	15998.40	320213.04	164250.00	533484.00
Customer Connection Cost	Rs.	8000.00	46156.32	22097.05	53032.92
Life	years	20.00	20.00	20.00	20.00
Annual Connection Cost	Rs./a	972.09	5608.53	2685.05	6444.12
O&M Costs Per Annum	%	0.10	0.20	0.20	0.20
Annual O&M Cost	Rs./a	800.00	9231.26	4419.41	10606.58
Total Electricity Cost	Rs.	17770.49	335052.83	171354.46	550534.70
Unit Cost	Rs./kWh	12.34	14.65	18.78	14.96
Willingness To Pay	Rs.	53924.754			
Unit Cost	Rs./kWh	37.45	33.93	34.41	33.26
Weight	%	48.87	13.78	6.3568	30.99
Weighted Willingness In Pay	Rs/kWh	35.47			

2. Surplus by Customer Category Class

2.1 Consumer Surplus

Measurable benefits have been valued in terms of the incremental demand that can be served under the proposed investment compared to the lower level of demand that can be served if no new supply capacity were added to the power system.

Costs are also defined as the difference between power supply costs for meeting the demand forecast with the proposed investment and system costs without any investments in the new supply capacity and related services.

2.2 Residential Customers

Total benefits for new residential users are divided into:

Substitution of existing methods of lighting i.e. kerosene by electricity.

Consumer's surplus derived from the additional quantity of electricity above the substituted level, caused by the large drop in the price of energy that results from a switch from kerosene to electricity for lighting purposes.

The benefit calculations are as shown in the tables above. It should be noted that there is considerable uncertainty behind the estimates of annual kerosene usage,

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concerning the number of kerosene lamps per household, the usage in hours/day and consumption in liters/hour/lamp, etc.

The Household Energy Strategy Study (HESS) indicates that the average consumption of kerosene is about 60 litres/year (out of which 98% is used for lighting purposes). However, the HESS estimate is a conservative one and for the purposes of this analysis the higher estimate derived from various rural electrification surveys is utilized. These surveys indicate annual kerosene usage of 97.6 liters/annum. Each lantern is treated as equal to a 25 watts lamp. The resulting annual cost provides the first point on the load curve.

The consumption of a mature domestic electricity connection, valued at the applicable tariff, provides the second point on the load curve. The benefits attributed to such induced demand are a function of the area under the consumers' demand curve. Assuming a non-linear, semi-log curve and assuming that this results in reduction of benefits by a factor of 50%, the benefits are as shown in the above tables.

2.3 Industrial, Commercial and Agricultural Customers

For industrial, agricultural and other customers, the basis for benefit evaluation is given by their avoided costs; that is, the cost that these users would pay if they had to meet their electricity needs by installing and operating diesel based generators or tube wells instead of taking electricity from the national grid.

a) Industrial Customers

The basis for valuing the benefits of incremental sales to industrial users is the cost that these users would incur if they had to meet their electricity needs by investing in and operating diesel generators. Industrial customers are divided into two categories; small users with 11 kW generating sets and an annual consumption of about 25000 kWh, and medium/large customers with an annual consumption of about 65000 kWh. This study assumes an annual industrial consumption at about 37000 kWh/customer.

b) Agricultural Customers

Agricultural customers utilize diesel oil tube wells as the alternative to electricity. The agricultural benefits are estimated on the basis of substitution of electricity for diesel for motive power.

c) Commercial Customers

Commercial customer benefits are also evaluated on the basis of avoided diesel costs.

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Annex 3: Voltage Level Weights

Weight of Each Voltage Level in Total Cost of Supply

The willingness to pay estimates have been worked out at consumption level, while the project benefits are at the generation level .. The total project benefits are calculated as WTP for energy delivered at the generation level.

The weights assigned to each voltage level have been estimated on the above data and are presented as follows:

LRMC Estimates			
US$ 30/barrel			
	Capacity Cost	Energy Cost	
		Off-Peak	Peak
Voltage Level	$/kW	c/kWh	c/kWh
Generation	417	4.51	5.88
500 kV	506	4.58	5.99
220kV	540	4.66	6.05
132 kV	623	4.80	6.20
66 kV	718	4.94	6.44
11 kV	755	6.04	8.24
Energy Generated (GWh)		73520	
Maximum Demand (MW)		12595	
Losses			
Aux		1.99	2.89
Transmission		7.44	10.79
500 kV		1.75	2.54
220 kV		1.25	1.81
Secondary		4.44	6.44
Distribution		15.28	22.16
System		24.71	35.83

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Voltage	Demand M $	Off-Peak Energy M $	Peak Energy M $	Total M $	Tariff c/kWh	% Weight	Cumulative Weight
Level							
Gen	651	2397	1200	4248	5.778	68.83	68.83
500 kV	129	35	21	185	0.262	3.00	71.83
220kV	50	16	34	101	0.144	1.63	73.46
132 kV	241	132	255	627	0.939	10.17	83.62
66 kV							
11 kV	421	362	227	1011	2.226	16.38	
Total				**6172**		**100**	
Energy Consumption							
	MW	GWh	GWh				
	12595	73520					
	12232	72057					
	11921	70796					
	11705	69911					
	10952	66807	13200				
	8997	45416	2725				

Source: Various (NEPRA, Financial Statements if NTDC, DISCOs GENCOs)

Allocation of generation cost in total cost works out to be 22.84 c/kWh (gross benefits or tariff 33,179 c/kWh, allocated 68.83% to generation). The generation surplus benefit is derived from 2012 bulk tariff and is presented as follows:

Average Cost of Delivered Energy 2012			
Allocation of Bulk Tariff, Hydel and Others			
	Hydro	Total	Others
GWh	28643	89941	61298
M.Rs.	4660	636793	632133
Rs./kWh	0.16	7.08	10.31
Surplus	0.52	22.84	33.26

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14. Conclusion and Recommendations

Chitral Valley is endowed with rich potential for Hydropower generation. An inventory of most promising sites was therefore, prepared in 2001 within an Inventory Study "Identification Study of hydropower potential in northern areas of Khyber Pakhtunkhwa" jointly carried out by PHYDO/ GoKP, Ministry of Water and Power/ GoP and GTZ. Uchhatur-Andakht / Arkari Gol Hydropower Project is one of the 12 promising sites available for development of hydropower generation in Chitral District.

The project is proposed to be established on Arkari River, a left bank tributary of Lutkho River. Its embankment dam shall be built near Uchhatur village about 8 km upstream of the river mouth into Lutkho River, with power house 7 km downstream near Andakht Village on Chitral - Garam Chashma Road some 27 kilometers from Chitral Town.
For complete appreciation of the project, main feasibility report respecting the project needs to be studied which covers wide range of studies essentially needed for setting up of a hydropower project.

The present feasibility study addresses three key aspects:

- **Technical Feasibility:** Is the project technically feasible from topographical, hydrological, geological, geotechnical, seismo-tectonic, structural, environmental, socio-economic and construction aspects?
- **Economic Feasibility:** Is the project beneficial to the economy of the country?
- **Financial Feasibility:** Is the project profitable from investment point of view?

All above three questions have been dealt with at length and analyzed in detail in the feasibility study report with a positive outcome and an answer in affirmative.

14.1 Economic and Financial Analysis

14.1.1 Economic Analysis

The economic viability of the proposed project has been analyzed according to the following methodology: firstly, establishing the need for the project, secondly, establishing that the project represents the least-cost means of achieving the desired objectives, and finally, establishing that the project has a positive economic return – i.e. that its economic internal rate of return (EIRR) exceeds the economic opportunity cost of capital. Economic Feasibility of a project can be established with either Long Run Marginal Cost (LRMC) or on consumer surplus basis ..

The results of economic analysis show very candidly that construction of MSHPP is viable from economic point of view when benefits are valued at the LRMC at 132 kV level or on basis of consumer surplus . The EIRR is well above the acceptable

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levels under present market requirements. At the same time the positive NPV also supports the project suitability. Basically the prevailing vulnerability of fossil fuel prices in the world and non availability of gas for new projects in Pakistan favor a hydropower generating facility.

14.1.2 Financial Analysis

The financial model developed for study of anticipated financing conditions and the proposed levelized tariff required to achieve financial viability was based on information currently available as well as the provisions available in the current power policy and the applicable frame work of the Govt. of Pakistan for anticipated costs and revenues, reasonable assumptions have been applied as provided by the sources.

The financial model evaluates the net cash flow with rates received over the construction period and operating life of the project. To support the investment decision, a range of key financial indicators were employed in the model. Life cycle of the project has been assumed to be 30 years .

It has been assumed that source of financing would be primarily from International Lending Institutions. All assumptions as well as loan repayment period and interest rates have been shown in the table relevant sections. Nevertheless, the final decision on financing will be governed by the market conditions at the time immediately proceeding the period of implementation of the project.

It has been envisaged that the project on realization would be inter-connected to the national transmission grid. It is assumed that the power produced by the project shall be dispatched to the grid using the prevailing river flows. It has also been assumed that PHYDO shall supply power to National Transmission and Dispatch Company at plants' out going bus bars as is being practiced by Independent Power Producers. Accordingly, losses incurred in power transmission and distribution have not been taken into account.

The financial analysis does not take into account the Certified Emission Reduction (CER) credit from Clean Development Mechanism (CDM) of Kyoto Protocol.

14.2 Conclusions

On the basis of detailed analysis of power potential and plant operation options, it has been concluded that a rated discharge of 36 m3/s and net head of 319 m, the optimum installed capacity will be 99 MW with average mean annual energy of 377.92 GWh. The plant factor has been taken as 43.6%.

The financial model was developed and analysis carried out to determine feasibility of the project. The project seems to be financially feasible. The project is, however,

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sensitive to cost overruns of reduction in tariffs, the variations induced in the key parameters do not affect the overall financial viability of the project.

14.3 Recommendations

- A power plant with installed capacity of (3 x 33) 99.0 MW is recommended for implementation.
- Observations and recordings of flow and sediment data should be continued to build up a data bank to make available as much data as possible for detailed design stage.
- Model studies of the spillway, intake structure and desanders may be carried out to confirm the following:
    a. Functioning of low level outlets at the dam/spillway
    b. Sediment flushing
    c. Efficiency of desanders
- Integrated planning of dispatch and transmission of power produced by the Chitral Valley projects to the National Transmission and Dispatch Company.
- In view of the power shortage in the country, the project is recommended to be implemented on fast track.

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VOLUME 1 MAIN REPORT- Part I

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9.1 HYDRAULIC STEEL WORKS

9.1.1 Weir

Technical parameters of individual weir components are detailed as follows.

9.1.1.1 Spillway Gates / Flood Control Gates

- No. of units: 4
- Width: 6.0 m
- Height: 6.0 m
- Bottom pressure of 1.6bar
- 4 vertical roller gates with rolls at the side are provided.
- The gates shall be oil hydraulically operated.
- A servo-motor will be installed in the bridge approximately 10.2 m above the gate upper sealing.
- The gate should be remote controlled.
- Embedded parts with strips in the area of sealing will have stainless steel or stainless plated steel.

9.1.1.2 Stoplogs for Outlets

- No. of units: 4
- Width: 6.0 m
- Height: 8.0 m
- Bottom Pressure: 1.6bar
- All stoplogs should be designed for enabling lifting by a movable gantry crane.
- Sealing of the panels at the non-pressure side shall be provided with music-note type rubber seals.
- All screws and sealing strips shall be of stainless steel or stainless steel plated.
- Embedded parts of the slots shall be equipped with dangling devices to enable the storing of the logs inside the slots.
- Both sets shall be designed as roller type sub-divided horizontally in parts to reduce the weight to be lifted.
- One grappling beam shall allow the placing and pick-up of both sizes of stoplogs by the same gantry crane

9.1.1.3 Gantry Crane

- No of units: 1
- Capacity: 10 tonne
- Length of Rails: 32.0 m

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9.1.1.4 Monorail Crane in Assembly Gallery

- No of units: 1
- Capacity: 10 tonne
- Length of Rail 32 M
- For the maintenance of the spillway gates in the dam structure, one movable crane has to be provided.
- All necessary parts and embedded parts belong to the supply volume.

9.1.2 Intake

Technical details of individual Intake components are presented below.

9.1.2.1 Trashrack

- No. of units: 2
- Angle: 80°
- Width: 5.10 m
- Height: 5.1 m
- Clear between bars: max. 10 cm
- Pressure: 0.9 bar
- 2 sets of intake trashrack shall be sub-divided into panels of equal size, which will be connected by stiffening bars.
- The trashrack panels should be interchangeable and fixed by stainless steel bolts.

9.1.2.2 Rack Cleaning Machine

- No of units: 1
- Velocity of Lifting (v_{li}) = 0.3 m/s
- Velocity of Lowering (v_{lo}) = 0.6 m/s
- Velocity of Drive (v_{dr}) = 0.2 - 0.4 m/s
- Lifting Height (h) = 16.0 m
- The mobile trashrack cleaner shall be operated by electro motors and should be controlled automatically by the difference of the water levels measured in front and behind the trashrack.

9.1.2.3 Intake Gate

- No. of Units: 2
- Width: 3 m
- Height: 4 m
- Bottom Pressure: 0.9 bar
- In emergency cases, the intake gate should be designed to close against full discharge.
- For the first filling of the tunnel, the gate will be partially opened and must operate without inadmissible vibrations during the filling procedure.

- The gate should be of roller type, hydraulically operated by oil pressure.
- The sealing of the gate will be towards the upstream side.
- The gate shall have a total of 8 wheels with self-lubricating bushing. The bottom seals shall be made from flat rubber, the lateral seals will be of music note type. If necessary the gate should be filled in the lower part with concrete as ballast to ensure a self-closing tendency without additional pressure on the top side of the servo-motor.
- The gate shall be guided between the downstream lateral guide rails and the upstream counter guide, where the machined seal sliding strips of stainless steel are welded on.
- The gate will be operated by one oil hydraulic servo-motor, mounted on a bridge allowing the hoisting of the complete gate above the upper tunnel level.
- The hydraulic pressure system must be equipped with two electric motor driven pumps for regular and stand-by service and shall be supplied with all necessary connection pipes, valves and instruments for remote supervision and operation.
- The auxiliary devices for the maintenance of the gate are part of the delivery

9.1.2.4 Stoplogs for Intake Gates

- No. of units: 2
- Width: 3 m
- Height: 4 m
- Bottom Pressure: 0.9 bar
- All stoplogs should be designed to enable lifting by a movable gantry crane.
- The sealing of the panels at the non-pressure side shall be provided with music-note type rubber seals.
- All screws and sealing strips shall be of stainless steel or stainless steel plated.
- The embedded parts of the slots shall be equipped with dangling devices to enable the storing of the logs inside the slots.
- Both sets shall be designed as roller type and will be sub-divided horizontally in parts to reduce the weight to be lifted.
- One grappling beam shall allow the placing and pick-up of both sizes of stoplogs by the same gantry crane.

9.1.3 SandTrap

Technical Parameters of the Sand Trap are presented below.

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9.1.3.1 Outlet Gates

- Outlet Gates
- No. of Units: 4
- Width: 6.0m
- Height: 4.50m
- Bottom Pressure: 0.45 bar
- Each sandtrap chamber outlet will be equipped with one gate. It should be designed as roller gate and shall be hydraulically operated.
- The sealing of the gate will be towards the upstream side.
- The oil pressure shall be supplied by a common oil pressure system for all units.
- The remote indication of the position of the gates and the remote control of the gates should be provided in the Powerhouse control board.

9.1.3.2 Headrace Lock Gate

- No. of Units: 1
- Width: 4m
- Height: 4.5m
- Bottom Pressure: 0.9 bar
- The headrace tunnel will be equipped with one gate, installed in a common gallery with the Sandtrap Outlet Gates.
- It should be designed as roller gate and shall be hydraulically operated.
- The sealing of the gate will be towards the upstream side.
- The oil pressure shall be supplied by a common oil pressure system for all units.
- The remote indication of the position of the gate and the remote control of the gate should be provided in the Powerhouse control board.

9.1.3.3 Sand Flushing Gates

- No. of Units: 4
- Width: 1.0m
- Height: 1.0m
- Bottom Pressure: 8.4 bar
- In case of flushing of the sand trap chambers, these gates will be operated by oil pressure.
- The remote indication of the position of the gate and the remote control of the gate should be provided in the Powerhouse control board.

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9.1.3.4 Assembling Crane in Gate Chamber

- No. of Units: 1
- Capacity: 5 tons
- Length of Rails: 27.0 m
- For the maintenance of the Sand Trap Gates in the Gated Gallery, one movable crane has to be provided.
- All necessary parts and embedded parts belong to the supply volume.

9.1.4 Penstock

Technical parameters of the Penstock are presented as follows.

9.1.4.1 Pressure Shaft and Pressure Tunnel

- No of pipes: 1
- Total Length: 790 m
- Diameter: 3.2 to 3.0 m
- Wall Thickness: 12 to 22 mm
- The total length of water pipe with underground penstock is 840 m.
- 50m is the length of the penstock pipe, i = ∅12 to 22mm thickness plate corresponds to the transition section at the end of the headrace tunnel, penstock to the vertical, and the two vertical curves.
- The vertical connection is 296m long and 12mm thick, which connects the lower chamber of the surge to the top of the vertical curve penstock.
- Penstock length and thickness of the horizontal pressure tunnel are 50 m and 19 to 22 mm respectively.
- 37.75, 21.38 and 7.00 m are the lengths of penstock arms, with 1800 mm diameter and 19 mm thickness from the fork in the horizontal tunnel to safety valves of the turbine in the Powerhouse.
- Q = 36.00 m^3/s (design flow)
- A36 steel (fee = 2530 kg/cm^2)
- The horizontal pressure tunnel has the same features as the headrace tunnel,
- The tunnel junction has a lower arm section excavation width of 4.65m.

All underground penstock is embedded in concrete, including the segments in-between.

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9.2 Hydro-Mechanical Equipment

9.2.1 Design Parameters

On the basis of the results of the support report "Comparative Analysis for Selection of Turbine" of November 2013 (a copy of which is attached with this study in Appendix 9.2), the following number and type of hydropower generating units have been selected:

Design Discharge:	**36 m^3/s**
Net Head:	**318 m**
Total Plant Capacity:	**99 MW**
Number of Units:	**3**
Turbine Type:	**Pelton, 6 jets, vertical axis**
Design Discharge per Unit:	**12 m^3/s**
Design Capacity per Unit:	**33.0 MW (44.880 HP)**
Generator Frequency:	**50 Hz**
Number of Poles per Unit:	**16**
Speed:	**375 rpm**

Main dimensions and parameters of the Pelton turbines are:

Number of jets:	**6**
Discharge per nozzle:	**2.0 m^3/s**
Specific Speed:	**7.04 rpm**
Runner diameter:	**1.91 m**
Bucket width:	**0.56 m**
Jet Speed:	**78.9 m/s**
Rotation Speed:	**37.5 m/s**
Jet diameter:	**0.181 m**

For selection of number of turbo-generating units for this total installed capacity of approximately 99 MW, two options are to be considered only, i.e. installation of either two or three turbo-generating units.

In case of two units:

- With Francis turbines, there is the technical limitation that partial load of less than 40% of rated capacity is not permitted and consequently, it will

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be not possible to operate in off-peak hours during months with very low discharge.

- With Pelton turbines, the required rotation speed that would have to be selected is extremely low which would require generators very large in size and weight, beyond the limits that could be transported to and handled at site for installation.
- Consequently, the option to equip the power station with two units appears to be not feasible. Thus the installation of three units becomes the only suitable solution.

Selection of Pelton turbines is based mainly on the following reasons:

- Simpler design
- Better efficiency in full and low part load resulting in higher energy production.
- High flexibility for peak hour's operation, with reduced water hammer and longer closing time.
- Pelton turbines are heavier but more robust in design.
- Sensitive to abrasion but as compared to Francis turbines, a lesser number of machine elements are affected by abrasion. Furthermore, the affected parts are easy to repair.
- Only a limited number of machine elements at nozzles and deflector are sensitive to abrasion, whereas in case of Francis turbines a larger number of machine elements are affected.
- Furthermore, the affected parts are easy accessible for replacement and cheaper to repair.
- Spare parts are lower in cost than those for Francis turbines.
- Easier and cheaper operation and maintenance, especially for remote areas where O&M resources are limited.
- No Relief Valve and protection of water levels is needed on tail race side.

This altogether results in lower life time cost. Slightly higher investment cost of the generator is compensated by lower investment cost for turbine and lower cost of O&M.

Cooling water will be collected in 2 tanks, each approximately 5 m^3 in size, placed in a room at the generator floor. The water will be distributed from either chamber by a pipe system to the generator coolers, turbine guide bearings, thrust and guide bearings, shaft seal etc. and block transformers.

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The maximum inlet temperature should not be higher than 30°C.

The heated water will be collected by a main pipe leading into the tailrace tunnel.

Heat back-cooling will be realized over a ring-pipe system, dimensioned for a minimal back-cooling temperature of 30°C at 20°C tailrace water temperature The pipe system includes manual and automatic shut-off valves, thermometers, flow meters and flow relays.

Detailed comparisons supporting this decisions are carried out in the document Appendix 9.2 "Comparative Analysis For Seletion of Turbine".

9.2.2. Ventilation

The power station is located above the ground level. To avoid entrance of dust, no openings should be allowed in exterior walls, for the purpose of natural ventilation for instance.

The power station building will have a forced ventilation system, circulating air through a filter to an air inlet shaft down to the turbine floor and further on up through the assembly shaft. Temperature control will be effected by water cooled heat exchangers and electrical heaters placed in the inlet shaft.

A fresh air intake will constantly add about 10% fresh air to the recirculation system.

Battery rooms will have their own exhaust air system.

The Control room will have a separate ventilation system with equipment controlling the air temperature and humidity.

- The powerhouse will be designed by targeting the following objectives:
- To maintain the indoor temperature at a pre-determined level;
- To provide clean air to air-conditioned space by the filtration of re-circulated and outside (fresh) air;
- To pressurize the building so as to prevent the infiltration of uncontrolled outside air;
- To provide general winter heating in some areas such as the control room, administration areas, workshops etc., by adding heat to the indoor environment;

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- To recover heat dissipated by the equipment in winter and to use it for space heating where possible and useful.

9.2.3 Auxiliary Equipment

9.2.3.1 Powerhouse Crane

The powerhouse crane will be a bridge crane with a main hoist which can serve any requirements for lifting and moving of heavy components during installation, maintenance work and operation; the generator rotors being the heaviest components. The lifting height is determined by the generators.

Additionally, the crane shall be provided with an auxiliary hoist travelling under the main crane-girder and away from the entrance gate. This will increase the crane operated area and offer quicker operation for smaller components.

The main crane hook shall be capable of lifting the tallest component off the transport-vehicle and both the main and auxiliary hooks should be capable of reaching as far down as required to serve the turbine floor.

Main Data:

Main hoist capacity (expected)	95 t
Auxiliary hoist capacity	20 t
Bridge span (distance between rails)	15 m
Crane travel	46 m
Hoisting height	18 m

9.2.3.2 Auxiliary Cranes

Additional auxiliary cranes are necessary at the turbine floor, in workshops, etc.

The following table presents information on broad crane parameters

CRANE	
Number of Crane(s)	1
Number of Beam(s)	2
Capacity (Main Hook)	87.99 t
Capacity (Aux. Hook)	16.37 t
Allowable Steel Stress	1600.00 kg/cm^2
Height of Beam(s)	910 mm
Weight of Crane(s)	10.45 t
Weight of Rails	4.10 t

9.2.3.3 Workshop Equipment

The workshop equipment should be sufficient to perform the following functions:

Dismantling and erection of all turbine parts, as well as most other components related to the power plant.

Allow the repair or renewal of components which do not need specialized skill or experience. This includes welding, drilling, turning, grinding etc. and the repair of the power plant's trucks and cars.

9.2.3.4 Oil Handling Equipment

A centralized oil handling system is not foreseen. Spare oil, as well-as used oil, will be stored in ordinary oil drums. The scope of supply should include equipment for taking oil samples, manual and electrical transfer pumps with pipes/hoses and filters, as well as a mobile, high grade filtering unit with oil separator. The latter can be coupled in parallel into all oil systems, including transformers, during ordinary operation.

9.2.3.5 Fire Fighting Equipment

In general, 6 kg hand held and 25 kg mobile fire extinguishers shall be placed at central locations in both the power station and at the intake. In addition, the power station will be provided with several taps for fire hoses on each floor. The water for the firefighting system shall be taken directly from the bifurcation pipe. With special fog-spray nozzles, the equipment can even be used for putting out oil fires as well as being operated close to the electrical equipment

9.2.4 Speed Governor

The turbine shall have an automatic control with speed governor, of adequate capacity to operate the turbine inlet valve under all conditions including emergency stops. The governor should be connected to the control system of the plant and the monitoring equipment and will be fully compatible with it. It shall be possible to control and drive the turbine both from the control room or where the system control center is located, and from a local control panel, required for commissioning and testing operation. The governor will allow the proper operation of the unit under all conditions of load and speed, steadily.

During the interconnection to the grid, the speed governor should be able to operate within the operating conditions being imposed.

9.2.4.1 Functions of Governor

a. Facilitate manual start of units through actions of individual control.

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b. Enabling automatic start and stop units for actions related sequences control.
c. Operation with automatic power limitation, with feedback power.
d. Maintenance of a pre-set reservoir level.
e. Regulate idle running.
f. Regulate normal stopping.
g. Regulate emergency stopping.
h. Maintenance of oil pressure to control injectors and protection valve of turbine.

9.2.4.2 Control Types

The following control types will be necessary:

A. Speed Control for synchronizing and unexpected isolated operation,
B. Power Output Control for normal operation and peaking,
C. Water Level Control

9.2.4.3 Elements of Control System

The control system shall include the following elements as a minimum:

a. Electronic Cabinet with electronic governor PID type.
b. The speed sensor equipment.
c. The electrical feedback system.
d. The equipment supply oil pressure.
e. Accumulator pressure oil system (piston accumulators) connected to gas cylinders filled with nitrogen gas. Includes charger game nitrogen bottles.
f. The equipment of electro-hydraulic control to transform electrical signals into hydraulic signals.
g. Instrumentation, alarm and security devices.
h. Speed Switches for starting speed signals for controlling the generator brake, the generator excitation system, etc.
i. A system mounted on the shaft of the turbine or generator to provide speed signals speed breakers.

Regulating Parameters

Flywheel Effect (req.)	219.63 tm^2
Acceleration Time	1.59 s
Opening Time	10.62 s

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Closing Time	10.62 s
Reflection Time	1.51 s
Velocity of Pressure Wave	1289.65 m/s
Pressure Rise	15.00 %
Pressure Drop	15.00 %
Speed Rise	23.88 %

9.2.5 Spherical Valve (Inlet Valves)

The turbine will be equipped with a protective spherical valve located immediately upstream of the turbine inlet. The valve is used to cut the flow of water in case of failure of the turbine, relieving pressure in the distributor during stop and allowing draining of the turbine. The valve should be able to affect a safe emergency closure under full flow conditions.

Scope of Supply

The inlet valve shall be spherical type with horizontal axis, double rubber seal and expansion joint. The valve will be connected at the upstream side to the pressure tunnel by a flange and at the downstream side to the turbine distributor through an expansion joint. The valve body will be provided and sized such that there is no obstruction to the flow of water, and that the free area of flow through the valve is equal to the sectional area of the pressure penstock.

The valve will be controlled by hydraulic cylinders, which will also be used for opening and closing of the valve. The valve opens by pumping hydraulic fluid (high pressure oil from the control system) to the valve operation cylinder (s) and can be maintained in open position through automatic locking.

Closure of the valve is also through pressurized oil and energy of accumulator must be sufficient to ensure the closure of the injectors and spherical valve.

Broad parameters of the inlet valve are presented in the following table.

INLET VALVE	
Type	Spherical
Number of Valves	3
Diameter	1.24 m
Pressure Head	377.07 m
Weight per Valve	18.98 t

4.8 Prospectus

Please see attached the Project Prospectus as required pursuant to Regulation 3(5)(i) of the Licensing Regulations.

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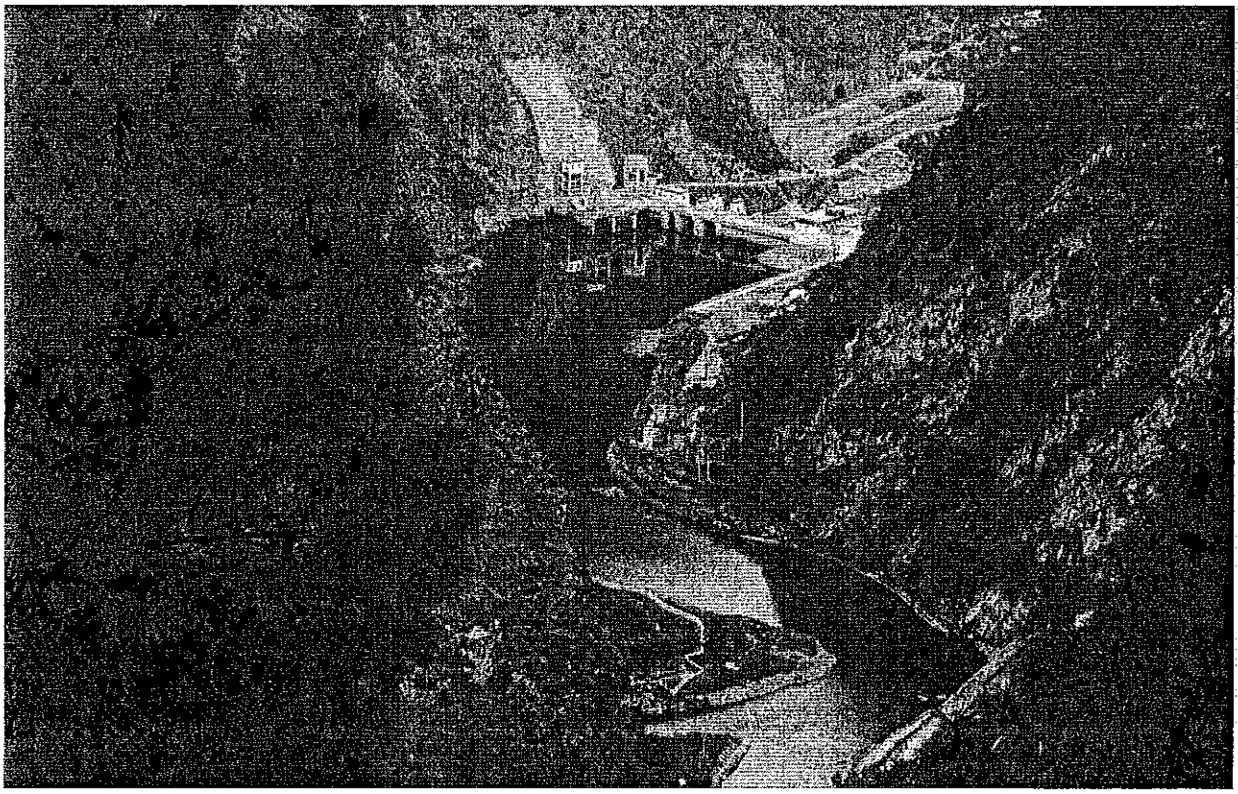

ARKARI GOL HYDROPOWER PROJECT

99 MW (102 MW Gross)

In District Chitral, KPK, Pakistan

PROSPECTUS

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Executive Summary

Project Name	Arkari Gol Hydropower Project
Main Sponsors	Master Group of Industries
Location	Chitral District, KPK, Pakistan
Installed Capacity	102MW (Net capacity: 99MW)
Annual Energy	372GWh (Plant Factor: 43.60%)
Hydrological Risk	Borne by Power Purchaser
Generating Type	Run-of-the-River
Project Type	Build Own Operate Transfer (BOOT)
Construction Period	3 Years
Concession Period	30 Years
Total Project Cost	US$ 214.55 million
Levelized Tariff	7.917 US c / kWh
Equity IRR	14.25%
Debt : Equity	75:25
Expected FC	April, 2019
Expected COD	Mid 2023
Debt Amount	US$ 160.91 million
Tenor	17 Years
Grace Period	4 Years
Repayment Period	13 Years

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Pakistan Energy Sector

Pakistan currently has 28.089 GW of installed capacity for electricity generation. Conventional thermal plants (oil, natural gas, coal) account for 65.50% of Pakistan's capacity, with hydroelectricity making up 28.04%, nuclear 3.10% and renewables contributing 3.26%. The generation mix in Pakistan is currently heavily dominated by expensive and inefficient thermal power projects whichprojects, which rely on imported fuels for power production.

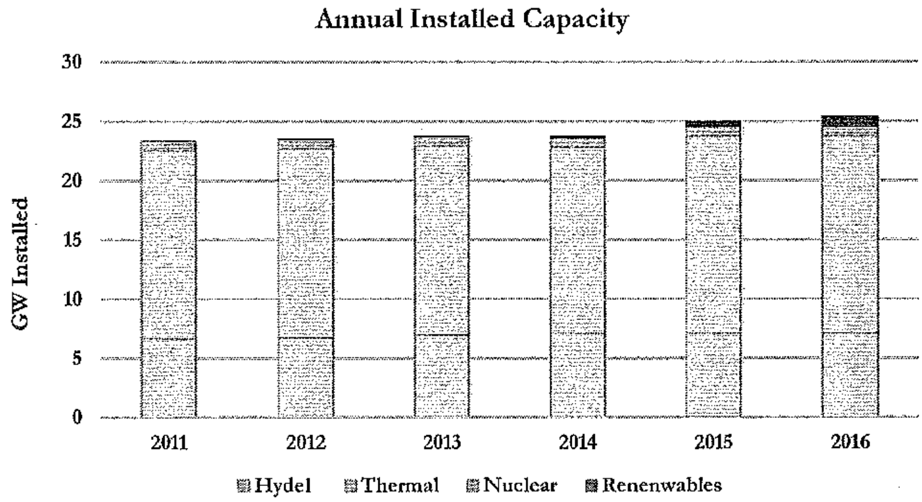

Fig-1: Annual installed generation capacity in Pakistan (*State of Industry Report, 2016*)

In the last decade, Pakistan has faced a chronic power shortage, which has hampered the growth and economic development of the country. The major reasons for the energy crises are the lack of timely investment in power sector, non-development of renewable energy sector i.e. hydel, wind & solar etc. and the depleting oil & gas reserves. It is imperative for Pakistan to look for indigenous/cheap energy resources for sustainable growth through self-reliance.

Over the last two years, significant generation capacity has been approved by the authority and project development and construction is duly underway, however it It is pertinent to note, however, that a majority of the approved projects under development are thermal power projects, this will inadvertently lead to further skewing of the energy mix towards non-renewables and create even greater dependency on imported fuel sources.

Due to the mega projects that have been initiated over the last few years, the supply of electricity is expected to exceed demand for the first time in recent history by the year 2018. However, it is pertinent to highlight that demand projections are based on an almost linear growth rate, and do not appear to account for the exponential growth in demand that is expected due to population growth, industry growth and rural electrification as well as the higher per capita power usage that is usual in a growing and stable economy.

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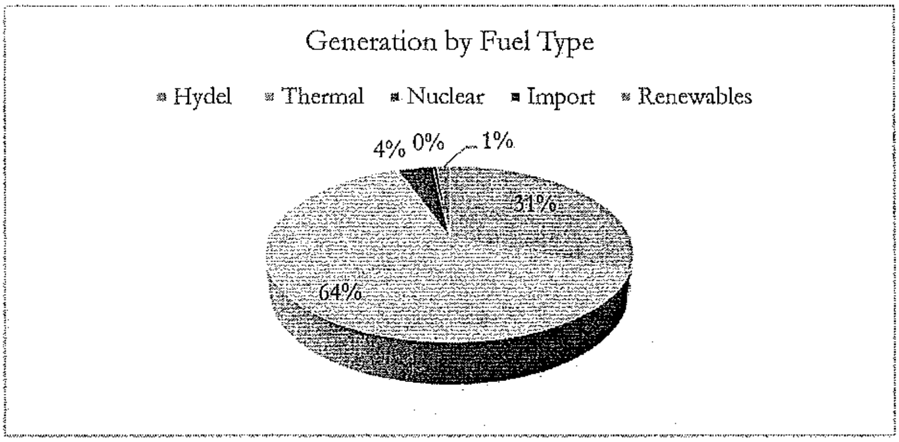

Fig-2: Generation breakdown 2016 (*State of Industry Report, 2016*)

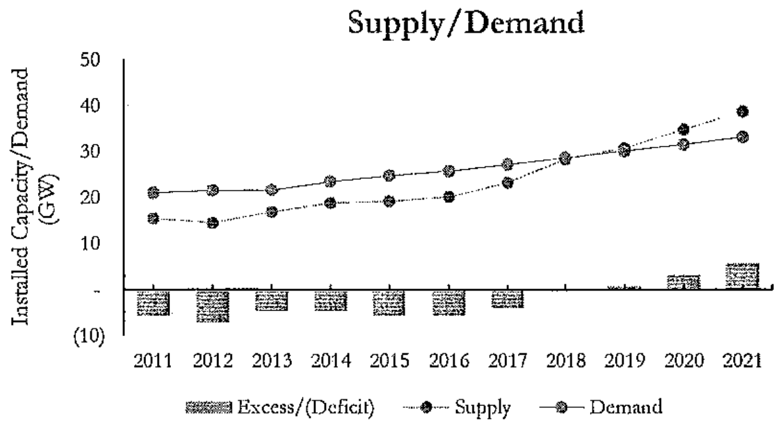

Figure: 3 Electricity Demand and Supply in Pakistan (State of Industry Report, 2016)

Pakistan Hydro Generation Potential

Pakistan is blessed with an estimated hydro power potential of over 41,000 MW, most of which lies in Khyber Pakhtunkhwa province, Northern Areas, Azad Jammu and Kashmir and Punjab.

To date, only around 7,000 MW of hydropower projects are operational in Pakistan, most of which have been developed by the Water and Power Development Authority. In order to efficiently harness the immense hydel potential, significant investment is required by private investors. Since the development of the first hydropower IPP, the 84 MW New Bong Escape hydropower project, numerous other developers have taken up the cause and four major projects are currently under construction by private parties, totaling around 1800 MW, as detailed in the table below:

Project Name	Capacity (MW)	Expected COD
Gulpur Hydropower Project	102	2019
Karot Hydropower Project	720	2021
Suki Kinari Hydropower Project	870	2022
Total	**1839**	

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Advantages of Hydropower

- Hydroelectric plants tend to have longer lives as compared to their fuel-fired counterparts, with some plants now in service having been built 50 to 100 years ago;
- Hydroelectric projects do not result in emissions of harmful greenhouse gases which are understood to cause global warming and climate change;
- Due to the long plant life, hydropower plants are the most economical renewable energy source available;
- Hydropower generating units can start and stop quickly; this allows them to follow system loads efficiently. They can reshape water flows (through storage systems) to more closely match daily and seasonal system energy demands;
- Hydroelectric plants with reliable hydrological histories are despatchable and can be considered firm capacity. Consequently, in normal water years hydroelectric plants designed for a firm load will have a useful amount of surplus energy that may be exportable if transmission is available;
- Hydro power plants convert about 90 percent of the energy in falling water into electrical energy. This is much more efficient than fossil-fueled power plants, which lose more than half of the energy content of their fuel as waste heat and gases;
- Labour cost tends to be low since plants are generally heavily automated and have few personnel on site during normal operation;
- Hydropower plants provide a means for flood prevention and can act as a means of storage during drought.

Arkari Gol Hydropower Plant

Project Profile

With fluctuating prices and supply of oil and gas across the globe, relying only on conventional thermal sources for generating electricity is becoming very expensive and almost beyond the reach of developing nations like Pakistan.

Master Group (the **Sponsor** or the **Group**) is committed to helping Pakistan overcome the current energy shortage affecting the country. The Group entered the energy sector with its first 52.8 MW wind power project, Master Wind Energy Limited located in Jhimpir, Sindh. MWEL successfully achieved financial close in March 2015, and commenced commercial operations in October 2016.In line with its commitment, the Group is currently pursuing development of a second 50 MW wind in Jhimpir, Sindh

The 99 MW (102 MW gross) Arkari Gol hydropower project was identified as part of a comprehensive study conducted by GoKP in collaboration with the German Agency for Technical Cooperation. The Project is proposed on the Arkari River, a left tributary of the Luthko River in District Chitral. The Project Feasibility Study was conducted by PEDO in 2013-14; subsequently the Project was advertised for bidding under the Policy and the NEPRA Regulations. PEDO has recently notified MTML as the first ranked bidder for the Project.

The Project will sell power to the Central Power Purchasing Agency Guarantee Limited (CPPA) within the framework of the project documents specified under the Policy for Development of Renewable Energy for Power Generation, 2006 (the RE Policy). The term of the off-take agreement, to be executed between MHPL and CPPA, is 30 years (as per prevailing policy and tariff regime).

In May, 2017, NEPRA notified its Competitive Bidding Tariff (Approval Procedures) Regulations, 2017 (NEPRA Regulations), which lay out the procedure to be adopted for conducting a competitive bidding process for award of projects, including the pre-qualification process, the request and evaluation for bids and the process of submission of a tariff petition to NEPRA for approval. This tariff petition is submitted in accordance with the requirements of the NEPRA Regulations.

The Project will be developed under a standard, lump-sum, fixed schedule, turn-key EPC contract, in line with market norms and standards for such projects. Potential EPC contractors were contacted regarding the Project and invited to submit bids for development for the Project. Bids were received from interested parties, and after a comprehensive evaluation of technical, financial and commercial terms, Sinohydro was selected as the preferred EPC contractor.

Competitive Bidding and Low Cost of Generation

The Project is one of the first projects in Pakistan to be developed under the competitive bidding regime envisaged by the NEPRA Regulations. The tariff proposed in the Bid and subsequently discounted through the MLR and proposed in this Tariff Application is extremely competitive, thereby fulfilling one of NEPRA's key objective of development of Pakistan's hydropower reserves in a cost-efficient manner. Successful development of the Project will lay the ground work for the holistic move towards competitive bidding for determining tariffs of future power projects across different technologies.

Project Status

MHPL's current progress and development milestones are summarized below:

April 2016	Project advertised by PEDO as solicited site and interested parties invited to submit pre-qualification documents
14 Jun 2016	Pre-qualification documents submitted by interested parties
10 Oct 2016	Notification of pre-qualification issued to applicants, and pre-qualified applicants invited to purchase the request for proposal document (**RFP**)
07 Nov 2016	A comprehensive RFP package issued by PEDO, outlining the mechanism to be adopted for award of the Project through competitive bidding
01 Jan 2017	Pre-bid meeting held in Islamabad to clarify queries of pre-qualified applicants
25 Apr 2017	Submission of technical and commercial bids by pre-qualified bidders and bid opening of technical proposals (Envelope I)
19 Jul 2017	Technically responsive bidders notified by PEDO
24 Jul 2017	Bid opening of commercial proposals (Envelope II) of technically responsive bidders
23 Oct 2017	First Ranked Bidders notified by PEDO
19th March, 2017	Motion for Leave for Review (**MLR**) filed by PEDO
27th June, 2017	Successful bidder notified by PEDO

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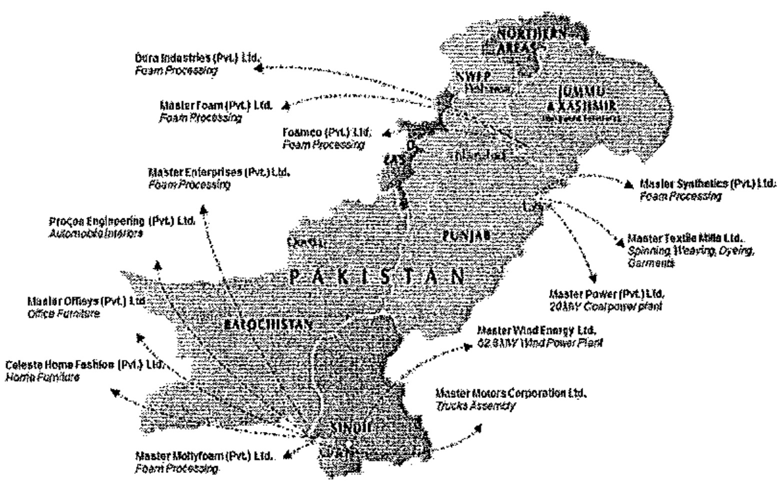
The Sponsors

Master Textile Mills Limited was incorporated on February 13, 1992 as a private limited company under the Companies Ordinance, 1984 and was subsequently converted into a public limited company in 1992. MTML is principally engaged in the manufacturing and trade of yarn, grey cloth, dyed fabric and stitched garments.

Master Group

The Main Sponsor is part of Master Group of Companies (the Group), one of the most dynamic business groups of Pakistan. The Group started its core business in the bedding industry followed by diversification into textile, automobile, engineering, retail and power sectors. The Group comprises the following key companies:

- Master Textile Mills Limited
- Master Enterprises (Private) Limited
- Dura Industries (Private) Limited
- Procon Engineering (Private) Limited
- Master Motor Corporation (Private) Limited
- Master Wind Energy Limited
- Master Green Energy Limited
- Master Offisys (Private) Limited
- Celeste Home Fashion (Private) Limited



The Group is committed to play its part in the development of Pakistan's various sectors. Realising the role of clean energy in development of the nation, Master Group ventured into the power generation sector by developing a 52.8 MW wind power project in Jhimpir, Sindh. Master Wind Energy Limited successfully commenced commercial operation in October 2016. Master Green Energy Limited is the Sponsor's second project in the wind power sector, which is expected to achieve Financial close by end 2018.

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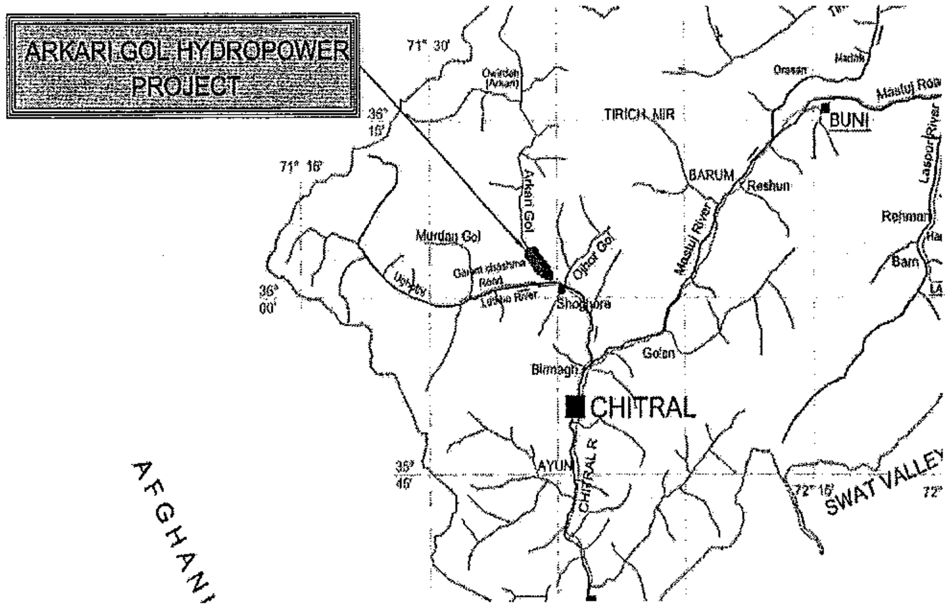
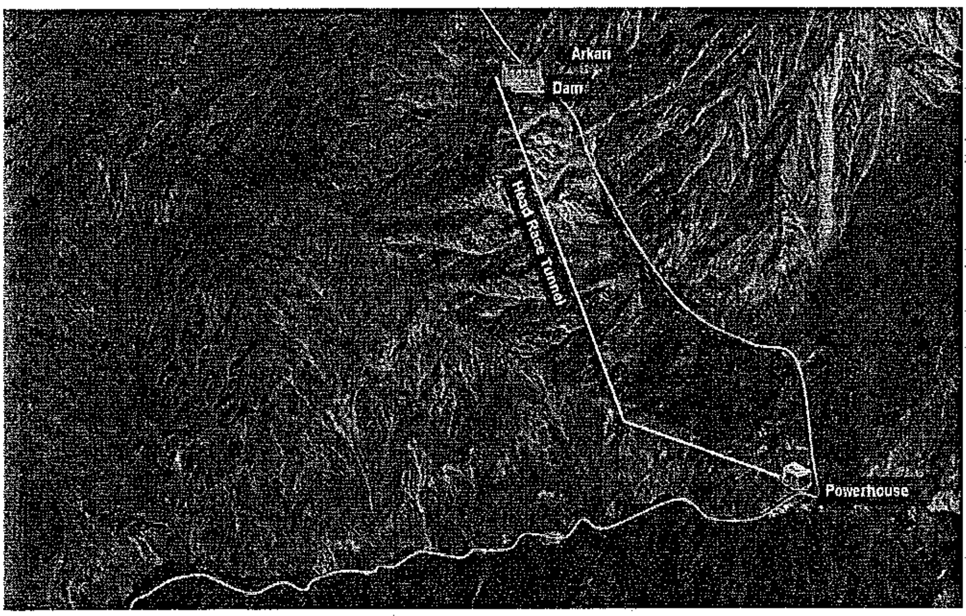
Project Location



Site Layout



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Project Cost & Funding Plan

Uses of Funds	Millions US$		Millions US$
EPC Cost	150.00	Long Term Debt – 75%	
Non-EPC Cost	33.79	Foreign	95.89
Interest During Construction	21.06	Local	65.03
Insurance	1.50		
Financial Charges	6.18	Equity – 25%	53.64
Feasibility Study	2.04		
Total	214.55	**Total**	214.55

25% of the project costs will be injected by the sponsors as equity, while the remaining 75% will be financed through debt. The sponsors have adequate resources and financial strength to take on development of the Project, as evidenced in section of this document. On the debt financing front, Overseas Private Investment Corporation (OPIC) and National Bank of Pakistan (NBP) have committed to arrangement of the required local and foreign financing.The Project will receive foreign financing of USD $95.89 Million from Overseas Private Investment Corporation and USD $65.03 Million from NBP.

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Project Implementation

EPC Contractor- Hydrochina International Corporation

Hydrochina Corporation is an affiliate of the Powerchina Group, one of the world's top 500 enterprises and a comprehensive construction group. Hydrochina Corporation serves as an important institution for undertaking and implementation of oversea business in the Powerchina Group. The company provides the following services: surveys, planning, design, construction, EPC contracts, operations and maintenance, and investments in renewable energy projects, hydropower projects, and water conservancy projects.

Over the years, HDC has developed three core business sectors, design and consultation, EPC contract and investments, and setting up of overseas representative offices or branches for providing high quality services abroad. Hydrochina has been actively engaged in development of hydropower projects both in China and globally and has completed over 2,000 MW of hydropower projects on an EPC model (13 projects across 6 countries). Hydrochina has also been incloved in resource planning of 278,000 MW within China and design works for around 30,000 MW.

Hydrochina has expanded its business scope to the sectors of transmission, thermal power, power grid construction, environment protection, municipal construction, port and navigation and oil underground structure as well.

EPC Contractor- Sinhydro Corporation Limited

Sinohydro Corporation Limited is well known as China's leading contractors in hydropower construction, responsible for 65% of large and medium scale hydropower stations in China. With over 60 years of development and expertise, SHCL is the key international brand of Powerchina, a Fortune Global 500 company. In 2016, Powerchina was ranked no. 5 on the ENR lists of Top 250 Global Contractors and no. 11 in Top 250 International Contractors. With diversified operations in over 100 countries, SHCL's businesses cover almost all areas of the construction sector, including energy, transport, water works, civil engineering and building.

Over the past decade, SHCL has constructed more than 78 hydropower plants globally with a total capacity of 27,780 MW. In addition, it has built 16 thermal and renewable power plants overseas, with a total capacity of approximately 2,776 MW. SHCL has been awarded ISO 9001, ISO 14001 and OHSAS 18001 for their high performance standards. Currently, SHCL has 65 water projects under construction in more than 24 countries, with a total contract value of nearly US dollar 3.45 billion. As of 2017, SHCL has over 500 international construction projects under construction in more than 70 countries with a cumulative contract value of $50 Billion.

SHCL's operating revenue for 2016 was $4.9 Billion. The company's outstanding liabilities also declined by 2.5%, the asset base amounted to $ 4.79 Billion and the registered capital of the company has increased to $ 967 Million. Sinohydro Corporation Limited, the international subsidiairy of Powerchina Corporation, is known as China's first brand in hydropower construction. The company has been responsible for 65 percent of large and medium-scale hydropower stations in China. Sinohydro has over 60 years of development expertise in renewable energy construction projects. As the international business flagship and a subsidiary of Powerchina Corporation, Sinohydro Corporation Limited has diversified operations in over 80 countries. Its busineses cover almost all areas of the construction sector, including energy, transport, water works, civil engineering and building.

Project Consultants

Technical	Fichtner Gmbh
Legal	Vellani & Vellani
Financial	Specialised In-house team

O&M Contractor- General Electric Limited

General Electric International (GE) is a publicly held New York corporation that is one of the largest and most diversified technology and financial services corporations in the world. Its products and services range from aircraft engines, power generation, water processing, and household appliances to medical imaging, business and consumer financing and industrial products. GE common stock is widely held and listed primarily on the New York Stock Exchange but is also listed on the London Stock Exchange and on Euronext Paris.

The company's power segment offers technologies, solutions, and services related to energy production, including gas and steam turbines, engines, generators, and high voltage equipment; and power generation services and digital solutions. GE's renewable energy segment provides wind turbine platforms, and hardware and software; offshore wind turbines; solutions, products, and services to hydropower industry; and blades for onshore and offshore wind turbines.

In 2017, GE ranked among the Fortune 500 as the 13th-largest firm in the U.S. by gross revenue. The company's profit margin rose by 7.1% in their last fiscal year, with a revenue increase from $ 9.0 Billion to $10.3 Billion, and annual profit increase of $0.1 Billion in 2017. GE is actively expanding its operational base, by early 2018 the company has entered into 18 full O&M contracts plus an additional 20 custom assistance agreements for hydropower projects globally.

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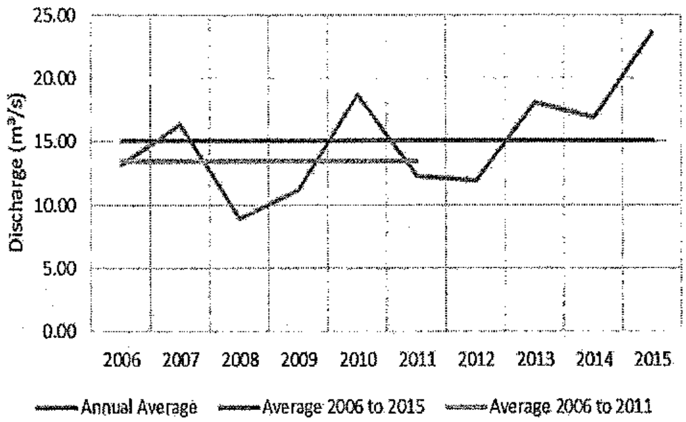
Technical Summary

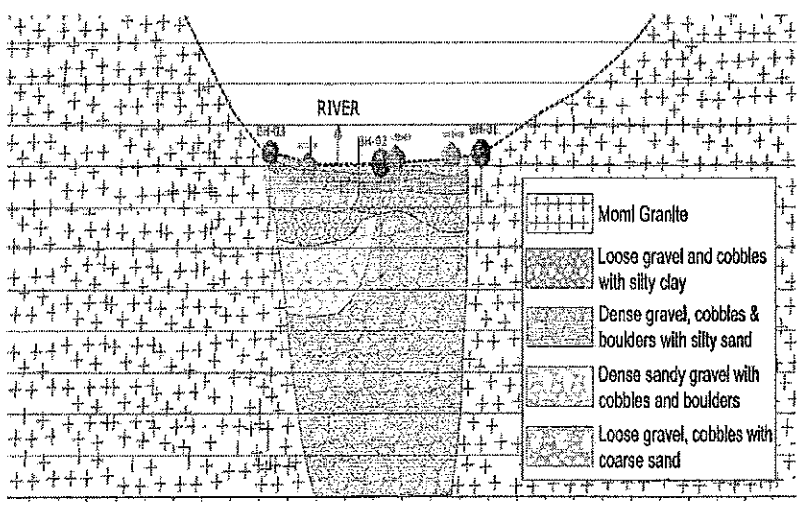
Hydrology



The hydrological study for the project was carried out in two phases, initially a regional analysis approach was adopted to establish the mean annual flow at the site, followed by utilisation of the Arkari gauge data to form its temporal distribution. To carry out the flow study using the regional analysis approach, flow data of 8 stream gauging stations were collected and used.

Mean annual flows estimated for the Arkari stream gauging station, Arkari weir site and Arkari powerhouse site are 16.66, 17.02 and 17.41 m3/s, respectively.

Rock Formation at Weir Site



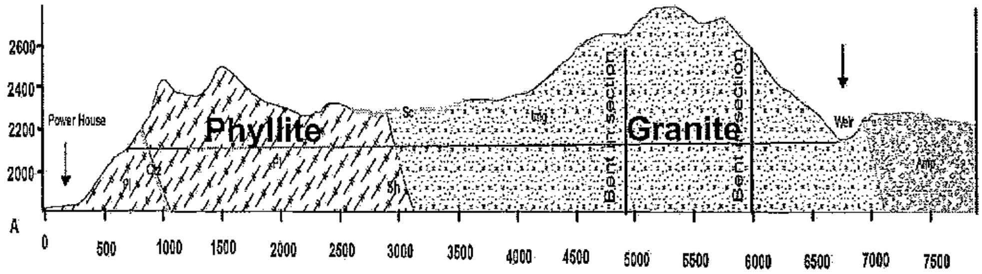
Based on extensive field investigations, the geology of the Project site was determined as follows:

- The powerhouse site is located on metamorphic rocks i.e. Phyllites and Gneiss. The bed rock is covered with quaternary deposits. The general strike of bed rock is in NE-SW direction and dipping is towards NW with 400 to 600 angle of dip.
- From the weir site to the powerhouse, the tunnel passes through various metamorphic and igneous rocks i.e. phyllites, schist, quartzite, gneiss and granite.
- The weir site is located in a granitic outcrop which is part of the Tirichmir Boundary Zone (TBZ) in Chitral region. The TBZ separates the Hindu Kush and Karakorum ranges in the project area.

Strictly Confidential

The granitic outcrop has an inclusion along the strike of the Wakhan Formation which consists of slate, gneiss and quartzite.

Rock Formation at Head Tunnel



Salient Features of the Project

Hydrology (Design Flows)	
Design Discharge	36 m^3/s
Design Flood at dam site	562 m^3/s (1000-year flood)
Design Flood at powerhouse site	571 m^3/s (1000-year flood)
Head	
Minimum Head (gross)	331.3 m
Maximum Head (gross)	335.3 m
Rated Net Head	318 m
Power Generation	
Installed capacity (turbine exit)	102 MW
Plant Efficiency	88.38%
Capacity (excluding auxiliary losses)	99 MW
Auxiliary consumption	1.5 MW
Net Capacity	97.5 MW
Annual Energy	372 GWh per annum
Plant Factor	43.6%
Turbine Technology	3 × Vertical axis Pelton Turbines
Reservoir	
Reservoir Length	1.30 km
Reservoir Area	0.121 km^2
Max. Reservoir Operating Level	2190 m.a.s.l.
Min. Reservoir Operating Level	2186 m.a.s.l.
Reservoir Capacity (Live Storage)	0.489 m.c.m.
Dam Structure	
Max Dam Height	26 m
Dam Crest Level	2192 m.a .s .l .
Discharging and flushing sluice	
No. of Gates	2

RAD

Gate Type	Radial Gates
Gate Size (W×H)	8m × 12m
Discharge Capacity	1294 m^3/s

Turbine Type

No. of Units	3
Installed capacity (turbine exit)	3 × 34.1 MW
Powerhouse Type	Surface External
Size of Powerhouse (L×W×H)	46.71m × 19.40m × 29.5 m

Tailrace Channel

Length of Tailrace Channel	100m

Intake

Type	Lateral Intake
No. of Gates	2
Gate Size (W×H)	3.8m × 4.0m
Deck Elevation	2184 m.a.s.l.
Intake Sill Level	2180 m.a.s.l.

Desander (Underground Periodic Flushing Desander)

No. of Chambers	3
Size of Chamber	100m×15m×21m (L×W×H)

Low Pressure Headrace Tunnel

Inside shape and dimension	Door Shape
Dimensions	5.6m×5.8m (without lining) / 3.8m×4.0m (with lining)
Length	6265 m

Surge Tank

Surge Shaft Diameter (inner)	4.50 m
Height	75 m
No. of Surge Chambers	2
Lengths	96m, 74.5m

Pressure Shaft

Diameter	3.10 m
Length	296 m

Pressure Tunnel

Diameter	3m
Length	379 m

Environmental & Social Impact

A preliminary Environmental and Social Impact Assessment was carried out by PEDO as part of the Project Feasibility Study. Master Hydro conducted a more detailed environmental and social impact assessment after being notified by PEDO as being chosen as the first ranked bidder. Hagler Bailly Pakistan was engaged for the assessment of the project site and for drafting of a Resettlement Action Plan (**RAP**) for the 48 households that have been identified in the site layout.

Please refer to section 4.10 of the Generation License for further details.

Resettlement Concerns

A comprehensive resettlement action plan for the project has been developed based on a detailed survey of the project area. According to our survey, the area is sparsely populated and a total of 48 households will require resettlement due to the project.

Land acquisition will be conducted in accordance with the frameworks specified in the Land Acquistion Act 1894, and affected persons will be adequately compensated.

4.9 Grid Interconnection Study

Pursuant to Schedule III, Section A(c) of the Licensing Regulations, we understand that the Grid Interconnection Study (**GIS**) for the Project is required for this Application. However, as this requirement was added vide the amendment to the Licensing Rules dated May 2, 2017, post initiation of the bidding process, such requirement cannot be applicable to the Project at this stage.

Based on information provided by PEDO as part of the RFP, the Project is proposed to be connected to the national grid at 132 kV through the grid station of the nearby Golen Gol hydropower project.

Please find attached herewith, the preliminary GIS conducted by PEDO as included in the Project Feasibility Study. A more detailed interconnection study will be carried out by the Applicant post issuance of Letter of Award.

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10.2 Grid Interconnection Chitral District

10.2.1 Introduction

Government of Khyber Pakthunkhwa (KPK) has embarked upon the development of the significant hydroelectric potential in the Province. PHYDO (Khyber Pakthunkhawa Hydel Development Organization) has been entrusted with the responsibility of managing this development. A number of feasibility studies have been out sourced to consulting firms.

A number of feasibility studies in Chitral District aim to develop the power potential. These potential sites will feed the national grid. There is need to evolve a common strategy for interconnection of these sires to the national grid. A summary if the scope of development is presented as follows:

PHYDO Hydropower Projects under Development					
Sr. No.	Name	Installed Capacity MW	Completion Target	Status	Area
1	SHORT TERM				
1.1	Daral Khwar	36	2015	Under Construction	Swat
1.2	Ranolia	17	2015	Under Construction	Kohistan
1.3	Machai	2.6	2015	Under Construction	Mardan
	Sub Total	55.6			
2	MEDIUM TERM		TENDERING STAGE		
2.1	Matiltan	84	2016	Tendering stage	Swat
2.1	Lawi	69	2017	Tendering stage	Chitral
2.2	Sushgai-Zindhali	144	2018	PC-1 under approval	Chitral
2.3	Shogo-Sin	132	2018	PC-1 under approval	Chitral
2.4	Sharmai	150	2018	PC-1 under approval	Upper Dir
2.5	Kato	31	31	MC Consultant selection	Lower Dir
2.6	Karora	9.3	2014	MC Consultant selection	Shangla
2.7	Jabori	7	2016	MC Consultant selection	Mansherea
	Sub Total	626.3			
3	LONG TERM		FEASIBILITY STAGE		
3.1	Balakot	190	2014(2019)	Feasibility Study	Kaghan
3.2	Naran	210	2014(2019)	Feasibility Study	Kaghan
3.3	Barikot-Patrak	34	2014(2018)	Feasibility Study	Dir
3.4	Patrak-Shingal	21	2014(2018)	Feasibility Study	Dir
3.5	Shigo-Kach	26	2014(2018)	Feasibility Study	Dir
3.6	Ghorband	14	2013(2016)	Feasibility Study	Sangla
3.7	Nandihar	10	2013(2016)	Feasibility Study	Batagram
3.8	Arkari Gol	110	2013(2017)	Feasibility Study	Chitral
3.9	Mugigaram-Shogore	51	2014(2018)	Feasibility Study	Chitral
3.1	Istaru-Bunni	52	2014(2018)	Feasibility Study	Chitral
3.11	Gahrit Swir Lasht	334	2014(2019)	Feasibility Study	Chitral
3.12	Korgrah Parit	223	2014(2019)	Feasibility Study	Chitral
3.13	Laspur Miragram	133	2014(2018)	Feasibility Study	Chitral

PHYDO Hydropower Projects under Development					
Sr. No.	Name	Installed Capacity MW	Completion Target	Status	Area
	Sub Total	1328.6			
4	Long Term		Prefeasibility Stage		
4.1	Kari Mushkai	446		Prefeasibility Stage	Chitral
4.2	Torkum Gudubar	409		Prefeasibility Stage	Chitral
4.3	Kalam Gabbral	110		Prefeasibility Stage	Swat
	Sub Total	965			
	Grand Total	2975.5			

10.2.2 Transmission:

10.2.2.1 Existing WAPDA (NTDC) Transmission Lines Arrangement:

Two numbers transmission lines of 132KV and 66KV capacity have been constructed and energized at Timergarah Grid Station duly fed from 132/66 KV Chakdara Grid Station. The 66KV Transmission line is further extended to Dir Grid Station from where 33KV transmission line has been constructed for district Chitral. There are two numbers Grid Station 33/11 KV in Chitral District, provided by WAPDA (NTDC).

The detail of the above mentioned Transmission Lines is given as under:

Name of Grid Station	Capacity of T/L	Total length in KM	Type of Tower	Type of conductor	Loading Capacity	Recorded Load
1.Chakdara	132KV Chakdara Swat	42.00 KM	TBA,TM TYD	LYNX	488/400 A	82%
	66KV Chakdara – Timergara	32.00 KM	GS	Dog	846/260 A	75%
	132KV Chakdara-Timergara	30.00 KM	TBA,TM TYD	LYNX	488/280 A	58%
2. 66 KV Timergarah	66KV Timergara –Wari-Dir	80.00 KM	GS	Dog	346/200 A	71%
3. 66 KV Dir	33KV Dir-Chitral Section	110 KM	STP+ Structure	Dog	345/50 A	16%

10.2.2.2 Existing Power Facilities Provided By PHYDO and NTDC Within Chitral District:

In lower and Upper Chitral electric power generation, transmission and distribution system is being operated by PHYDO. A power house of 1800 KW capacity installed at Shishi Gol which supplies power to Drosh area.

In Central Chitral most of the power generation transmission and distribution is maintained and operated by WAPDA (NTDC). There are two power stations one

Hydel of 1000KW and the other Thermal generation of 960 KW capacity in Chitral city. After the interconnection of Chitral city with the National grid of 33KV Transmission line about 2.1 MW power is being imported from WAPDA (NTDC) source.

Further at Booni and Garam Chasma a diesel power station of 216 KW each are in operation. While hydel power stations of installed capacity 4.2 MW at Reshun Gol and 1000 KW (1MW) capacity at Garam Chashma are being operated by PHYDO

Existing Loading Condition 11 KV Feeder distributed from 66kV Grid station at Dir during the year 2011-2012 Name of Grid Station : 66 KV DIR				
Power transformer code #	Make	Rating [MVA]	Voltage Rating [kV]	Current Rating [A]
T1	Elprom	10/13	66/11	653
T2	Elprom	5/6.3	66/33	121

10.2.2.3 Survey of Transmission Lines

The existing power transmission network in the area consisting of 66 KV Dir and 33 KV across Lowari to Drosh Chitral city Drasan, the details are presented in the table on the following page.

Sr. No.	Name of 11 KV Feeder	C.T Ratio	Cable size	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12	May-12	Jun-12
A	INCOMING-1	800/5	1000MCM	540	440	440	470	565	530	500	460	510	460	480	510
1	Wari	200/5	120MM	190	190	200	200	195	190	180	180	180	170	170	200
2	Dir	200/5	500MCM	180	195	190	170	195	200	180	195	170	-	-	-
3	Barawal	400/5	4/0AWG	90	90	90	80	90	80	80	80	80	80	80	90
4	Sheringal	200/5	500 MCM	80	80	80	240	90	80	70	70	250	220	230	240
–	33KV O/G Chitral(T/I)	150/5	Overhead Bus Bar	30	40	40	40	50	50	40	40	40	50	40	40

Existing Power Transmission Network in the Area

RAD
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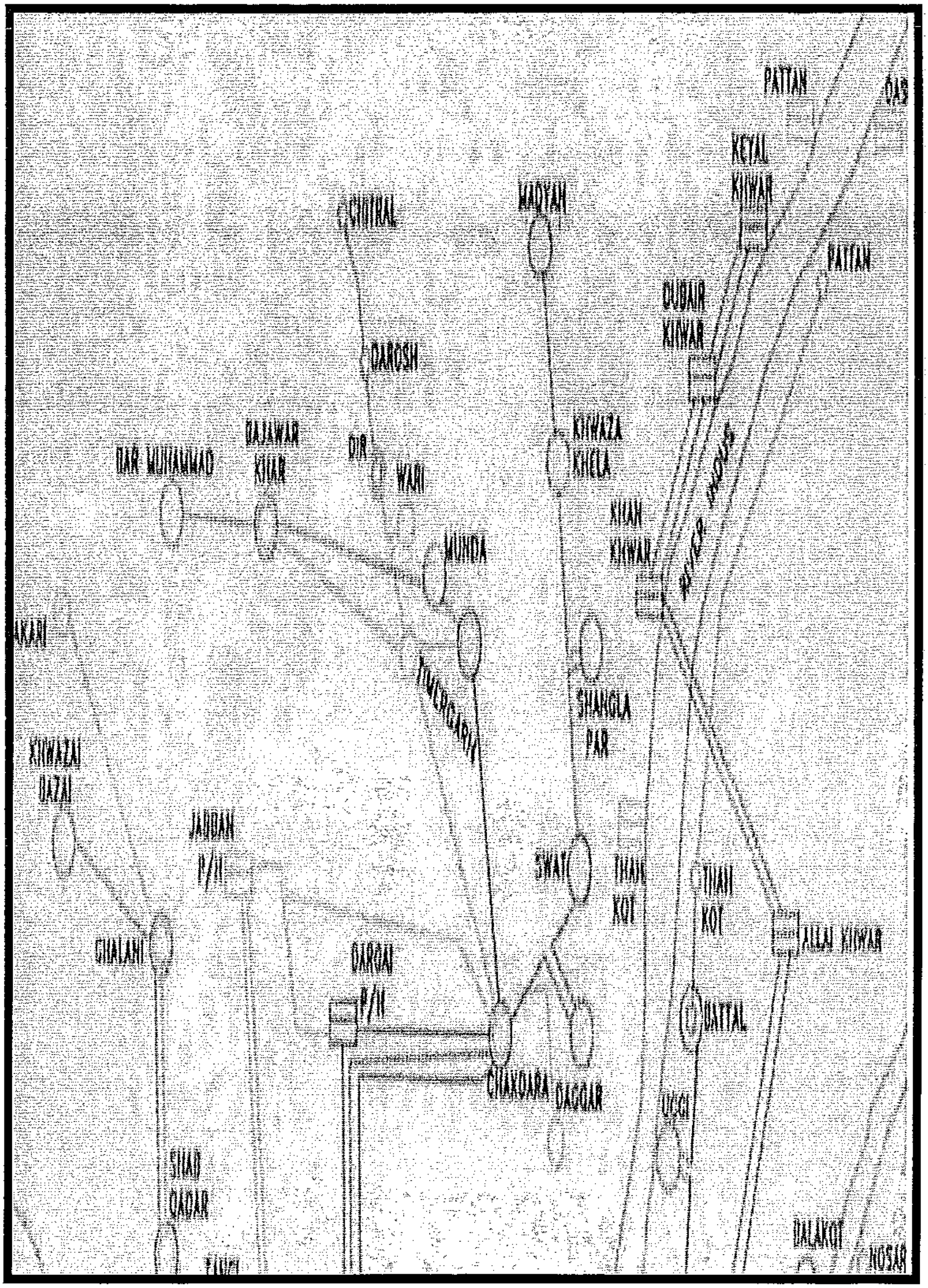
10.2.2.4 Secondary Network Related to Chitral District

PESCO secondary transmission network is presented as follows



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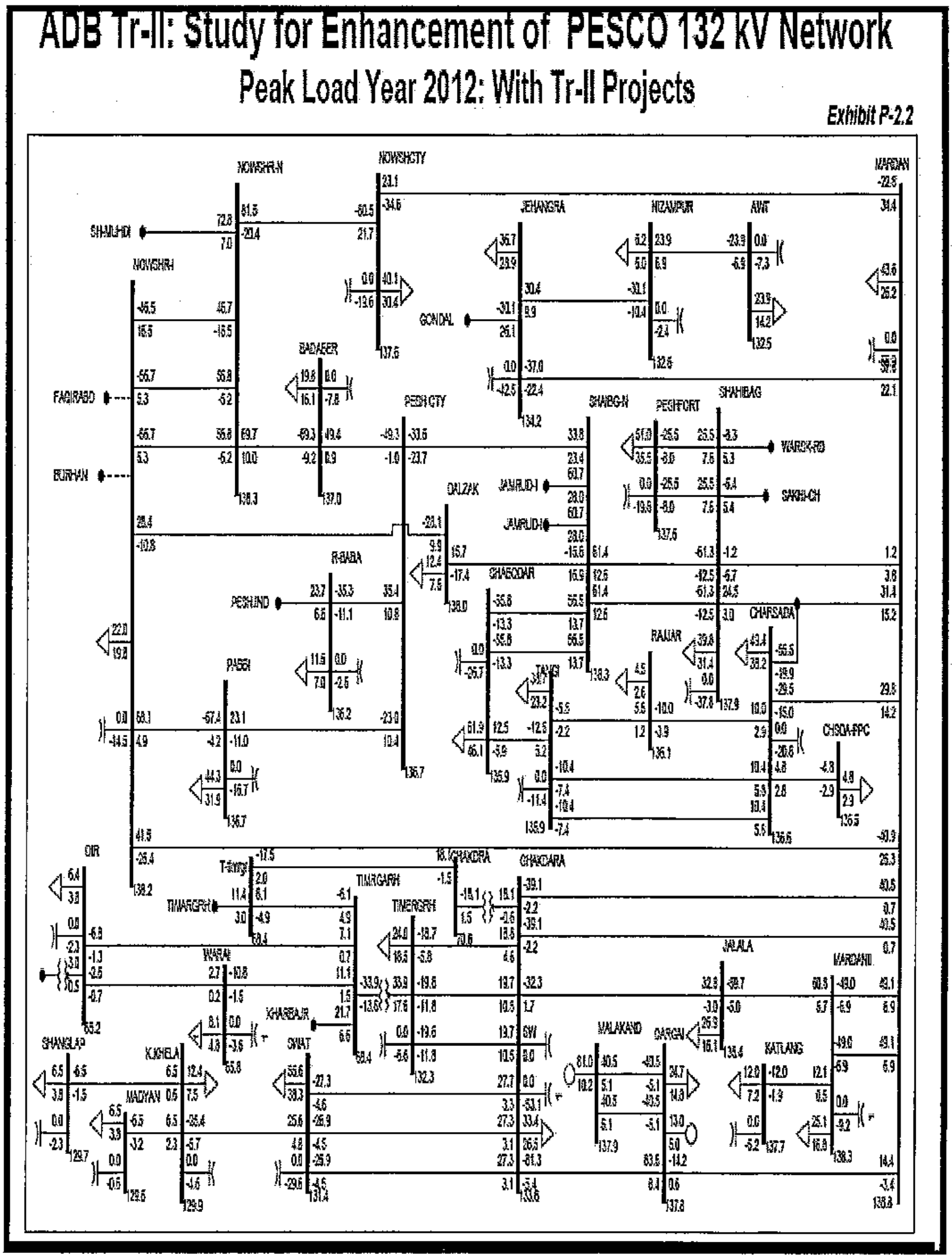
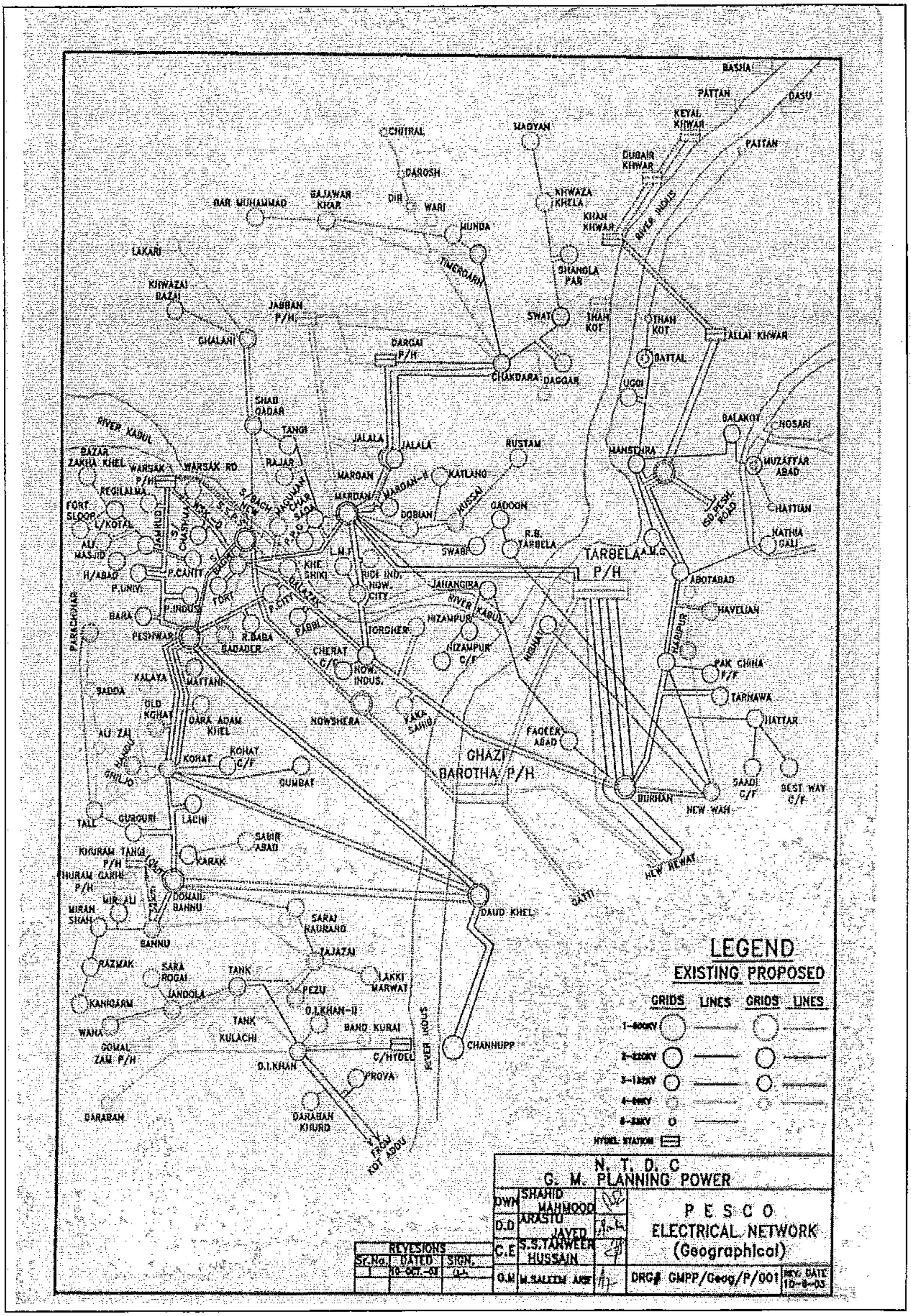
10.2.2.5 Transmission and Distribution Expansion Studies

Asian Development Bank (ADB) has provided with 2 MFF (Multi Financing Facility) to the Government of Pakistan , this has resulted in provision of funds to NTDC (National Transmission and Dispatch Company)and PESCO for expansion of the primary and secondary network , as a part of project preparation load flow studies were carried . These are presented as follows:





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10.2.3 Existing Power Facility provided by WAPDA (NTDC)/PESCO in Chitral District:

Parts of Chitral district is electrified from two (2) numbers 33KV Grid Stations at Drosh and Jutlisht through 33KV transmission line extended from 66 KV of Dir Grid Station. For operation and distribution of power supply a sub-division has been established which controls and maintain whole of the distribution network of Central Chitral District. The detail of customers and energy consumption from June 2007 to June 2012 is given as under:

Number of Customers , Category Wise for PEPCO System							
Customers No	2007	2008	2009	2010	2011	2012	Growth 2007-11
Domestic	9279	9791	9792	10295	10470	10645	2.78
Commercial	1613	1677	1681	1763	1795	1820	2.44
Industrial	50	50	50	50	50	50	0.00
Total	**10942**	**11518**	**11523**	**12108**	**12315**	**12515**	**2.72**

Consumption , Category Wise for PEPCO System kWh/a							
Customers	2007	2008	2009	2010	2011	2012	Growth 2007-11
							Avg. pa.
Domestic	8668804	8553619	8022900	8437247	9510167	10262162	3.43
Commercial	1330797	1355267	1275481	1310353	1371501	1441139	1.61
Industrial	239599	237173	231015	232951	249175	252318	1.04
Total	**10239200**	**10146059**	**9529396**	**9980551**	**11130843**	**11955619**	**3.15**

Per Customer Consumption , Category Wise for PEPCO System kWh/a							
Customers	2007	2008	2009	2010	2011	2012	Growth 2007-11
Domestic	934.24	873.62	819.33	819.55	908.33	964.04	0.63
Commercial	825.04	808.15	758.76	743.25	764.07	791.83	-0.82
Industrial	4791.98	4743.46	4620.30	4659.02	4983.50	5046.36	1.04
Total	**935.77**	**880.89**	**826.99**	**824.29**	**903.84**	**955.30**	**0.41**

There are 4 Nos. 11 kV feeders in Chitral, there are also 4 Nos. Sub Divisions, the WAPDA (NTDC) served area has 2 Nos. 33kV sub stations. Villages/Towns electrified by the WAPDA (NTDC) served area are: Chitral; Drosh; and Garam Chashma .

In central Chitral most of the power generation transmission and distribution is maintained and operated by WAPDA (NTDC). There are two power station one Hydel of 1000 kW and the other Thermal generation of 960 KW capacity in Chitral city. After the interconnection of Chitral city with the National grid of 33KV transmission line about 2.1 MW power is being imported from WAPDA (NTDC) source

10.2.4 Existing Power Facility Provided by Phydo at Chitral District

In lower and upper Chitral electric power generation, transmission and distribution system is being operated by PHYDO. A power house of 1800 kW capacity is installed at Shishi Gol which supplies power to Drosh area. Further at Booni and Garam Chashma diesel power stations of 216 KW each are in operation, whilst hydel power stations of installed capacity 4.2 MW at Reshun Gol and 1 MW capacity at Garam Chashma are being operated by PHYDO.

Reshun hydroelectric power plant feeds a 33kV regional transmission and distribution System consisting of three main feeders.

FEEDER NO. I

- Length of Transmission Line 73 km
- Transmission Voltage 33 kV

This feeder is interconnected with the existing 33 kV WAPDA (NTDC) Grid Station at Jutilasht. Beside this the villages like Reshun, Greenlasht, Parpish,Riri, Shachar, Jugumi, Jumsheli, Barenis, Prait, Moroy,Mori Lasht, Mori Bala, Mori Payeen, Chumuruk, Shaililasht, Istangol,Koghuzi, Barghozi, Kuju and Ragh.

FEEDER NO. II

- Length of Transmission Line 70 km
- Transmission Voltage 33kV

This feeder is electrifying villages of Lot Oweer, Loon, Gohkir, Kosht Bala, Kosht Payen, Morder, Muzhgol, Khotakan Warijun, Drasun, Authol, Nogram, Shono, Gaht, Samagol, Warzodor, Zainee, Saht, Kushum, Madak,Zezdi, Nishko,Sorwakht, Dru, Tarich, Istaru, Rayeen, Shagram, and Wirkup.

FEEDER NO. III

- Length of Transmission Line 68 km
- Transmission Voltage 33 kV

This feeder electrifies Shogram, Zait, Koragh, Gashtlasht, Charoun, Charounower, Bombagh, Junalikoch, Booni, Driyano Booni, Awi, Awilasht, Miragram, Parwak, Sonoghor, Nisorgol, Sarghoz, Mastuj, Mastuj Chinar, Mastuj Tooq, Chapali, Chuinj, Parkusab and Kargin,

Reshun Power Plant statistics are presented as follow:

Reshun HPP Statistics 2010-2011				
Feeder No.	Energy Generated	Energy Sold	Energy Lost	Energy Lost
	kWh	kWh	kWh	%
Feeder 1	1978520	1585142	393378	19.88
Feeder 2	3734544	3277625	456919	12.23
Feeder 3	3732480	2755902	976578	26.16
Total	9445544	7618669	1826875	19.34
	Installed Capacity	4200	kW	
	Plant Factor	25.67	%	

The customers connected are presented as follow;

Reshun : Number of Customers Served June 2012						
Feeder No.	Domestic No.	Mosque No.	Jamat Khana No.	Commercial No.	Industrial No.	Total No.
1	2848	74	5	71	13	3011
2	6525	277	19	97	38	6956
3	12957	387	76	351	103	13874
Booni						850
3	12957	387	76	351	103	14724
Total	**22330**	**738**	**100**	**519**	**154**	**24691**

10.2.5 Micro Hydels

The Aga Khan Rural Support Program (AKRSP) has installed over 180 micro-hydro power units in Chitral District, KPK Province, Pakistan. So far, AKRSP Chitral has assisted the communities in constructing 171 units (ranging from 20 kW to 100 kW of power generation capacity) of Micro hydels in Chitral District.

10.2.6. Identified Power Potential Chitral District

10.2.6.1 Identification Study

The 1997 identification Study, by GTZ Hydropower Development Program, on behalf of the Ministry of Water and Power (HEPO, Hydroelectric Electric Planning Organization, WAPDA were closely associated with the study), Government of Pakistan, identified 10 sites. The sites were ranked in order of economic merit as well as technical feasibility

The summary of this identification is presented as follow:

Ranking of Identified Sites, Chitral District				
Ranking	Scheme	Installed Capacity	Cost Estimate	Annual Energy
1	Golen Gol 1_/	106	73.68	436
2	Shogo-Sin	127	129.67	586
3	Shusghai-Zhendoli	102	118.22	442
4	Uchhatur-Andokht	79	76.30	339
5	Laspur-Muri Gram	133	193.58	550
6	Loo-Nissar Lawi	65	80.48	275
7	Turtonas-Uzghar	58	67.68	254
8	Istoru-Buni	52	66.49	213
9	Ushan-Ayun	30	44.07	131
10	Darband-Barbuno	40	66.24	167
11	Mujiggram-Shogo	51	92.50	231
12	Nechhchcherdim-Paur	80	139.56	321
	TOTAL	923	1148.47	3945
	1_/ Identified earlier			

10.2.6.2 Subsequent Development

10.2.6.2.1 Golen Gol

The Golen Gol site was identified during the identification of potential for rural electrification and subsequently upgraded for development for grid interconnection. The site is now under construction, which is partially funded by Saudi Fund. The expected commissioning of the site is 2015

10.2.6.2.2 PPIB Studies

Private Power and Infrastructure Board (PPIB) engaged consultants to study two (2) sites; this was funded by the Asian Development Bank (ADB) under the Renewable Energy Resources Multi- Financing Facility Fund (MFF). The result of the two sites studied is summarized as follows:

10.2.6.2.2.1 Shogo-Sin Hydropower Project

Shogo-Sin Hydropower Project was sized with a total installed capacity of 144.01 MW and annual energy generation of about 613.10 GWh/a. The total cost is estimated to be US$ 194 M, this works out to be 1347 $/kW (exclusive of IDC and escalation during construction).

The power and Energy outputs of the plant are summarized in the following table.

SHOGO-SIN HYDROPOWER PROJECT					
Dam Height = 35 m		Surface Area		cu. M	74,340
		Live Storage		cu. M	656,800
Capacity	135	Plant Factor		%	49.4
	Peak Capacity	Off Peak Capacity	Peak Energy	Off Peak Energy	Total Energy
Month	MW	MW	GWh/a	GWh/a	GWh/a
Jan.	131	4	16.28	3.14	19.42
Feb.	131	1	14.70	0.90	15.60
Mar.	125	2	15.97	0.35	16.32
Apr.	129	20	15.70	5.29	20.99
May	132	71	16.42	27.78	44.20
Jun.	134	135	16.15	80.74	96.89
Jul.	134	135	10.76	83.38	94.14
Aug.	134	134	16.67	83.34	100.01
Sep.	133	135	16.06	60.13	76.18
Oct.	132	56	16.41	27.27	43.68
Nov.	132	22	15.80	11.43	27.23
Dec.	131	12	16.30	6.81	23.11
Annual	129	135	187	391	578

10.2.6.2.2.2 Shushghai-Zhendoli Hydro-Power Project

Shushghai-Zhendoli Hydro-Power Project was sized at total installed capacity of 144.01 MW and annual energy generation of about 613.10 MkWh, at a total cost of US $ 179 M (inclusive of IDC and escalation during construction), this works out to be US $ 1246/kW. Estimated Project outputs are given below:

Power and Energy Calculations Shushgal HPP

Capacity 144 MW, Head 615.4 m, Reservoir 453,000 m³

Month	Capacity		Energy		
	Peak Capacity	Off-Peak Capacity	Peak Energy	Off-peak Energy	Total Energy
	MW	MW	GWh/a	GWh/a	GWh/a
Jan	144	4	17.84	1.66	19.50
Feb	137	0	15.40	0.00	15.40
Mar	135	0	17.42	0.00	17.42
Apr	144	24	17.28	7.77	25.04
May	144	44	17.86	17.61	35.48
Jun	145	145	17.36	75.37	92.73
Jul	145	145	17.94	89.72	107.66
Aug	145	145	17.94	89.72	107.66
Sep	145	145	17.35	72.52	89.87

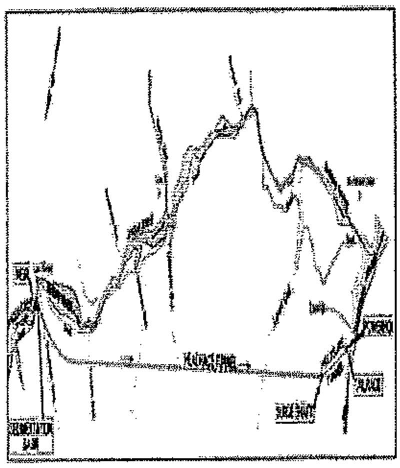
RAD

Month	Capacity		Energy		
	Peak Capacity	Off-Peak Capacity	Peak Energy	Off-peak Energy	Total Energy
	MW	MW	GWh/a	GWh/a	GWh/a
Oct	144	59	17.87	25.30	43.18
Nov	144	27	17.28	14.41	31.69
Dec	144	16	17.85	8.39	26.24
Total	**137**	**145**	**209.40**	**402.45**	**611.85**

10.2.6.2.2.3 Lawi Hydropower Project

LOCATION

The project area is located on the right bank of Shishi River, a left tributary of Chitral River. The project involves diversion of Shishi River into Chitral River. The Project is about 350 km from Islamabad.



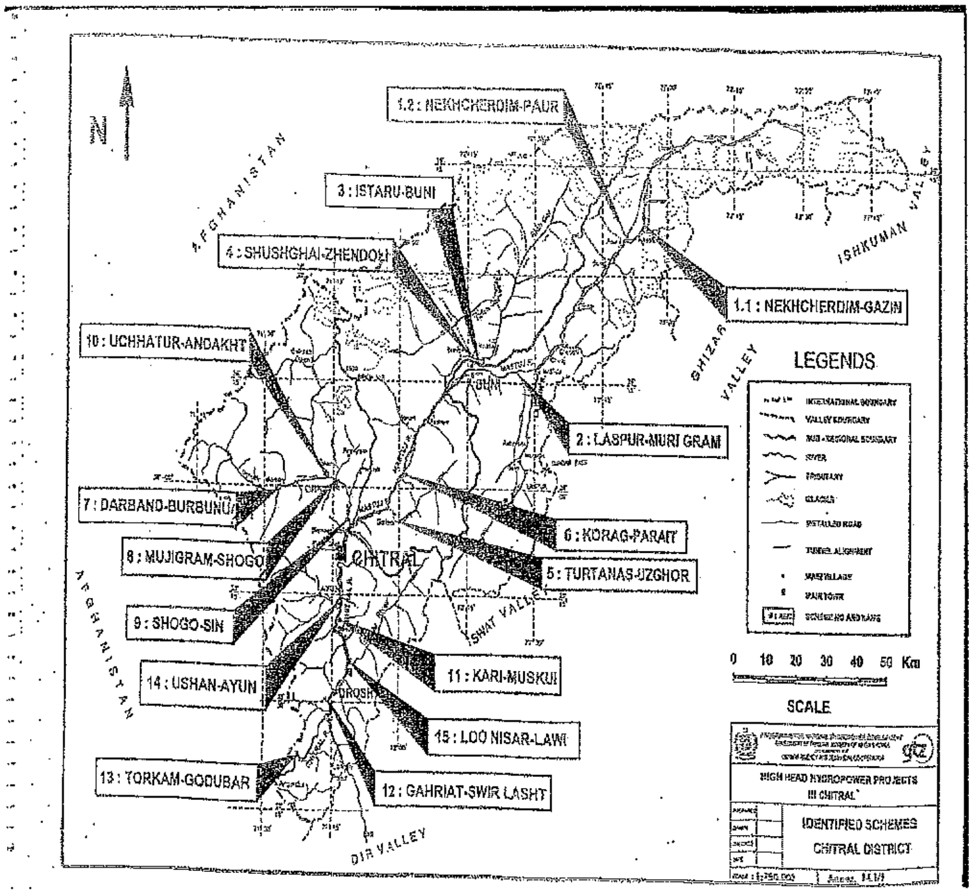
SALIENT FEATURES

Installed Capacity	70 MW
Gross Head	413 m
Design Discharge	20 m^3/sec
Mean Annual Energy	303 Mil. KWh
No. & Type of Turbine	3 (Pelton)
Project Base Cost	US$ 120 Million
EIRR	18.51%
Implementation Period	4½ Years

The project includes the Interconnection with WAPDA (NTDC) National Grid 132 KV at Timergara (Dir) along-with all interfacing requirement for the system for sale of Power in bulk to WAPDA (NTDC) / NTDC / PESCO .One double Circuit 132 KV Transmission line complete in all respect with an estimated length of 132 km (Length could be varied according to the site requirement.)

10.2.7 Estimates of Power Transfer from Chitral District

The power plants that are proposed are presented as follows:



The power plants that are considered economic are discussed above. The schedule of addition of the plants is presented as follow.

Capacity Addition and Power and Energy Outputs (Chitral District)										
No.	Name of Scheme	Installed Capacity	Annual Energy	July Capacity	Energy	Feb. Cap	Energy	Total Cap	Energy	Year of Addition
		MW	GWh/a	MW	GWh/a	MW	GWh/a	MW	GWh/a	
1	Golen Gol	106	436	106	71	106	12	106	436	2016
2	Lawi	70	303	70	49	70	8	70	303	2018
3	Akrari Gol	79	342	79	56	79	9	79	342	2020
4	Laspur-Muri Gram	133	538	133	88	133	15	133	538	2022
7	Turtonas-Uzghar	58	254	58	41	58	7	58	254	2024
6	Istoru-Buni	52	213	52	35	52	6	52	213	2026
7	Shogo-Khura Lasht	144	578	135	94	131	16	144	578	2028
8	Shusghui-Zhendoli	145	612	145	108	137	15	145	612	2030
9	Ushan-Ayun	30	131	30	21	30	4	30	131	2032
10	Darband-Barbuno	40	167	40	27	40	5	40	167	2034

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Capacity Addition and Power and Energy Outputs (Chitral District)										
No.	Name of Scheme	Installed Capacity	Annual Energy	July Capacity	Energy	Feb. Cap	Energy	Total Cap	Energy	Year of Addition
11	Mujiggram-Shogo	51	231	51	38	51	6	51	231	2036
12	Nechhchcherdim-Paur	80	321	80	52	80	9	80	321	2038

The expected power flow from Chitral District to The NTDC system is as follows:

Power Flow Chitral District						
	Jul		Feb.		Total	
	Capacity	Energy	Capacity	Energy	Capacity	Energy
Year	MW	GWh/a	MW	GWh/a	MW	GWh/a
2016	106	71	106	12	106	436
2017	106	71	106	12	106	436
2018	185	150	185	91	185	515
2019	185	150	185	91	185	515
2020	264	206	264	100	264	857
2021	264	206	264	100	264	857
2022	397	293	397	115	397	1395
2023	397	293	397	115	397	1395
2024	455	335	455	121	455	1649
2025	455	335	455	121	455	1649
2026	507	369	507	127	507	1862
2027	507	369	507	127	507	1862
2028	642	463	638	143	651	2440
2029	642	463	638	143	651	2440
2030	787	571	775	158	796	3052
2031	787	571	775	158	796	3052
2032	817	592	805	162	826	3183
2033	817	592	805	162	826	3183
2034	857	620	845	166	866	3350
2035	857	620	845	166	866	3350
2036	908	657	896	172	917	3581
2037	908	657	896	172	917	3581
2038	988	710	976	181	997	3902

10.2.8. Design Considerations

Chitral Valley and District can be accessed by the Lowari Pass, which is approximately 3200m and is closed during the winter due to snow and danger of avalanches. To transmit power produced within the Chitral Valley transmission lines need to cross the Lowari Pass and to connect to existing 66 kV Dir and 132 kV Timergara substations. The recommended line routing is to follow the Chitral River up to Mirkhani and to cross the Lowari Pass reaching Dir and Timergara Substations following the Panjkoora River from Dir Substation onwards.

In 1995 a 33 kV line was constructed from Did substation to Joti Lasht substation in Chitral crossing the Lowari Pass, during the winter of 1995/96 the line collapsed at the pass region due to climatic over loadings .It has been reported that the Lowari Pass, on average, gets 10-12 inches snow every winter , snow fall starts , usually , in December and lasts to March/April . Permanent snows during the winter start at 2000m. Freezing rain is rare and if it does happen it tends to occur at the end of the winter. Some 11 kV structures in Drosh also failed in one winter due to snow.

Lowari Top experiences high winds, the wind direction are from usually form the Chitral side and less frequently it can also be from the Dir side. Minimum temperatures of -25^{0}C accompanied with high winds is reported in the winter; in summer temperatures of up to 30^{0}C are expected. Inspections of the line during winter reveal covering of ice on the conductor (Dog) with an overall diameter of approximately 5cm. estimates (based upon 0.6 kp/dm3 for the ice on the 14.17 dia. Dog conductor results in approximately 1.083 kp weight per meter of conductor) of thickness of ice were approximately 18mm.. Lines in Dir District do not experience ice loading. Detailed specifications, ice loadings, total weight with ice, sag spans, conductor types and routes are presented in the report "132 kV Line Golen Gol –Chakdara- Feasibility Study" by H. Lugschitz ,Verbund , Vienna , and T.N Malik HEPO , Lahore, 19 November 1996 , GTZ-HEPO.

10.2.9 Transmission Interconnection Study

10.2.9.1 Introduction

The intake with the dam is located on Arkari River 8 km upstream its junction into Lutkho River nears the village of Uchhatur. From there, the water is transferred through a desander basin, horizontal low pressure tunnel , surge chamber system and vertical pressure shaft with horizontal pressure tunnel to the surface-type powerhouse situated on right bank of Arkari River near its junction with Lutkho River near the village of Andakht. The output from the Arkari HPP is to be interconnected to the Mujigram-Shoghore HPP.

The Mujigram-Shoghore Hydro Power Project is one of the identified hydel projects in Chitral valley which is under feasibility stage. The Project proposed weir site is located on Lutkho River near Mujigram Village approx. 3 km downstream of Garam Chashma. Lutkho River is a right tributary of Mastuj River and forms together with Chitral River. The confluence is about 5 km upstream of Chitral Town. The project layout is proposed on the right bank of Lutkho River with a powerhouse site near Shoghore village, which is located opposite to Ojhor Gol northwest of Chitral Town at a distance of approx. 26 km.

10.2.9.2 Overview

This feasibility report analyzes the role of Arkari and Mujigram-Shoghore Hydropower Project in meeting the growing power demand of the country and proposes a technically and economically feasible transmission system for dispersal of the power generated to the main Grid. The load demand and power supply analysis has been carried out based on the latest load forecast and generation expansion plan provided by NTDC and also describes the proposed corridor for the transmission line from Mujigram-Shoghore to the grid station to be constructed by NTDC near Chitral town. The output from the Arkari HPP will be fed to the Mugigram –Shoghore HPP.

10.2.9.3 Objectives of Study

The main objectives of the study are:-

- To provide guidance for selecting voltage level for power evacuation, bus bar arrangement for connected switchyard, interconnection with isolated load or grid, selection of necessary protection scheme for the selected grid interconnection.

- Flexibility to deal contingencies with safety and reliability, fulfil the criteria of NTDC Grid Code approved by NEPRA in terms of acceptable transmission parameters for normal (N-0) and contingency (N-1) conditions both under disturbed dynamic/transient conditions and steady state conditions.
- To establish a reliable, economical and viable Inter-connection Scheme for dispersal of power from the Arkari and Mujigram-Shoghore HPP.

- To ensure that the generation of Arkari and Mujigram-Shoghore HPP can be delivered to proposed 220/132 kV Chitral grid station which will be constructed by NTDC.

10.2.9.4 Transmission Corridor General Description

Transmission Corridor is an approachable passage of at least 25 meters width and considerable length between the two terminal stations. It is usually selected to safely accommodate the proposed transmission line taking in to account all the technical, economic, social, environmental and cultural parameters.

10.2.9.4.1 Weather Conditions

The weather conditions in the Project Area are severe and the terrain is snowy in winters thus there is a possibility of landslides and avalanches. To overcome these hazards or to increase the reliability of transmission lines following measures have to be taken care of:

- Installation of stronger conductors with better mechanical properties to carry increased ice and wind loads.
- Installation of stronger towers to withstand snow slide, snow pressure, ice and wind loads and the forces from stronger conductors.
- The towers shall be so spotted that strips with danger of snow slide or avalanches can be avoided to cross or are crossed in long free span.

10.2.9.4.2 Terrain Description

The terrain is mostly dry, rugged and barren, the land uses of the corridor is rural and typical in nature, agricultural-based land uses are seen in small patches scattered in the corridor area. The predominant developed land use throughout the Project Area is slightly developed including semi-rural residential patches with single-family houses. Residential development reaches its highest density in Chitral Town or in its vicinity.

It is anticipated that land uses will remain relatively unchanged during the next few decades. Increase in growth rate is expected, but the overall rural character of the project /corridor area should remain unchanged.

10.2.9.4.3 Transmission Corridor Routes

The transmission line corridor route emerging from Mujigram-Shoghore Hydro Power Project on the right bank of Lutkho River goes down stream towards Shali. Then corridor enters Sin, which has high altitude mountains on the right bank of the river, thus the corridor has to divert to the left bank of the river, which has big terraces and with small agricultural activity. The corridor, before entering Lasht, again diverts to the right bank Before Singur, River Luthkho joins River Mastuj and becomes Chitral River. From Singur, the corridor enters Balach. At Chew Bridge, the corridor on the right bank of the River Chitral enters Chitral Town, from where the corridor cross the river and enters Devashish on the left bank of the river. From this point, the corridor pass through Jughor, The routes then pass through Bakarabad and Chamarkun before entering proposed new Chitral grid station (to be constructed by NTDC) near 33/11 kV Jutilasht grid station.

10.2.9.4.4 Selection of Voltage Level for Dispersal of Power from Project

The system voltage in ehv system very much affect the capital cost of transmission line. The weight of conductor material, the efficiency of the line, the voltage drop in the line and system stability depends upon system voltage. The choice of voltage therefore, is a major factor in the line designs.

While selecting the transmission voltage, the present and future expected voltage of other lines in vicinity of the line under design are taken into account. The selection of highest system voltage to be used at the generating step up substation depends upon the following main consideration.

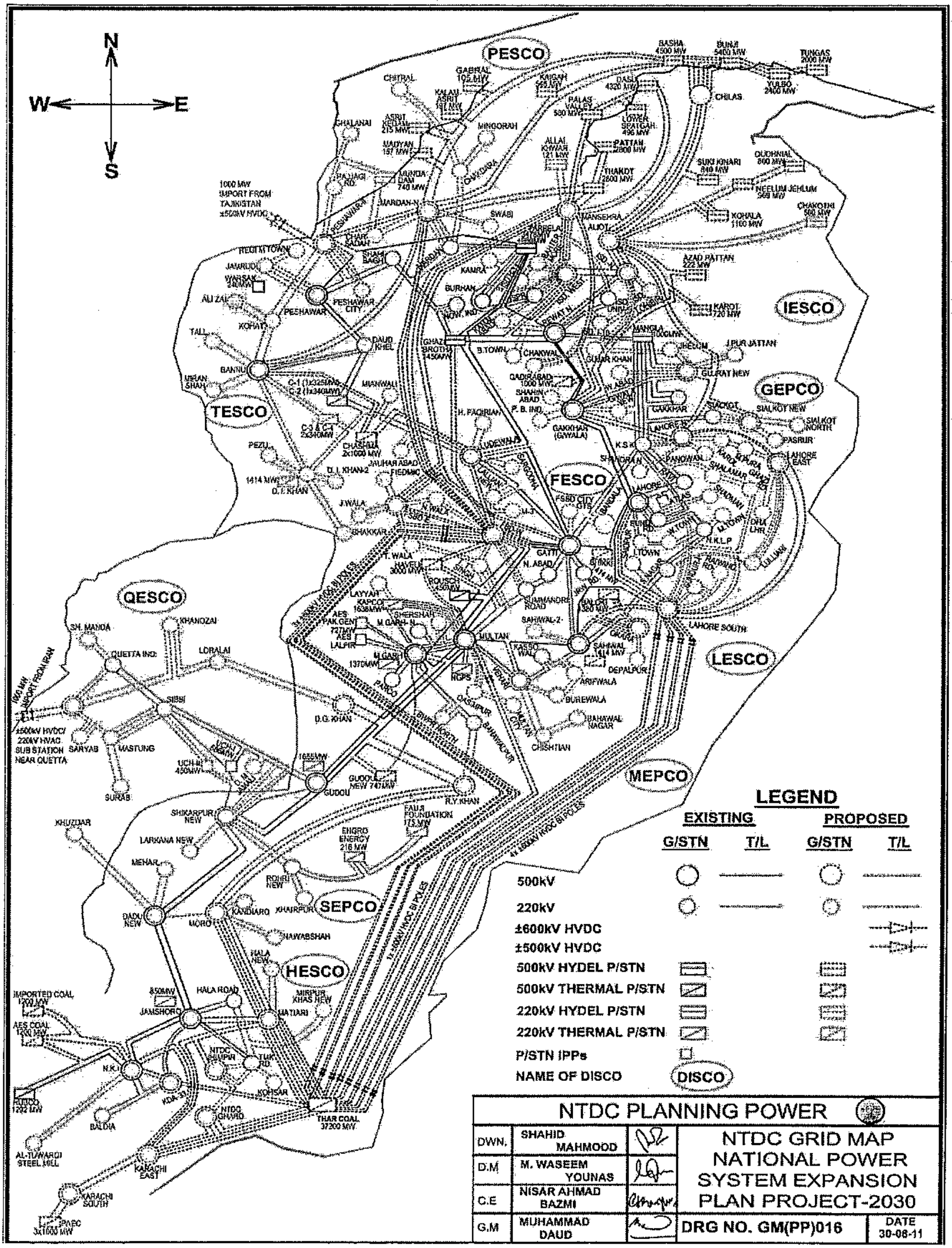
- Length of transmission line from Arkari to Mujigram-Shoghore and from Mujigram-Shoghore HPP to 220/132 kV Chitral grid station.
- Voltage level available at the receiving substation and suitability of
- connectivity.
- Power System Network of the area for stability and future extension works in the vicinity of the generating stations
- Safety, Reliability, Economy and Simplicity of operation and good technical performance.
- Selection of required voltage level by using standard empirical formulae.

Keeping in view of the existing network and after studying the all factors, capacity and location of proposed power project site and to provide flexible transmission interconnection, the team of experts studied various possible interconnection arrangements / options to connect the proposed power plant with the bus bar of 220/132 kV Chitral grid station. The arrangement should fit in the planning criteria used to design the connected transmission system.

10.2.9.4.5 Interconnection Alternatives

Strategic approach for dispersal of power from large hydropower stations on Chitral River and its tributaries requires a very strong, reliable and stable transmission system. Hydropower projects like Golen-Gol, Shogo-Sin and Shushghai-Zhendoli have completed their feasibility studies and now these projects are under various construction and implementation stages. Their capacities are expected to be 106 MW, 132 MW and 144 MW respectively. **Figure 10.2.1** on the following page shows the conceptual scheme of development of transmission system, as envisaged by National Power Expansion Plan 2011-2030. The concept is to connect hydropower plants at 132 kV level with a collector hub of 220/132 kV at Chitral from where a 220 kV double circuit Chitral-Chakdara (using Greely conductor) would be adequate to evacuate all the collected power to the main grid. However the additional 132 kV circuits in the collector network in Chitral Valley may be required depending on the sequence of additions of hydropower plants in this valley.

Figure 10.2.1: 500/220 kV System In the Ultimate Year 2030



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10.2.9.4.6 Interconnection Options

A comprehensive scheme for dispersal of power from Mujigram-Shoghore Hydro Power Project to load centers has been envisaged for transmitting power emanating from Mujigram-Shoghore Hydro Power Project to the National grid. A set of voltage levels along with the number of circuits have been considered, based on the technical parameters and general load ability indices of HV lines. Presently the expansions of DISCO transmission network are frozen up to 66kV level while it is assumed that the expansion of transmission network up to the 132 kV level will be frozen at the year 2020.

Option – I

In this option, a 132 kV transmission line may originate from the Mujigram-Shoghore HPP and will directly connected to proposed 220/132 kV Chitral grid station.

Option – II

In second option, the evacuation of generation from Mujigram-Shoghore HPP to proposed 220/132 kV Chitral grid station will be carried out through two 132 kV transmission lines. One transmission line will be directly connected with 220/132 kV proposed Chitral grid station and other will be connected with 132 MW Shogo-Sin HPP via an In/Out arrangement.

Option – III

In this option, 132 kV double circuit transmission lines may originate from Mujigram-Shoghore HPP and will be directly connected to the 132 kV bus bar of Shogo-Sin HPP which is about 6 km downstream from Mujigram-Shoghore HPP, from where the combine generation of both hydro power project will be transmitted to 220/132 kV proposed Chitral grid station.

However, details will be provided in the load flow studies which are under preparation. Load flow studies for Arkari to Mugigram interconnection are to be carried out under separate arrangements.

10.2.10. Conclusion

Two power plants, Golen Gol and Lawi are under implementation. There are ten others that are being planned for addition over time. There is need to develop a consolidated , long term plan for the transmission interconnection between Chitral District and The System .The 132 kV double circuit Interconnection presently planned for Golen Gol may need to be changed to 220 kV Double Circuit , so as to cater for the planned schemes.

It is suggested that NTDC, Office of General Manager Planning (Power) may be requested to undertake load flow studies and develop a long term interconnection for transmission interconnection of Chitral District with the System. Line design will need special considerations related to: spans; ice loading; and conductor types, for portions identified to be prone to heavy winter snow falls.

PHYDO convened a meeting of all consultants engaged in development of feasibility studies IN KPK, on September 17, 2013. The meeting concluded that PHYDO will coordinate with NTDC and if necessary engage a consultant to prepare a transmission interconnection plan for KPK.

Load flow and stability studies to interconnect the Arkari HPP will be carried out under separate arrangements. The analysis is based on the fact that the output from the proposed power plant will be delivered to the NTDC system, since the local demand is already met or is being met with existing and ongoing projects.

4.10 Environment & Social Impact Assessment

The proposed facility is a hydropower generation plant and does not release emissions or harmful pollutants into the atmosphere. On the whole, hydropower projects benefits the environment as it reduces the requirement for fossil fuel based thermal power generation.

Master Hydro conducted a detailed environmental and social impact assessment after being notified by PEDO as the first ranked bidder for the Project. Hagler Bailly Pakistan was engaged for the detailed environmental assessment of the Project site. The complete ESIA is attached in this section.

Hagler Bailly Pakistan

Arkari Gol Hydropower Project

Environmental and Social Impact Assessment

Volume 3 - Draft Report

HBP Ref.: D8E03AGH

June 13, 2018

Master Hydro (Pvt.) Ltd. (MHL)

Lahore

Rao

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1. Introduction

Master Hydro (Pvt.) Ltd. (MHL) intends to develop the 99 megawatt (MW) Arkari Gol Hydropower Project (the Arkari HPP or the Project) on the Arkari Gol, about 8 kilometer (km) upstream of the confluence of Arkari Gol with Lutkho River in the Chitral District of Khyber Pakhtunkhwa (KP). The dam is located 370 km from Peshawar. The location of the Project is shown in **Exhibit 1.1**. The dam and powerhouse are at a distance of 7.5 km. The Project is required to comply with the laws of KP.

The environmental and social safeguard documents that are prepared for the Project are as follows:

1. Environment and Social Impact Assessment (ESIA) including the Environmental Management Plan (EMP), Environmental Flow (EFlow) Assessment, and Cumulative Impact Assessment (CIA)
2. Resettlement Action Plan (RAP)

A Feasibility Study of the Project (FS) was released in March 2014. MHL has acquired the services of Hagler Bailly Pakistan (Pvt.) Ltd. (HBP) to prepare the environmental and social safeguard documents for the Project that meet the requirements of the Overseas Private Investment Corporation (OPIC) and conform to environmental legislation of KP and of Pakistan.

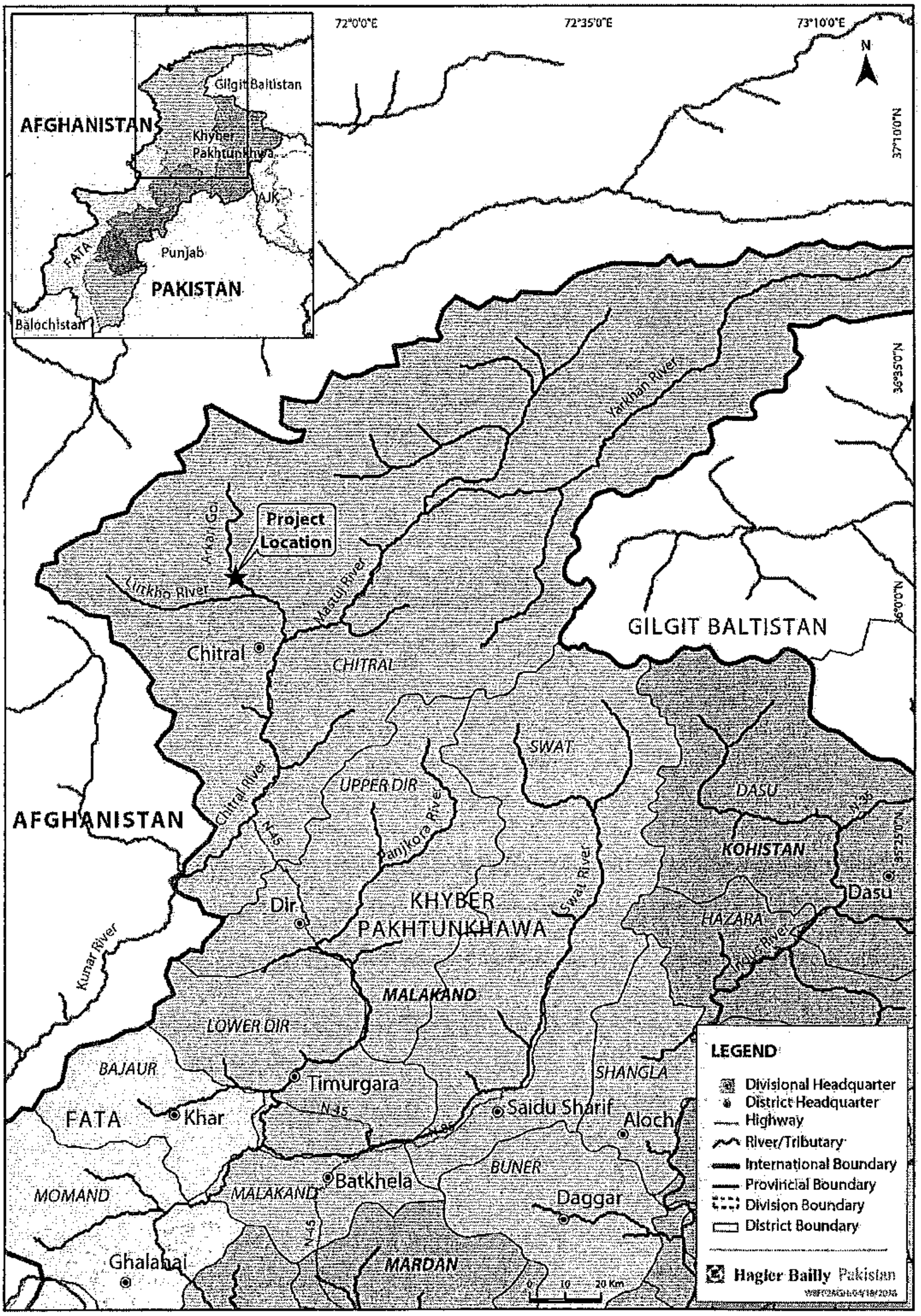
This document is the ESIA of the proposed Project.

1.1 Project Proponents

Master Hydro (Pvt.) Limited is a special purpose corporate vehicle established under the laws of Pakistan, to develop, construct, own and operate the Arkari Gol HPP. Master Hydro (Pvt.) Limited is owned by Master Group of Industries.

Master Group of Industries is a diverse business that started its operations in the mattress industry in 1963 as a licensee of Bayer A.G (Germany). Since then the group has expanded into textile, automobile, engineering and energy sectors. In the renewable energy sector Master Group of Industries established the Master Wind Energy Limited which operates a 52.8 MW wind power project. The wind energy project successfully came into operation in October 2016. The group is looking to increase its investments in the power sector.

Exhibit 1.1: Arkari Gol Hydropower Project Location



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1.2 Project Overview

The Project is a run of the river hydropower project with daily peaking in winter, to be constructed on the Arakri Gol (**Exhibit 1.2**). The Project site is located 40.5 km upstream of the Chitral main town, about 370 km by road from Peshawar, near the Ucchatur village, Chitral District, KP. The geographical coordinates of the proposed dam site are 36° 4'3.49"N, 71°41'33.99"Eand of the proposed powerhouse site are36° 1'15.32"N, 71°44'13.07"E. The Project site is about 495 km by road from Islamabad.

The total installed capacity of the Project will be 99 MW. The average annual energy generation will be 378 Gigawatt-hour (GWh).

The main dam will be a concrete structure with a height of 20 m from the foundation level and dam crest width of 6 m. The reservoir capacity at full supply level (FSL) of 2,190 m above mean sea level (amsl) will be 1.06 million cubic meters (MCM) of which live storage will be 0.489 MCM. The surface area of the reservoir will extend to approximately 0.121 km upstream of the dam and will cover an area of 0.101 km^2 (10.143 hectares).

The average annual discharge at the proposed dam site is 17 m^3/s. The design discharge is 36 m^3/s. There will be a headrace tunnel with a length of 5.9 km.

The powerhouse will be a surface-type powerhouse with an open 132 kilovolt (kV) switchyard.

There will also be permanent and temporary camp facilities, a workshop area and offices. As the Project is following IFC guidelines these facilities will be established in compliance with IFC standards.

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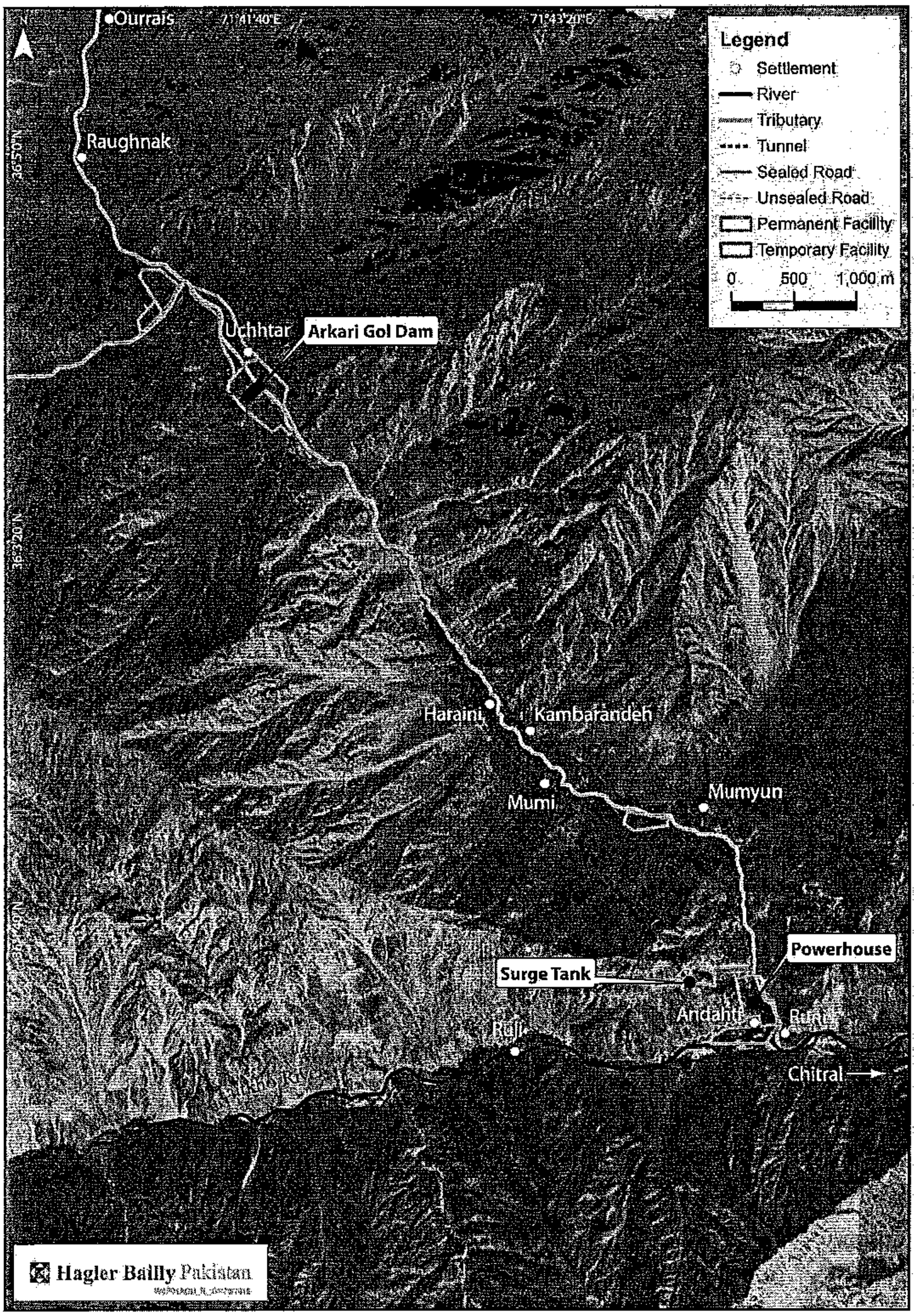
Exhibit 1.2: Arkari Gol Hydropower Project Layout



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1.3 Objectives and Scope of the ESIA

The overall purpose of the ESIA is to identify the potential environmental and social impacts of the proposed Project and evaluate them following the process which is acceptable to regulatory authorities in Pakistan, and the Project developers. In this process, the ESIA identified measures to minimize any anticipated adverse impact of the proposed Project as far as possible but at least to a level that meets the national standards and good international industry practice (GIIP) criteria for evaluation of environmental and social impacts.

The specific objectives of this ESIA were to:

- Assess the existing environmental conditions in the Project area, including the identification of environmentally sensitive areas.
- Assess the proposed activities to identify their potential impacts, evaluate the impacts, and determine their significance.
- Assess cumulative impacts of proposed hydropower projects on in the basin.
- Propose appropriate mitigation and monitoring measures that can be incorporated into the design of the proposed activities to minimize any damaging effects or any lasting negative consequences identified by the assessment.
- Assess the proposed activities and determine whether they comply with the relevant environmental regulations in Pakistan as well as the requirements of Project developers.
- Prepare an ESIA report for submittal to the Environmental Protection Agency of KP.

The scope of the ESIA includes the environmental and social impacts of all activities proposed by MHL in the immediate vicinity of the proposed Project site during construction and operation stages of the Project. The scope does not include the transportation of equipment and supplies through ships on international waters and the unloading of the same at the Karachi ports.

To evacuate power from the proposed Project, a 132 kV transmission line is to be constructed by National Transmission and Despatch Company (NTDC), which falls in the category of associated project.[1] The length of the transmission line is not known at this stage as the interconnection point is not yet finalized. To achieve environmental or social outcomes consistent with the national regulatory requirements and the IFC guidelines, it is essential that NTDC undertake the ESIA of the transmission line following the requirements stated in **Section 2** of this report and develop a sound environmental Management Plan (EMP). The scope of this ESIA does not include the design, construction, and operation of the transmission line, however, recognizing the potential impacts and risks associated with the transmission line, measures to ensure that a full EIA of the transmission line is undertaken, the EMP identifies and defines a set of management measures to be taken in the contractual arrangement with NTDC.

1 IFC defines associated facilities as "facilities that are not funded as part of the project and that would not have been constructed or expanded if the project did not exist and without which the project would not be viable"

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1.4 Study Areas

The spatial boundaries of the Study Areas for the ESIA were selected to cover all areas where any measureable change to any component of the environment is likely to take place, directly or indirectly, due to any activity directly associated with the proposed Project. The selection of the Study Areas took into account the environmentally sensitive receptors[2] that are most likely to be impacted by the Project's development activities. It also took into account the different stages of the Project specifically construction and operation. To ensure assessment of cumulative impacts, the Study Areas were selected to be large enough to allow the assessment of the Valued Ecosystem Components (VECs) that may be affected by the Project activities.

The permanent footprint of the proposed Project includes the area that will be acquired for the dam, reservoir, powerhouse, roads and some other facilities.

The Study Areas are considerably larger than the Project footprint. The proposed Project has different types of impacts spread over a relatively large area; therefore a single study area for all types of impacts is difficult to define.

The ecological Study Area was defined as follows:

- **Aquatic Study Area:** The part of the Arkari Gol starting from Azhpi upstream of the Project to Mastuj River downstream of the powerhouse. It includes tributaries in this stretch but only those with a significant perennial flow that support breeding of fish.
- **Terrestrial Study Area**: This was defined as a 1 km buffer around locations where Project-related facilities are to be located as well as the reservoir.

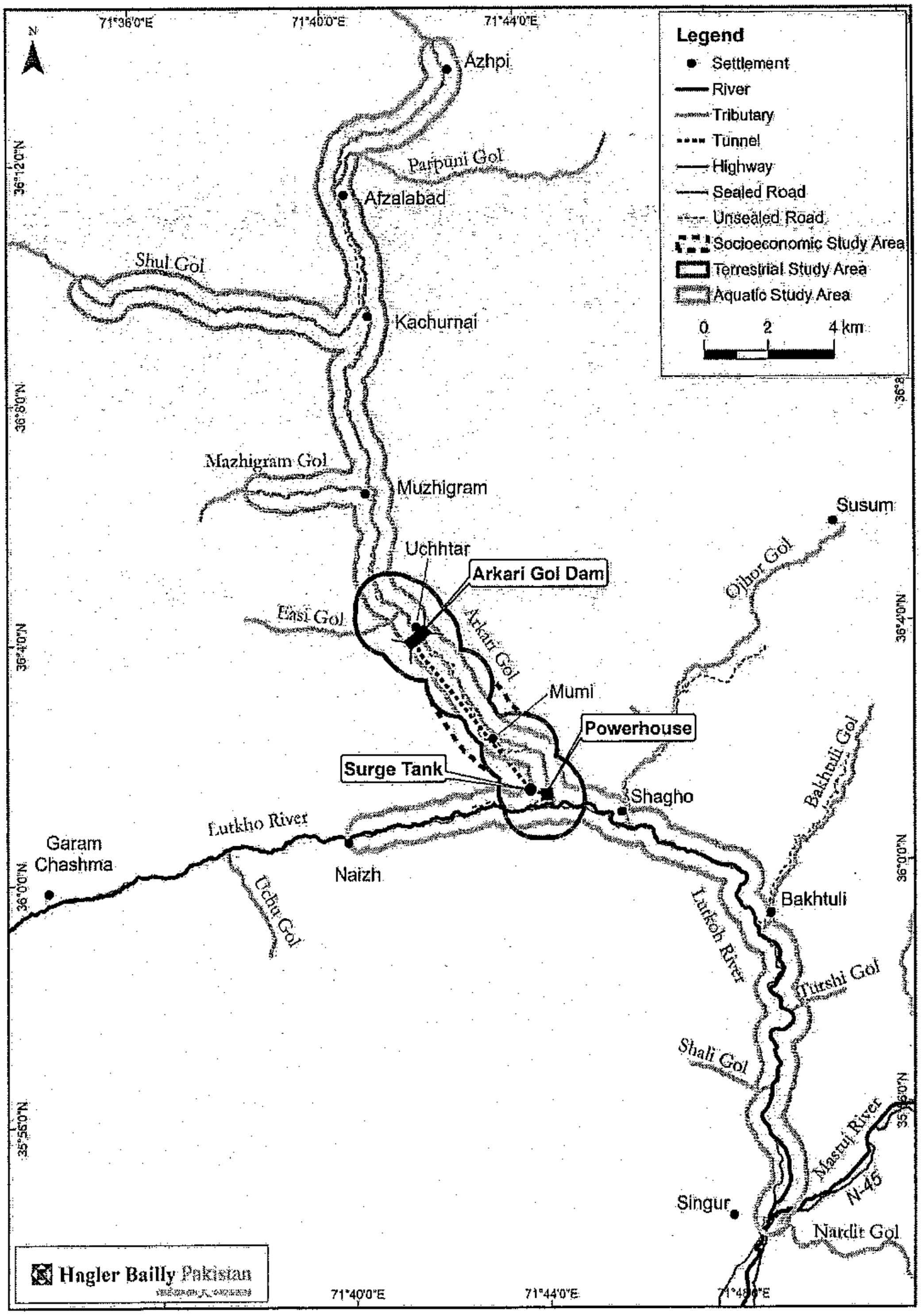
The Socioeconomic Study Area was defined as follows:

- **1 km buffer around Reservoir**: along reaches that may be impacted due to the Project, and the zone where there is river dependence (either through use of drift wood, use of sand and gravel as building materials, fishing, etc.).
  - All settlements with a center within the 1 km buffer are included.
  - All settlements with more than 50% of their land area within the 1 km buffer are also included.
- **1 km buffer around Project facilities:** For coverage of communities that will be directly impacted through either resettlement, or construction related impacts. This includes the low flow section.
- **Upstream Extent:** Selected as the top end of the reservoir, upstream of the dam.
- **Downstream Extent:** The downstream extent of the Socioeconomic Study Area is the confluence of Lutkho River and Arkari GolGol.

The Study Areas defined for this baseline study are shown in **Exhibit 1.3**.

2 Sensitive receptors include, for example, residential areas, schools, places of worship, habitat of threatened or vulnerable flora and fauna species, drinking water sources, wetlands, and cultural heritage sites.

Exhibit 1.3: Study Areas



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1.5 Study Team

The ESIA has been conducted by a team of HBP professionals who are the leading experts in their respective fields in the country. The names of the study team members and their roles are shown in **Exhibit 1.4**.

Exhibit 1.4: Study Team

Name	*Education and Experience*	*Role and Main Activities*
HBP		
Vaqar Zakaria	▶ BS and MS in Chemical Engineering, MIT, USA 26 years of experience in environmental assessment and monitoring	▶ Project Team Leader ▶ EFlow Assessment Expert ▶ Supervision of the Biodiversity Management Plan ▶ Supervision of the Cumulative Impact Assessment
Anwar Fazal Ahmed	▶ MSc (Hons) Rural Development ▶ MA Economics 16 years of experience in resettlement planning and implementation	▶ Land Acquisition and Resettlement Expert ▶ Household socioeconomic data collection, analysis and reporting
Aziz Karim	▶ MSc Biochemistry ▶ BSc Biochemistry, Microbiology, Chemistry Over 10 years of experience in environmental assessment	▶ Physical Environment Expert ▶ Supervision of physical data collection (noise, air quality, traffic and visual) ▶ Water quality, visual and traffic analysis and reporting
Fareeha Irfan Ovais	▶ MSc – Environmental Change and Management ▶ MSc – Zoology ▶ BSc – Botany, Zoology, Chemistry Over 10 years of experience in ecology and climate change	▶ Development of the Biodiversity Management Plan ▶ Reviews for ecology baseline and impact assessment
Hassan Bukhari	▶ MS Natural Resources and Environment ▶ BS Physics 2 years of experience in environmental assessment	▶ Coordination of Physical Environment field teams ▶ Water quality, noise, traffic and air quality data analysis and reporting ▶ Physical impact assessment
Saeed Nawaz	▶ BA Journalism and Education ▶ FSc Physics, Chemistry, Biology 19 years of experience in water, wastewater and soil sample analysis	▶ Hydrocensus and water sample data collection ▶ Water physical parameters laboratory analysis

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Name	Education and Experience	Role and Main Activities
Sadia Asghar	▶ BSc Environmental Engineering ▶ FSc Pre-Engineering 2 years of experience in environmental assessment	▶ Climate data review, analysis and reporting ▶ Physical baseline reporting ▶ Air quality, traffic and visual impact assessment
Kamran Minai	▶ MSc Environmental Science and Management ▶ BSc Biology 4 years of experience in environmental assessments	▶ Project management support ▶ Compilation and standardization of the Project reports ▶ Quality assurance checks ▶ Coordination of Terrestrial Ecology field teams ▶ Compilation of Ecological Baseline ▶ Terrestrial ecology desktop research, data collection, analysis and reporting ▶ Terrestrial ecology impact assessment ▶ Aquatic ecology impact assessment
Shakeel Ahmad	▶ MPhil. Wildlife and Ecology ▶ BS (Hons.) Zoology 3 years of experience in ecology data collection, analysis, reporting and assessments	▶ Project management activities ▶ Ecology surveys ▶ Ecology baseline preparation
Ahmad Shoaib	▶ MPhil. Fisheries and Aquaculture ▶ BS (Hons.) Applied Zoology ▶ BS (Hons.) Fisheries and Aquaculture 3 years of experience in aquaculture and 1 year of experience in fish surveys for environmental assessments	▶ Aquatic ecology field investigation, data analysis and reporting
Muhammad Usman Berches Niazi	▶ MSc. Geography ▶ BA. Geography and Economics 4 years of experience in Geographic Information Systems (GIS)	▶ Socioeconomic, physical and ecological report mapping
Jan Muhammad	▶ MS Economics 8 years of experience in social development	▶ Socioeconomic field data collection
Ghulam Murtaza	▶ MSc Sociology ▶ BA Sociology ▶ FSc Pre-Engineering 7 years of experience in geographic information systems (GIS) and 8 years of experience in ecology field surveys	▶ Socioeconomic, physical and ecological report mapping

Name	Education and Experience	Role and Main Activities
Naseer ud din Ahmad	▶ MA Economics and Statistics 50 years of experience in project management and administration	▶ Administrative and logistic support
Imran Khalid	▶ Certification in MS Office and Hardware ▶ Graduation 12 years of experience in formatting and designing of technical documents	▶ Document formatting services
Umer Jehangir	▶ Graduation 7 years of experience in formatting and designing of technical documents	▶ Document formatting services
HBP Associates		
Dr Mohammad Rafique	▶ PhD Zoology ▶ MPhil Genetics ▶ MSc Zoology ▶ BSc 27 years of experience in fisheries assessments	▶ Biodiversity expert and lead aquatic ecologist ▶ Aquatic ecology field investigation, data analysis and reporting
Mishkatullah	▶ MSc (Hons) Agriculture and Entomology ▶ BSc (Hons) Agricultural Entomology ▶ FSc Pre-Engineering 12 years of experience in entomological studies	▶ Aquatic ecology field investigation (macroinvertebrates), data analysis and reporting
Rafaqat Masroor	▶ PhD Zoology (Herpetology) ▶ MSc Zoology ▶ BSc Zoology, Botany, Geography 14 years of experience in wildlife studies and conservation assessments	▶ Terrestrial ecology field investigation and data collection
Muhammad Yasir Asad	▶ MS Sociology 7 years of experience in social development	▶ Household socioeconomic data collection
HBP Consultants		
Bilal Khan	▶ BSc Geology ▶ BEng Environmental Engineering Over 10 years of experience in hydrology, geology and environmental impact assessment	▶ Climate Change Risk Assessment

1.6 Organization of the Report

The ESIA is organized in 10 sections. Following this section, **Section 1** (*Introduction*), there are two sections that provide the information that put the Project into context. These are:

- **Section 2** (*Policy Legal and Administrative Framework*) describes the legal, policy, and regulatory requirements applicable to the ESIA process and the project design.
- **Section 3** (*Description of the Project*) describes the Project facilities, its main components, the construction activities, land requirement and the technical design summary.

The environmental baseline, or current status of environmental conditions, is discussed in the following three sections:

- **Section 4** (Description of the Environment) is divided into three parts:
  - **Section 4.1** (Physical Baseline) describes the geology, soils, hazards, topography, land use, climate, air quality, sound levels, visual character, and the water resources of the Study Area.
  - **Section 4.2** (Ecology Baseline) describes the fish, macro-invertebrates, riparian vegetation, terrestrial flora, mammals, avifauna, and herpetofauna of the Study Area.
  - **Section 4.3** (Socioeconomic Baseline) provides a narrative description of the socioeconomic zones, a description of the demographics, ethnicity, religion, governance, and administrative setup, social service infrastructure, physical infrastructure, local economy household socioeconomic conditions, indigenous people, and cultural heritage of the Study Area.
- **Section 5** (*Analysis of Alternatives*) identifies and analyzes various alternatives to the Project and its design. This includes a 'no project' option, alternative technology and scale of power generation, alternative Project location and layout, peaking and non-peaking operation, environmental flow and management option, and options for equipment and supplies transportation.
- **Section 6** (*Information Disclosure, Consultation, and Participation*) describes the scoping consultations undertaken for the Project and the results of consultations.

The impact assessment is organized in three sections:

- **Section 7** (*Anticipated Environmental Impacts and Mitigation Measures*) is the main assessment chapter that assesses the impact of the proposed Project design, construction and operation on the physical, ecological and socioeconomic environment of the area. The aspects that are covered include aquatic ecology, terrestrial ecology, air quality, hydrology and water quality, noise, soil, topography, land stability, land acquisition, livelihood and well-being, macroeconomic impacts, aesthetics and tourism, climate change, cumulative impacts, traffic and road.

- **Section 8** (*Grievance Redress Mechanism*) provides the framework for reporting, recording, and taking actions on complaints of the community.
- **Section 9** (*Environmental Management Plan*) provides details on management and mitigation measures to be carried out during the design, construction and operation phases of the Project. It also categorizes these measures based on the responsibilities of various members of the Project execution team and lays out the main aspects for monitoring of the implementation of management and mitigation measures.

Finally the outcome of the impact assessment is combined to produce the following sections:

- **Section 10** (*Conclusions and Recommendations*). It brings together the salient findings of the assessment and highlights the key applicable standards and guidelines. It also briefly describes the main measures recommended if the Project is to be executed.

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2. Policy, Legal, and Administrative Framework

This section provides a summary of the national and international legislation and guidelines that are relevant to the assessment of the Project's environmental components. The review of the legal and institutional framework and relevant laws help identify the policy directives and required procedures to investigate social responsibility, environmental accountability and financial soundness of the Project.

2.1 Provincial Legislative and Regulatory Framework

The development of statutory and other instruments for environmental protection and management has steadily gained priority in Pakistan since the late 1970s. The Pakistan Environmental Protection Ordinance 1983 was the first piece of legislation designed specifically for protection of the environment. The promulgation of this ordinance was followed in 1984 by the establishment of the Pakistan Environmental Protection Agency, the primary government institution dealing with environmental issues. Significant work on developing environmental policy was carried out in the late 1980s, which culminated in the drafting of the Pakistan National Conservation Strategy. Provincial environmental protection agencies were also established at about the same time. The National Environmental Quality Standards (NEQS) (**Appendix A**) were established in 1993. The enactment of the Pakistan Environmental Protection Act 1997 (PEPA 1997) conferred broad-based enforcement powers to the environmental protection agencies. Publication of the Pakistan Environmental Protection Agency Review of Initial Environmental Examination and Environmental Impact Assessment Regulations 2000 (IEE-EIA Regulations 2000) provided the necessary details on the preparation, submission, and review of an IEE and EIA. In addition to the PEPA 1997, Pakistan's statute books contain a number of other laws that have clauses concerning regulation and protection of the environment.

One of the key components of the 18th Amendment to the Constitution, passed by the parliament in 2010, was devolution of power from the federal to provincial governments. Through this amendment, the concurrent legislative list of the constitution was abolished, and all legislative powers on subjects included in the concurrent legislative list, which included environmental protection, were transferred to the provinces. Thus, after the passage of the 18th amendment, the federal government lost its power to legislate on environmental protection, and only provincial governments could make laws regarding protection of the environment.

2.1.1 Statutory Framework for Environment

The key national environmental legislation was the Pakistan Environmental Protection Act (PEPA 1997). After devolution through the 18th Constitutional Amendment 2010 the provinces have sole authority and responsibility to legislate on 'environment and ecology'. In this respect Khyber Pakhtunkhwa Environmental Protection Act 2014 (KP Act 2014), promulgated in 2014, is the relevant environmental act that will apply to this Project. This Act is largely based on PEPA 1997, with minor changes. Under the Act, all

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decisions made under PEPA 1997 are protected and applicable (Section 40(2)). Hence the environmental approval and conditions of approval, which were conferred before the enforcement of this act, are fully valid and applicable.

2.1.2 Khyber Pakhtunkhwa Environmental Protection Act 2014

The KP Environmental Protection Act 2014 is applicable to a broad range of issues and extends to air, water, industrial liquid effluent, and noise pollution, as well as to the handling of hazardous wastes. The articles of KP Act 2014 that have a direct bearing on the proposed Project are listed below.

The details are discussed in the following sections:

- Article 11 that deals with the KP environmental quality standards (KPEQS) and its application.
- Article 12 that deals with discharges, emissions and waste disposal.
- Article 13 that deals with IEE and EIA with review and approval process.
- Article 14 that prohibits import of hazardous waste.
- Article 15 that provides rules on handling of hazardous substances.
- Article 16 that provides regulations on motor vehicles.
- Article 17 that prohibits various acts detrimental to the environment.

The main features of the KP Act 2014 are discussed in **Exhibit 2.1**.

Exhibit 2.1: Khyber Pakhtunkhwa Environmental Protection Act 2014

Purpose	To provide for the protection, conservation, rehabilitation and improvement of the environment, for the prevention and control of pollution, and promotion of sustainable development
Definition of *Adverse Environmental Effect*	pollution or Impairment of, or damage to, the environment, and includes,— i. impairment of, or damage to, human health and safety or to property or biodiversity; ii. pollution to physical, biological, social, economic environment or to geological, hydrological resources or various land forms; iii. damage to public comfort, aesthetic conditions, ecological balance and meteorological conditions; iv. damage to aquifers, vegetal canopy, cultural heritage or archeological sites; and v. any other adverse environmental effect as may be specified in the rules
Definition of *Air Pollutant*	Any substance that causes pollution of air and includes soot, smoke, dust particles, odor, light, electro-magnetic radiation, heat, fumes, combustion exhaust, exhaust gases, noxious gases, hazardous substances and radioactive substances;
Definition of *Biodiversity or Biological Diversity*	The variability among living organisms from all sources, including inter-alia terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part, includes diversity within species, between species and of eco-systems;
Definition of *Environment*	i. air, water and land; ii. all layers of the atmosphere; iii. all organic and inorganic matter and living organisms; iv. the ecosystem or flora and fauna, and ecological relationships; v. buildings, structure's, roads, facilities, installations and works; vi. all social or cultural and economic conditions and activities affecting community life; and vii. the inter-relationships between any of the factors specified in sub-clauses (i) to (vi)
Definition of *Hazardous Waste*	The waste which contains hazardous substances or as may be prescribed and includes healthcare risk wastes and radioactive waste
Definition of *Hazardous Substance*	i. a substance or mixture of substances, except the pesticide as defined in the Agricultural Pesticides Ordinance, 1971 (II of 1971), which, by reason of its physical, chemical or biological properties or toxic, explosive, flammable, corrosive, infectious, radioactive, persistent or having any other characteristics as may be prescribed, or is likely to cause, directly or in combination with other substances, an adverse environmental effect; and ii. any substance which may be prescribed as a hazardous substance;

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Definition of *Discharge*	Spilling, leaking, pumping, depositing, seeping, releasing, flowing out, pouring, emitting, emptying or dumping;
Definition of *Ecosystem*	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit;
Definition of *Effluent*	Any material in solid, liquid or gaseous form or combination thereof being discharged from industrial activity or any other source and includes a slurry, suspension or vapour;
Definition of *Industrial Activity*	Any operation or process for manufacturing, making, formulating, synthesizing, altering, repairing, crushing, grinding, cleaning ornamenting, finishing, packing or otherwise treating any article or substance with a view to its use, sale, transport, delivery or disposal, or for mining, for oil and gas exploration and development, or for pumping water or sewage, or for generating, transforming or transmitting power or for any other industrial or commercial purposes;
Definition of *Industrial Waste*	Waste resulting from an industrial activity;
Definition of *Pollution*	The contamination of air, land or water by the discharge of emission of effluent or wastes or air pollutants or noise or other matter which either directly or indirectly or in combination with other discharges or substances alters unfavorably the chemical, physical, biological, radiational, thermal or radiological or aesthetic properties of the air, land or water or which may, or is likely to make the air, land or water unclean, noxious or impure or injurious, disagreeable or detrimental to the health, safety, welfare or property of persons or harmful to biodiversity;
Definition of *Noise*	The intensity, duration and character of sound from all sources, and includes vibration;
Definition of *Sewage*	Liquid or semi-solid wastes and sludge from sanitary conveniences, kitchens, laundries, washing and similar activities and from any sewerage system or sewage disposal works;
Definition of *Waste*	Substance or object or material which has been, is being or is intended to be, discarded or disposed of, and includes liquid waste, solid waste, waste gases, suspended waste, industrial waste, agricultural waste, radioactive and nuclear waste, mist, animal waste, electronic waste, municipal waste, hospital waste, pharmaceutical waste, plastic and polythene waste and residues from the incineration of all types of waste.
Definition of *Climate Change*	A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods;
Definition of *Emission*	The extent of pollutant's discharges per unit time or the extent of pollutant per unit volume of gas, liquid or vapor emitted
Definition of *Factory*	Any premises in which industrial activity is being undertaken;
Functions of the Agency	Administer and implement the provisions of this Act and the rules made there under;
	Prepare, in coordination with the appropriate Government Agency or local council and in consultation with the concerned sectoral Advisory Committees where established, environmental policies for the approval of the Council

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	Prepare, revise and establish the Khyber Pakhtunkhwa Environmental Quality Standards with the approval of the Council: Provided that before seeking approval of the Council, the Agency shall publish the proposed Khyber Pakhtunkhwa Environmental Quality Standards for public opinion in accordance with the prescribed procedure;
	Ensure enforcement of the Khyber Pakhtunkhwa Environmental Quality Standards; resources, solid waste management and water sanitation
	Establish standards for the quality of the ambient air, water and land, by notification establish different standards for discharge or emission from different sources and for different areas and conditions as may be necessary: Provided that- (a) where these standards are less stringent than the Khyber Pakhtunkhwa Environmental Quality Standards prior approval of the Council shall be obtained; and (b) list of areas, with the approval of the Council, in which any class of activities or projects shall not be carried out or shall only be carried out subject to certain specified safeguards;
	Co-ordinate with other Provinces, Federal Government, National and International Organizations for the implementation of environmental policies, issues concerns and programs as may be prescribed
	Co-ordinate and facilitate the Government departments, agencies, organizations and institutions in the Khyber Pakhtunkhwa in adaptation to address the impacts of climate change;
	Establish systems and procedures for surveys, surveillance, monitoring, measurement, examination, investigation, research, inspection and audit to prevent and control pollution, and to estimate the costs of cleaning up pollution and rehabilitating the environment in various sectors
	Carry out and conduct environmental monitoring and implementation of environmental approvals provided in this Act;
	Carry out and conduct environmental audits of old industrial units in accordance with rules(Old industrial units means those established before the commencement of this Act)
	Issue licenses for the consignment, handling, transport, treatment, disposal, storage, handling or otherwise dealing with hazardous substances;
	Assist Government Agencies, local councils, local authorities and other persons to implement schemes for the proper disposal of wastes so as to ensure compliance with the Khyber Pakhtunkhwa Environmental Quality Standards
	Provide information and guidance to the public on environmental matters
	Specify safeguards for the prevention of accidents and disasters which may cause pollution, collaborate with the concerned

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	persons in the preparation of contingency plans for control of such accidents and disasters, and co-ordinate implementation of such plans;
	Review and approve mitigation plans and give guidance and directions, where necessary, for cleanup operations ordered under this Act
Prohibition of certain discharges or emissions	(1) Subject to the provisions of this Act, rules, notifications and guidelines made thereunder i. no person shall discharge or emit or allow the discharge or emission of any effluent or wastes or air pollutant or noise, load, concentration or level which is in excess of the Khyber Pakhtunkhwa Environmental Quality Standards or, where applicable, the standards established under sub clause (vii) and (viii) of sub-section (1) of section 6; and ii. No person shall discharge effluents, emissions or wastes in excess of load permitted in the conditions of environmental permit or environmental approval or license. (2) The Agency, with the approval of Government, may levy a pollution charge on any person who contravenes or fails to comply with the provisions of sub-section (1), to be calculated at such rate, and collected in accordance with such procedure as may be prescribed. (3) Any person who pays the pollution charge levied under sub-section (2), shall not be charged with an offence with respect to that contravention or failure.
Initial Environmental Examination and Environmental Impact Assessment	1) No proponent of a project shall commence construction and operation unless he has filed with the Agency an initial environmental examination or where the project is likely to cause an adverse environmental effect, an environmental impact assessment, and has obtained from the Agency, environmental approval in respect thereof. (2) The Agency shall (a) review the initial environmental examination and accord its approval or require submission of an environmental impact assessment by the proponent; or (b) review the environmental impact assessment and accord its approval subject to such conditions as it may deem fit to impose, require that the environmental impact assessment be resubmitted after such modifications as may be stipulated, or reject the project as being contrary to environmental objectives. (3) Every review of an environmental impact assessment shall be carried out with public participation and no information will be disclosed during the course of such public participation which relates to: (a) trade, manufacturing or business activities, processes or techniques of a proprietary nature, or financial, commercial, scientific or technical matters which the proponent has requested should remain confidential, unless for reasons to be recorded in writing, the Director-General of the Agency is of the opinion that the request for confidentiality is not well-founded or the public interest in the disclosure outweighs the possible prejudice to the competitive position of the project or its proponent; or (b) International relations, national security or maintenance of law and order, except with the consent of Government; or

	(c) Matters covered by legal professional privilege. (4) The Agency shall communicate its approval or otherwise within a period of four months from the date of the initial environmental examination or environmental impact assessment is filed complete in all respects in accordance with the prescribed procedure, failing which the initial environmental examination or, as the case may be, the environmental impact assessment shall be deemed to have been approved, to the extent to which it does not contravene the provisions of this Act and the rules, provided that delay is not on part of the proponent for the provision of additional information asked for during the review process or conductance of public hearing of the project. (5) Subject to sub-section (4), Government may in a particular case extend the aforementioned period of four months if the nature of the project so warrants. (6) The provisions of sub-sections (1), (2), (3), (4) and (5) shall apply to such categories of projects and in such manner as may be prescribed. (7) The projects or any activity of a proponent not covered under sub-section (6), specified in guidelines shall obtain a general environmental approval in a manner prescribed in guidelines in respect thereof. (8) The Agency shall maintain separate Registers for initial environmental examination and environmental impact assessment projects, which shall contain brief particulars of each project and a summary of decisions taken thereon, and which shall be open to inspection by the public at all reasonable hours and the disclosure of information in such Registers shall be subject to the restrictions specified in sub-section (3).
Handling of Hazardous Substances	Subject to the provisions of this Act, no person shall generate, collect, consign, transport, treat, dispose of, store, handle, deal in and use or import any hazardous substance except— (a) under a license issued by the Agency and in such manner as may be prescribed; or (b) in accordance with the provisions of any other law for the time being in force, or of any International Treaty, Convention, Protocol, Code, Standard, Agreement or other instrument to which Pakistan or the Province of the Khyber Pakhtunkhwa is a party.
Regulation of motor vehicles	(1) Subject to the provisions of this Act, and the rules, notification and guidelines made thereunder, no person shall operate a motor vehicle from which air pollutants or noise are being emitted in an amount, concentration or level which is in excess of the Khyber Pakhtunkhwa Environmental Quality Standards or where applicable the standards established under clauses (vii) and (viii) of sub-section (1) of section 6. (2) For ensuring compliance with the standards mentioned in sub-section (1), the Agency may direct that any motor vehicle or class of vehicles or locomotive shall install such pollution control devices or other equipment or use such fuels or undergo such maintenance or testing as may be prescribed. (3) Where a direction has been issued by the Agency under sub-section (2) in respect of any motor vehicles or class of motor vehicles, or locomotives, no person shall operate any such vehicle till such direction has been complied with.

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2.1.3 Preparation and Submission of EIA

Article 13 of KP Act states that "No proponent of a project shall commence construction and operation unless he has filed with the Agency an initial environmental examination (IEE) or where the project is likely to cause an adverse environmental effect, an environmental impact assessment (EIA), and has obtained from the Agency, environmental approval in respect thereof".

Hydroelectric power generation projects with capacities greater than 50 MW require an EIA as per the categorization of the IEE-EIA Regulations 2000. The law requires that the EIA must be submitted and approved by the provincial EPA before any construction activities can commence.

2.2 Environmental Standards

2.2.1 National Environmental Quality Standards

KP EPA is yet to formulate the *Khyber Pakhtunkhwa Environmental* Quality Standards (KPEQS) as per Article 6 (v) of the KP Act 2014. So, the National Environmental Quality Standards (NEQS) will be applicable to the Project. Article 11(1) of the PEPA 1997 states that

"Subject to the provisions of this Act and the rules and regulations made thereunder no person shall discharge or emit or allow the discharge or emission of any effluent or waste or air pollutant or noise in an amount, concentration or level which is in excess of the National Environmental Quality Standards."

NEQS have been established for gaseous emission, liquid effluent, ambient air quality, noise and drinking water. From the date of enforcement of the NEQS, all projects, whether in operation on the date or constructed later, are required to comply with these standards.

The Project needs to comply with all applicable standards, and Project proponents and contractors should ensure that no activity will result in the emission of pollutants and effluents exceeding limits as prescribed in the NEQS. The applicability of the NEQS to the Project is described in **Exhibit 2.2**. The complete set of NEQS are included in **Appendix A**.

Exhibit 2.2: NEQS Applicable to the Project

NEQS	*Applicability During Construction*	*Applicability During Operation*
Gaseous Emission	All power generators	Any back-up generator
Noise emission	All noise sources	Not applicable
Emission from motor vehicles	All project vehicles	All project vehicles
Noise from motor vehicles	All project vehicles	All project vehicles

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NEQS	Applicability During Construction	Applicability During Operation
Ambient air quality	Changes in air quality of the surrounding area due to construction activities	Not applicable
Liquid effluent	Sanitary waste and other liquid waste discharged to the environment	Sanitary waste and other liquid waste discharged to the environment
Drinking water	Water supplied by the owners and contractors to staff	Water supplied by the owners and contractors to staff

2.3 Other Environmental Laws

2.3.1 Land Acquisition Act 1894

The national law governing land acquisition is the Land Acquisition Act 1894 (LAA 1894) and successive amendments to it. The LAA 1894 regulates the land acquisition process and enables the government to acquire private land for public purposes through the exercise of the right of eminent domain. Land acquisition is a provincial responsibility in Pakistan and provinces also have their own province-specific implementation rules.

The LAA 1894 and its implementation rules require that, following an impact identification and valuation exercise, land and crops are compensated in cash at the current market rate to titled landowners. In past practice land acquisition was usually based on the last 3 to 5 years average registered land–sale rates. However, in several recent cases like Faisalabad Khanewal motorway project and the Expressway 35 project, the median rate over the past 1 year, or even the current rates have been applied. Under section 23 of LAA 1894 and its amendments, in addition to the market–value of the land a sum of 15% of the amount as compulsory acquisition surcharge is also paid to the affected persons (APs), if the acquisition has been made for public purpose and a sum of 25% on such market–value if the acquisition has been made for a Company. The APs, if not satisfied, can go to the Court of Law to contest the compensation award of the LAC.

The various sections relating to the land acquisition are briefly discussed below and summarized in **Exhibit 2.3.**

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Exhibit 2.3: Key Feature of the LAA 1894

Section	Actions [Person Responsible]	Purpose and Effect
4	▶ Publication in the official gazette of a notification that a "land in any locality is needed or is likely to be needed for any public purpose or for a Company" [Collector] ▶ Public notice of the substance of such notification at convenient places in the said locality [Collector]	Allows preliminary investigation. In affect it demonstrates the interest of the government that the "land in any locality is needed or is likely to be needed for any public purpose or for a Company" Allows the Collector to authorize persons to enter, and where necessary, clear the land to: survey the land; undertake soil and other studies for determining the suitability of the land; measure land and demarcate boundaries by placing markers.
5 and 5A	▶ Publication in the official gazette by the government a) the intention of the government that any particular land included in Section 4 notification is needed for public purposes or for a Company, b) the administrative location of the land, c) the purpose of land acquisition, d) its approximate area, and e) location where the development plan for the land, if required, is available for public inspection, if required, [DC, if land required for public purposes or the provincial government if land required for a Company] ▶ Public notice of the substance of such notification at convenient places in the said locality Collector	Notifies the intention of the government to acquire land for the particular purpose in order to give opportunity to the interested persons (persons who would be entitled to claim an interest in compensation if the land were acquired) to file an objection to the land acquisition. The objection can be filed within 30 days.
6	▶ The Collector, if satisfied after reviewing the report made under section 5–A, subsection (2), will make a declaration in the official Gazette with conclusive evidence, stating that particular land is required for public/private purpose. The declaration will include the location of the land, the purpose and its approximate area. ▶ The declaration shall be made only after ensuring that the compensation is to be paid by the company.	Provides the declaration from the collector for the purchase of required land. Declaration is published and communicated to the public in large to notify the acquisition of land including its location, area and purpose.
7	▶ After declaration under Section 6 Collector, to take order for the acquisition of the land.	Official orders are given by the [Executive District Officer (Revenue)], directing the Collector, to initiate the formal land acquisition process.
8	▶ If the required land is not demarcated under section 4, the Collector, will give orders to mark, measure and plan out the required land.	Demarcation of required land as per the exact requirement of the project.

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Section	Actions [Person Responsible]	Purpose and Effect
9	▸ The Collector to issue public notice at convenient places on or near the land to show intentions for acquiring required land and inviting to file claims for compensation, objections to measurements etc., indicating date, time and place for all the land owners, indicating such date not earlier than 15 days. ▸ The Collector also to serve notice, by post, to the occupier or to the known land owners (if any), residing within the revenue district or elsewhere. ▸ The Collector shall also serve notice, not less than 15 days prior to the date fixed under sub–section (2) of section 9, to the land owners about the inquiry to be held under section 11 for determination of claims and objections.	To inform the land owners and public at large, well ahead the time, about the acquisition of the demarcated land to ensure that interested persons are given sufficient time to object or claim.
10	▸ The collector will also require and send a notice to any other interested person (co–proprietor, sub–proprietor, mortgagee, tenant or otherwise) with interest/claim pertaining to the required land. ▸ Any person claiming any interest under this section or section 9 will be bound to do so within the meaning of section 175 and 176 of Pakistan Penal Code.	To ensure that there are no financial discrepancies left unaddressed during the process of land acquisition and every person associated with the land is duly informed and their objection/claims are appropriately addressed.
11	▸ On the fixed date, the Collector to enquire into the claims and objections of interested persons with regard to measurements made under section 8, value of the land (at the date of the publication of the notification under section 4, sub–section (1) and respective claims. The Collector can make an award (under his jurisdictions) of true area of the land, compensation which in his opinion should be allowed for the land and the distribution of the compensation among all the known or believed to be interested in the land, whether they have appeared before him or not.	To determine the actual land owners and precise measurements of the required land. This section also ensures that the compensation paid is true representation of the value of land. To ensure that the compensation is fairly distributed among all the owners of the land.

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Section	Actions [Person Responsible]	Purpose and Effect
12	▶ The award filed in the Collector's office shall be deemed conclusive, whether the interested persons have appeared before the Collector or not. ▶ The Collector shall issue immediate notice of the award to the land owners whether they have appeared personally or by their representatives when the award is made.	To avoid potential future conflicts between the government and the owners of the land. This ensures that the decision made by the collector is final. To convey complete information in a timely manner to the land owners. This section ensures that the land owners have complete information on the award irrespective of their presence in Collector's office.
12 –A	▶ The Collector can rectify any mistake (typographical, arithmetical errors) in the award by his own motion or on the application of any of the parties.	To ensure that there are no errors or mistakes in the award or the assessment of the land. This ensures that the measurement and valuation of the land is done justly.
13	▶ The Collector may conduct or discontinue and reschedule the enquiry for any reason, any day/time fixed by him.	To implement check and balance on the system. This ensures sense of responsibility on the government officers.
14	▶ The Collector is empowered by this section to call, and enforce the attendance of witnesses, including the interested parties or any of them to produce the documents by the same means, and in the same manner as provided the case of a Civil Court under the Code of Civil Procedures.	To avoid future conflicts and increase transparency in the land acquisition process. To ensure that only the rightful legal owners who have proper documents are paid the award and no illegal claims are entertained.
15	▶ The Collector shall be guided by section 23 and 24 in determining compensation.	
16	▶ Under this section, the collector may take possession of the land, after the compensation paid to the owner of the land or deposited in the Civil Court in his name by the acquisitioning authority and the required land, shall then be granted to the government without any further claim.	To ensure smooth transfer of land rights from the owner to the acquisitioning authority. This gives security to the acquiring authority that once the award is paid in full, the Collector will take the possession of the land.

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2.3.2 Key Biodiversity Laws

There are a number of other laws in the statute books of Pakistan which have a bearing on the environmental performance of the Project. The three primary laws are described in **Exhibit 2.4.**

Exhibit 2.4: Three Key Laws Relevant to the Project

Law	*Description*	*Applicability to the Project*
The Khyber Pakhtunkhwa Forest Ordinance, 2002	This Act authorizes provincial forest departments to establish forest reserves and protected forests. The Act prohibits any person from: setting fires in the forest; quarrying stone; removal of any forest produce; or causing any damage to the forest by cutting trees or clearing areas for cultivation or any other purpose without express permission of the relevant provincial forest department.	Based on a discussion with locals the Project area does not include any land owned by the Forest Department, KP.
The Khyber Pakhtunkhwa Wildlife and Biodiversity (Protection, Preservation, Conservation and Management) Act, 2015	This law was enacted to protect the province's wildlife resources directly and other natural resources indirectly. It classifies wildlife by degree of protection, i.e., animals that may be hunted on a permit or special license, and species that are protected and cannot be hunted under any circumstances. The Act specifies restrictions on hunting and trade in animals, trophies, or meat. The Act also defines various categories of wildlife-protected areas, i.e., National Parks, Wildlife Sanctuaries, and Game Reserves.	Based on a discussion with staff from the Fisheries Department, KP the Arkari Gol does not include any Protected Areas.
NWFP Fisheries Rules 1976	This law prohibits destruction of fish by explosives, poisoning water and the hunting of protected fish species. The law also forbids the use of net or fixed engine traps without a permit or license. The law grants power to the Director General (DG) Fisheries to issue permits to catch fish. It protects fish against 1) Destruction of fish by explosives, and 2) Destruction of fish by poisoning water.	This law is applicable to the Project as there is a possibility of catching fish as sustenance by the Project staff and also makes it obligatory to obtain a license from the fisheries department before commencing any fishing activities.

2.3.3 Other Laws

In addition to the laws cited above, a number of other laws were reviewed for provisions that can affect the environmental and social performance of this Project. A list is provided in **Exhibit 2.5**. These were reviewed and the results of the review are provided in this section, in particular information about their potential to impact the Project.

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Exhibit 2.5: Other Laws Reviewed

Antiquities Act, 2016	Industrial Relations Act, 2010
Delimitation of Local Councils Act, 2015	Forestry Commission Act, 1999
Environmental Protection Act, 2014	Irrigation and Drainage Authority Act, 1997
Factories Act, 2013	Minimum Wages Act, 2013
Forest Ordinance, 2002	Payment of Wages Act, 2013
Industrial and Commercial Employment (Standing Orders) Act, 2013	Rivers Protection Ordinance, 2002
Energy Development Organization Act, 1993	Worker's Compensation Act, 2013
Integrated Water Resources Management Board Ordinance, 2002	The Khyber Pakhtunkhwa Local Government Act, 2013
Prohibition of Employment of Children Act, 2015	The West Pakistan Firewood and Charcoal (Restriction) Act, 1964
Protection of Trees and Brushwood Act, 1949	Wildlife and Biodiversity (Protection, Preservation, Conservation and Management) Act, 2015
Rural Drinking Water Supply Scheme Act, 1985.	
The Khyber Pakhtunkhwa Right to Information Act,2013	

Energy Development Organization Act, 1993

The Pakhtunkhwa Energy Development Organization (PEDO) is granted authority by this Act to develop the energy resources in KP. Under this Act, development of hydropower is transferred to PEDO.

Forest Ordinance, 2002

The Forest Ordinance, 2002 has been instated to protect, conserve, manage and sustainably develop forests and other renewable natural resources. The ordinance empowers the government to declare any forest land as reserved or no longer reserved, designate reserve forests for village communities to use, declare forest land or wasteland as Protected Forests or remove protected status, control Guzara Forests, Mazri and Mazri produce, as well as timber and timber produce. Under the ordinance the government is granted powers of forest management, with authority given to forest officers. The government, through its officers, has the right to exercise penalties on violations on prohibitions as laid out in the ordinance.

Certain plant species are protected under the Act when found in reserved forests, protected forests and protected wastelands. A list of these species is provided in Schedule I of the Act.

The Project will not impact Reserve Forests, Protected Forests, Village Forests or Guzara Forests. It is important to ensure that Project-related activities do not encroach on any of

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the above-mentioned types of forests. It is also important that Project staff not engage in the collection or trade of forest produce. The area has very limited forest cover, therefore, this unlikely to be a concern.

Forest Development Corporation Ordinance, 1980

The Forest Development Corporation has been established under this ordinance. The corporation functions to "make suitable arrangements for the

(i) economic and scientific exploitation of forests;

(ii) sale of forest produce;

(iii) establishment of primary wood-processing units;

(iv) regeneration in areas to be specified by Government; and

(v) performance of such other functions as may be assigned to it by Government."

The Project will not be impacted by this ordinance. It should be ensured that Project staff do not engage in activities that are under the jurisdiction of this corporation for example in the trade of forest products.

Forestry Commission Act, 1999

The Act is aimed at establishing a Forestry Commission to improve the protection, management sustainable development of forests in KP. Under this Act the Commission established is empowered and entrusted to further this aim by taking steps such as giving vision and a framework for the sustainable development of forests in KP, guiding and overseeing the process of institutional and legislative reforms in the Department, advocating policies for sustainable development of forests etc. The Project will not be impacted by this Act, however, any initiatives undertaken by the Commission may be of interest to the Project for biodiversity management and mitigation.

Protection of Trees and Brushwood Act, 1949

The Act provides protection for trees and brushwood. Under this Act it is illegal to clear trees and brushwood belonging to the local government. Project-related activities should only be undertaken on land acquired for the Project. They should not clear trees or brushwood outside the acquired area.

Wildlife and Biodiversity (Protection, Preservation, Conservation and Management) Act, 2015

The Act has been instated to consolidate the laws relating to protection, preservation, conservation and management of wildlife in KP. Its aims include the following:

"(a) strengthening the administration of the organization[1] to effectively manage wild animals and their habitats;

(b) to holistically manage Protected Areas in a sustainable manners for the best interest of the indigenous communities and local stakeholders;

[1] Wildlife Department, KP

(c) securing appropriately the goods and services produced from wild animals and their habitats at the level of local communities;

(d) fulfilling the obligations envisaged under the biodiversity related multilateral environmental agreements ratified by the Government of Pakistan;

(e) promotion of public awareness and capacity building for proper appreciation of the environmental significance and socio-economic values of wildlife; and

(f) conservation of biological diversity and realization of its intrinsic and extrinsic values through sustainable use and community participation."

The Act empowers Wildlife Officers to enforce the laws relating to wildlife conservation and management and to use reasonable force to do so, if necessary. It places restrictions on hunting, possession and display of wildlife, trade and trafficking of wildlife or wildlife products, and protected areas. Wildlife offences and penalties for those offences are provided in the Act.

The Project and Project-related activities will be affected by the Act if there is violation of the rules pertaining to wildlife. This will be the case if staff engage in activities prohibited under the Act such as hunting, possession and display of wildlife, trade in wildlife and wildlife products, introduction of alien invasive species and so on. To ensure compliance with law, staff should report any wildlife sightings to the concerned government department.

Rivers Protection Ordinance, 2002

The ordinance has been instated to provide for the protection of aquatic ecology, water quality, economic and environmental value of rivers and their tributaries in KP. The ordinance has been instated keeping in view the increasing developments along rivers in KP and the need to maintain the quality of the rivers for public use. The rules set out will be applicable on any length of a particular river or stream or any part of a river or its tributary that has been specified by the Government. The Project is a hydropower project being developed on the main Arkari Gol. If the Government of KP designates the Arkari Gol or specifically a stretch of the Arkari Gol which includes the stretch to be used by the Project, then the rules set out in this ordinance will be applicable.

The rules laid out in the ordinance relate mainly to encroachment onto the river and pollution of the river. It is important that Project-related activities do not pollute the river and that all construction activities along the river banks be carried out within the area designated for them.

Integrated Water Resources Management Board Ordinance, 2002

The Integrated Water Resources Management Board has been established to devise and oversee the implementation of an integrated water resources management strategy aimed at sustainable economic, social and environmental returns on water resource development. Under the ordinance a Board has been established, the functions of which include conducting studies to accurately assess the various demands of water for consumptive or non-consumptive use. This includes the use of water resources for hydropower itself, as well as areas that will potentially be affected by the Project such as

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fisheries, water-related sports, environmental sustainability, forestry, lakes and water bodies etc.

The Project will be affected by this ordinance as it is impacting the flow of the Arkari Gol. Any policies, rules and procedures put in place by the Board need to be complied with. In addition to this studies conducted as part of this assessment should be shared with the Board.

Rural Drinking Water Supply Scheme Act, 1985

The Act has been instated to facilitate the execution of schemes for supply of drinking water in rural areas. Project-related activities should not disrupt any schemes established under this Act. As long as Project-related activities take place within the land acquired for the Project, this law will not affect the Project.

Irrigation and Drainage Authority Act, 1997

The Act addresses the irrigation and drainage system in KP by requiring the adoption of a strategy for streamlining it. It includes the implementation of policies in the water resources sector to improve and sustainably develop supply for irrigated agriculture along with operating and maintaining irrigation, drainage, storage reservoirs and flood control infrastructure in KP. The Project will not be affected by the Act if it does not affect the irrigation system in KP. Irrigation is not expected to be impacted by the Project.

The West Pakistan Firewood and Charcoal (Restriction) Act, 1964

The Act prohibits the burning of firewood and charcoal in factories, brick-kilns, limekilns and other specified places. The Project can be considered a factory under the definition provided in the Act. The Project owner and developer should ensure that no burning of firewood and charcoal is carried out in premises under its control.

Antiquities Act, 2016

The Antiquities Act, 2016 is applicable to the Project. Chapter IV, Clause 56 'Execution of mega project' requires a clearance to be obtained from the Director (as defined in the Act) before construction of a dam. Chapter VI, Clause 70, 'Regulation of mining, quarrying, etc.' gives the Director authority to prohibit mining, quarrying, excavation, blasting and movement of heavy vehicles for the purpose of protecting or preserving any immovable antiquity.

Factories Act, 2013

The Factories Act, 2013 provides for the regulation of labor in KP. A factory is defined as "...any premises, including the precincts thereof, whereon ten or more workers are working, or were working on any day of the preceding twelve months, and in any part of which a manufacturing process is being carried on or is ordinarily carried on with or without the aid of power, but does not include a mine, subject to the operation of the Mines Act, 1923 (Act No. IV of 1923);" Based on this definition, the Act is applicable to the Project.

The Act regulates a range of conditions relating to labor. These include health and safety, restrictions on working hours of adults, holiday with pay, and special provisions for adolescents with children. It also provides for government inspection staff to function as directed by the government, penalties and procedures relating to violations of the Act as

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well as supplemental information for staff (such as display of factory notices, removal of difficulties, protection against discrimination etc.). The Project needs to comply with the requirements under these regulations.

Industrial and Commercial Employment (Standing Orders) Act, 2013

The Industrial and Commercial Employment (Standing Orders) Act, 2013 provides for the regulation of industrial and commercial employment in KP. It provides a list of standing orders for workers in the province. These include classification of workers based on types of contracts, identification of workers, the requirement for documenting terms and conditions, publications of working times, publication of wage rates, shift working, payment of wages, incentive schemes, insurance, bonuses, stoppage of work, closure of establishment, termination of employment, punishments, liability of the employer, amongst others.

The Project is required to comply with the clauses in this Act. The terms and conditions for the workers need to be published and all matters related to agreements between workers and the developer, outlined in the Act, need to be documented and adhered to.

Prohibition of Employment of Children Act, 2015

The Act has been instated to prohibit the employment of children and to regulate the employment of adolescents in KP. The Project will be impacted by the Act only if it employs children under the age of 14. The Project should not employ children or adolescents for any Project-related activities. Under the Act, staff designated by the government, can inspect the Project facilities to ensure compliance with its rules. The inspector may require the establishment to provide evidence of age of staff in case of dispute over age.

Industrial Relations Act, 2010

The Act has been instated to regulate relationships between workers and employers. It outlines the rights and responsibilities of the workers and the employer. For example, workers and employers can, without distinction, establish and join associations of their own choice. Every trade union and employer's association shall frame its own constitution and rules to elect its representatives.

The owners and developers of the Project need to ensure that no unfair conditions are placed on labor in terms of employment practices. The workers also must not partake in any unfair labor practices. Furthermore, under the Act, participation of workers in management is important. Under the Act the government can appoint an inspector to ensure compliance with provisions of the Act. The Act also provides for penalties in case of violations of provisions in the Act.

Minimum Wages Act, 2013

The Act provides for the regulation of minimum rates of wages and various allowances for different categories of workers employed in certain industrial and commercial undertakings and establishments. The Project needs to ensure that all workers are paid at least minimum wages. If this is ensured, the Act will not affect the Project.

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Payment of Wages Act, 2013

The Act regulates the payment of wages to persons employed in factories, industrial establishments and commercial establishment in KP. The Project can be considered a factory under the definition in the Act. Therefore, it needs to comply with the provisions of the Act by ensuring payment of wages by all responsible people.

Worker's Compensation Act, 2013

The Act provides for workers or their legal heirs compensation for injury or death by accident. The Project owner will be liable to provide compensation if personal injury is caused to a worker by accident during the course of his employment.

The Khyber Pakhtunkhwa Local Government Act, 2013

The Act has been instated to construct and regulate local government institutions in KP and to consolidate laws relating to these institutions. The Act defines the functions and powers of various heads of local government such as District Councils, Villages, City Districts etc.

The local government is a stakeholder with whom the Project needs to coordinate. Any changes in the organization, powers and functions of the local government, directed by the Act, can affect the Project.

Delimitation of Local Councils Act, 2015

The Act mainly concerns the defining of local councils by providing for the delimitation of village councils, neighborhood councils and territorial wards for general seats to tehsil councils, and district councils, for elections to local councils in KP. The Act may affect the Project if there is a change in the delimitation of local councils.

The Khyber Pakhtunkhwa Right to Information Act, 2013

The Act provides for ensuring transparency and access to information in KP. The Project is a public sector Project, therefore, it needs to provide information to the public and not compromise transparency under this Act.

2.4 Federal and Provincial Conservation Strategies

Pakistan National Conservation Strategy (PNCS)[2] was prepared jointly by the then federal Ministry of Environment with assistance from the International Union for the Conservation of Nature (IUCN). It was approved by the federal cabinet in 1992 as the basic policy document on environmental sustainability.

The Sarhad Provincial Conservation Strategy (SPCS)[3] was prepared by the Government of KP with assistance from IUCN. It was approved by the provincial cabinet in 1996 and was considered a sustainable development action plan for the KP.

Both these documents are no longer used for planning purposes and as such are obsolete as a policy document. However, they can be used where relevant as a guideline.

2 The Pakistan National Conservation Strategy, 1992.

3 The Sarhad Provincial Conservation Strategy, 1996, Government of North West Frontier Province in collaboration with IUCN–The World Conservation Union.

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National Sustainable Development Strategy, 2012 (NSDS): The NSDS envisions the evolution of a just and harmonious society via the promotion of vibrant and equitable economic growth without the over-exploitation of natural resources and the fair distribution of development dividends to all, in particular marginalized, poor, and vulnerable in society and to future generations. The strategy is aligned with the emerging concept of 'green economy' as an alternate to the Framework for Economic Growth (2011), prepared by the Planning Commission of Pakistan.

National Climate Change Policy (2012): The National Climate Change Policy, approved by the Government in 2012 has the overall goal 'to ensure that climate change is mainstreamed in the economically and socially vulnerable sectors of the economy and to steer Pakistan towards climate resilient development'. One of the major objectives of this policy is conservation of natural resources and long term sustainability further elaborated through specific measures under forestry, biodiversity, and other vulnerable ecosystems. With respect to forestry, the National Climate Change Policy (NCCP) outlines the need to restore and enhance Pakistan's forest cover under sustainable forest management to 'withstand present and probable future impacts of climate change.' Biodiversity-related policy measures include setting national biodiversity indicators and provision of requisite financial resources for implementation of the BAP (2000).

To support the Climate Change Policy, in 2013 the Government prepared a Framework for Implementation of the Climate Change Policy (2014-2030) which lists priority, short-term, medium-term and long-term actions to be implemented in various sectors including forestry.

2.5 Institutional Framework

The success of environmental assessments as a means of ensuring that development projects are environmentally sound and sustainable depends in large measure on the capability of regulatory institutions for environmental management. The institutional framework for decision-making and policy formulation in environmental and conservation issues is briefly described below.

The Khyber Pakhtunkhwa Environmental Protection Agency (KP EPA) is primarily responsible for administering the provisions of the KP Environmental Protection Act, 2014. The institutional framework for decision-making and policy formulation in environmental and conservation issues is summarized in **Exhibit 2.6.**

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Exhibit 2.6: Institutional Responsibilities

Agency	*Law*	*Functions*	*Relevance to the Project*
KP Environmental Protection Agency and KP Environmental Protection Council	KP Environmental Protection Act 2014	Enforcement of provisions of the KP Environmental Protection Act 2014 in KP	KP-EPA has the key jurisdiction in the context of environmental protection over the Project
National Electric Power Regulatory Authority (NEPRA)	Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997	Regulating the provision of electric power services, specifically grant licenses for generation, transmission and distribution of electric power. The Act requires the licensee to follow performance standards laid down by the Authority for distribution and transmission of electric power, including safety, health and environmental protection instructions issued by the Authority or any Governmental agency, with the least environmentally harmful supply of electricity.	The Authority requires preparation and approval of EIA from the respective EPA as a condition of grant of generation license. Beyond this the authority has no direct role in environmental management as per current practice.
Provincial Disaster Management Authority KP	National Disaster Management Act (Amended) 2012	The Authority may: lay down policies on disaster management; lay down guidelines to be followed by government; and take such measures for the prevention of disaster or the mitigation or for preparedness and capacity building for dealing with disaster situation as it may consider necessary.	Will be the key agency in case of any natural or human-made emergency and disaster in the Project area.
Fisheries Department, KP	NWFP Fisheries Rules 1976	The Fisheries Department has the authority to enforce the laws and regulations provided in the Fisheries Rules, 1976. This includes regulation of fishing methods using permits and licenses, the species that can be caught and associated penalties for violation of regulations pertaining to wild fish.	All wild fish fauna is under the jurisdiction of the Fisheries Department, therefore, they need to be informed about any impacts on fish fauna and related mitigation measures need to be agreed with them.
Forest Department, KP	The Khyber Pakhtunkhwa Forest Ordinance, 2002. Khyber Pakhtunkhwa Ordinance No. XIX of 2002.	The Forest Department enforces the provisions of the Forest Ordinance, 2002 to meet its objectives which include protection, conservation, management and sustainable development of forests by engaging the community and defining the role of the government.	All forest areas including reserved forests, village forests, protected forests, guzara forests and wastelands, and produce from forests is under the jurisdiction of this department. They need to be

Agency	Law	Functions	Relevance to the Project
			informed about impacts on forests and they need to agree with related mitigation measures.
Wildlife Department, KP	The Khyber Pakhtunkhwa Wildlife and Biodiversity (Protection, Preservation, Conservation and Management) Act, 2015	The Wildlife Department enforces the provisions of the Khyber Pakhtunkhwa Wildlife and Biodiversity Act, 2015 to meet its objectives which include strengthening the administration of the organization to effectively manage wild animals and their habitats, to fulfil the obligations of the government under its commitments to managing biodiversity, and promoting public awareness for the value of wildlife and conservation.	All wildlife is under the jurisdiction of this department. The department needs to be informed of impacts on wildlife and they need to agree to related mitigation measures.
Local Governments	The Khyber Pakhtunkhwa Local Government Act, 2013 Act No. XXVIII	Under this Act the local governments are established and function within the provincial framework. Local areas for local government include villages, neighborhoods, tehsils, towns, districts, and city districts. The Act foresees a role for the district government in environmental management.	The District Administration, if it has enacted any of the procedures for environmental management, will be involved in certain aspects of environmental management of the Project.

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2.5.1 Environmental Protection Agency

The KP EPA was established in 1989. It is a monitoring and regulating agency with the following main functions:

- Administer and implement the KP Environmental Protection Act 2014, its rules and regulations,
- Review the IEE-EIA, including preparation of procedures and guidelines,
- Preparation, revision and enforcement of NEQS (industries, municipalities and vehicular emissions),
- Establish and maintain laboratories, certification of laboratories, for conducting tests and analysis,
- Assist local councils/authorities and government agencies in execution of projects,
- Establish a system for surveys, monitoring, examination and inspection to combat pollution,
- Conduct training for government functionaries and industrial management,
- Provide information and education to the public on environmental issues,
- Publish an annual state of the environment report. Survey qualitative and quantitative data on air, soil, water, industrial/municipal and traffic emissions,
- Take measures to promote environment related research and development activities.

2.5.2 Environmental Protection Council

The Pakistan Environmental Protection Council established in 1984 does not have regulatory power over KP. The KP environmental protection Act 2014 allows for a provincial level environmental protection council which has yet to be established. It will be the highest inter-ministerial statutory body in the province and will be responsible for:

- Formulating environmental policies.
- Overseeing enforcement of environmental law.
- Approval of the NEQS.
- Incorporation of environmental considerations into development plans and policies.

2.5.3 Pakistan Environmental Protection Agency

Regulation 7 of the IEE-EIA.Regulations 2000 pertains to the guidelines. It states that: '(1) The Agency may issue guidelines for preparation of an IEE or EIA or an environmental checklist, including guidelines of general applicability and sectoral guidelines indicating specific assessment requirements for planning, construction and operation of projects relating to a particular sector. (2) where guidelines have been issued under sub-regulation (1), an IEE or EIA shall be prepared, to the extent practicable, in accordance therewith and the proponent shall justify in the IEE or EIA or in environmental checklist any departure therefrom.'

The relevant guidelines are the follows:

- *Policy and Procedures for Filing, Review and Approval of Environmental Assessments,* Pakistan Environmental Protection Agency, September 1997

  These guidelines define the policy context and the administrative procedures that will govern the environmental assessment process, from the project pre-feasibility stage, to the approval of the environmental report. The section on administrative procedures has been superseded by the IEE-EIA Regulations, 2000.

- *Guidelines for the Preparation and Review of Environmental Reports,* Pakistan Environmental Protection Agency, 1997

  These guidelines target the project proponents and specify:

  - The nature of the information to be included in environmental reports
  - The minimum qualifications of the EIA conductors appointed
  - The need to incorporate suitable mitigation measures at every stage of project implementation
  - The need to specify monitoring procedures.

  The terms of reference for the reports are to be prepared by the project proponents themselves. The report must contain baseline data on the project area, detailed assessment thereof, and mitigation measures.

- *Guidelines for Public Consultation,* Pakistan Environmental Protection Agency, May, 1997

  These guidelines support the two guidelines mentioned earlier. It deals with possible approaches to public consultation and techniques for designing an effective program of consultation that reaches out to all major stakeholders and ensures the incorporation of their concerns in any impact assessment study.

- *Guidelines for Sensitive and Critical Areas,* Pakistan Environmental Protection Agency, October, 1997

  The guidelines on sensitive areas are more specific in that they identify the officially notified protected areas in Pakistan, including critical ecosystems, archeological sites, etc., and present checklists for environmental assessment procedures to be carried out inside or in the vicinity of such sites. Environmentally sensitive areas include, among others, archeological sites, biosphere reserves and natural parks, and wildlife sanctuaries and preserves. The guidelines state that the approach recommended in the document should extend to areas in the vicinity of such sensitive and critical sites, although the term 'vicinity' is not explicitly defined.

2.6 Guidelines and Standards of International Financial Institutions

The environmental assessment of the Project and all documents produced as part of it are required to comply with the guidelines and standards of international financial institutions including the Overseas Private Investment Corporation (OPIC). OPIC, in its guidelines on projects funded by it, refers to compliance of projects with the guidelines of the International Finance Corporation (IFC). Therefore, the requirements of OPIC are briefly described in this section followed by a more detailed discussion of IFC's Performance Standards (PSs) and guidelines which are applicable to the Project.

2.6.1 Overseas Private Investment Corporation (OPIC) Guidelines

The Overseas Private Investment Corporation (OPIC) is the United States Government's development finance institution. Its role is to mobilize private capital to help address critical development challenges.

OPIC has an Environmental and Social Policy Statement (ESPS) which details the organization's policy and guidelines on environmental and social issues including environmental and social impacts of development projects and their management. The ESPS provides those applying for OPIC's support ('Applicant') with notice of the general environmental and social requirements that OPIC applies in evaluating prospective projects and monitoring on-going OPIC-supported projects. These environmental and social requirements apply to all projects supported through OPIC insurance, reinsurance, direct loans, or investment guaranties, including support through Financial Intermediaries.

OPIC's ESPS adopts as a standard for the environmental and social review process, the IFC's Performance Standards (PSs) on Social and Environmental Sustainability and Industry Sector Guidelines and any subsequent revisions to those standards (see **Section 2.6.4**). At a minimum, OPIC requires that all projects must meet the PSs, applicable Industry Sector Guidelines, including any revisions issued by IFC, Internationally Recognized Worker Rights, and host country laws, regulations and standards related to environmental and social performance, including host country obligations under international law. OPIC has released an environmental guidance note on hydro-electric projects.[4] The guidelines within it draw on the IFC's PSs and other guidelines that are applicable to hydropower development.

Applicants seeking OPIC support must demonstrate compliance with host country environmental, health, safety and social requirements. Where host country requirements differ from the PSs, Industry Sector Guidelines, and Internationally Recognized Worker Rights, the project is expected to meet whichever is more stringent.

Projects are required to develop and implement a Stakeholder Engagement Plan (SEP) tailored to Project risks and impacts in accordance with the requirements of PS 1. The SEP is required to be included as part of the document(s) submitted to OPIC for disclosure.

4 Overseas Private Investment Corporation, September 2012, Environmental Guidance Renewable Energy – Hydro Projects,

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As part of stakeholder engagement under OPIC's guidelines, applicants are required to provide periodic reports (at a frequency of not less than annually) to Project Affected People on (1) implementation of any ESAP and Remediation Plan and (2) issues that have been identified as of concern to those Project Affected People. Any material changes to the project design, management systems or mitigation measures will also be communicated to Project Affected People. All reports must be in a language and format accessible to the Project Affected People. Applicants investing in Category A projects are required to conduct additional certified third-party audits.

All OPIC-supported projects that have been operational for at least 12 months are required to submit an Annual Self-Monitoring Questionnaire. The questionnaire is one of the tools used by OPIC to indicate compliance with OPIC's policy requirements, including environmental and social requirements. Category A projects also require annual environmental and social reports. Annual environmental and social reports enable OPIC to monitor the performance of the project with respect to environmental, occupational and community health, safety and social issues. At a minimum, the reports include information on the following:

- Results of environmental and social monitoring or sampling activity.
- Compliance with all conditions and covenants in OPIC Agreements.
- Project-related accidents impacting the environment or Project Affected People or resulting in a disability or loss of life.
- Summary of training provided on environment, health, and safety issues.
- Environmental and safety deficiencies identified by the local regulatory authorities as well as any remedial actions taken.
- Community engagement activities.
- Complaints or grievances received from Project Affected People or Stakeholders and actions taken to resolve the issues.

Screening and Categorization

Environmental screening is the process of identifying, at the earliest stage possible, the potential adverse environmental impacts of a proposed project that could preclude OPIC support on categorical grounds. If a project is determined to be categorically prohibited, OPIC will promptly notify the investor that the application cannot be considered for environmental clearance and ultimate project approval.

For projects involving the construction and operation of large dams, OPIC applies screening and environmental assessment criteria that incorporates core values and strategic priorities identified in the November 16, 2000 Report of the World Commission on Dams (WCD). Although there is a lack of consensus on the advisability of adopting all of the guidelines and recommendations contained within the WCD Report, OPIC has adopted and implemented those elements of the WCD policy that inform good public policy and that are within OPIC's capacity to implement.

The Arkari Gol Hydropower Project will have significant adverse environmental impacts that are sensitive (e.g., irreversible, affect sensitive ecosystems, involve involuntary

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resettlement, etc.), and diverse. Therefore, it is categorized as a Category A Project and will require a full scale EIA.

EIAs prepared for hydroelectric and irrigation projects should, at a minimum, address issues cited in the IFC's Application of Environmental Assessment to Large Dam and Reservoir Projects (IFC Procedure for Environmental and Social Review of Projects). OPIC's assessment also includes at least an evaluation of the following factors:

- Hydrological and Limnological Impacts. Impacts on water resources due to impoundments include effects on stream flow; groundwater; surface water quality; potential for increased floods; and potential for alteration of sediment deposition patterns. Additional guidance may be found in WCD Strategic Priority4 (Sustaining Rivers and Livelihoods).
- Catchment Area Impacts. Impacts on terrestrial environments surrounding impoundments include induced seismic and geologic events, impacts on terrestrial wildlife and impacts on downstream aquatic life. Additional guidance may be found in WCD Strategic Priority 4 (Sustaining Rivers and Livelihoods).
- Construction Impacts. Impacts resulting from land use requirements in excess of the dam/reservoir footprint include supportive power structures, worker housing, borrow areas, access roads, power transmission corridors and waste disposal units.
- Air Quality and Global Climate Change Impacts. Impacts evaluated include decomposition of submerged biomass; vehicle and machinery emissions; and potential impacts associated with deforestation and elimination of potential carbon sinks. Additional guidance may be found in WCD Strategic Priority 2 (Comprehensive Options Assessment) and Guideline 8 (Greenhouse Gas Emissions).
- Resettlement. Factors evaluated include public consultation and disclosure procedures; community development planning; livelihoods assessment; potential for income restoration; compensation; and dispute resolution mechanisms. Additional guidance may be found in WCD Guideline 18 (Impoverishment Risk Assessment) and Guideline 19 (Mitigation, Resettlement and Development Action Plan).
- Safety. Factors include structural stability of the dam and the capacity of the spillway(s) to pass flood flows. In the case of high hazard potential dams the analysis must examine the capacity to pass the probable maximum flood and the adequacy of monitoring and warning devices and downstream warning and evacuation procedures. Additional guidance may be found in WCD Strategic Priority 2 (Comprehensive Options Assessment), Strategic Priority 3 (Addressing Existing Dams) and Guideline 11 (Economic Risk Assessment).
- Project Acceptability. Factors include an evaluation of consultation and disclosure procedures; land acquisition process; stakeholder identification; and compliance with local laws and regulations. Additional guidance may be found in WCD Strategic Priority 1 (Gaining Public Acceptance), Strategic Priority 5 (Recognizing Entitlements and Sharing Benefits) and Guidelines 17 (Baseline

Social Conditions), 19 (Mitigation, Resettlement and Development Action Plan) and 20 (Project Benefit-Sharing Mechanisms).

The ESIA must adequately describe potential risks and proposed mitigation measures and include a draft ESAP, draft Remediation Plan (if required) and Stakeholder engagement plan. At a minimum, the Applicant is required to provide a local language translation of the executive summary of the ESIA and make the summary available to Project Affected People in a format that is readily understandable and tailored to meet the information needs of Project Affected People. The translated summary should be distributed by means that take into account the ability of Project Affected People to receive, address and effectively comment on the content. OPIC also discloses this summary on its web site.

2.6.2 International Finance Corporation's (IFC) Environmental and Social Performance Standards on Sustainability

IFC's Environmental and Social Performance Standards are part of the IFC's Sustainability Framework. It applies to all projects financed by IFC and defines the responsibility of project proponents for managing their environmental and social risks. There are eight PS, last released in 2012. Together, they establish standards that the IFC's client are required to meet throughout the project life.

The applicability of these PS is established during the Social and Environmental Impact Assessment process, while implementation of the actions is necessary to meet the requirements of IFC, the PS are managed through the owner's ESMS.

PS 1 Social and Environmental Assessment and Management System

It establishes the importance of integrated assessment to identify the social and environmental impacts, risks, and opportunities in the Project's area of influence. PS 1 requires Social and Environmental Assessment and Management Systems for managing social and environmental performance throughout the life cycle of this Project and runs through all subsequent PSs. The main elements of PS 1 includes the following elements: (i) Social and Environmental Assessment; (ii) Management program; (iii) organizational capacity; (iv) training; (v) community engagement; (vi) monitoring; and (vii) reporting.

The ESIA will be based on the guidelines described in PS 1.

PS 2 Labor and working conditions

This standard requires that worker-management relationship is established and maintained and, compliance with national labor and employment laws and safe and healthy working conditions are ensured for the workers.

The Project will have to adhere to the regulations laid down in the standard for hiring workers during construction and operation, along with performing due diligence for workers in the supply chain for Project materials.

PS 3 Pollution Prevention and Abatement

This standard outlines the approach to pollution prevention and abatement in line with internationally disseminated technologies and practices with objectives to (a) avoid or minimize adverse impacts on human health and the environment by avoiding or minimizing pollution from activities; and (b) promote the reduction of emissions that

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contribute to climate change. It requires a project to avoid, minimize, or reduce adverse impacts on human health and the environment by avoiding or minimizing pollution from project activities.

This PS is applicable to the emissions and effluents resulting from Project activities.

PS 4 Community Health, Safety and Security

PS 4 concentrates on the responsibility that must be undertaken by the client to avoid or minimize the risks and impacts to the community's health, safety and security that may arise from Project activities. This PS is applicable to the Project.

PS 5 Land Acquisition and Involuntary Resettlement

This standard requires that Project does not result in involuntary resettlement or at least if unavoidable it is minimized by exploring alternative Project designs. In addition, the Project will ensure that social and economic impacts from land acquisition or restrictions on affected persons' use of land are mitigated.

The Project includes the acquisition of land which will result in resettlement and loss of livelihood. The associated RAP will conform to the guidelines of IFC PS 5.

PS 6 Biodiversity Conservation and Sustainable Natural Resource Management

This standard aims at protecting and conserving biodiversity, the variety of life in all its forms, including genetic, species and ecosystem diversity and its ability to change and evolve, is fundamental to sustainable development. This PS addresses how clients can avoid or mitigate threats to biodiversity arising from their operations as well as incorporate sustainable management of renewable natural resources. The PS6 defines a Critical Habitat as outlined below.

Critical Habitat is designated by the IFC PS 6[5] and is described as having a high biodiversity value, as defined by:

- Habitat of significant importance to Critically Endangered (CR) and/or Endangered (EN) species;
- Habitat of significant importance to endemic and/or restricted-range species;
- Habitat supporting globally significant concentrations of migratory species and/or congregatory species;
- Highly threatened and/or unique ecosystems; and/or
- Areas associated with key evolutionary processes.

PS 7 Indigenous Peoples

PS 7 acknowledges the possibility of vulnerability of indigenous people owing to their culture, beliefs, institutions and living standards and that it may further get compromised by one or other project activity throughout the life cycle of the project. The PS underlines the requirement of minimizing adverse impacts an indigenous people in the Project area,

5 Policy on Social and Environmental Sustainability, January 2012. Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources, International Finance Corporation. The World Bank Group.

respecting the local culture and customs, fostering good relationship and ensuring that development benefits are provided to improve their standard of living and livelihoods.

The Project area is not used by Indigenous Peoples as defined by IFC PS 7.

PS 8 Cultural Heritage

This standard aims to protect the irreplaceable cultural heritage and to guide clients on protecting cultural heritage in the course of their business operations.

The Project area does not contain any cultural heritage as defined by PS 8.

2.6.3 Other IFC Guidelines

Other guidelines developed by IFC include general Environmental Health Safety (EHS) guidelines along with content specific guidelines for cumulative impact assessment, and land acquisition.

EHS General Guidelines

The EHS Guidelines are technical reference documents with general and industry-specific examples of GIIP. The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project based on the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are taken into account. The General EHS Guidelines consist of the following components:

Environmental: This guideline applies to facilities or projects that generate emissions to air at any stage of the project life cycle. They also look into aspects of energy conservation, wastewater and ambient water quality, water conservation, hazardous materials management, waste management, noise and contaminated land.

Occupational Health and Safety: This section provides guidance and examples of reasonable precautions to implement in managing principal risks to occupational health and safety. Although the focus is placed on the operational phase of projects, much of the guidance also applies to construction and decommissioning activities. This incorporates general facility design and operation, communication and training, physical hazards, chemical hazards, biological hazards, radioactive hazards, Personal Protective Equipment (PPE), special hazard environment and monitoring.

Community Health and Safety: This guidance complements the above two guidelines by specifically addressing aspects of project activities which fall outside the traditional project boundaries but which are related to the project operations as and when they occur.

Construction and Decommissioning: This section provides an additional and specific guidance to the prevention and control of community health and safety impacts that may occur during new project development, at the end of the project life cycle or due to expansion or modification of existing project facilities.

These guidelines present ambient air quality and noise level standards against which the baseline conditions and Project Impacts are compared. It also provides good practices which will be adopted in the ESIA.

IFC's EHS Guidelines for Electric Power Transmission and Distribution

The EHS Guidelines for Electric Power Transmission and Distribution include information relevant to power transmission between a generation facility and a substation located within an electricity grid, in addition to power distribution from a substation to consumers located in residential, commercial, and industrial areas. The various aspects comprising this guidance are industry specific impacts and management and performance indicators and monitoring.

Applicability: The transmission lines will be developed by NTDC as a separate project.

Land Acquisition Handbook

Involuntary resettlement may entail both the physical displacement of people and the disruption of their livelihoods. The purpose of the IFC Handbook for Preparing a RAP is to provide guidance in the planning and execution of involuntary resettlement associated with IFC investment projects. IFC's policy on involuntary resettlement applies to any project that may result in the loss of assets, the impairment of livelihood, or the physical relocation of an individual, household, or community.

The associated Resettlement Action Plan (RAP) to be developed as part of Phase 2 will follow the guidelines detailed in this handbook.

Cumulative Impact Assessment Guidelines

IFC's Good Practice Handbook of Cumulative Impact Assessment (CIA) and Management: Guidance for the Private Sector in Emerging Markets, describes the need and presents guidelines for an effective CIA. It builds upon the requirements set in PS 1, which recognizes that in some instances, private sector developers need to consider cumulative effects in their identification and management of environmental and social impacts and risks. Although the total cumulative impacts due to multiple projects typically should be identified in government-sponsored assessments and regional planning efforts, according to PS 1, IFC clients are expected to ensure that their own assessment determines the degree to which each project under review is contributing to the cumulative effects. Under the IFC guidelines, if a project is the first hydropower project in the basin, a CIA is recommended. This is the case for the Arkari Gol HPP.

2.6.4 World Bank Group

OPIC recognizes the environmental safeguards documents of the World Bank Group, of which the IFC is a part, as an example of good international industry practice.

The specific requirements are as follows:

Apply pollution prevention and control technologies and practices consistent with international good practices as reflected in internationally recognized standards such as the World Bank Group's Environmental, Health and Safety Guidelines. .... [Page 16 of SPS 2009]

During the design, construction, and operation of the project the borrower/client will apply pollution prevention and control technologies and practices consistent with international good practice, as reflected in internationally recognized standards such as the World Bank Group's Environment, Health and Safety Guidelines. These standards contain performance levels and measures that are normally acceptable and applicable to projects. When host country regulations differ from these levels and measures, the borrower/client will achieve whichever is more stringent. If less stringent levels or measures are appropriate in view of specific project circumstances, the borrower/client will provide full and detailed justification for any proposed alternatives that are consistent with the requirements presented in this document. [Page 36 of SPS 2009]

The borrower/client will provide workers with a safe and healthy working environment, taking into account risks inherent to the particular sector and specific classes of hazards in the borrower's/client's work areas, including physical, chemical, biological, and radiological hazards. The borrower/client will take steps to prevent accidents, injury, and disease arising from, associated with, or occurring during the course of work by (i) identifying and minimizing, so far as reasonably practicable, the causes of potential hazards to workers; (ii) providing preventive and protective measures, including modification, substitution, or elimination of hazardous conditions or substances; (iii) providing appropriate equipment to minimize risks and requiring and enforcing its use; (iv) training workers and providing them with appropriate incentives to use and comply with health and safety procedures and protective equipment; (v) documenting and reporting occupational accidents, diseases, and incidents; and (vi) having emergency prevention, preparedness, and response arrangements in place. The borrower/client will apply preventive and protective measures consistent with international good practice, as reflected in internationally recognized standards such as the World Bank Group's Environment, Health and Safety Guidelines. [Page 38 of SPS 2009]

The IFC has guidelines on Environmental Health and Safety (EHS) for emission and effluent.[6] It also has guidelines in the form of Performance Standards such as the IFC's Performance Standard 3: Resource Efficiency and Pollution Prevention, for assessment and compliance with greenhouse gas emission standards.[7] There are a total of eight IFC Performance Standards which were published in April 2006 and revised in 2012. In addition to this, the World Bank Group's Environmental and Social Framework includes ten Environmental and Social Standards (ESS). ESS4. Community Health and Safety addresses the health, safety, and security risks and impacts on project-affected communities. Annex 1 of ESS4 "Safety of Dams" applies to new, existing and under-construction dams.[8] For large dams the World Bank requires:

- reviews by an independent panel of experts (the Panel) of the investigation, design, and construction of the dam and the start of operations;
- preparation and implementation of detailed plans: a plan for construction supervision and quality assurance, an instrumentation plan, an operation and maintenance plan, and an emergency preparedness plan;

6 The International Finance Corporation, Environmental, Health, and Safety General Guidelines, The World Bank Group, April 2007.

7 Asian Development Bank (ADB), Environmental Safeguards: A Good Practice Sourcebook Draft Working Document, December 2012.

8 The World Bank Group, The Environmental and Social Framework, March 30, 2017, <http://www.worldbank.org/en/programs/environmental-and-social-policies-for-projects/brief/the-environmental-and-social-framework-esf>, accessed May 1, 2017

- prequalification of bidders during procurement and bid tendering,
- periodic safety inspections of the dam after completion.

2.6.5 World Commission on Dams 2000

The World Commission on Dams (WCD) established the most comprehensive guidelines for dam building. It describes an innovative framework for planning water and energy projects that is intended to protect dam-affected people and the environment, and ensure that the benefits from dams are more equitably distributed. The WCD framework covers key areas for improved planning of dams, including the need to fully assess all available options for meeting water and energy needs; addressing outstanding social issues from existing dams before building new ones, gaining public acceptance for key decisions, and the importance of protecting healthy rivers.[9] The Project is being constructed in an area with natural resources of value both in terms of ecology and socioeconomics. It is being financed by an international funding body, therefore, international standards, guidelines and best practices need to be considered.

2.7 International Treaties and Agreements

Important international environmental treaties that have been signed by Pakistan and may have relevance to the Project are listed in **Exhibit 2.7**. They concern climate change and depletion of the ozone layer; biological diversity and trade in wild flora and fauna; desertification; waste and pollution; and cultural heritage.

[9] International Rivers, The World Commission on Dams, Available at <https://www.internationalrivers.org/campaigns/the-world-commission-on-dams>, accessed April 18, 2017

Exhibit 2.7: International Environmental Treaties Endorsed by Pakistan

Topic	*Convention*	*Date of Treaty*	*Entry into Force in Pakistan*
Climate change and the ozone layer	United Nations Framework Convention on Climate Change - the primary objective is the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.	1992	1994
	Kyoto Protocol to the United Nations Framework Convention on Climate Change - enabled by the above Convention on Climate Change. It has more powerful and legally binding measures. It sets binding targets for 37 industrialized countries and the European community for reducing greenhouse gas emissions.	1997	2005
	Vienna Convention for the Protection of the Ozone Layer - acts as a framework for the international efforts to protect the ozone layer with a primary objective to protect human health and the environment against adverse effects resulting from human activities that modify or are likely to modify the ozone layer.	1985	1993
	The Montreal Protocol on Substances that Deplete Ozone Layer and associated amendments - enabled by the Vienna Convention, it is designed to protect the ozone layer by phasing out the production and consumption of a number of substances believed to be responsible for ozone depletion.	1987	1993
Waste and pollution	Basel Convention on the Control of Trans Boundary Movements of Hazardous Wastes and their Disposal - regulates the trans boundary movement of hazardous waste and other waste with a stated purpose to protect human health and the environment against the adverse effects from generation and management of hazardous waste and other waste. The Convention provides for three sets of measures with binding obligations. These are: Strict control of trans boundary movement of hazardous waste; Environmentally sound management of hazardous waste; and Enforcement and Implementation of the provisions of the convention at international and national levels.	1989	1994
	International Convention on Oil Pollution Preparedness, Response and Co-operation	1990	1995
	Stockholm Convention on Persistent Organic Pollutants - seeks to protect human health and the environment from Persistent Organic Pollutants, which are chemicals that remain intact in the environment for long periods, become widely distributed geographically and accumulate in the fatty tissue of humans and wildlife.	2001	2008

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Topic	Convention	Date of Treaty	Entry into Force in Pakistan
	International Convention for the Prevention of Pollution from Ships (MARPOL) – is the main international convention that's covers prevention of pollution of the marine environment by ships from operational or accidental causes. The Convention includes regulations aimed at preventing and minimizing pollution from ships, both accidental pollution and that from routine operations, and currently includes six technical Annexes.	1983	
Desertification	International Convention to Combat Desertification – with an objective to combat desertification and mitigate the effects of drought. It is supported by international cooperation and partnership arrangements, with the aim of achieving sustainable use of land and water resources and sustainable development in affected areas.	1994	1997
Biodiversity and the protection of plants and animals	Convention on Biological Diversity – covering ecosystems, species, and genetic resources and also the field of biotechnology. The objectives are: ► conserve of biological diversity; ► sustainable use of its components; and ► fair and equitable sharing of benefits arising from genetic resources.	1992	1994
	Cartagena Protocol on Biosafety to the Convention on Biological Diversity - addresses potential risks posed by living modified organisms resulting from modern biotechnology.	2000	2009
	Bonn Convention on the Conservation of Migratory Species of Wild Animals - aims to conserve terrestrial, marine and avian migratory species throughout their range. It is concerned with the conservation of wildlife and habitats on a global scale.	1979	1987
	Memorandum of Understanding concerning Conservation Measures for the Siberian Crane - parties undertakes to provide strict protection to Siberian Cranes, and identify and conserve wetland habitats essential for their survival.	1998	1999
	Convention on International Trade in Endangered Species of Wild Fauna and Flora - to ensure that international trade in specimens of wild animals and plants does not threaten their survival.	1973	1976

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Topic	Convention	Date of Treaty	Entry into Force in Pakistan
	International Plant Protection Convention (1997 Revised Text) - to prevent the international spread of pests and plant diseases. It requires maintenance of lists of plant pests, tracking of pest outbreaks, and coordination of technical assistance between member nations.	1951/52	1954
	Agreement for the Establishment of the Near East Plant Protection Organization - to establish the Near East Plant Protection Organization (NEPPO), which promotes international co-operation with a view to implementing International Plant Protection Convention.	1993	2009
	Plant Protection Agreement for the Asia and Pacific Region and amendments – establishes the Asia and Pacific Plant Protection Commission to review and promote the region's progress in the implementation of the Agreement. Trade in plants and plant products are regulated by certification, prohibition, inspection, disinfection, quarantine, destruction, etc., as necessary.	1955 (amendment 1967)	1958 (amendment 1969)
	Convention on Wetlands of International Importance especially as Waterfowl Habitat and associated protocols and amendments - to promote conservation and sustainable use of wetlands. The Ramsar List of Wetlands of International Importance now includes almost 1,800 sites (known as Ramsar Sites). There are currently 19 Ramsar sites in Pakistan.	1971 (amended 1987)	1976 (amended 1994)
Cultural heritage	Convention concerning the Protection of the World Cultural and Natural Heritage - requires parties to adapt a general policy on the protection of the natural and cultural heritage, to set up services for such protection, to develop scientific and technical studies, to take appropriate legal, technical, scientific and administrative measures and to foster training and education for such protection.	1972	1976

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Pakistan is a party to a number of conventions in relation to biodiversity, including the Convention on the Conservation of Migratory Species of Wild Animals (CMS), the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES), the Convention on Wetlands of International Importance (Ramsar Convention) and the United Nations Convention on Biological Diversity (CBD).

The CBD defines biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems". As a signatory country, Pakistan has a responsibility to:

- Safeguard its biodiversity.
- Introduce procedures requiring environmental impact assessment (EIA) for projects likely to have significant impacts on biological diversity.
- Introduce legislative provisions that ensure environmental policies and procedures are duly taken into account.

There are no direct bearing of these treaties on the Project. Wherever required, the federal or provincial governments have enacted laws to comply with the provisions of the treaties listed in this section. Thus the obligations of the Project are to comply with pertinent laws only.

3. Project Description

This section provides a brief description of the Project. The description is based on the FS carried out for the Project, released in March 2014.[2]

The Arkari Gol HPP is a run-of-river hydropower project with daily peaking throughout the year, to be constructed on the Arkari Gol. The Arkari Gol is a left tributary of Lutkho River. It joins Lutkho River about 1 km upstream Shoghore Village. The Arkari Gol is called Arkari Gol ('Gol' being tributary in local language). The drainage area of Arkari Gol up to the proposed dam site is about 1,036 km^2.

The dam and intake structure will be located 8 km upstream of the confluence of Arkari Gol and Lutkho River, near the village of Ucchatur in Chitral District, KP. The powerhouse will be located 7.5 km downstream of the dam on the right bank of Arkari Gol, near the village of Andakht.

The Project area is accessible via road, at a distance of 460 km from Islamabad and 370 km from Peshawar, the capital of KP province.

Chitral is situated in the extreme northern part of Pakistan. It is about 14,850 km^2 and is bordered for about 480 km along Afghanistan. The area is sandwiched between Hindu Kush Range in the north and the Hindu Raj Range in the south and has an approximate NE-SE trend. Located further east are the Great Himalayas. The entire Chitral Valley is a mountainous region cut into deep and steep sided valleys by Chitral River and its numerous tributaries. The mountain elevations range from 3,500 m to 7700 m. The latter is the elevation of Terchmir, the highest peak in the region. Several streams drain into Arkari Gol upstream of the proposed site and contribute appreciable amount of water for hydropower. The valley of Arkari Gol descends from an elevation of 6,952 meters above mean sea level (masl) and at Uchhatur up to 2,169.8 masl at the proposed weir site. On the basis of the 100 m Digital Elevation Model (DEM), the elevation in the watershed varies from 2,172 masl to 6,732 masl.

A map showing the Project setting is provided in **Exhibit 3.1**. The general layout of the Project facilities is shown in **Exhibit 3.2.**

3.1 Main Components

The main permanent structures to be designed are as follows:

- Concrete gravity dam.
- Roller-compacted concrete (RCC) spillway.
- Bottom outlets for sediment flushing.

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2 Pakhtunkhwa Hydel Development Organization (PHYDO), Government of Khyber Pakhtunkhwa, March 2014, Feasibility Study for the Arkari Gol Hydropower Project, District Chitral, (Lower), Khyber Pakhtunkhwa, Volume 1, Main Report

- Intake structure.
- Headrace tunnel.
- Pressure shaft and pressure tunnel.
- Surface-type powerhouse.
- Tailrace channel.

Temporary works comprise the diversion structures including the cofferdams and a diversion tunnel. The main structures are described below.

3.1.1 The Main Dam

The main dam will be a concrete structure, with a height of 20 m above the riverbed. The soil investigations of the dam site show that the rock is about 100 m deep. Therefore a rock-fill type dam was recommended. Axis of the weir and diversion embankment has been selected on the basis of prevailing hydrological, topographical, geological and environmental conditions.

There spillway will comprise four units having four vertical roller gates with stoplog arrangements.

Exhibit 3.1: Project Location

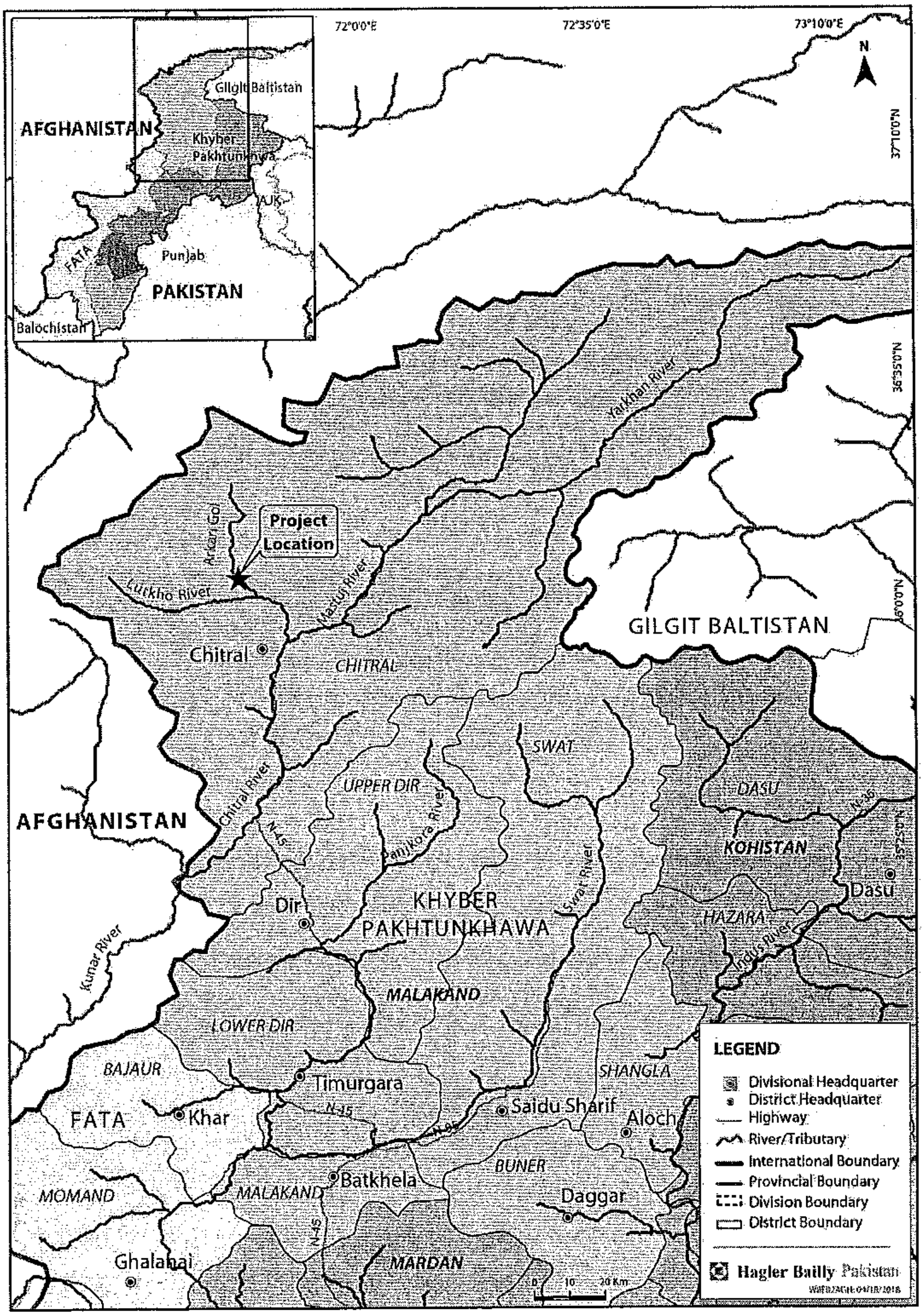

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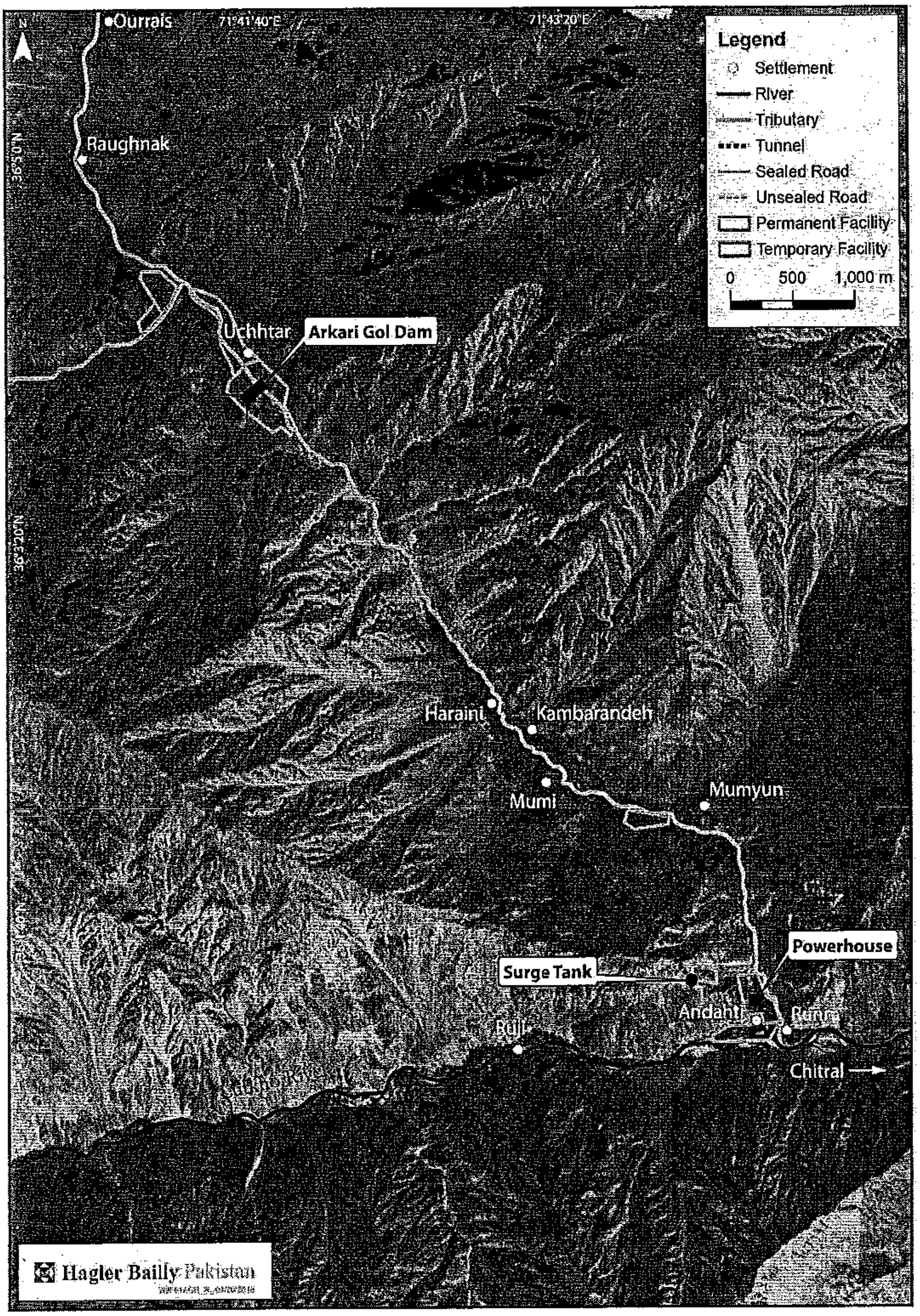
Exhibit 3.2: Project Layout



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3.1.2 Powerhouse

Studies have shown a clear superiority of an external type powerhouse, located on the right bank of Arkari Gol near Andahti Village at the confluence of Arkari Gol and Lutkho River. The power station comprises following main structures:

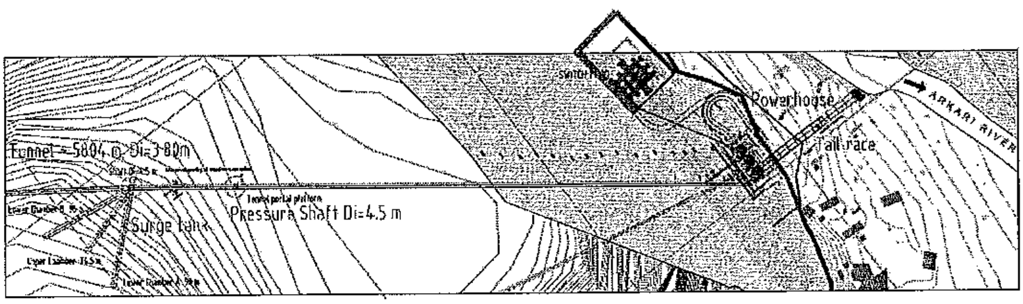
- Turbine shaft for installation of three Pelton wheel turbines.
- Surface machine hall and operation building.
- Tailrace channel.

Three vertical shaft Pelton turbines are proposed. Each unit will be designed for a rated flow of 12 m^3/s producing a discharge of 36 m^3/s. This will result in a net head of 318 m and a rated mechanical turbine power of 33 MW. Therefore, total capacity will be 99 MW.

The gross head will be 335.33 m and net head 318 m. Maximum reservoir level will be 2,190 masl and tail water level will be 1,854.7 masl.

A schematic showing the powerhouse, surge tank and switch yard is provided in **Exhibit 3.3.**

Exhibit 3.3: Schematic



Source: Pakhtunkhwa Hydel Development Organization (PHYDO), Government of Khyber Pakhtunkhwa, not dated, Feasibility Study for the Arkari Gol Hydropower Project, District Chitral, (Lower), Khyber Pakhtunkhwa, Volume 1, Main Report

3.1.3 Intake Structure

The intake structure will comprise two bays fitted with vertical gates to regulate inflow from the reservoir. On each bay a trash rack will be provided upstream of the gates to check the entry of floating debris into the power waterway. The intake structure is proposed along the right bank of the river as close to the embankment of the dam as possible. This will facilitate flushing of sediment and maintenance of maximum submergence. A lateral structure is proposed to minimize head losses and accelerate flow uniformly for the trash rack to the gate downstream. The intake structure is designed to be capable of discharging the total design discharge for the turbines plus 20% of the design discharge for flushing of the sediments settled in the de-sanding chambers. Total design discharge of the intakes will be about 36 m^3/s.

3.1.4 Headrace Tunnel from Intake to Surge Tank

The headrace tunnel will run from the intake to the surge structure. The optimal internal tunnel diameter will be 4.4 m to give a rated discharge of 36 m^3/s for the Pelton turbines. The resulting flow will be approximately 3 m/s which is within the range allowed for concrete-lined tunnels.

Based on the feasibility study the headrace channel will be concrete lined throughout its length. In case the geotechnical conditions allow, Powerchina has mentioned that they see the possibility for unlined sections with increased tunnel diameter to account for the hydraulic higher hydraulic losses.

3.1.5 Surge Tank

The surge structure branches at an elevation of 2,165.96 masl & 2,209.6 masl. The surge shaft is of an internal diameter of 4.5 m and is of 71.18 m high. A three-chamber surge tank has been selected.

- The Lower Chamber-A has a horseshoe section and a length of 96 m.
- The Lower Chamber-B has a horse shoe section and a length of 96 m.
- The end of the lower chambers will be connected again over a horizontal/vertical connection tunnel with the headrace tunnel.
- The upper chamber will be excavated from the working platform at an elevation of 74.5 m. The chamber has to be closed by a concrete wall with sufficient freeboard to the maximum surge level.
- Ventilation for the surge tank is proposed by an opening at the portal top.

The final dimensioning of the surge structures will need detail of basic requirements of the manufacturers for the hydro-mechanical equipment.

3.1.6 Pressure Shaft, Pressure Tunnel and Tailrace

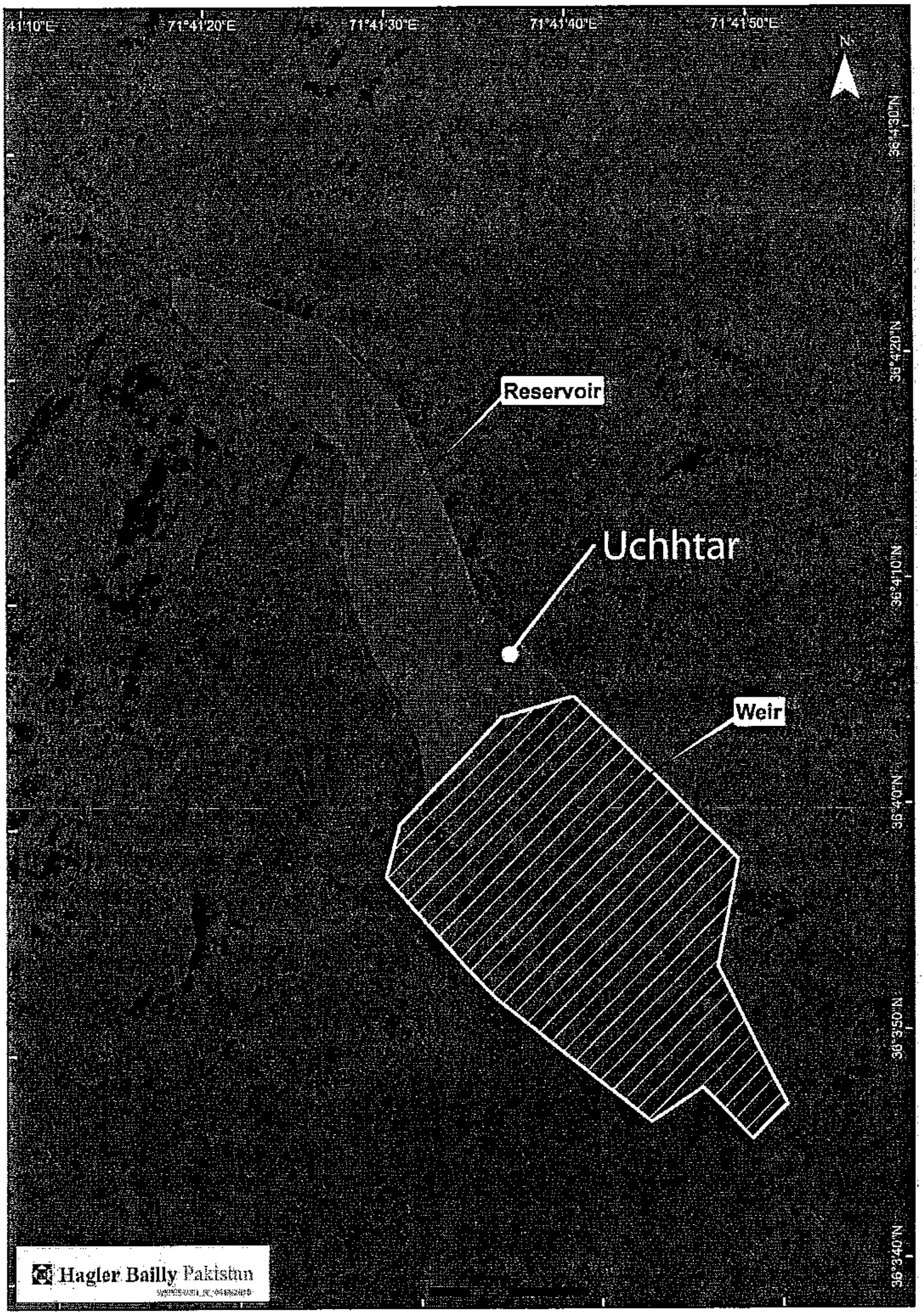
The powerhouse and the pressure shaft will be connected by a pressure tunnel with a vertical length of 296 m. The total length of the pressure tunnel will be 700-900 m including a length of 300 m for the pressure shaft. The total length of the tailrace channel to the outlet structure will be 100 m.

3.1.7 Reservoir

The Project is designed for a full supply level (FSL) at 2,190 masl creating a reservoir of volume of approximately 1.06 million m^3. The live operating storage is 0.489 million m^3. The reservoir will have a length of 1.3 km and an area of 0.101 km^2 (10.1423 hectares).

The extent of the reservoir is shown in **Exhibit 3.4**.

Exhibit 3.4: Reservoir Extent



3.1.8 Sediment Flushing

Mean annual suspended sediment load at the weir site is about 0.259 million m^3. Mean annual bed load at the weir site is about 0.039 million m^3. Mean annual total sediment inflow to the Arkari reservoir is about 0.297 million m^3.

Based on information from the developers the reservoir will reach equilibrium seven years after construction. Flushing will be carried out annually over a period of 3-7 days during July (high flow season) depending on the sediment inflow.

3.1.9 Associated Facilities

To evacuate power from the proposed Project, the transmission line to be constructed by NTDC falls in the category of an associated project.[3] NTDC will be responsible for the design and construction, as well as the EIA, of these facilities.[4] To achieve environmental or social outcomes consistent with the IFC guidelines, which are being followed by OPIC, it is essential that NTDC undertake the environmental assessment of the transmission line and develop a sound ESMS consistent with the national and provincial legal environmental requirements as well as that of the IFC PSs. The scope of Consultant's assignment does not include the evaluation of the design, construction, and operation of the transmission line for evacuation of the power produced by the Project.

Based on currently available information the sub-station at Golen Gol, located about 20 km from the powerhouse will be used to transmit power from the Project. A 132 kV line will be used to carry power from the Project to the sub-station and another 132 kV line will be used to transmit it onwards from the sub-station. The location of the sub-station at Golen Gol is shown in **Exhibit 3.5** along with the location of the Project.

3 The associated facility is defined as "facilities that are not funded as part of the project and that would not have been constructed or expanded if the project did not exist and without which the project would not be viable"

4 Specific details on the transmission lines are not yet available, as these will be commissioned by NTDC two years before commissioning of the Project.

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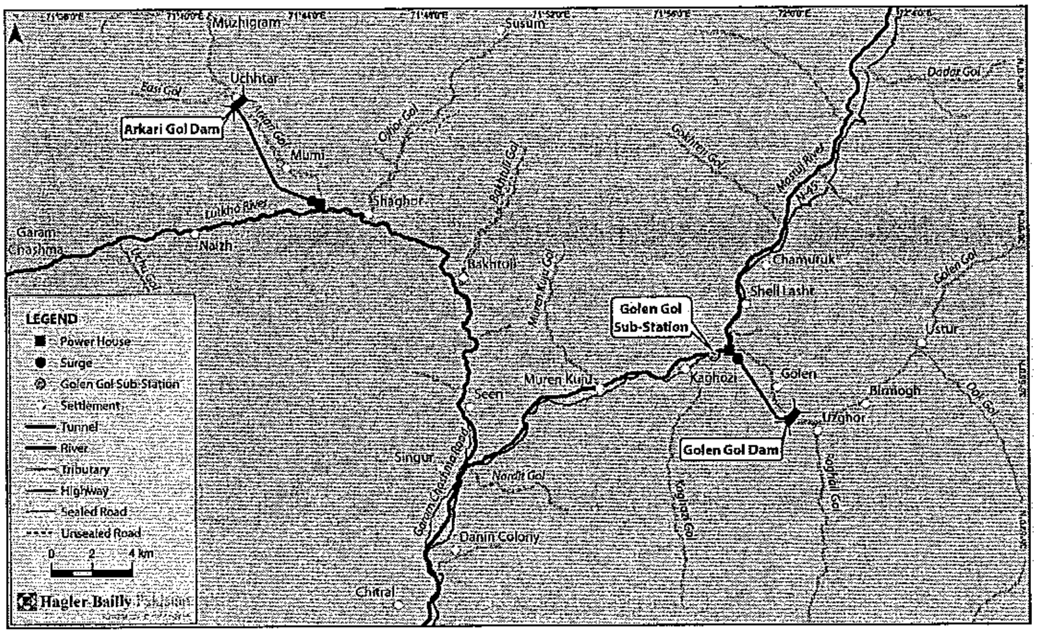
Exhibit 3.5: Locations of Interconnection Points for Transmission of Power



3.1.10 Camps and Offices

Camps and offices will be required during the construction phase for the contractors' staff and engineers as well as for the clients engineering staff. As is the case with other hydropower projects, it is anticipated that low density housing and amenities will be provided. In addition, there will likely be a large labor workforce which will require accommodation. This may be a combination of married and single quarters.

3.1.11 Technical Design Summary

Exhibit 3.6 provides the technical design summary of the Project.

Exhibit 3.6: Salient Features of the Project Design

River	Arkari Gol, left side tributary to Lutkho River	
	Catchment Area at dam site (km²)	1,036
	Mean Annual Discharge (m³/s)	17.00
	Total annual flow (Mm³)	536
Reservoir	Total Storage Capacity (Mm³)	1.06
	Live Storage Capacity (Mm³)	0.489
	Dead Storage Capacity (Mm³)	0.656
	Surface Area (km²)	0.121
	Length of Reservoir (km)	1.3
	Full Reservoir Level (masl)	2,190

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Dam Structure	Dam Type	Concrete gravity dam
	Catchment Area at dam location (km^2)	1,036
	Dam Top Elevation (masl)	2,192
	Foundation Level (masl)	2,168
	Height above Riverbed (m)	20
	Crest Length (m)	150
	Crest Width (m)	6
Spillway Gates	Type of Gate	Roller
	Number of Gates	4
	Rated discharge of gates (m3/s) – total for all	1,436
	Type of low level outlet	Roller
	Number of low level outlets	4 undersluices
Stilling Basin	Length (m)	90
Flood Control	Design Flood (Return Period 1000a) (m^3/s)	562
	4 Vertical Gates	6 m x 6 m each
	4 Bottom Outlets	6 m x 6 m each
River Diversion	Diversion Flood (Construction Phase Return Period = 10 a) (m^3/s)	162
	1 Diversion Tunnel (Horse Shoe) (Protected by upstream & downstream cofferdams) Cross Sectional Area (m^2)	50
Intake Components	2 Stoplogs	3 m x 4 m each
	2 Trashracks	5.89 x 7.63 m each
	Rack Cleaning Machine	
	Velocity of lifting (m/s)	0.3
	2 Intake gates	3 m x 4m each
Headrace Tunnel		
	Number	1
	Length (km)	6.25
	Excavation Diameter (TBM) (m)	4.4
	Adit 1	
Tailrace	Type	Open Channel
	Length (m)	100
Surge Tank	Surge Shaft Internal Diameter (m)	4.5
	Height (m)	71.2
	Length (m)	75

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Lower Chambers	Units	2
	Length of each (m)	96
	Cross Section of each (m²)	21.9
Upper Chamber	Length (m)	74.5
	Cross Section (m²)	33.5
Pressure Shaft	Vertical Shaft, Steel Lined	
	Internal Diameter (m)	3.0 to 3.2
	Difference in Height (m)	296
Pressure Tunnel	Horizontal Tunnel, Steel Lined	
	Length from Pressure Shaft to Power House (m)	494
	Internal Diameter (m)	3.0
Powerhouse	External powerhouse	
	Turbine Shaft depth below machine hall floor (m)	15
Turbines	Type of Turbine	Pelton
	Capacity of each Turbine (MW)	33
	Total Capacity (MW)	99
	Rated unit discharge of each turbine (m^3/s)	12
	Number of Turbines	3
	Maximum water head (m)	335 m gross head, 17 m losses
	Minimum water head (m)	331 m gross head, 17 m losses
	Weighted average water head	334 m gross head
	Power coefficient (MW/m3/s)	99 MW / 36m3/s = 2,75 MW/(m3/s)
	Flow release required or planned (m^3/s)	0.8 m^3/s in winter and 2.0 m^3/s in summer
Machine Hall	Length (m)	46.7
	Width (m)	24.2
	Height (m)	13.5

Source: Pakhtunkhwa Hydel Development Organization (PHYDO), Government of Khyber Pakhtunkhwa, March 2014, Feasibility Study for the Arkari Gol Hydropower Project, District Chitral, (Lower), Khyber Pakhtunkhwa, Volume 1, Main Report

3.2 Project Preparation and Construction

This section describes the following aspects related to Project construction:

- River Diversion
- Construction Timeline and Materials
- Spoil Disposal

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- Quarry Areas

3.2.1 Main Construction Activities

River Diversion

River diversion facilities have been designed for a to 10-years return period of 284 m^3/s. The diversion facilities will be in service for approximately three years during construction. In case of floods with higher frequency the cofferdams would be over spilled and flushed downstream. The safety of completed concrete blocks in such an event depends on the stage of actual construction progress (bottom outlets). Design floods of higher frequency results in increasing cost for the temporary river diversion.

Construction Timeline

Based on the FS the Project will take 4 years (48 months) to construct. The construction will follow the following sequence:

- Mobilization
- Pre-construction works
- Diversion tunnel
- Dam
- Spillway
- Power canal from Intake structure
- Headrace tunnel
- Surge chambers
- Pressure shaft and pressure tunnel
- Tailrace canal

In parallel construction will be carried out on the powerhouse, switchyard and erection of equipment. Following this testing and commission will be done.

3.2.2 Construction Material

Materials required to carry out the construction of civil works include concrete, various types of fill materials and steel products.

Estimates of quantities are provided in **Exhibit 3.7**.

Exhibit 3.7: Estimates of Quantities

Material Type	*Tonnes*
Concrete	240,000
Fill Material	27,500
Steel	8,000
Total	**275,500**

3.2.3 Spoil Disposal

Excavation of tunnels, desanders, and fore bay will result in the production of huge quantities of muck comprising various rock types. In the weir area the rocks expected from the excavation of desanders and the portion of headrace tunnel comprise of granitic gneisses and amphibolites. Based on the indicative bill of quantities it is assumed that the total quantity of spoil material from dam site, tunnel and powerhouse will be between 300,000 m^3 and 500,000 m^3.

MHL have suggested that the material be used to provide terraces that can be used by the local population.

3.2.4 Quarry Areas

Two huge deposits of crushed aggregate exist in the vicinity of Aawi village and are about 2 km from Shoghore. Coarse aggregates of this area are being extensively used in construction of road building and concrete production.

3.3 Transport Corridor

The Arkari Gol HPP will entail procurement, transportation and installation of heavy and large sized construction and powerhouse equipment such as cranes, turbines, generators, transformers etc. Most of the equipment will be imported from foreign countries and will land at Karachi Port before being transported to the Project site.

The road infrastructure beyond Chakdara will need rehabilitation/upgradation at certain sections. This will entail upgradation/maintenance of roads, bridges, culverts, tunnels etc. and improvements in their existing design parameters such as widths, clear heights, profiles, cross-sections, curves, slopes, loading class etc.

A final decision with regard to the route and mode of transport will however be taken after sufficient data is available for making a comparative analysis of the competing options. **Exhibit 3.8** the road to be built as part of the Project based on currently available information.

The transport route is shown in **Exhibit 3.9**.

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Exhibit 3.8: Road construction as part of the Project

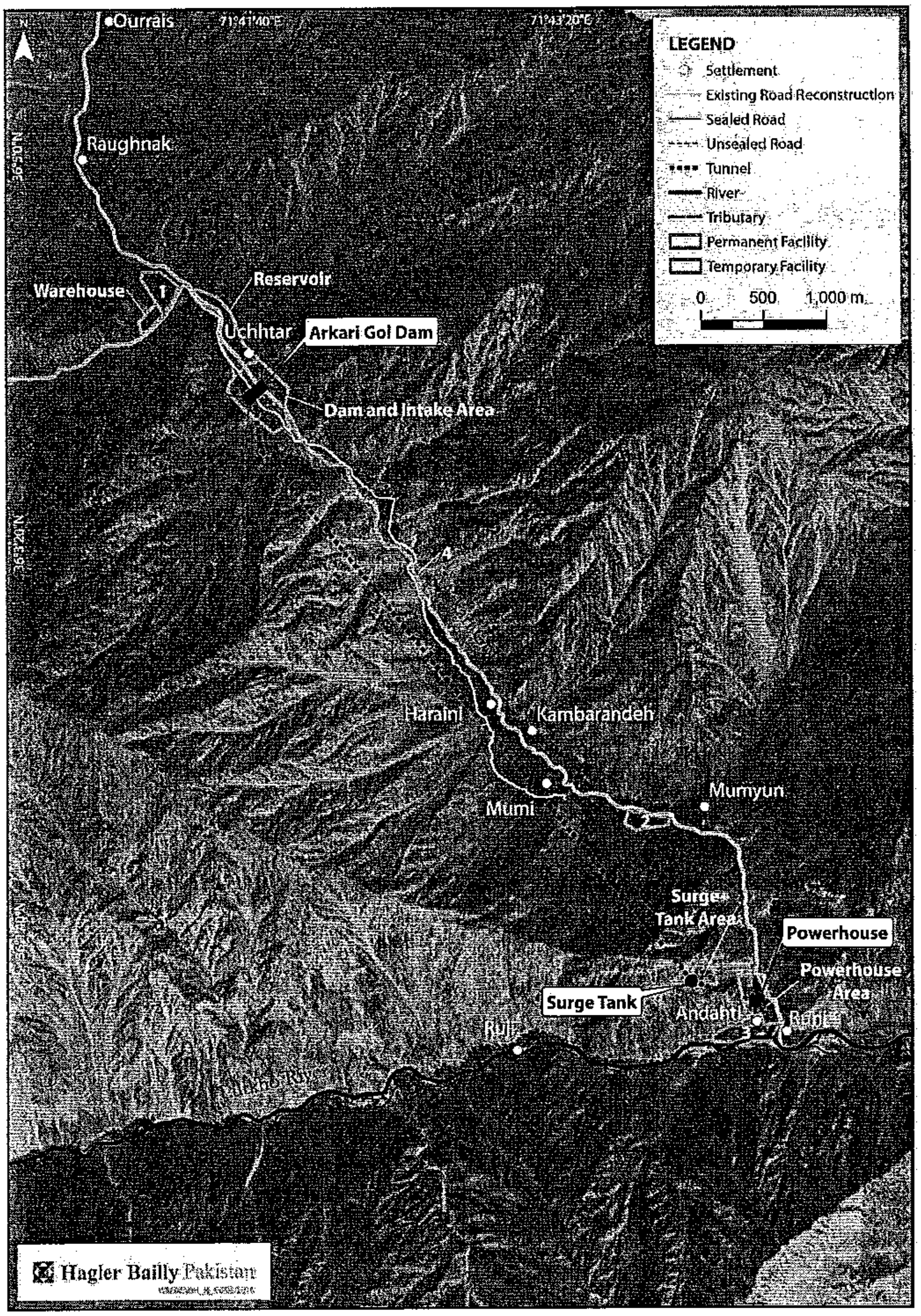

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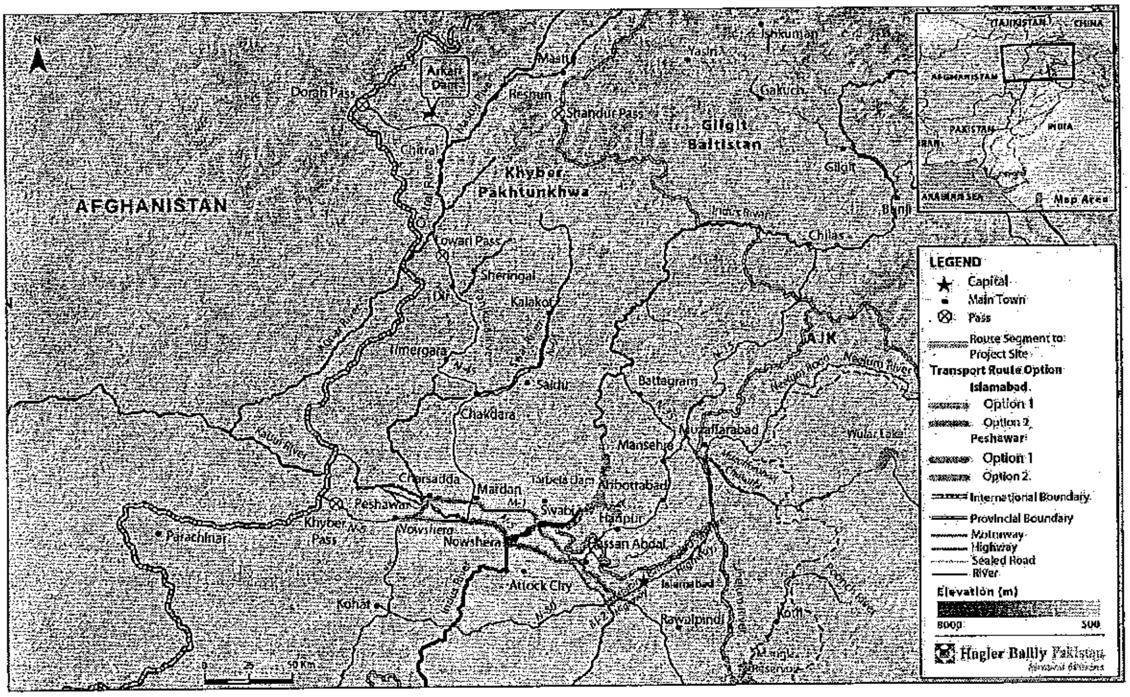
Exhibit 3.9: Transport Route



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3.4 Land Requirement

The Project will involve acquisition of land for various components. Some of the land will be occupied permanently and some temporarily during the construction phase. The Project will involve acquisition of land for various components. A total of 140.0 acres of land will be required of which 26.5 acres is cultivated land, 4.0 acres is residential land and 109.5 acres is barren land or river bed. This will include 19.0 acres for Powerhouse, 5.6 acres for Surge tank, 5.4 acres for Warehouse, 45.15 acres for Dam and Intake structure, 25.9 acres for Reservoir and 38.96 acres for Temporary facilities.

3.5 Regional Hydropower Developments

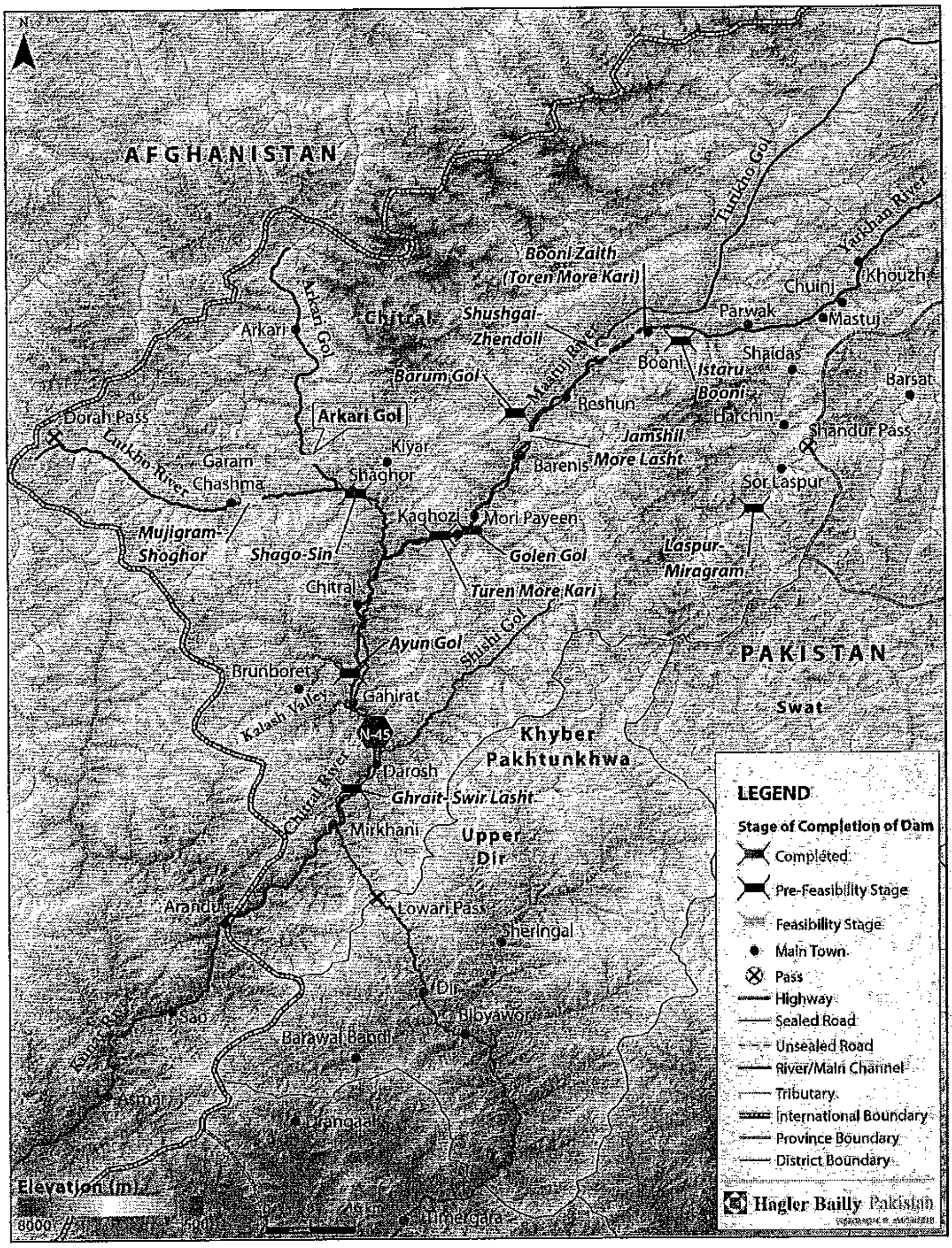
A number of hydropower projects have been planned or are under construction in District Chitral, of which one is located on the Arkari Gol. Of these projects only Golen Gol is currently operational. A list of these hydropower projects is provided in **Exhibit 3.10.** The cascade of projects is shown in **Exhibit 3.11.**

Exhibit 3.10: Hydropower Projects Planned or Under Construction in District Chitral

No	*Project Name*	*Capacity (MW)*	*Tunnel Length (km)*	*Planned/Under Construction*
1	Golen Gol	108	3.8	Completed
2	Arkari Gol	99	6.25	Feasibility Stage
3	Mujigram-Shoghor	64.26	13.75	Feasibility Stage
4	Shushgai-Zhendoli	144	8.5	Feasibility Stage
5	Turen More Kari	350	14.1	Feasibility Study Completed
6	Jamshil More Lasht	260	13.6	Feasibility Study Completed
7	Ayun Gol	15.17	5.4	Pre-Feasibility Study Completed
8	Barum Gol	24.93	4.4	Pre-Feasibility Study Completed
9	Turen More Kari	350	NA	Pre-Feasibility Study Completed
10	Laspur-Miragram	230	32.40	Prefeasibility of Conceptual Stage
11	Istaru Booni	72	4.024	Proposed
12	Ghrait- Swir Lasht	377	14.50	Proposed
	Total	**2094.36**		

Notes: 1. Only developments within District Chitral are listed. 2. NA = Not Available

Exhibit 3.11: Hydropower Projects Planned or Under Construction in Distric Chitral



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4. Description of the Environment

4.1 Ecology Baseline

The ecology baseline has been prepared to provide an overview of the ecological conditions in the Study Area and surroundings.

Sources of information for preparation of this baseline included published literature and reports, scientific journals as well as ESIA reports of other projects in the vicinity of the Study Area including the Rapid Environmental Analysis of 108 MW Golen Gol Hydroelectric Power Project.[1] In addition, a field survey was carried out between March 28, 2018 and April 3, 2018 (March 2018 Surveys) to collect field data and information about the aquatic and terrestrial ecological resources in the Study Area in the spring season.

4.1.1 Objectives and Scope

The baseline was prepared with the following objectives:

- A review of the available literature on the biodiversity of the Ecological Study Area.
- Field surveys including:
  - Qualitative and quantitative assessment of flora, mammals, reptiles, birds and invertebrates.
  - Identification of key species, their population and their conservation status in the country and worldwide.
  - Reports of wildlife sightings in the Ecological Study Area by the resident communities.
- Analysis of ecological interaction of selected species with the environment.
- Analysis was also carried out to further develop the basis for evaluating the potential impacts of Project related activities on the biodiversity, specifically seeking any potential critical habitat and ecosystem services in the Ecological Study Area.

4.1.2 Study Areas

There are two types of ecological resources that are of concern, aquatic and terrestrial. Therefore, two types of Study Areas were defined, an Aquatic Study Area and a Terrestrial Study Area.

The Aquatic Study Area was selected taking into consideration the maximum extent of impacts of the Project both upstream and downstream of the dam. It includes the stretch

1. Hagler Bailly Pakistan, December 2016, Rapid Environmental Analysis of 108 MW Golen Gol Hydroelectric Power Project for Water and Power Development Authority (WAPDA)

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of the Arkari Gol from upstream Azhpi Village to confluence of Arkari Gol and Lutkho River (29 Km), including all major tributaries in this stretch.[2] The reservoir is expected to form on the Arkari Gol stretch 1.3 km upstream of the dam as a result of which the Riverne habitat will be changed to a lake–like habitat and the Study Area includes this entire stretch. Moreover, since the dam on the Arkari Gol will create a barrier to migration for the fish species of concern, a stretch of 21 km of Arkari Gol upstream of the dam has been included in the Aquatic Study Area. The stretch of Lutkho River from Naizh Village to confluence of Mastuj River (Chitral River) is also included in the Aquatic Study Area. A small stretch (1 km) of Chitral River, downstream of the confluence of Lutkho and Chitral Rivers is also included in the Aquatic Study Area. The Aquatic Study Area is shown in **Exhibit 4.1.**

The Terrestrial Study Area comprises the Project facilities as well as a 1 km buffer around Project–related facilities which are likely to be impacted by Project–related activities. **Exhibit 4.2** shows the Terrestrial Study Area.

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2 Only those tributaries with a significant perennial flow that have the potential to support breeding of fish are included`

Exhibit 4.1: Aquatic Study Area

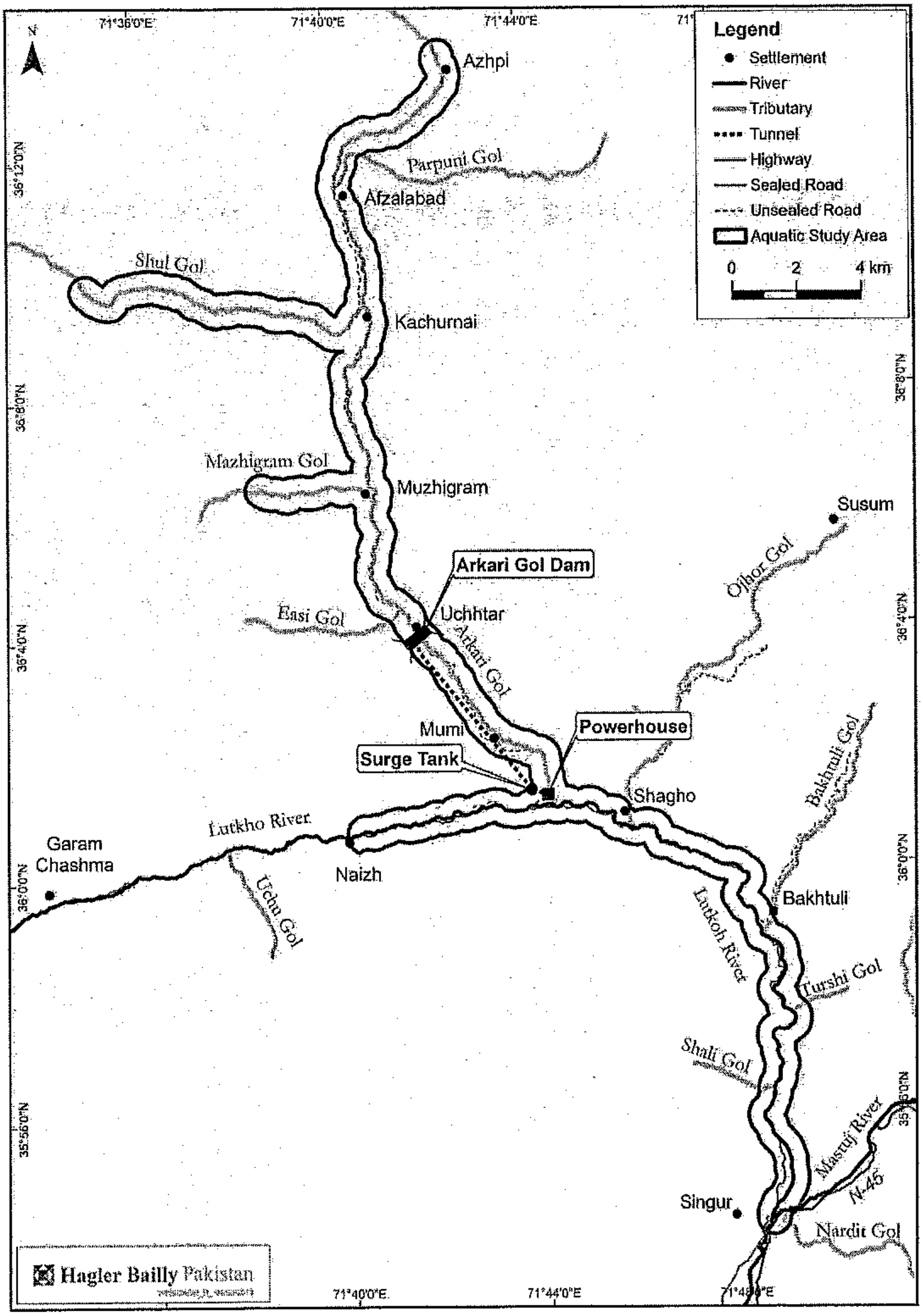
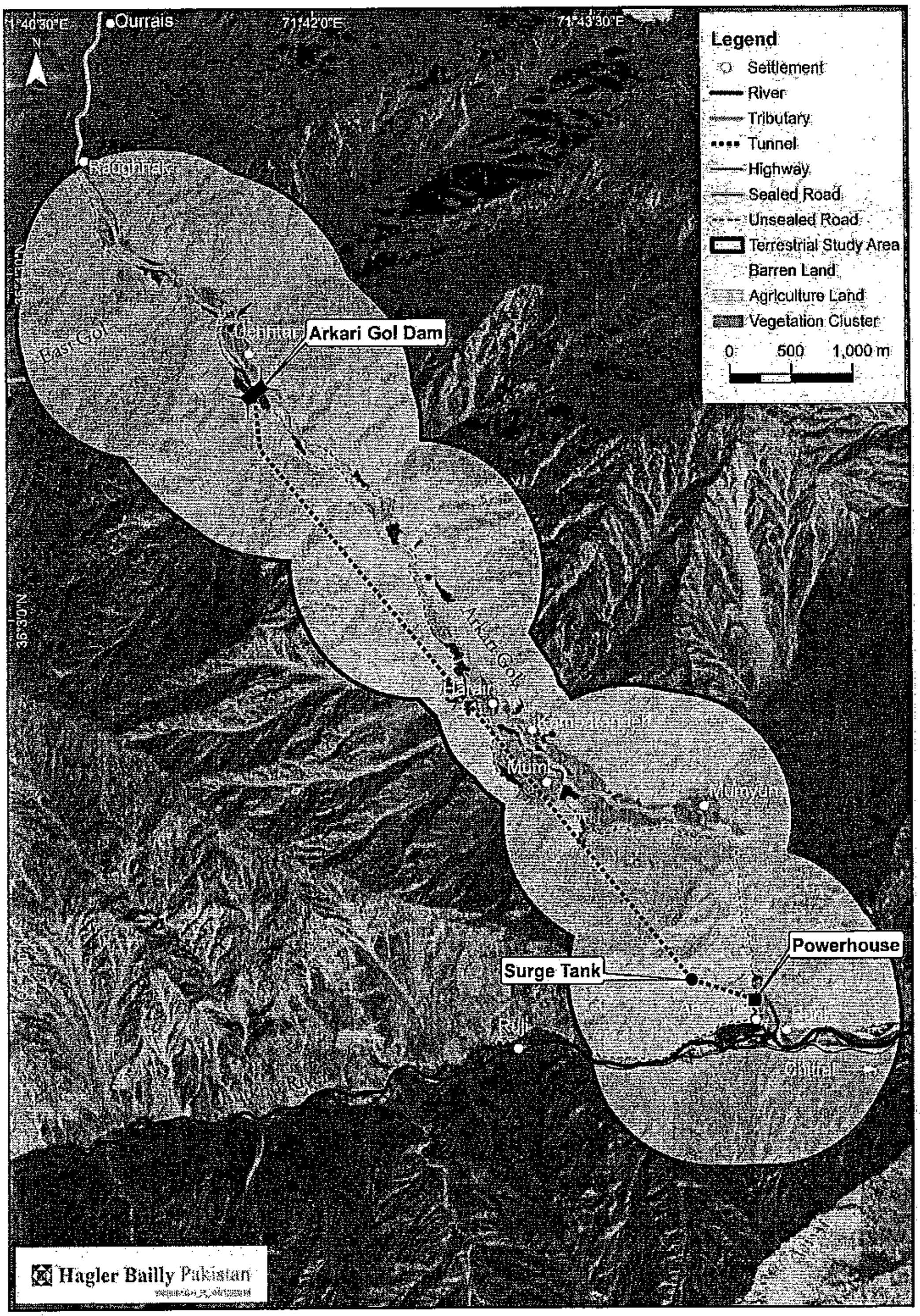


Exhibit 4.2: Terrestrial Study Area



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4.1.3 Field Survey

The field surveys were carried out between March 28, 2018 and April 3, 2018 (March 2018 Surveys).

Sampling Locations

Sampling locations for aquatic ecological resources including fish fauna, macro–invertebrates, periphyton and riparian vegetation are shown in **Exhibit 4.3.** The justification for the selection of these sampling locations is provided in **Exhibit 4.4.** The list of sampling locations in the tributaries is provided in **Exhibit 4.5.**

Sampling locations for terrestrial ecology are provided in **Exhibit 4.6.** The locations were selected taking into account three main habitat types identified using ***Google Earth™*** satellite imagery. These include Barren Land, Vegetation Cluster and Agricultural Land. The number of sampling locations was based on percentage representation of the habitats in the Terrestrial Study Area. Four sampling locations were selected in the Barren Land and two sampling locations in the Vegetation Cluster Habitat. No sampling was carried out in the Agriculture Land habitat because most of this habitat was located very close to the homes of the local community members and was private property. The habitat type at each sampling location is listed in **Exhibit 4.7.**

Methodology

The methodology used to collect data on each biological resource is summarized below. The field survey plan for data collection is provided in **Appendix B.**

Aquatic Ecological Resources

Fish

Fish sampling was conducted using electrofishing and cast nets mainly in Arkari Gol, Lutkho River and its main tributaries with appropriate depth and flow of water. The method used at each location depended on the morphology of the river or tributary, accessibility, the target fish species, and the possibility of finding the fish in a particular habitat in view of temperatures and fish activity at the time of sampling.

Fish fauna were collected using cast nets at selected sampling sites. Two types of cast nets were used. Mesh sizes of 25 mm and 30 mm were used. A total of 30 castings were carried out – 15 castings per mesh size, spread over a distance of about 90 m, depending on site conditions.

Electrofishing was employed for sampling where water levels were low and wading was possible. The LR–24 was used for electrofishing.[3] Electrofishing was carried out in a 150 m^2 area.

Macro–invertebrates

Macro–invertebrates were sampled by adopting the standardized rapid biological assessment sampling techniques (using multi–habitat approach) developed by Barbour et

[3] Available at Smith Root, http://www.smith–root.com/electrofishers/lr–24/

al 1999.[4] A Surber Sampler or D frame kick net was used for sampling. Twenty efforts were taken at each sampling site based on percent availability of each biotope. For example if a sampling site comprises of 80% riffle and 20% pool habitat, then 16 efforts of the Surber Sampler was conducted in the riffles and 4 efforts in pool (ratio of 80% to 20%). At each sampling site, the collected materials were rinsed using running clean stream water through the net two to three times. The materials were transferred into a large (white) tray or a bucket. The samples were then transferred to a container and covered with 10% formalin.

Periphyton

Periphyton sampling was carried out at a total three sampling location of the Arkari Gol but no periphyton biomass was observed at any location.

Riparian Vegetation

The usual means of sampling vegetation for floristic composition is the quadrat. The vegetation in the marginal zone and flood plain in the Study Area were sampled by the quadrate method, taking 3 quadrates of 5m x 5m at each sampling site. The first quadrat was taken at the beginning of the transect, the second at 250 meters and the third at 500 m. Plants from each quadrate was noted. Additional plant species in the area adjacent to the quadrate was also noted down. Cover, relative cover, density, relative density, frequency, relative frequency percentages and Importance Value Index (IVI) for each species from the study were calculated.

Terrestrial Ecological Resources

Terrestrial Flora

The usual means of sampling vegetation for floristic composition is the quadrat. The vegetation in the terrestrial Study Area were sampled by the quadrate method, taking 3 quadrates of 5m x 5m at each sampling site. The first quadrat was taken at the beginning of the transect, the second at 250 meters and the third at 500 m. Plants from each quadrate was noted. Additional plant species in the area adjacent to the quadrate was also noted down. Cover, relative cover, density, relative density, frequency, relative frequency percentages and Importance Value Index (IVI) for each species from the study were calculated.

Mammals

Line transects (500 m by 20 m) was placed at each sampling site to record all animals or their signs detected. All the animals sighted, or their signs (foot marks, droppings, dens) were recorded. GPS coordinates of the location and habitat type were also documented. Transects were walked as early as possible in the day and covered all possible habitat types in order to avoid bias of stratification. In addition, incidental sightings of all mammals were recorded; number of individuals, location and habitat type were recorded

4 Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841–B–99–002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C.

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for each sighting. Anecdotal information regarding specific mammals was collected from the local people and relevant literature was also consulted.

Birds

Line transects (500 m by 50 m) was used. Line transects were placed at each sampling site to record all birds observed. Transects was started as early as possible in the morning and in late afternoon and covered all possible habitats. The start time and coordinates of the starting point was recorded. The bird species were identified using the most recent keys available in literature.[5] Density and diversity of birds were calculated.

Herpeto–fauna

Line transects 500 m long and 20 m wide were placed systematically at each sampling site in the Study Area. The sampling sites were actively searched for all types of reptiles and amphibians along the line transects. Active searching was also carried out in sampling areas with a focus on suitable microhabitats. The species collected or observed during the survey were photographed with a digital camera and necessary field data was recorded. The coordinates and elevations were recorded using GPS, and other features of interest like habitat type was documented.

5 Grimmett, R., Roberts, T., and Inskipp, T. 2008. Birds of Pakistan, Yale University Press.

Exhibit 4.3: Sampling Locations for Fish, Macro–invertebrates, Periphyton and Riparian Vegetation in the Aquatic Study Area, March 2018 Surveys

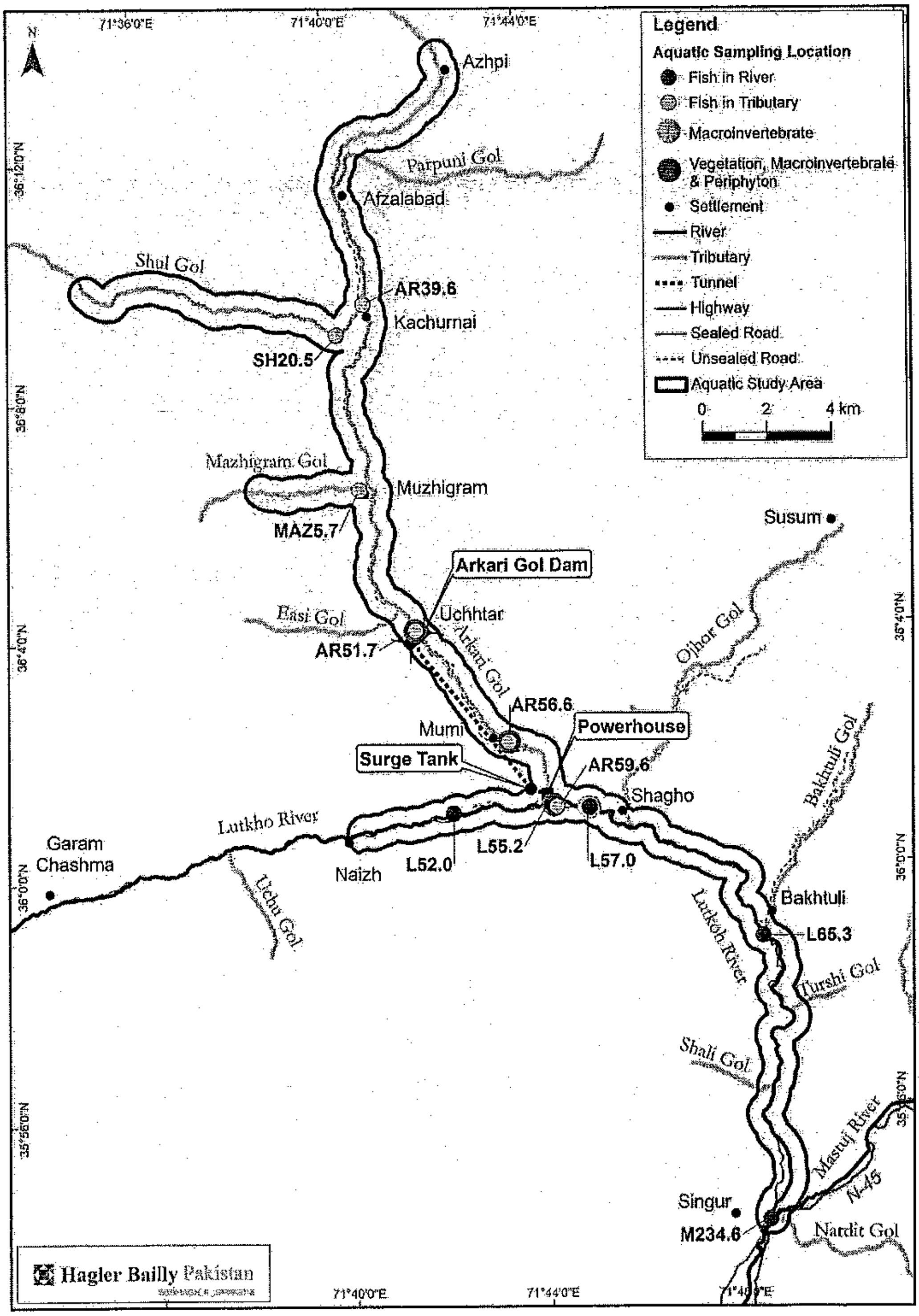

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Exhibit 4.4: Justification for Selection of Sampling Locations on Main River

River Segment	*Sampling Site ID*	*Expected impacts from the Project*	*Expected variation in ecology triggered by variations in water temperature and flows*
Upstream of Dam	AR51.7 and AR39.6	The sites are located upstream of the reservoir of proposed dam and will be impacted by the barrier created by the dam	Variations mainly in fish fauna especially migratory fish species due to the barrier created by the dam. Inundation at the reservoir will result in impacts on riparian vegetation
Downstream of Dam	AR56.6	The site will be impacted by the lower flows due to the diversion of the river flow into the power generation tunnel	Variations in macro–invertebrates, periphyton and fish fauna due to changes in flows caused by diversion tunnel that will result in changes in the temperature of the water
Downstream of Powerhouse	AR59.6, L57.0, L65.3, and M234.6	Both temperature and flow of water in this segment will be impacted by variations in flow due to peaking of dam	Variations in macro–invertebrates, periphyton, riparian vegetation and fish fauna mainly due to changes in the temperature and flow of the water in the River

Exhibit 4.5: List of Sampling Sites for the Tributaries

Tributary (Local Name)	*Sampling Site ID*
Mazhigram Gol	MAZ5.7
Shul Gol	SH20.5

Exhibit 4.6: Sampling Locations for Terrestrial Flora and Fauna

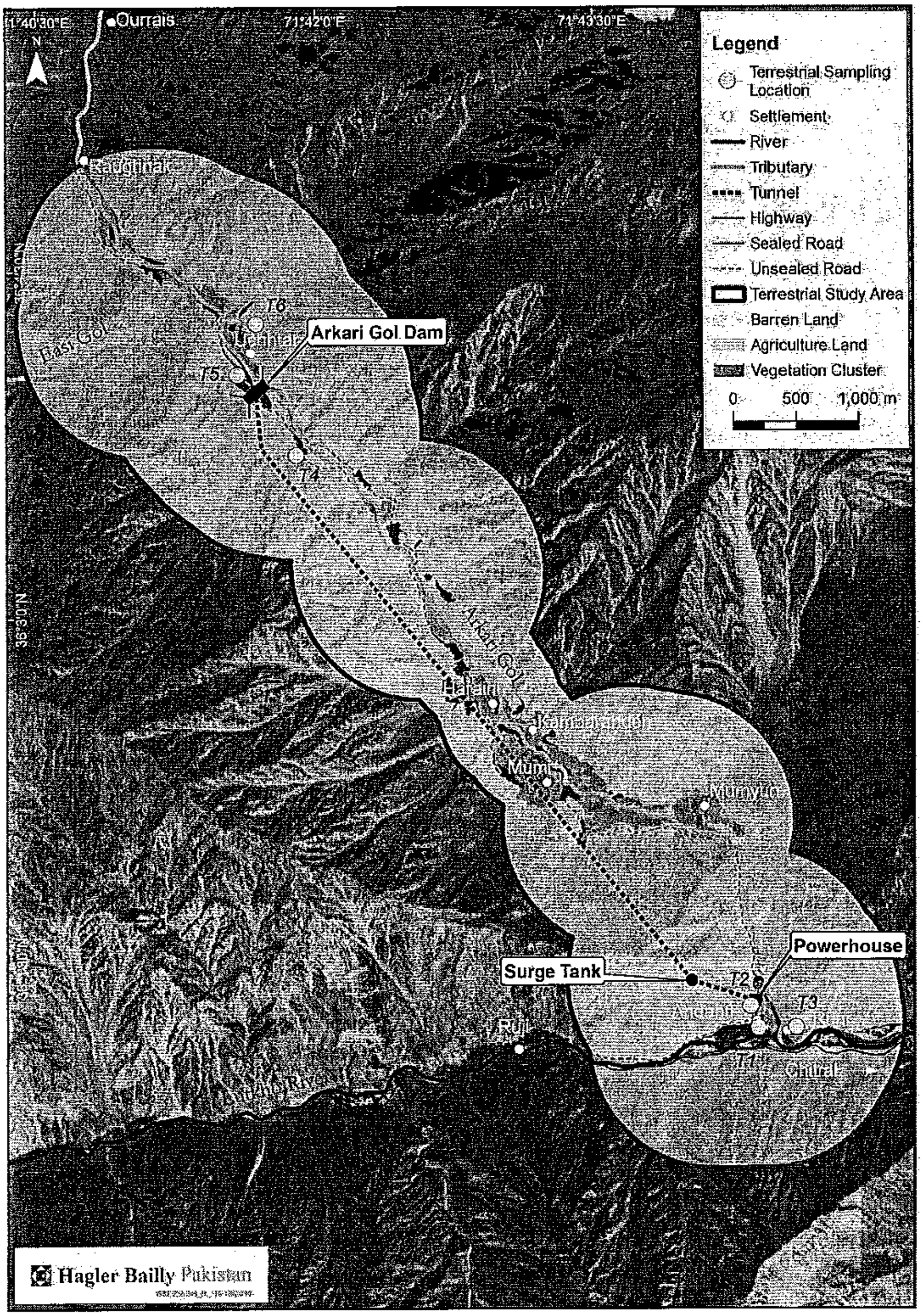

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Exhibit 4.7: Habitat Types for the Terrestrial Sampling Locations

Habitat Type of Sampling Locations	*Sampling Locations*
Barren Land	T2, T3, T4, and T6
Vegetation Cluster	T1 and T5

4.1.4 Aquatic Ecology

This section presents an overview of the aquatic ecological resources in the Aquatic Study Area based on a review of available literature as well as field survey assessment carried out in March 2018. Ecological resources assessed include fish fauna, macro–invertebrates, periphyton and riparian vegetation.

Fish

This section provides an overview of the fish fauna in the Aquatic Study Area.

Overview of Fish Fauna

The Chitral River, which is the principal river of the Chitral Valley, is formed by the union of two sub rivers, the Lutkho River from the north–west and the Mastuj River from the north–east. These two rivers join about four miles above the town of Chitral. In its lower reaches, the river is called the Kunar River and joins the Kabul River near Jallalabad. Summer temperatures range between 14 to 19°C, while winter temperature range between 2 to 6°C. Tributaries of Chitral River include the Barum Gol, Turikho Gol, Yarkhun Gol, Arkari Gol, Lutkho Gol, Bomboret Gol, Rambur Gol, Birir Gol, Shishi Gol and Ayun Gol. The Project is located on the Arkari Gol.

Fish fauna of the Chitral River has ichthyological affinities with the Kabul River. A total of six species of fish have been reported from Chitral River and its tributaries, including Snow Trout *Schizothorax plagiostmous (richadsonii)*, Kunar Snow Trout *Schizothorax labiatus*, Chirruh Snow Trout *Schizopyge esocinus*, Chitral Loach *Triplophysa choprai*, Himalayan Catfish *Glyptosternum reticulatum* and Khyber Loach *Schistura prashari*. Chirruh Snow Trout is very rare, and only one or two specimens have been reported from the lower reaches of the river.[6]

The main Chitral River, upstream area, is flat and open, dividing into many channels with plenty of vegetation on the banks. The river in this stretch provides ideal breeding habitats for fish, especially for Snow Trout, Chitral Loach and Himalayan Catfish. The abundance of these species in this stretch of the river is higher compared to the downstream reaches. In the summer season, Chitral River is very turbid and torrential during due to rainfall and rapid melting of snow. The summer season is also the breeding period for the fish. However, due the high turbidity and torrential flows, it becomes difficult for the fish to breed in the main river. In contrast, the tributaries have physical conditions favorable for fish (turbidity, flow, food availably). Therefore, many species depend mainly on the tributaries for breeding and feeding. Most of the tributaries have crystal clear waters as well as shallow depths and a bed of gravel and cobbles which

6 Hora, S. L., (1934). The fish of Chitral. Rec. Ind. Mus., (36): 279–320.

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provide ideal breeding grounds for the fish. Fish species, particularly the Snow Trout, Kunar Snow Trout, Chitral Loach and Himalayan Catfish use these tributaries as breeding grounds.

A complete list of fish species reported from the Chitral River and surrounding tributaries is given in **Exhibit 4.8.** Information is also provided about their IUCN Red List status, commercial importance, endemism and migratory behavior. Of the six fish species reported from the Study Area, only the Snow Trout is a fish species of concern as it is a long distance migratory species and listed as Vulnerable in the IUCN Red List.[7] It also has high commercial importance.

Exhibit 4.8: List of Species Reported from Chitral River and its Tributaries

No	*Scientific Name*	*Common Name*	*IUCN Status*	*Commercial Importance*	*Migratory*	*Endemism*
1.	*Schizothorax richadsonii*	Snow Trout	Vulnerable	High	✓	–
2.	*Schizothorax labiatus*	Kunar Snow Trout	Not assessed	Low	–	–
3.	*Schizopyge esocinus*	Chirruh Snow Trout	Not Assessed	Low	–	–
4.	*Triplophysa choprai*	Chitral Loach	Not Assessed	Low	–	–
5.	*Glyptosternum reticulatum*	Himalayan Catfish	Least Concern	Low	–	–
6.	*Schistura prashari*	Khyber Loach	Not Assessed	Low	–	–

The Arkari Gol where the Project is located mainly originates from the Arkari Glacier at an altitude of 5,065 m. Many smaller tributaries connect with the Arkari Gol including Parpuni Gol, Shul Gol, Mazhigram Gol, and Easi Gol. A total of four fish species have been reported from the Arkari Gol i.e. Snow Trout, Himalayan Catfish, Chitral Loach and Khyber Loach.

Lutkho River and Arkari Gol are the main tributaries in the vicinity of project where fish species migrate for breeding. During the low flow season (December to February), the main water channel contracts, but the flow in the river remains swift due to the steep river gradient. Thus the oxygen concentration is high in winter and not a limiting factor. However the combination of low water temperature and the fast current make the river almost unfit for the survival of most of the fish species. This forces them to migrate and the species adopt different modes of migration to cope with the severe winters in the mountainous areas.

Three types of migration take place at the onset of winter season, longitudinal, lateral and local migration. Longitudinal migration is long distance migration, shown by fish which have strong pectoral fins and streamlined bodies such as Snow Trout *Schizothorax richardsonii*. Lateral and local migration is demonstrated by fish which do not have

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7 The IUCN Red List of Threatened Species. Version 2017-3. <www.iucnredlist.org>. Downloaded on **16 April 2018**.

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strong pectoral fins and their bodies are also not streamlined enough to cope with the flow of the river. Thus the species of the genera *Schistura* and *Glyptosternum* show lateral migration as they move from the main river channel and tributaries to side streams having comparatively higher temperature and slower water currents. They also occupy the crevices, boulder areas and trenches along the river bed.

During winter, the Snow Trout migrates to lower parts of the Chitral River to avoid the low water temperature. During the spring season (middle of April) the Snow Trout migrates back to the upper reaches of Lutkho River and Arkari Gol. In the Arkari Gol the Snow Trout can only migrate upstream up to a distance of 5.2 km from the Lutkho River. At this point the elevation of the river increases. Also there is a waterfall of about 5 feet (2.5 km downstream of the proposed dam site) which restricts the fish from upstream migration. No fish specimen of any species was captured at any location upstream of this waterfall. Locals of the area were consulted about distribution of the Snow Trout in the Arkari Gol and they confirmed that fish cannot migrate upstream of the waterfall.

Survey Results

A total of 11 locations in the Aquatic Study Area were sampled for fish (**Exhibit 4.3**). Four of these locations were in the Arkari Gol, two were located in the tributaries of Arkari Gol, four were located in the Lutkho River and one was located in Chitral River.

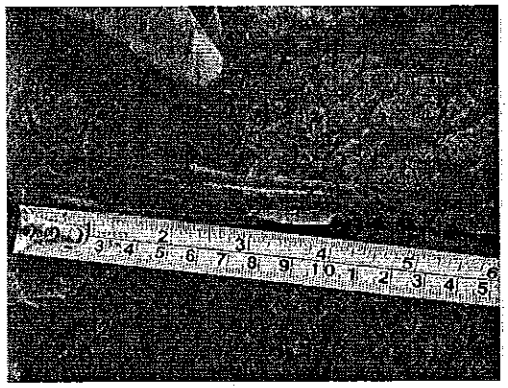
Exhibit 4.9 shows photographs of field activities during the March 2018 Surveys.

Exhibit 4.9: Photographs of Field Activities (March 2018 Survey)

a) Electrofishing

b) Electrofishing

c) Cast netting



d) Measuring Fish Length

Key Observations

A total of 159 specimens of 3 species were collected from the Aquatic Study Area. These included 25 Snow Trout specimens which were all captured from Lutkho River

Main Arkari Gol

Cast netting and electrofishing was the sampling methods used in the main Arkari Gol as it was not possible to apply other sampling methods (gill nets) due to the fast river flow at the time of sampling.

- Water temperature in Arkari Gol was 12°C
- A total of 32 specimens of 2 fish species were collected from the main Arkari Gol.
- Maximum relative abundance (26 specimens) was observed at Sampling Location AR59.6, near the confluence of Arkari Gol and Lutkho River.
- The most abundant fish species observed during the surveys in the Arkari Gol was Chitral Loach. A total of 30 specimens were collected.
- The second most abundant fish species was the Himalayan Catfish with two specimens collected. All the specimens were collected from four sampling locations in the Arkari Gol. Two of these sampling locations were located upstream of proposed dam.

Main Lutkho River

Cast netting and electrofishing was the sampling methods used in the main Lutkho River as it was not possible to apply other sampling methods (Gill Nets) due to the fast river flow at the time of sampling.

- Water Temperature in Lutkho River was between 12 to 13°C.
- A total of 112 specimens of 3 fish species were collected from the main Lutkho River.
- Maximum relative abundance (51 specimens) was observed at Sampling Location L55.2, near the confluence of Lutkho River and Arkari Gol.

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- The most abundant fish species observed during the surveys in the Lutkho River was Chitral Loach. A total of 77 specimens were collected.
- The second most abundant fish species was Snow Trout, with 25 specimens collected and this was followed by Himalayan Catfish with 10 specimens collected. All the specimens were collected from four sampling locations in the Lutkho River. Two of these sampling locations were located downstream of proposed powerhouse.

Main Chitral River

Cast netting and electrofishing was the sampling methods used in the main Chitral River as it was not possible to apply other sampling methods (Gill Nets) due to the fast river flow at the time of sampling.

- Water Temperature in Lutkho River was between 13 to 14°C.
- A total of 15 specimens of 2 fish species were collected from the main Chitral River.
- The most abundant fish species observed during the surveys in the Chitral River was Chitral Loach. A total of 14 specimens were collected.

Tributaries of Arkari Gol

Only electrofishing was conducted in the tributaries due to low flow in these tributaries.

- Sampling was carried out at one location each, in two tributaries (SH20.5 and MAZ5.7) of Arkari Gol
- Although extensive electrofishing was carried out, no specimen of any fish species was captured
- The water temperature in both tributaries was 9°C which is lower than the water temperature recorded from Arkari Gol (12°C)
- Low temperature restricts fish activity and this may be the reason that no fish were recorded from the tributaries

Relative abundance of fish observed during March 2018 surveys is provided in **Exhibit 4.10** while species richness observed in the Aquatic Study Area is provided in **Exhibit 4.11.**

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Exhibit 4.10: Relative Abundance Observed in the Aquatic Study Area, March 2018 Survey

Sampling Location		Arkari Gol				Total	Lutkho River				Total	Chitral River	Total	Tributaries		Total	Grand Total
Scientific Name	*Common Name*	*AR39.8*	*AR51.7*	*AR56.6*	*AR59.6*		*L52.0*	*L55.2*	*L57*	*L65.3*		*M234.6*		*SH20.5*	*MAZ5.7*		
Glyptosternum reticulatum	Himalayan Catfish	–	–	1	1	2	6	–	–	4	10	1	1	–	–	–	13
Schizothorax richardsonii	Snow Trout	–	–	–	–	–	–	7	12	6	25	–	–	–	–	–	25
Triplophysa choprai	Chitral Loach	–	–	5	25	30	6	44	20	7	77	14	14	–	–	–	121
Relative Abundance		–	–	6	26	32	12	51	32	17	112	15	15	–	–	–	159

Exhibit 4.11: Species Richness Observed at different Sampling Location, March 2018 Survey

Sampling Location		Arkari Gol				Total	Lutkho River				Total	Chitral River	Total	Tributaries		Total	Grand Total
Scientific Name	*Common Name*	*AR39.8*	*AR51.7*	*AR56.6*	*AR59.6*		*L52.0*	*L55.2*	*L57*	*L65.3*		*M234.6*		*SH20.5*	*MAZ5.7*		
Glyptosternum reticulatum	*Himalayan Catfish*	–	–	✓	✓	✓	✓	–	–	✓	✓	✓	✓	–	–	–	✓
Schizothorax richardsonii	*Snow Trout*	–	–	–	–	–	–	✓	✓	✓	✓	–	–	–	–	–	✓
Triplophysa choprai	*Chitral Loach*	–	–	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	–	–	–	✓
Richness (Cast Net)		–	–	–	1	1	–	1	–	1	2	1	1	–	–	–	2
Richness (Electrofishing)		–	–	2	2	2	2	2	3	3	3	2	1	–	–	–	3
Species Richness (Overall)		–	–	2	2	2	2	3	3	3	3	2	2	–	–	–	3

Summary

Most Abundant Species	Chitral Loach	Highest Abundance Location	L55.2	Highest Richness	L55.2, L57 and L65.3
2nd Most Abundant Species	Snow Trout	2nd Highest Abundance Location	L57	2nd Highest Richness	AR56.6, AR59.6, L52 and M234.6

RAD

A list of the fish species captured during the March 2018 surveys is given in **Exhibit 4.12**, along with information on their IUCN status, endemism[8] and migratory status. None of these fish species are restricted range species or endemic to the area. Of the species reported from the Study Area, only one species, the Snow Trout is listed as Vulnerable in the IUCN Red List 2018.

Exhibit 4.13 shows photographs of some of the fish species observed during the March 2018 survey surveys. A map of the relative abundance and richness observed during the surveys is given in **Exhibit 4.14.**

A summary table for the results and findings of March 2018 surveys is given in **Appendix C.** The summary table indicates different sampling methods applied, relative abundance, species richness and topography at each sampling location.

Catch per unit effort is number of specimens captured with a particular sampling method applied in a given time or sampling unit at a particular location. **Exhibit 4.15** shows the catch per unit effort for various capture techniques used. The effort in case of cast nets includes 20 castings, 10 each of two mesh sizes spread over a defined stretch of about 100 – 200 m. Electrofishing was applied to an area of 150 m^2.

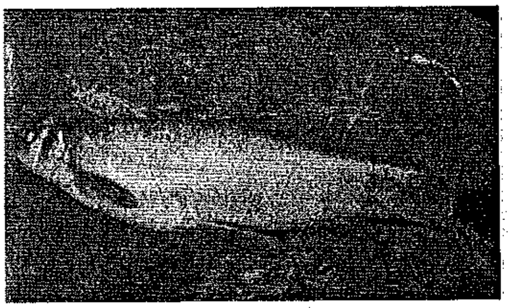
Exhibit 4.12: Fish Fauna Recorded from Aquatic Study Area, March 2018 Survey

No	*Scientific Name*	*Common Name*	*IUCN Status*	*Commercial Importance*	*Migratory*	*Endemism*
1.	*Schizothorax richardsonii*	Snow Trout	Vulnerable	High	✓	–
2.	*Glyptosternum reticulatum*	Himalayan Catfish	Not Assessed	Low	–	–
3.	*Triplophysa choprai*	Chitral Loach	Not Assessed	Low	–	–

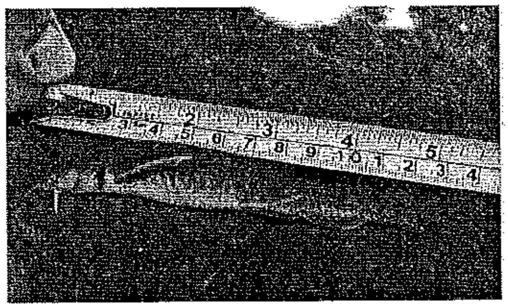
8 Endemic species refers to species that are endemic to the Chitral River basin.

RAD

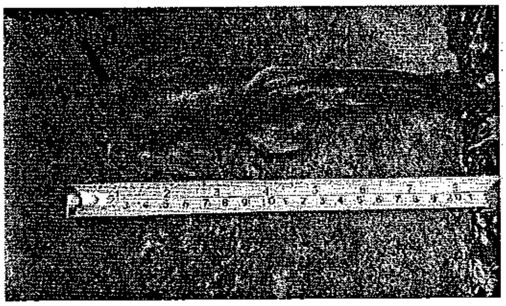
Exhibit 4.13: Photographs of Fish Fauna Recorded from Aquatic Study Area, March 2018 Survey



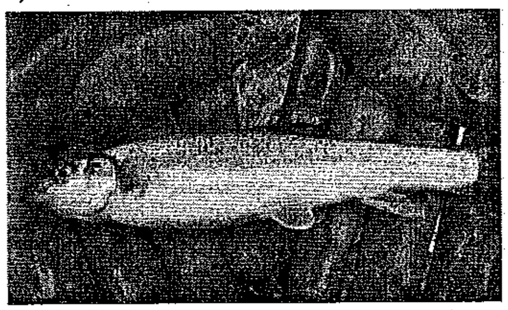
a) Snow Trout



b) Chitral Loach



c) Himalayan Catfish



d) Snow Trout

RAD

Exhibit 4.14: Fish Relative Abundance and Richness, March 2018 Survey

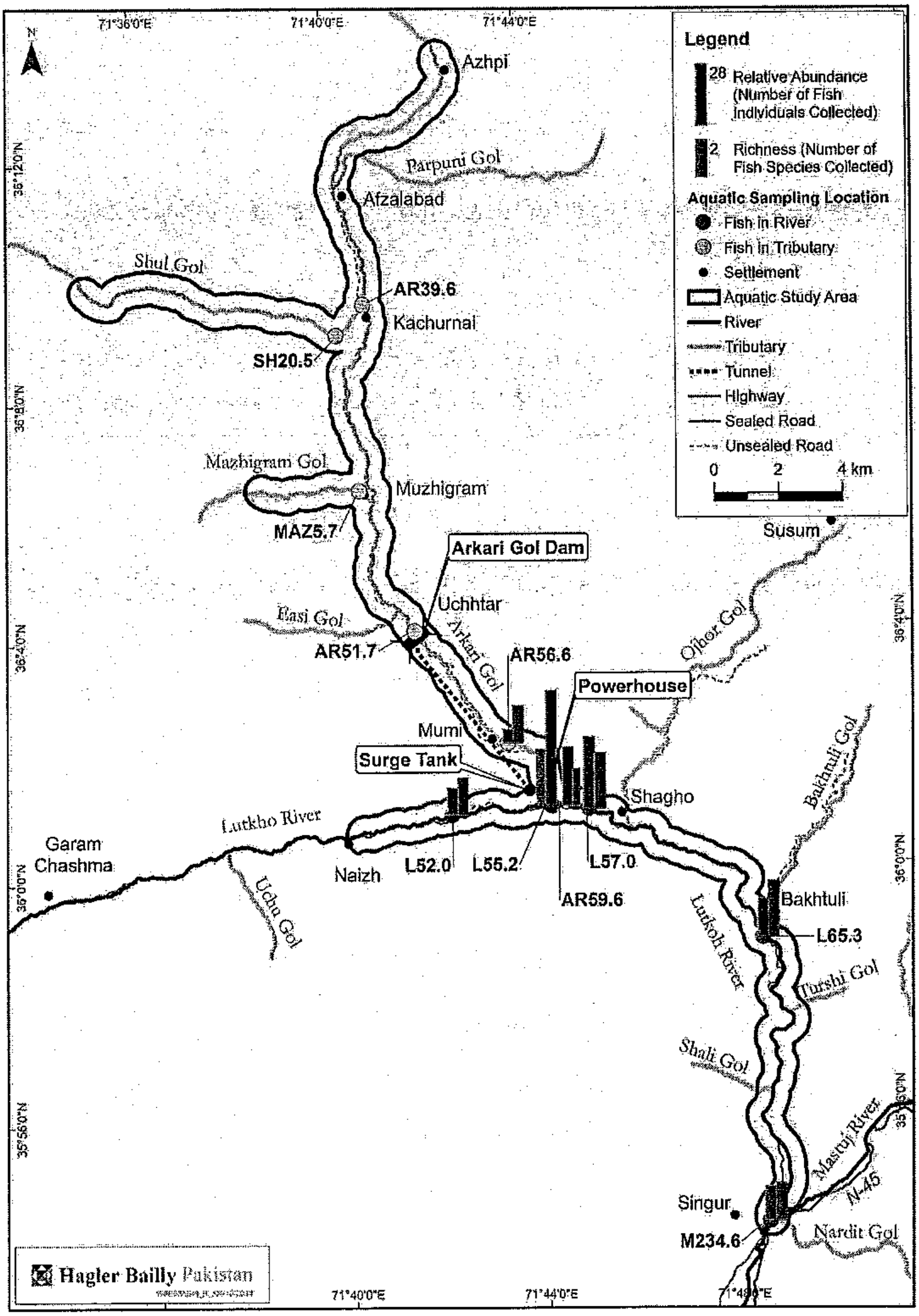


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Exhibit 4.15: Catch per Unit Effort, March 2018 Surveys

River/Tributary	Sampling ID	Location	Cast Net	Electro Fishing	Total
			Fish Captured/ 20 castings	Fish Captured/ 150 sq. m	
Chitral River	M234.6	Downstraem of the conflence of Lutkho and Chitral River	4	11	15
Arkari Gol	AR51.7	Arkari Gol near Dam site	–	–	0
Lutkho River	L52.0	Lutkho River near Ruji Village	–	12	12
Arkari Gol	AR59.6	Arkari Gol near to Powerhouse	7	19	26
Lutkho River	L55.2	Lutkho River near to Powerhouse	14	37	51
Lutkho River	L57	Lutkho River, Downstream of Powerhouse	–	32	32
Arkari Gol	AR56.6	Arkari Gol near Momi Village	–	6	6
Arkari Gol	AR39.6	Arkari Gol near Kachumai Village	–	–	–
Lutkho River	L65.3	Lutkho River near Bakhtoli Village	5	12	17
Shul Tributary	SH20.5	Near Kachumai Village	–	–	–
Mazhigram Tributary	MAZ5.7	Near Dam site	–	–	–
Total			**30**	**129**	**159**

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Threats to Fish Fauna

During the surveys carried out in March 2018, no major threats to fish fauna in the Aquatic Study Area were observed. In some parts of the Aquatic Study Area, locals were involved in fishing using rods and cast nets. However, fishing through illegal means like electrofishing, blasting and gill netting was not observed at any location in the Aquatic Study Area. Sand and gravel mining activity was also not observed at any location in the Arkari Gol or Lutkho River, although in lower part of the Lutkho River stone mining on a small scale was observed.

Conservation Status

The Snow Trout is listed as Vulnerable in the IUCN Red List 2018. It is also a long distance migratory fish with high commercial importance.

Fish Indicators and their Flow–related Needs

The following four species were selected as indicators for EFlow assessment using Downstream Response to Imposed Flow Transformations (DRIFT) model.

- Snow Trout
- Himalayan Catfish
- Khyber Loach

All species selected as indicators demonstrate a comparatively higher degree of specialization in habitat preference in the Aquatic Study Area. In other words, the habitat range of these species was observed to terminate either moving upstream or downstream within the Aquatic Study Area. Changes in flow regime are therefore likely to have a comparatively higher level of impact on these species.

Snow Trout

Preferences for flow dependent habitat, breeding, and migratory behavior of the Snow Trout are summarized in **Exhibit 4.16. Exhibit 4.17** summarizes the annual cycle of breeding and growth of the Snow Trout:

Exhibit 4.16: Preferences for Flow Dependent Habitat, Breeding, and Movement of the Snow Trout:

	Adults	*Juveniles*	*Spawning*
Depth	0.5–1.5 m	0.1–0.5m	0.1–0.3 m
Velocity	1–3 m/s	0–0.5 m/s	1–2 m/s
Habitat	Swift running water with rocky beds	Quiet parts of the streams or in the side branches of the main streams	Spawns on gravelly / stony ground or on fine pebbles with gravel size of 50-60 mm
Substrate	Rocky/Cobbly/Gravely	Cobble/Gravel	Gravel
Temperature	12–20 °C	12 –20 °C	18–22 °C
Dissolved O_2	6–8 mg/l and can survive 5-6 mg/l	6–8 mg/l	6–8 mg/l

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	Adults	Juveniles	Spawning
Food	Insect larvae and eggs, Detritus	Micro-invertebrates	–
Breeding Period and Trigger	May-June in the Flood Season. Breeding is triggered by rise in temperature after the Dry Season. Spawning in side channels in shallow waters (10-30 cm) with boulders and low currents.		
Movement Pattern	Shows limited movement.		
Movement Timing	Limited movement to side channels for spawning.		
Movement Triggers	Availability of side pools with shallow waters, rise in temperature.		
Other Flow-related Needs	Is sensitive to pollution. Can tolerate turbidity.		

Exhibit 4.17: Annual Cycle of Breeding and Growth of the Snow Trout

Months	*Flow Conditions*	*Fish Behavior*
May–June	Flood Season	Breeding is triggered by snow melt and rise in turbidity. Fish move to breeding grounds in shallow side pools, and channels of the river with cobbles. Eggs hatch in this period, and fries and fingerlings remain in shallow waters in side channels under the cobbles.
July–October	Flood Season – Transition-2 and Dry Onset	Spent fish move to areas with boulders, cobbles in its general preferred habitat ranging from a depth of 0.5–1.0 m. Fries and fingerlings remain in the side channels. Both adult and young fish feed actively in this period to gain fat for wintering.
November – March	Dry Season	Fish move mainly to crevices under cobbles or in pools for overwintering. Food intake drops and also supplemented by fat reserves for survival.
April	Transition-1	Fish become active, takes maximum food and move to areas where it can get maximum food.

Himalayan Catfish

Preferences for flow dependent habitat, breeding, and migratory behavior of the Himalayan Catfish are summarized in **Exhibit 4.18**, Annual cycle of breeding and growth of the Himalayan Catfish is shown in the **Exhibit 4.19.**

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Exhibit 4.18: Preferences for Flow Dependent Habitat, Breeding, and Movement of the Himalayan Catfish

	Adults	*Juveniles*	*Spawning*
Depth	Shallow (<1.0 m), can withstand both stagnant and fast flowing water. Avoids deep pools. Can survive low flows in Dry Season by taking shelter under boulders.	Shallow (<0.75 m)	Shallow (<0.75 m)
Velocity	Slow (0-2 m/s), can tolerate floods by taking shelter under boulders	Slow (0-2 m/s)	Slow (0-2 m/s)
Habitat	Underneath stone piles	Underneath stone piles	Riffles, shallow pools, with stony beds
Substrate	Rocky	Cobble	Cobble
Temperature	10–20 °C	10–20 °C	10–14 °C
Dissolved O_2	6–8 mg/l and can survive 5–6 mg/l	6–8 mg/l	6–8 mg/l
Food	Insect larvae, micro-invertebrate	Micro-invertebrates	–
Breeding Period and Trigger	May-June in the Flood Season. Breeding is triggered by rise in temperature after the Dry Season. Spawning in side channels in shallow waters (10-20 cm) with boulders and low currents.		
Movement Pattern	Shows limited movement.		
Movement Timing	Limited movement to side channels for spawning.		
Movement Triggers	Availability of side pools with shallow waters, rise in temperature.		
Other Flow-related Needs	Is sensitive to pollution. Can tolerate turbidity.		

Exhibit 4.19: Annual Cycle of Breeding and Growth of the Himalayan Catfish

Months	*Flow Conditions*	*Fish Behavior*
May–June	Flood Season	Breeding is triggered by snow melt and rise in turbidity. Fish move to breeding grounds in shallow side pools, and channels of the river with cobbles. Eggs hatch in this period, and fries and fingerlings remain in shallow waters in side channels under the cobbles.
July–October	Flood Season – Transition-2 and Dry Onset	Spent fish move to areas with boulders avoiding fast flowing water. Fingerlings remain under the cobbles. Both adult and young fish feed actively in this period.
November–March	Dry Season	Fish move mainly to crevices under cobbles for overwintering. Avoid pools. Food intake drops and also supplemented by fat reserves for survival.

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Months	*Flow Conditions*	*Fish Behavior*
April	Transition-1	Fish emerge and move to areas with boulders, avoiding fast flows, in search of food to get ready for the breeding season.

Chitral Loach

Preferences for flow dependent habitat, breeding, and migratory behavior of the Chitral Loach are summarized in **Exhibit 4.20**, Annual cycle of breeding and growth of the Chitral Loach is shown in the **Exhibit 4.21.**

Exhibit 4.20: Preferences for Flow Dependent Habitat, Breeding, and Movement of the Chitral Loach

	Adults	*Juveniles*	*Spawning*
Depth	Banks, shallow riffles (<0.75 m)	Shallow side pools (<0.75 m)	Shallow side channels and pools (<0.30 m)
Velocity	Low to moderate (0–2 m/s)	Low to moderate (0–2 m/s)	Low to moderate (0–2 m/s)
Habitat	Pools, riffles, glides	Banks	Pools, riffles
Substrate	Rocky, stony	Cobbles	Stones, cobbles
Temperature	6–14 °C	6–14 °C	10–14 °C
Dissolved O_2	6–8 mg/l	6–8 mg/l	6–8 mg/l
Food	Insect larvae, micro-invertebrate	Micro-invertebrates	–
Breeding Period and Trigger	May–August in the Flood Season. Breeding is triggered by rise in temperature after the Dry Season. Breeds both in river as well as in tributaries in suitable habitat.		
Movement Pattern	Does not show any significant movement except for breeding, when it moves to shallow side pools.		
Movement Timing	Limited movement to side channels for spawning.		
Movement Triggers	Availability of side pools with shallow waters, rise in temperature.		
Other Flow-related Needs	Is sensitive to pollution.		

Exhibit 4.21: Annual Cycle of Breeding and Growth of the Chitral Loach

Months	*Flow Conditions*	*Fish Behavior*
June – August	Flood Season	Breeding is triggered by snow melt and rise in turbidity. Fish move to breeding grounds in shallow side pools, and channels of the river with cobbles and gravely beds. Eggs hatch in this season, and fries and fingerlings remain in shallow waters in side channels.

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Months	Flow Conditions	Fish Behavior
September–October	Flood Season – Transition-2 and Dry Onset	Spent fish move to banks of the mainstream. Fingerlings remain in shallow side channels. Both adult and young fish feed actively in this period.
November–March	Dry Season	Fish move mainly to crevices for overwintering. Food intake drops significantly as fish is inactive and also utilizes fat reserves for survival.
April-May	Transition-1 and Flood Season	Fish emerge and move to banks, avoiding fast flows, in search of food to get ready for the breeding season.

Macro–Invertebrates

Overview

Benthic macro–invertebrates are an important part of the food chain in aquatic ecosystems, especially for fish. Many invertebrates feed on algae and bacteria, which are at the lower end of the food chain. Some shred and eat leaves and other organic matter that enters or is produced in the water. Because of their abundance and position as 'intermediaries' in the aquatic food chain, benthos plays a critical role in the natural flow of energy and nutrients.[9]

Stream regulation by damming of rivers and ensuing impoundment are one of the most frequent causes of depletion of biological diversity of aquatic ecosystems resulting in interference with the natural process of dispersal.[10,11] Some authors have described several beneficial aspects of water regulation and impoundment, but the loss of aquatic habitat and the associated species and populations cannot be underestimated. Any variation in community structure of primary producers is reflected in subsequent changes in higher components of food chain e.g., benthic macro–invertebrates and fish fauna.[12]

The composition of invertebrate communities varies along and between rivers, with the main influences on distribution and abundance being current velocity, water temperature, substratum type, stability of both aquatic and riparian vegetation, dissolved substances, competition, and human practices. Large, stable substrata–such as boulders and cobbles–support larger, more productive invertebrate populations than do unstable gravels and sand. On mobile bottoms, such as gravel and sand, invertebrates are readily displaced and may be at risk through mechanical damage. A decrease in substratum size results in lower macro–invertebrate diversities and production.

Aubert, 1959[13] reported twenty species of stoneflies (extremely pollution intolerant organisms) belonging to seven genera from Pakistan (Hindukush including Gilgit–Baltistan and Chitral; Karakorum including Neelum valley, Kaghan valley; Rawalpindi including Murree). He reported six species of stoneflies species from Neelum Jhelum

9 Williams D. D. and Feltmate, B. W. 1992. Aquatic Insects. CAB International Wallingford, Oxon. 360 pp.

10 Richter, B.D., Braun, D.P., Mendelson, M.A., Master, L. L. 1997. Threats to imperiled freshwater fauna. Conservation Biology. 11, 1081–1093.

11 Zalewski, M., Janauer, G. A., Jolankai, G., 1997. Ecohydrology. IHP–V, UNESCO. 7, 7–18.

12 Ibid

13 Aubert, J. 1959: Plécoptères du Pakistan. Memoires de la Societe vaudoise des Sciences naturelles, 75, Vol. 12, fasc. 3:65–91.

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area which include *Nemoura (Amphinemura) mirabilis* (Muzaffarabad after the confluence of the Neelum and Jhelum Rivers), *Nemoura (Amphinemura) schmidi* (Kel, Neelum Valley), *Nemoura (Amphinemura) skardui* (Rampur Neelum Valley), *Nemoura* s. s. *lilami* (Kel, Neelum Valley), *Nemoura* s. s. *polystigma* (Lilam, Neelum Valley) and *Cholroperla kishanganga* (Kel, Neelum Valley). Organism's pollution tolerance was taken from HKH bios scoring list (Hindukush Himalayan Score Bio–assessment) (Hartmann *et al.*, Deliverable 10). [14]

Survey Results

During the March 2018 Survey, a total of four locations were sampled to determine the abundance and diversity of macro–invertebrate fauna in the Aquatic Study Area. Three of these sampling locations were located along the Arkari Gol while one location was located downstream of the powerhouse in the Lotkoh River. The sampling locations for macro–invertebrates are shown in **Exhibit 4.3**. The abundance, species diversity and HKH Bios Score[15] of macro–invertebrate recorded during the March 2018 Survey is shown in **Exhibit 4.22**. Photographs of field activities are given in **Exhibit 4.23.** A map showing the relative abundance and species diversity of macro–invertebrate taxa is shown in **Exhibit 4.24.**

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[14] Hartmann, A., O. Moog, T. Ofenböck, T. Korte, S. Sharma and D. Hering. Deliverable No. 10. ASSESS–HKH Methodology Manual describing fundamentals a application of three approaches to evaluate river quality based on benthic macroinvertebrates: HKH screening, HKH score bioassessment & HKH multimatric bioassessment. 80pp. www.assess–hkh.at

[15] It is a biotic score that determines the tolerance level of biota i.e. macro–invertebrates. A lower HKH Bios Score of an organism means higher pollution tolerance of that particular organism while the higher the Bios Score the lower its pollution tolerance level.

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Exhibit 4.22: Macro–invertebrate Abundance and Richness, March 2018 Survey

Sample ID					AR51.7	AR56.6	AR59.6	L57.0	Total	HKH Bio Score
No	Order	Sub–Family	Genus	Feeding Habit						
1	Ephemeroptera	Heptageniidae	Rhithrogena sp.	Scraper	–	–	2	1	3	9
2	Ephemeroptera	Heptageniidae		Scraper	–	–	–	1	1	8
3	Ephemeroptera	Baetidae	Acentrella sp.	Collector gatherer	1	–	3	–	4	8
4	Ephemeroptera	Baetidae	Baetis sp.	Collector gatherer	75	74	18	45	212	–
5	Plecoptera	Chloroperlidae		Unknown	1	–	–	–	1	9
6	Trichoptera	Hydropsychidae	Hydropsyche sp.	Collector filterer	–	1	2	2	5	7
7	Trichoptera	Rhyacophilidae	Rhyacophila sp.	Predator	1		1		2	8
8	Diptera	Simuliidae		Collector filterer	1	–	–	–	1	7
9	Diptera	Chironomidae		Unkonwn	–	10	–	–	10	–
10	Diptera	Tipulidae		Unknown	–	–	2	–	2	7
Abundance (Order/ Family/ Genus)					79	85	28	49	241	–
Richness					5	3	6	4	7	–

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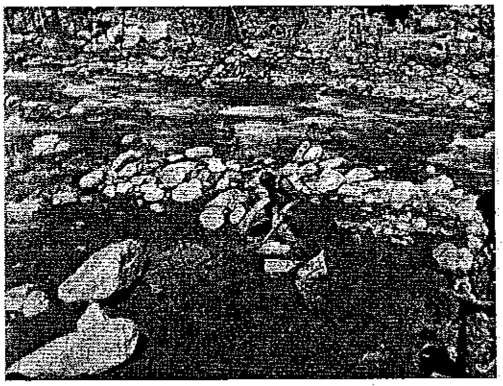
Exhibit 4.23: Photographs of Field Activities, March 2018 Survey



Collection of Macro–Invertebrates

Key Observations

Key observations during the March 2018 Survey are summarized below.

1. A total of 10 macro–invertebrate taxa were identified. Identification was at the order/family/genus level.
2. Abundance was highest at Sampling Location AR56.6, main Arkari Gol near Momi village.
3. The most abundant macro–invertebrate taxa observed was *Baetis* sp. followed by Chironomidae.
4. Most of pollution intolerant genera of macro–invertebrates were observed indicating good water quality. One moderately pollution tolerant genus i.e. *Hydropsyche sp* was also observed.
5. Maximum richness was seen at Sampling Location AR59.6.

Conservation and Protection Status

None of the macro-invertebrate taxa reported from the Study Area are identified as threatened or included in the IUCN Red List 2018.

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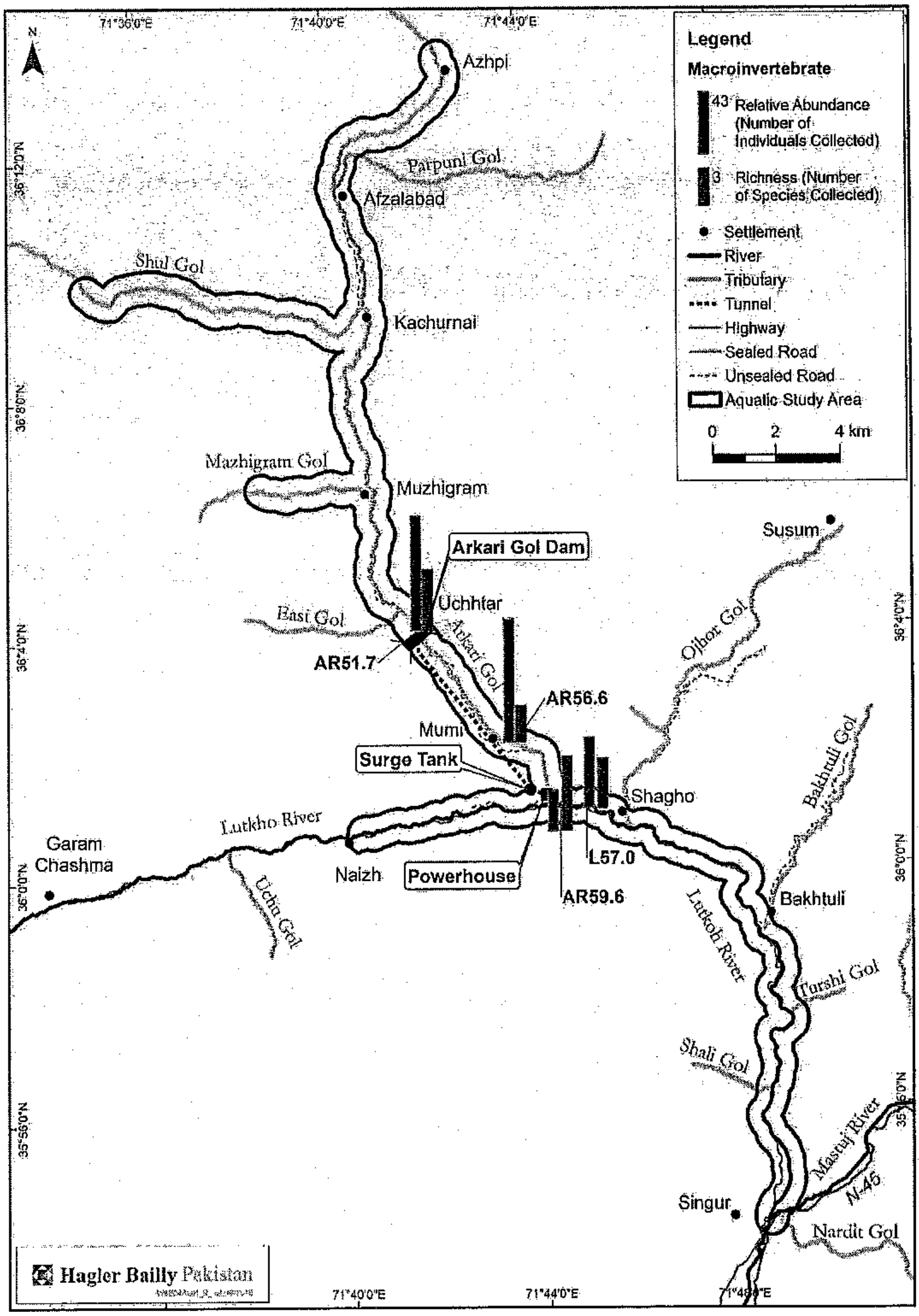
Exhibit 4.24: Macro–invertebrate Abundance and Richness
March 2018 Survey



Riparian Vegetation

Overview

Riparian vegetation is the plant community sustained by river flow, groundwater or generally moist conditions along river margins, and is typically distinct in species composition from adjacent terrestrial communities.[16]

Riparian vegetation plays a central role in the functioning of Riverne ecosystems: bank erosion is reduced through armoring; water quality is maintained through trapping of sediment, nutrients and other contaminants, and shading regulates river water temperature and thus primary productivity; food is provided for riparian animals in the form of fruits, nuts and leaves, and for aquatic macro-invertebrates in the form of leaf litter; the plants themselves offer a diverse array of habitats as well as a corridor for the movement of migratory terrestrial and semi-aquatic animals.[17]

Survey Results

The range of vegetation cover observed in the riparian areas in the Aquatic Study Area during the March 2018 survey was between 1.36% and 2.60%. The average plant count was 15 per sampling location. Floral diversity in this habitat type was 4.0 species per sampling location. The dominant species included *Salix viminalis, Artemisia maritima. Robinia pseudoacacia, Salix acmophylla* and *Rumex hastatus.*

The vegetation cover, plant count and diversity by habitat type are provided in **Exhibit 4.25**. The phyto–sociological attributes are provided in **Exhibit 4.26.** Photographs of riparian habitat are shown in **Exhibit 4.27.** Average and maximum vegetation cover in the riparian habitats was relatively low compared to that observed for terrestrial habitat types (Vegetation Cluster).

Exhibit 4.25: Vegetation Cover, Plant Count and Diversity in Riparian Habitat Type, March 2018 Survey

Habitat Types	*Plant Cover (%)*			*Plant Count (No. of Plants per Sampling Location)*			*Diversity (Average no of species per Sampling Location)*
	Avg	*Max*	*Min*	*Avg*	*Max*	*Min*	
Riparian	1.86%	2.60%	1.36%	15	21	11	4.0

[16] Parkyn, Stephanie. (2004). *Review of Riparian Buffer Zone Effectiveness.* Ministry of Agriculture and Forestry (New Zealand), www.maf.govt.nz/publications.

[17] PROSSER, I.P. 1999. Identifying priorities for riparian restoration aimed at sediment control. Second Australian stream management conference, 8-11 February. Adelaide, South Australia. Pg 511-516.

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Exhibit 4.26: Phyto–sociological Attributes of Plant Species in Habitats March 2018 Survey

Species Name	*D1, Density*	*D3, Relative Density*	*C1, Average Cover*	*C3, Relative Cover*	*F1, Frequency*	*F3, Relative Frequency*	*IVI, Importance Value Index*
Salix viminalis	0.67	13.33	0.85	13.36	0.11	8.33	11.68
Ailanthus altissima	0.44	8.89	53.41	0.14	0.11	8.33	5.79
Artemisia maritima	0.33	6.67	41.9	0.14	0.11	8.33	5.05
Ficus carica	0.11	2.22	1.15	1.65	0.11	8.33	4.07
Juniper spp	0.33	6.67	1.17	4.88	0.22	16.67	9.4
Platanus orientalis	0.11	2.22	0.12	15.6	0.11	8.33	8.72
Populus ciliata	0.22	4.44	1.38	2.75	0.22	16.67	7.95
Robinia pseudoacacia	0.33	6.67	0.5	11.38	0.22	16.67	11.57
Rubus ellipticus	0.11	2.22	7.79	0.24	0.11	8.33	3.6
Rumex hastatus	0.44	8.89	172.28	0.04	0.11	8.33	5.76
Salix acmophylla	1.11	22.22	0.4	47.53	0.56	41.67	37.14
Sisymbrium irio	0.78	15.56	5.81	2.29	0.22	16.67	11.5
Total	**5**	**100**	**286.76**	**100**	**2.22**	**166.67**	**122.22**

D1: Density
The number of individuals of a species counted on a unit area.

C1: Average cover in sq m for a single species

C3: Relative cover
The proportion of the total cover of a species to sum of the cover of all the species in area.

F3: Relative frequency
The proportion of the total frequency of a species to the sum of the frequency of all the plants of all species in the area.

D3: Relative density
The proportion of a density of a species to that of a stand as a whole.

F1: Frequency
Percentage of sampling plots in which a given species occurs.

IVI: Importance value index
It can be obtained by adding the values of relative density, relative cover and relative frequency and dividing it by three will give the importance value IVI of the species

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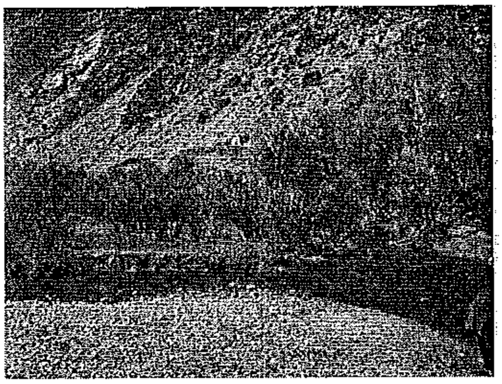
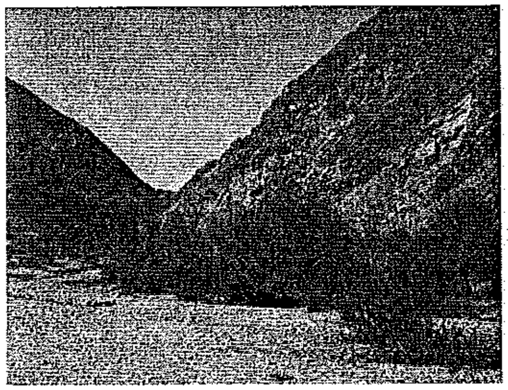
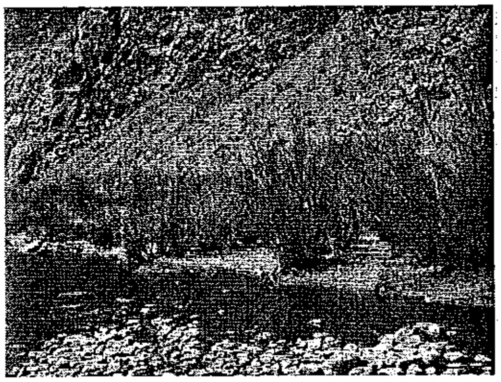
Exhibit 4.27: Riparian Habitat (March 2018 Survey)



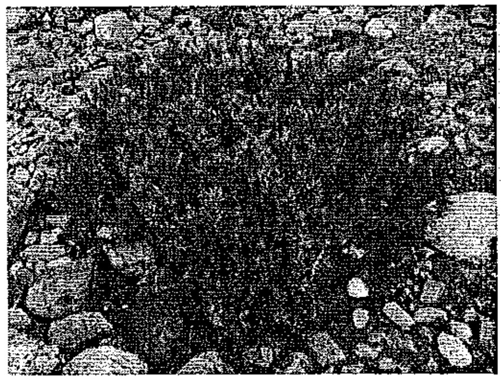
Riparian Habitat near Sampling Location AR59.6



Riparian Habitat near Sampling Location AR51.7



Riparian Habitat near Sampling Location AR59.6



Juniper spp. in Riparian Habitat

Conservation Status

None of the terrestrial vegetation species reported from the Study Area are identified as threatened or included in the IUCN Red List 2018.

Periphyton Biomass

The term periphyton refers to the film of living matter coating almost all surfaces in streams. It is usually dominated by benthic algae, but also includes diatoms, bacteria, fungi and other organic matter. Benthic algae are the primary producers in rivers, providing food for macro-invertebrates and fish. They respond rapidly to changing conditions, and they are often the first organisms to respond to and to recover from stress.

Periphyton is attached algae on the sediment deposited on stones. During the March 2018 survey, sampling for periphyton biomass was carried out at a total 3 sampling locations **(Exhibit 4.3)** but no periphyton biomass was collected from any sampling location. This is because of the fast flow of the river in the survey season, which erodes and washes out periphyton biomass from the cobble stones.

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4.1.5 Terrestrial Ecology

This section provides an overview of terrestrial ecology in the Terrestrial Study Area and surroundings based on a review of available literature and field surveys conducted in March 2018. Terrestrial sampling locations are shown in **Exhibit 4.6.** List of the terrestrial species found in the area are provided in **Appendix D,** while Field Data is provided in **Appendix E.**

Terrestrial Flora

Overview

Approximately 6000 plant species often of medicinal and/or commercial importance have been reported from Pakistan.[18] However, the floral diversity is subjected to progressive loss, owing to fragmentation and degradation of natural habitats that is leading to the disappearance of countless species.[19] Pakistan has five significant mountain systems, i.e. Western Himalayas, Karakoram, Hindukush, Suleiman and Khirthar range. Chitral the high mountainous dry temperate area of the Northern Pakistan lies in Hindukush range which is one of the oldest mountain ranges in the world.

There is very little information available in literature about the terrestrial flora of the Arkari valley. A total of 571 plant species belonging to 334 different genera have been reported from the wider area around the Terrestrial Study Area. Most of the plant species belong to Family Asteraceae (16%), Poaceae (10.16%), Papilionaceae (6.65 %), Lamiaceae (4.55%), Rosaceae (4.55%), Boraginaceae (3.50%), Brassicaceae (3.50%).[20] Most of these plant families are common and have a wide distribution range.

Habitat Types in the Terrestrial Study Area

Habitat classification approaches are subjective in nature, devised to assist in the understanding of ecological systems, the functions of those systems, and the interrelationship with species. Classically, wildlife habitat is described as containing three basic components: cover, food, and water (Morrison et al 2006)[21] with vegetation as the core descriptive component.

Habitats in the Terrestrial Study Area were classified relying primarily upon vegetation type. Following this classification approach, three types of habitats were defined: Barren Land, Agricultural Fields and Vegetation Cluster. Satellite imagery from ***Google Earth™*** was used to initially delineate spatial distribution of habitat types within the Terrestrial Study Area and this habitat characterization was confirmed during the field surveys. Most of the Terrestrial Study Area classified as Barren Land having no or very little vegetation.

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[18] Nasir E and Ali, S.I. (1972). Flora of West Pakistan. Published under P. L. 480, Research project of U.S.A.D., with coordination of A.R.C. Pakistan.

[19] Perveen, A. and Hussain, M.I. (2007). Plant Biodiversity and Phytosociological attributes of Gorakh hill (Khirthar range) Pak. J. Bot. 39(3): 691–698.

[20] Hussain, Farrukh, S. Mukaram Shah, Lal Badshah, and Mufakhira Jan Durrani. "Diversity and ecological characteristics of flora of Mastuj valley, district Chitral, Hindukush range, Pakistan." *Pak. J. Bot* 47, no. 2 (2015): 495–510.

[21] Morrison, M.L, Marcot, B., Mannan, W. 2006. Wildlife–Habitat Relationships: Concepts and Applications. Island Press, Washington, D.C.

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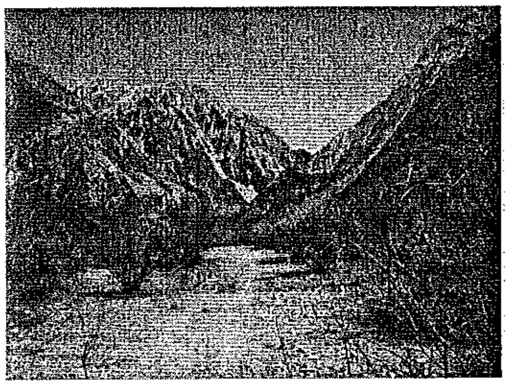
The relative percentages of each habitat type in the Terrestrial Study Area is provided in **Exhibit 4.28**. Photographs of different habitat types in the Terrestrial Study Area are shown in **Exhibit 4.29**.

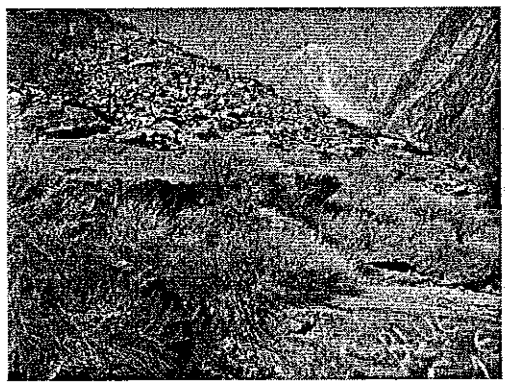
Exhibit 4.28: Habitat Types for the Terrestrial Sampling Locations

Habitat Type	*Area (km²)*	*Percentage*
Barren Land	18.29	92.1
Vegetation Cluster	0.31	1.6
Agricultural Land	0.83	4.2
River	0.42	2.1
Total	**19.8**	**100**

Exhibit 4.29: Photographs of Different Habitat types in the Terrestrial Study Area, March 2018 Survey



Vegetation Cluster



Barren Land

Barren Land

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Survey Results

During the March 2018 survey, a total of 14 species of plants were observed in the Terrestrial Study Area. The indicators, including plant cover, plant count and diversity per sampling location describe the floral conditions within each habitat type. The Agricultural Fields could not be sampled as these were located very close to, and sometimes within, the households of the local communities.

Barren Land is dominated by small size plants species such as *Sisymbrium irio, Artemisia maritima* and *Rumex hastatus* and large sized trees are largely absent. Therefore, low plant cover was observed in Barren Land. Vegetation Cluster habitat is dominated by large size tree species. The vegetation cover, plant count and diversity by habitat type are provided in **Exhibit 4.30.** The phyto–sociological attributes for the species in the two habitat types for the March 2018 Survey are provided in **Exhibit 4.31.**

Exhibit 4.30: Vegetation Cover, Plant Count and Diversity by Habitat type, March 2018 Survey

No.	Habitat Types	Plant Cover (%)			Plant Count			Diversity (Average no of species per Sampling Location)
		Average	Maximum	Minimum	Average	Maximum	Minimum	
1.	Barren Land	2.01%	3.34%	0.99%	16.25	27	8	1.75
2.	Vegetation Cluster	2.29%	2.35%	2.23%	18.5	19	18	5.5

Exhibit 4.31: Phyto–sociological Attributes of Plant Species in Habitats, March 2018 Survey

Habitat	Species Name	D1, Density	D3, Relative Density	C1, Average Cover	C3, Relative Cover	F1, Frequency	F3, Relative Frequency	IVI, Importance Value Index
Barren Land	*Ailanthus altissima*	0.11	3.08	5.79	8.11	0.06	14.29	8.49
	Artemisia maritima	1.78	49.23	43.84	17.13	0.56	142.86	69.74
	Juniper spp	0.11	3.08	1.23	38.31	0.06	14.29	18.56
	Mentha longifolia	0.33	9.23	117.16	1.2	0.06	14.29	8.24
	Robinia pseudoacacia	0.11	3.08	1.73	27.17	0.06	14.29	14.85
	Rumex hastatus	0.67	18.46	71.9	3.92	0.28	71.43	31.27
	Sisymbrium irio	0.5	13.85	50.74	4.16	0.11	28.57	15.53
	Total	**3.61**	**100**	**292.39**	**100**	**1.17**	**300**	**166.67**
Vegetation Cluster	*Salix viminalis*	0.5	24.32	1.22	10.33	0.11	18.18	17.61
	Ailanthus altissima	0.17	8.11	0.49	8.53	0.11	18.18	11.61
	Artemisia maritima	0.11	5.41	11.98	0.23	0.06	9.09	4.91

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Habitat	Species Name	D1, Density	D3, Relative Density	C1, Average Cover	C3, Relative Cover	F1, Frequency	F3, Relative Frequency	IVI, Importance Value Index
	Ficus carica	0.11	5.41	0.39	7.24	0.06	9.09	7.25
	Morus nigra	0.06	2.7	0.17	8.29	0.06	9.09	6.69
	Pistacia khinjuk	0.28	13.51	55.62	0.13	0.06	9.09	7.58
	Platanus orientalis	0.06	2.7	0.08	16.52	0.06	9.09	9.44
	Populus ciliata	0.11	5.41	0.52	5.37	0.06	9.09	6.62
	Robinia pseudoacacia	0.11	5.41	0.21	13.09	0.11	18.18	12.23
	Salix acmophylla	0.28	13.51	0.27	25.48	0.17	27.27	22.09
	Sisymbrium irio	0.28	13.51	1.46	4.78	0.11	18.18	12.16
	Total	**2.06**	**100**	**72.42**	**100**	**0.94**	**154.55**	**118.18**

D1: Density
The number of individuals of a species counted on a unit area.

D3: Relative density
The proportion of a density of a species to that of a stand as a whole.

C1: Average cover in sq m for a single species

C3: Relative cover
The proportion of the total cover of a species to sum of the cover of all the species in area.

F1: Frequency
Percentage of sampling plots in which a given species occurs.

F3: Relative frequency
The proportion of the total frequency of a species to the sum of the frequency of all the plants of all species in the area.

IVI: Importance value index
It can be obtained by adding the values of relative density, relative cover and relative frequency and dividing it by three will give the importance value IVI of the species

Barren Land

Barren Land habitat type constitutes 92.1% of the Terrestrial Study Area. The average vegetation cover is 2.01%. The average plant count is 16.25 and floral diversity is 1.75 species per sampling location. The dominant species include *Artemisia maritima, Rumex hastatus* and *Sisymbrium irio*. Photographs of some plant species found in this habitat type are shown in **Exhibit 4.32**.

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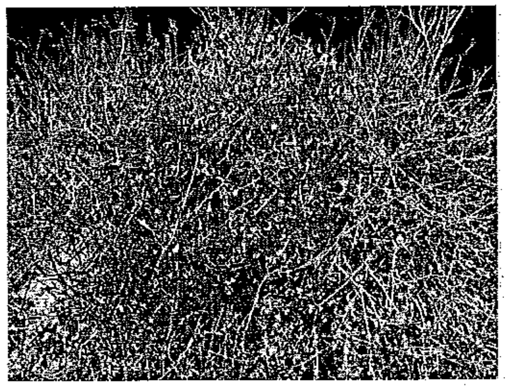
Exhibit 4.32: Plant Species in Barren Land, March 2018 Survey

Artemisia maritima



Rumex hastatus

Juniper spps.

Vegetation Cluster

Vegetation Cluster habitat type constitutes about 1.6% of the total Terrestrial Study Area. The range of vegetation cover is between 2.23% and 2.35%. The average plant count is 18.5. The floral diversity is 5.5 species per sampling location. The dominant species include *Artemisia maritima, Salix acmophyla, Robinia pseudoacacia and Sisymbrium irio*. Photographs of some plant species found in this habitat type are shown in **Exhibit 4.33.**

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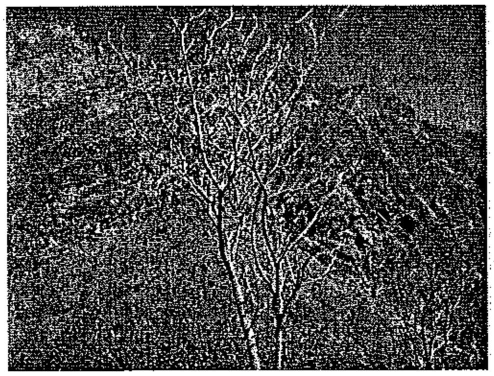
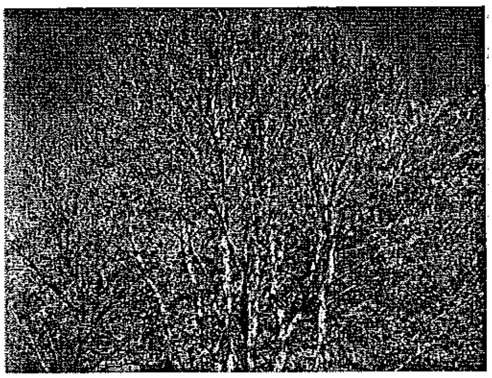
Exhibit 4.33: Plant Species in Vegetation Cluster, March 2018 Survey

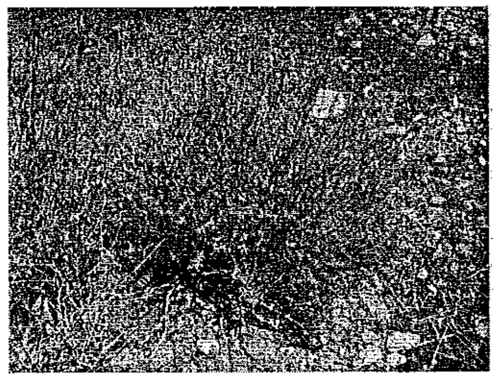
Salix acmophylla



Ailanthus altissima



Platanus orientalis



Artemisia maritima

Invasive Species

An alien or non–native plant or animal species is one that is introduced beyond its original range of distribution. Invasive alien species are non–native species that may become invasive or spread rapidly by outcompeting other native plants and animals when they are introduced into a new habitat that lacks their controlling factors as determined by natural evolution.[22]

Studies have indicated that 700 alien species are found in Pakistan. Of these six are considered to have extreme invasive nature including Paper Mulberry *Broussonetia papyrifera*, Mesquite *Prosopis juliflora*, Common Water Hyacinth *Eichhornia crassipes*, Giant Salvinia *Salvinia molesta*, Parthenium Weed *Parthenium hystrophorus*, and Lantana *Lantana camara*.[23]

During the March 2018 surveys, no invasive plant species was observed in the Terrestrial Study Area. However, three invasive plant species Marijuana *Cannabis sativa*,

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22 International Finance Corporation, 2012, Guidance Note 6 Biodiversity Conservation and Sustainable Management of Living Natural Resources

23 Mohammad Niaz, May 4, 2009, Invasive alien species: A threat to biodiversity, Dawn News, accessed November 8, 2016

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Strumarium *Xanthium strumarium* and Castor Oil Plant *Ricinus communis* were observed in the lower part of the Aquatic Study Area.

Cannabis sativa is distributed in northern Punjab and KP. It is not very aggressive with a medium degree of invasiveness. It invades waste areas and fence rows around farm building usually on bottomland soil. A very adaptable herb, it is found both in plains as well as at elevations up to 1000 feet.[24] *Xanthium strumarium* has been listed as a noxious weed and it is a major weed of crops such as soybeans, cotton, maize and groundnuts in many parts of the world. It produces large amounts of highly antigenic pollen and the glandular hairs on the leaves and stem secrete a substance which causes contact dermatitis in allergic individuals.[25] *Ricinus communis* is a fast–growing shrub or small tree which is a highly prolific and precocious producer of toxic seeds, very adaptable to different environments and has been widely distributed by man.[26]

Ethnobotany

Ethnobotany is the systematic study of the relationships between plants and people.[27] The popularity of herbal drugs is on the rise in many developed countries of the world, while in developing countries like Pakistan; medicinal plants contribute significantly to the income sources of people living in remote areas.[28]

Pakistan is among the top eight exporting countries of medicinal and aromatic plants in the world, exporting plants worth US$ 5.45 million per year. Over 60% of the total export originates from the Hindukush–Himalayas regions of the country.[29]

Previous studies on the ethnobotanical value of plant species in the wider area around the Project show that a number of plant species are used by the locals for treating diseases. Leaves of *Rumex hastatus* are eaten to increase appetite and also used as purgative, astringent and diuretic. Dried leaves of *Pistacia khinjuk* are burnt in smoke and are considering as devil repellent. *Sisymbrium irio* seeds are powdered and a paste is prepared, which is applied externally for pain. The paste is also used for clearing facial pimples and to prevent sunburn. The flowers of Artimisia species are dried, powdered and used as anthelmintic.[30]

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24 Qaiser, M. 1973. Cannabaceae in S.I. Ali and E. Nasir (Eds) Flora of West Pakistan, No. 44, pp 5.

25 Weaver SE, Lechowicz MJ (1982) The biology of Canadian weeds. Xanthium strumarium L. Can J plant sci 63(1): 211–225.

26 Bridgemohan P, Bridgemohan RSH, 2014. Invasive weed risk assessment of three potential bioenergy fuel species. International Journal of Biodiversity and Conservation, 6(11):790–796. http://academicjournals.org/article/article1416497061_Bridgemohan%20and%20Bridgemohan.pdf

27 New World Encyclopedia, http://www.newworldencyclopedia.org/entry/Ethnobotany, accessed April 13, 2017

28 Hassan Sher, Haidar Ali And Shafiqur Rehman, Identification And Conservation of Important Plant Areas (IPAS) For The Distribution Of Medicinal, Aromatic And Economic Plants In The Hindukush–Himalaya Mountain Range, Pak. J. Bot., 44: 187–194, Special Issue May 2012

29 Hassan Sher, Haidar Ali And Shafiqur Rehman, Identification And Conservation of Important Plant Areas (IPAS) For The Distribution Of Medicinal, Aromatic And Economic Plants In The Hindukush–Himalaya Mountain Range, Pak. J. Bot., 44: 187–194, Special Issue May 2012

30 Ali, Haidar, and M. Qaiser. "The ethnobotany of Chitral valley, Pakistan with particular reference to medicinal plants." *Pak. J. Bot* 41, no. 4 (2009): 2009–2041.

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Conservation and Protection Status

None of the species observed in the Study area or surroundings were found to be globally/nationally threatened species, endemic species or protected species.[31]

Mammals

Overview

Pakistan has rich diversity of mammalian fauna. About 195 mammalian species have been reported so far from different habitats in the country.[32] The diversity of large mammals in northern Pakistan is high compared to other parts of the country, yet majority of these species is either threatened or endangered.[33]

District Chitral provides habitat to a diverse group of threatened mammal species. Carnivores species reported from different areas of District Chitral include Common Leopard *Panthera pardus,* Snow Leopard *Panthera uncia,* Himalayan Lynx *Lynx lynx,* Pallas's Cat *Otocolobus manul,* Grey Wolf *Canis lupus,* Asiatic Jackal *Canis aureus,* Red Fox *Vulpes vulpes,* Stone Matin *Martes foina,* Yellow Throated Marten *Martes flavigula,* Himalayan Brown Bear *Ursus arctos,* Asiatic Black Bear *Ursus thibetanus.* Prey species found in different areas of district Chitral include Flare–horned Markhor *Capra falconeri,* Himalayan Ibex *Capra ibex,* Cape Hare *Lepus capensis,* Long Tail Marmot *Marmota caudata* etc. [343536]

Survey Results

Sampling was carried out at six sampling locations during the March 2018 Survey to study the mammalian species abundance and diversity within the Terrestrial Study Area. The locations of these are shown in **Exhibit 4.6**. The results of the surveys, based on the sightings or signs of the mammals observed are provided in **Exhibit 4.34**. Photographs of the mammalian signs and sightings observed are shown **in Exhibit 4.35**.

The locals were questioned about the sightings of wildlife species in the vicinity of the Terrestrial Study Area. They stated that the species Asiatic Jackal, Red Fox, Grey Wolf, Flare–horned Markhor and Himalayan Ibex are very common in the area. They also reported that Snow Leopard occasionally visits the area and kills their livestock.

The area around the Terrestrial Study Area provides habitat for Flare–horned Markhor and Himalayan Ibex which are animals for licensed trophy hunting. The income (80% amount) from trophy hunting is used for local community developments projects such as

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31 The IUCN Red List of Threatened Species. Version 2018.2. <http://www.iucnredlist.org>. Downloaded on 11 April 2018.

32 Molur, Sanjay. "Status and Red List of Pakistan's Mammals." (2003

33 Rao A, Marwat A (2003) NASSD background paper: Forestry. IUCN Pakistan, Northern Areas Progamme, Gilgit (Pakistan) 66p

34 Roberts, T.J. 1977. The Mammals of Pakistan. Ernest Benn, London and Tonbridge, pp 361.

35 Din, J. U., and M. A. Nawaz. "Status of the Himalayan lynx in district Chitral, NWFP, Pakistan." *Journal of Animal and Plant Sciences* 20 (2010): 17–22.

36 Din, J. U., S. Hameed, K. A. Shah, M. A. Khan, S. Khan, M. Ali, and M. A. Nawaz. "Assessment of Canid Abundance and Conflict with Humans in the Hindu Kush Mountain Range of Pakistan." *Wildlife Biology in Practice* 9, no. 2 (2013).

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schools, bridges, medical units. The remaining 20% amount is used by the wildlife department for conservation purposes.

Conservation and Protection Status

Some of the species reported from the wider area around the Project are included in the IUCN Red List.[37] The Common Leopard, Snow Leopard, and Asiatic Black Bear are listed as Vulnerable, while Pallas's Cat and Flare–horned Markhor are listed as Near Threatened in the IUCN Red List.[38] In Pakistan National Red List, the Snow Leopard is listed as Critically Endangered, the Grey Wolf and Flare–horned Markhor are listed as Endangered while the Asiatic Jackal and Red Fox are listed as Near Threatened.

37 The IUCN Red List of Threatened Species. Version 2018.2. <http://www.iucnredlist.org>. Downloaded on 11 April 2018.

38 Ibid

RAD

Exhibit 4.34: Abundance of Mammal Signs and Sightings, March 2018 Survey

No	Scientific Name	Common Name	IUCN Status[39]	Barren Land		Vegetation Cluster	
				Sightings	Signs	Sightings	Signs
	Canidae						
1.	*Canis aureus*	Asiatic Jackal	Least Concern	1	2	–	4
2.	*Vulpes vulpes*	Common Red Fox	Least Concern	–	4	–	4
3.	*Canis lupus*	Grey Wolf	Least Concern		2		
	Felidae						
4.	*Panthera uncia*	Snow Leopard	Vulnerable	–	1	–	1
	Bovidae						
5.	*Capra falconeri*	Flare–horned Markhor	Near Threatened	55	–	–	–

39 The IUCN Red List of Threatened Species. Version 2018.2. <http://www.iucnredlist.org>. Downloaded on 11 April 2018.

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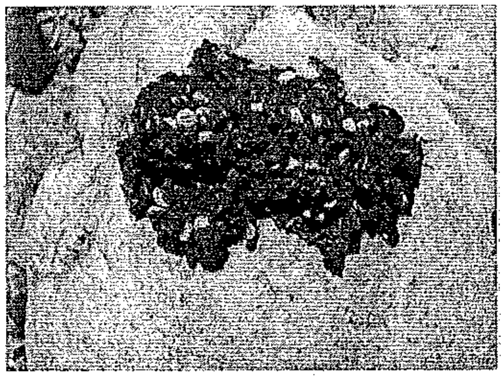
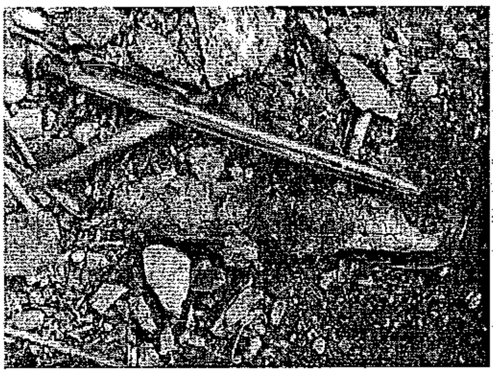
Exhibit 4.35: Signs of Mammals, March 2018 Survey

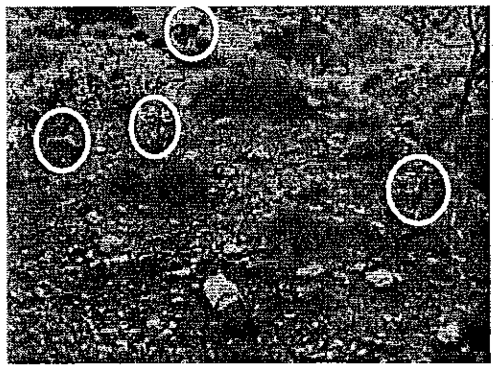


Scat of Red Fox

Scat of Snow Leopard



Scat of Grey Wolf



Flare–horned Markhors

Avifauna

Overview

Pakistan has a rich diversity of avian habitats, from the dry alpine and moist temperate forests of the western Himalayas to the deserts of Baluchistan and Sindh. These diverse habitats are of importance to some 669 recorded bird species.[40] Of these, 30% are long distance migratory birds, 43% are either Palearctic species visiting Pakistan only for breeding and 28% are regular winter visitors, which breed mainly in the northern trans–Himalayan regions.[41] The topographic variety of KP makes the province diverse in avifauna and the Himalayan forests provide habitat for a number of bird species. Of 669 bird species reported from Pakistan, 456 bird species are found in KP.[42]

The avifauna of District Chitral valley has not been studied in detail. However, a total 232 bird species, belonging to 58 different families, have been reported from Chitral

[40] Grimmett, Richard, Tom J. Roberts, Tim Inskipp, and Clive Byers. 2008. *Birds of Pakistan*. A&C Black.

[41] Grimmett, Richard, Tom J. Roberts, Tim Inskipp, and Clive Byers. *Birds of Pakistan*. A&C Black, 2008.

[42] Ahmad, D. (2012). Khyber Pakhtunkhwa State of the Environment. Peshawar: Environmental Protection Agency, Government of Khyber Pakhtunkhwa.

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Valley. These include birds belonging to Family Anatidae, Phasianidae, Podicipedidae, Ciconiidae, Pelecanidae, Ardeidae, Pandionidae, Accipitridae, Otididae, Rallidae, Burhinidae, Charadriidae, Rostratulidae.[43] The bird fauna of Chitral valley is interesting in many ways. Its zoogeographical position is on the border between the Palearctic and Indo–Malayan regions, with the fauna being a mixture of both regions. In addition, Chitral is situated on one of the major bird migration routes of the world – the Indus Flyway – and a large number of migratory birds can be observed here practically during the entire year.[44]

Survey Results

Surveys for bird diversity and abundance were carried out in the Terrestrial Study Area in March 2018. A total of six locations were sampled with four in Barren Land and two in Vegetation Cluster habitat type. A summary of the results by habitat type including the bird abundance and diversity is provided in **Exhibit 4.36**.

Exhibit 4.36: Total Sightings, Density and Diversity by Habitat Type, March 2018 Survey

Habitat	*No. of Sampling Points*	*Total Sightings*	*Density (Average no of species per Sampling Location)*	*No. of Species*
Barren Land	4	47	11.75	13
Vegetation Cluster	2	88	44	16
Total	**6**	**135**	**22.5**	**19**

A total of 135 bird individuals belonging to 19 species were observed. Maximum abundance was observed at Sampling Location T1, located in Vegetation Cluster habitat. Abundant bird species observed at this Sampling Location included the Mallard *Anas platyrhynchos*, Ferruginous Pochard *Aythya nyroca*, Black–billed Magpie *Pica hudsonia*, and White Wagtail *Motacilla alba*. Maximum diversity was also observed at Sampling Location T1. A total of 16 bird species were observed at this Sampling Location.

Abundant bird species in the Terrestrial Study Area included the, Mallard, Ferruginous Pochard, White Wagtail, Black–billed Magpie, Jungle Crow *Corvus macrorhynchos*, Blue Whistling Thrush *Myophonus caeruleus* and Brown Dipper *Cinclus pallasii*.

Hunting of migratory birds is quite common throughout the entire stretch of the Aquatic Study Area. Photographs of some bird species which were hunted by the locals within the Terrestrial Study Area are shown in **Exhibit 4.37**. Large size artificial ponds have been constructed near the bank of the river in the Aquatic Study Area and decoys ducks are used to attract migratory ducks. A small hunting hide, built from large stones, was used for hunting purposes (**Exhibit 4.37**). Consultations with the wildlife department confirmed that permits are issued for hunting of migratory ducks. Permits are issued at

[43] Grimmett, Richard, Tom J. Roberts, Tim Inskipp, and Clive Byers. *Birds of Pakistan*. A&C Black, 2008.

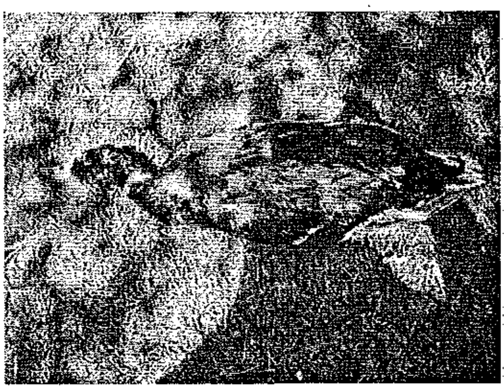
[44] Kylanpaa, J. "Birds of Dera Ismail Khan District of North West Frontier Province in Pakistan". *Forktail* (2000): 15–28.

the rate of PKR 2,000 to each hunter for a specific period of the year. With one permit each hunter can kill 20 waterfowls per day.

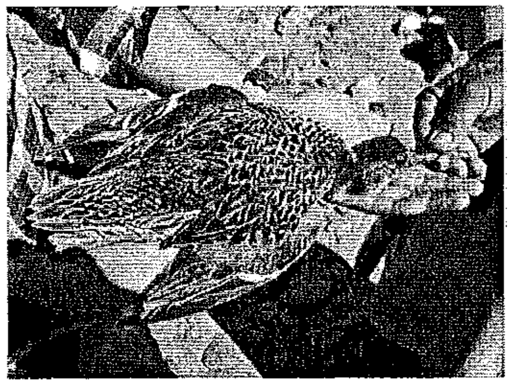
Conservation and Protection Status

Of the bird species reported from the Study Area, none are Endangered or Critically Endangered based on the IUCN Red List of Threatened Species.[45] Only, two species, the Lammergeier or Bearded Vulture and Ferruginous Pochard are included in the IUCN Red List as Near Threatened species. Mallard is included in CITES Appendix I while Lammergeier is included in CITES Appendix II.

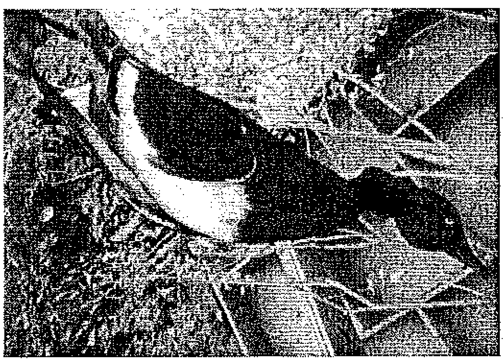
Exhibit 4.37: Migratory Birds Hunted by Local Hunters in the Terrestrial Study Area, March 2018 Survey



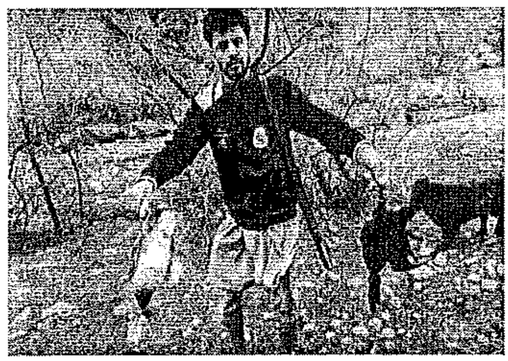
Mallard (Male)



Mallard (Female)

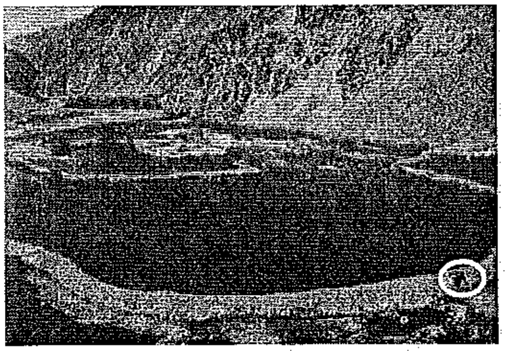


Ferruginous Pochard



Ferruginous Pochard (right) and Mallard (left)

[45] IUCN 2015. *The IUCN Red List of Threatened Species. Version 2015–4.* <http://www.iucnredlist.org>, accessed May 29, 2017.



Constructed Ponds and Hunting Hide (Circled)

Hunting Hide

Herpeto–fauna

Reptiles are highly habitat–specific, and therefore occupy small niches. Unlike birds and mammals that have very wide foraging ranges, reptiles have a restricted home range. Except for monitor lizards and large snakes, other species usually stay within an area of about a square kilometer for feeding and breeding.[46] Geckos or skinks may occupy microhabitats spread over even smaller areas. The breeding ground for a reptile species cannot be marked at one or two places; these are spread all over the area within suitable habitats at several scattered places, provided other climatic factors remain conducive.

Overview

The herpetofauna of Chitral Valley has not been studied in detail. However, the presence of about 41 herpeto–fauna species can be deduced from literature.[47] None of these species are of conservation importance based on the IUCN Red List. Five reported species are included in the CITES Appendices. These include the Bengal Monitor Lizard *Varanus bengalensis* (I), the Rope Snake *Ptyas mucosus mucosus* (II), Central Asian Cobra *Naja oxiana* (II), Common Sand Boa *Eryx johnii* (II) and the Checkered Keelback *Xenochrophis piscator piscator* (III).[48]

Survey Results

A total of six locations were sampled for herpeto–fauna during the March 2018 Survey. The locations of these are shown in **Exhibit 4.6**. A summary of the sampling locations by habitat type, number of sightings, density and number of species is provided in **Exhibit 4.38.**

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46 Mertens, R. 1969. "Die Amphibians und Reptilians West Pakistan". Stutt. Beit. *Naturkunde*, 197, pp. 1–96.

47 Khan, M.S., 2006. Amphibians and reptiles of Pakistan. Krieger Publishing Company, Malabar, Florida. pp 311.

48 CITES. Checklist of CITES Species. Accessed on December 12, 2017. Available at http://checklist.cites.org/#/en

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Exhibit 4.38: Herpetofauna Abundance and Diversity by Habitat Type, March 2018 Survey

Habitat	*No. of Sampling Locations*	*Total Signs/ Sightings*	*Average Signs/Sightings per Sampling Location (Density)*	*No. of Species*
Barren Land	4	52	13	2
Vegetation Cluster	2	12	6	3
Total	**6**	**64**	**10.67**	**4**

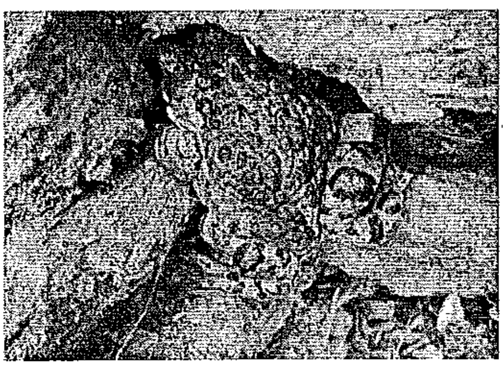
A total of 64 reptile and amphibian specimens belonging to four species were observed in the Terrestrial Study Area. These included Caucasian Agama *Paralaudakia Caucasia,* Swat Green Toad *Bufotes pseudoraddei*, Batura Glacier Toad *Bufotes baturae* and *Bufotes spps*.

The highest density of herpeto–fauna was observed in the Barren Land habitat (average of 13 sightings per sampling location). The greatest diversity was observed in the Vegetation Cluster habitat with a total of three species. The highest abundance was observed at Sampling Location T4 in Barren Land habitat with 30 individuals of Caucasian Agama sighted. The second highest abundance was observed at Sampling Location T2 in Barren Land habitat with ten individuals of Caucasian Agama sighted. Low diversity of the herpetofauna species observed in the Study Area was due to low temperatures at the time of sampling. Most herpetofauna species particularly reptiles hibernate in the cool months.

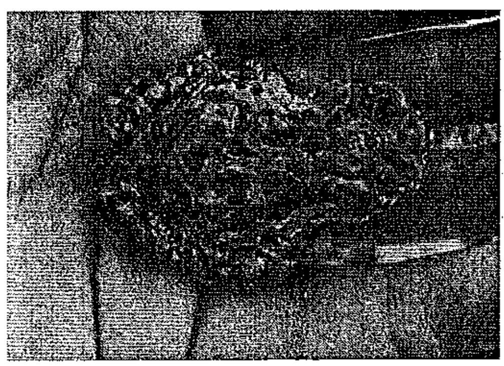
Conservation and Protection Status

Of the herpeto-fauna species reported from the Study Area, none are of conservation importance based on the IUCN Red List. None of the species observed are endemic. Photographs of some of reptile species observed during the March 2018 Survey are shown in **Exhibit 4.39**.

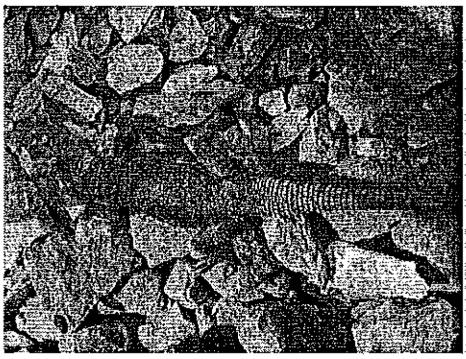
Exhibit 4.39: Herpetofauna Species, March 2018 Survey



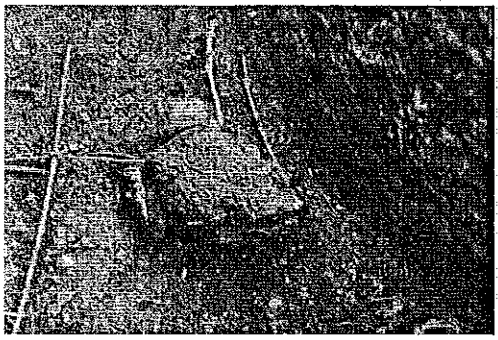
Swat Green Toad *Bufotes pseudoraddei*



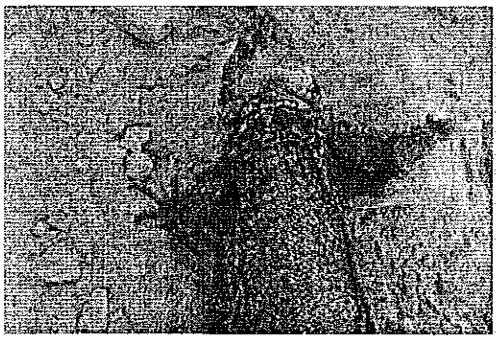
Batura Glacier Toad *Bufotes baturae*



Caucasian Agama *Paralaudakia caucasia*



Bufotes spps.



Caucasian Agama *Paralaudakia caucasia*

4.1.6 Protected Areas

A protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values.[49] In Pakistan a wildlife sanctuary is an area set aside for the protection of wildlife. Public access is prohibited or regulated and no exploitation of forest is allowed. Game reserves are areas, declared so by the government, where hunting of wild animals is not allowed, except under permit issued by the government. Other than this no other restriction applies in a game reserve. National Park is an area where the landscape, flora and fauna are protected and preserved in a natural state. Public access for recreation, education and research is provided for but hunting wild animals is prohibited.

Protected areas in the vicinity of the Arkari Gol Hydropower Project are shown in **Exhibit 4.40.** These include the Agram Basti Wildlife Sanctuary, Chitral Gol National Park, and Tooshi Game Reserve which are located 9 km, 14 km and 13 km from Project site respectively. The boundaries of Agram Basti Wildlife Sanctuary and Tooshi Game Reserve are not clearly demarcated in government documents. Therefore a circle corresponding to their area has been drawn in **Exhibit 4.40** to show the approximate area.

Agram Basti Wildlife Sanctuary is spread over an area of about 29,866 hectares and is located at a distance of about 9 km from the Project site. The important wildlife species

[49] IUCN Definition 2008, International Union for Conservation of Nature, Available at: https://www.iucn.org/theme/protected-areas/about;

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reported from the sanctuary include Grey Wolf, Himalayan Brown Bear, Red Fox, Flare–horned Markhor and Himalayan Ibex.

The Chitral Gol National park is situated, about 3 km west of Chitral Town and about 14 km from the Project site. It is spread over an area of about 7,750 hectares. The elevation ranges from about 1,500 m to 4,979 m. It was declared a wildlife sanctuary on 23 December 1971 and as a national park in 1984.[50] The important wildlife species reported from the Chitral Gol National Park include Snow Leopard, Himalayan Lynx, Grey Wolf, Red Fox, Asiatic Black Bear, Yellow Throated Marten, Flare–horned Markhor, Himalayan Ibex, Lammergier, Himalayan Griffon Vulture *Gyps himalayensis*, Himalayan Snowcock *Tetraogallus himalayensis*, Himalayan Monal Pheasant *Lophophorus impejanus*. Major threats to the wildlife include livestock grazing, firewood collection and poaching.

Tooshi Game Reserve is located at a distance of about 13 km from the Project site. It is located along the paved road to Garam Chashma in Chitral's Lutkho district and covers an area of 1000 hectares. It is proposed to be reclassified as a wildlife sanctuary, as it has a large (about 160 individuals) and readily viewable Markhor population. The habitat is dominated by alpine meadows and dry temperate forest.[51] Key wildlife species reported from this game reserve include Snow Leopard, Himalayan Lynx, Red Fox, Grey Wolf, Flare–horned Markhor and Chukar Partridge *Alectoris chukar*.

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[50] The Khyber Pakhtunkhwa Tribune, Articles, Wildlife Parks, http://ww.w.kpktribune.com/index.php/en/component/content/article/48–khyber–pakhtunkhwa/about–khyber–pakhtoonkhwa/1023–wildlife–parks, accessed on January 04, 2016

[51] The Khyber Pakhtunkhwa Tribune, Game Reserves, <http://ww.w.kpktribune.com/index.php/en/divisions/malakand–division/districts/400–khyber–pakhtunkhwa/sports/1025–game–reserves>, accessed on December 29, 2016>, accessed on Dec 30, 2016

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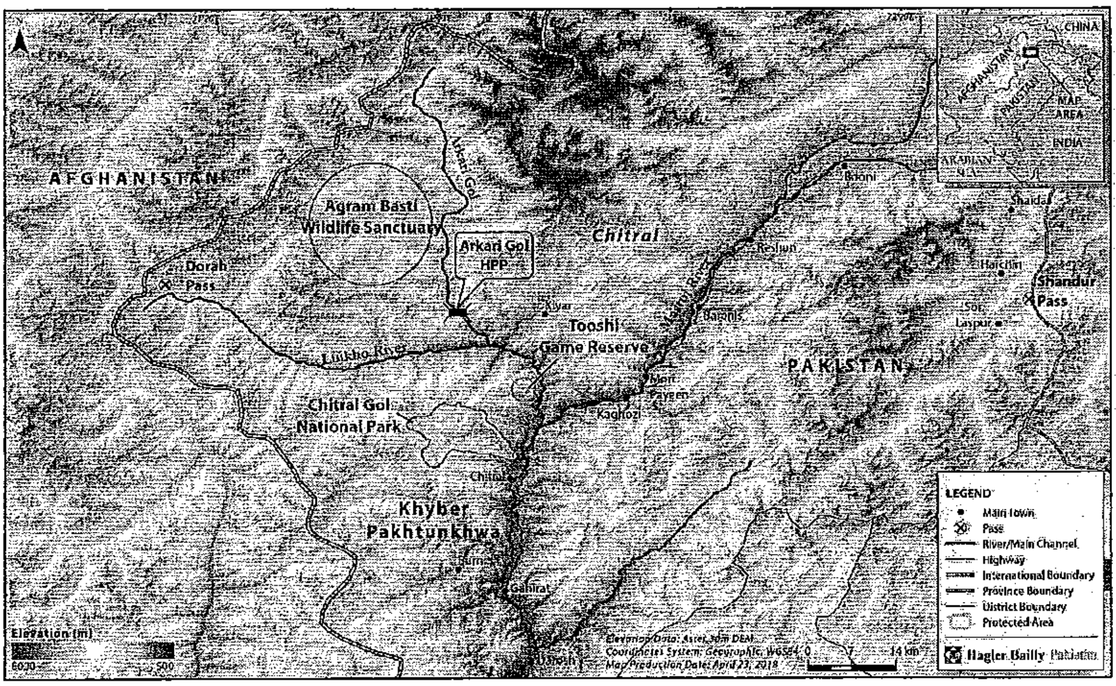
Exhibit 4.40: Protected Areas or Areas of Special Importance for Biodiversity



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4.1.7 Habitat Assessment

Performance Standard 6 (PS6) "Biodiversity Conservation and Sustainable Management of Living Natural Resources" requires the categorization of habitats into modified, natural and critical. Critical Habitats are a subset of modified or natural habitats. They are habitats of high biodiversity value.[52]

Natural and Modified Habitats

Natural and Modified Habitats are defined and described in IFC PS6.[53] Their definitions, according to IFC PS6, are as follows:

Natural Habitat: Natural habitats are areas composed of viable assemblages of plant and/or animal species of largely native origin, and/or where human activity has not essentially modified an area's primary ecological functions and species composition. Under IFC PS 6 No Net Loss is required in Natural Habitats.

Modified Habitat: Modified habitats are areas that may contain a large proportion of plant and/or animal species of non–native origin, and/or where human activity has substantially modified an area's primary ecological functions and species composition. Modified habitats may include areas managed for agriculture, forest plantations, reclaimed coastal zones, and reclaimed wetlands.

Aquatic Study Area

The Aquatic Study Area is considered a Natural Habitat as the river water is not regulated by dams or barrages. In addition sediment extraction from river bed and banks is very limited, primarily because the Arkari Gol is difficult to access and also because demand for sediment in low.

Terrestrial Study Area

The Terrestrial Study Area is classified as Natural Habitat. Agricultural in the area is limited (4%). Most of the area is naturally Barren Land habitat type (92%). Population density is also low.

Critical Habitat

Critical Habitat is a requirement under the International Finance Corporation's (IFC) Performance Standards (PS).[54]

Critical habitat is an area that has high biodiversity value and may include sites that are legally protected or officially proposed for protection. These may include:

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52 International Finance Corporation. January 2012. Policy on Social and Environmental Sustainability, Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources, The World Bank Group.

53 Ibid

54 International Finance Corporation (IFC). January 2012. Policy on Social and Environmental Sustainability, Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources, The World Bank Group.

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- Areas protected by the International Union for Conservation of Nature (Categories I–VI) [55],
- wetlands of international importance (according to the Ramsar Convention);[56]
- important bird areas (defined by Birdlife International);[57] and
- biosphere reserves (under the UNESCO Man and the Biosphere Programme;[58]

The Project does not fulfill any of these characteristics.

Critical Habitat Assessment as per IFC PS6 requires the defining of a Discrete Management Unit (DMU). This is based on the following:

"*For Criteria 1 through 3, the project should determine a sensible boundary (ecological or political) which defines the area of habitat to be considered for the Critical Habitat Assessment. This is called the "discrete management unit," an area with a definable boundary within which the biological communities and/or management issues have more in common with each other than they do with those in adjacent areas (adapted from the definition of discreteness by the Alliance for Zero Extinction). A discrete management unit may or may not have an actual management boundary (e.g., legally protected areas, World Heritage sites, KBAs, IBAs, community reserves) but could also be defined by some other sensible ecologically definable boundary (e.g., watershed, interfluvial zone, intact forest patch within patchy modified habitat, seagrass habitat, coral reef, concentrated upwelling area, etc.). The delineation of the management unit will depend on the species (and, at times, subspecies) of concern.*"[59]

DMUs has been defined for relevant species under consideration in Criteria 1 through 3.

The criteria for Critical Habitat Assessment[60] based on IFC's PS6 along with their application to the biodiversity within the Study Area is provided below.

1. *Habitat of significant importance to Critically Endangered and/or Endangered species:*

According to IFC's Guidance Note 6, Tier 1 sub–criteria for Criterion 1 are defined as follows[61]:

- *Habitat required to sustain ≥ 10 percent of the global population of an IUCN Red–listed Critically Endangered (CR) or Endangered (EN) species where these*

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55 IUCN. 1994. Guidelines for *Protected Areas* Management *Categories. IUCN*, Cambridge, UK.

56 Ramsar Convention, or Convention on the Wetlands of International Importance, Administered by the Ramsar Secretariat, Geneva, Switzerland

57 Birdlife International, UK

58 Administered by International Co–ordinating Council of the Man and the Biosphere (MAB), UNESCO.

59 Biodiversity Conservation and Sustainable Management of Living Natural Resources, Criterion 3, Guidance Note 6, International Finance Corporation, 1 January 2012

60 The determination of Critical Habitat, however, is not necessarily limited to these criteria. Other recognized high biodiversity values might also support a critical habitat designation, and the appropriateness of this decision would be evaluated on a case–by–case basis.

61 Ibid

are known, regular occurrences of the species and where the habitat could be considered a discrete management unit for that species.

- *Habitat with known, regular occurrences of CR or EN species where the habitat is one of 10 or fewer discrete management sites globally for that species.*

Tier 2 sub–criteria for Criterion 1 are defined as follows:

- *Habitat that supports the regular occurrence of a single individual of an IUCN Red–listed CR species and/or habitat containing regionally–important concentrations of an IUCN Red–listed EN species where the habitat could be considered a discrete management unit for that species.*
- *Habitat of significant importance to CR or EN species that are wide–ranging and/or whose population distribution is not well understood and where the loss of such a habitat could potentially impact the long–term survivability of the species.*
- *As appropriate, habitat containing nationally/regionally–important concentrations of an EN, CR or equivalent national/regional listing.*

Based on information available from literature and March 2018 survey, there is no Endangered or Critically Endangered fish species reported from the Aquatic Study Area. Therefore the Aquatic Study Area is not a critical habitat for any of the residing fish species.

Similarly, species that are listed as Critically Endangered or Endangered have not been reported from the Terrestrial Study Area.

2. *Habitat of significant importance to endemic and/or restricted–range species:*

According to IFC's GN6, Tier 1 sub–criteria for Criterion 2 are defined as follows:

- *Habitats know to sustain ≥ 95 percent of the global population of an endemic or restricted–range species where that habitat could be considered a discrete management unit for that species (e.g. a single–site endemic[62]).*

Tier 2 sub–criteria for Criterion 2 are defined as follows:

- *Habitat known to sustain ≥ 1 percent but < 95 percent of the global population of an endemic or restricted–range species where the habitat could be considered a discrete management unit for that species, where data are available and/or based on expert judgement*

No restricted range species has been reported from the Aquatic Study Area. None of the fish are endemic to the Arkari or Lutkho River. Similarly, no endemic and/or restricted range species has been reported from the Terrestrial Study Area. Therefore Critical Habitat is not triggered for Criterion 2 for either Aquatic or Terrestrial Study Area.

3. *Habitat supporting globally significant concentrations of migratory species and/or congregatory species:*

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62 An endemic species is defined as "one that has ≥ 95 percent of its global range inside the country or region of analysis" as stated in GN79 of Guidance Note 6, Biodiversity Conservation and Sustainable Management of Living Natural Resources. International Finance Corporation, January 2012

According to IFC's GN6, Tier 1 sub–criteria for Criterion 3 are defined as follows:

- *Habitat known to sustain, on a cyclical or otherwise regular basis, ≥ 95 of the global population of a migratory or congregatory species at any point of the species lifecycle where that habitat could be considered a discrete management unit for that species.*

Tier 2 sub–criteria for Criterion 3 are defined as follows:

- *Habitat known to sustain, on a cyclical or otherwise regular basis, ≥ 1 percent but < 95 percent of the global population of a migratory or congregatory species at any point of the species' lifecycle and where that habitat could be considered a discrete management unit for that species, where adequate data are available and/or based on expert judgment.*
- *For birds, habitat that meets BirdLife International's Criterion A4 for congregations and/or Ramsar Criteria 5 or 6 for Identifying Wetlands of International Importance.*
- *For species with large but clumped distributions, a provisional threshold is set at ≥5 percent of the global population for both terrestrial and marine species.*
- *Source sites that contribute ≥ 1 percent of the global population of recruits*

The Aquatic Study Area is home to the Snow Trout which is a long distance migratory fish. This fish species is distributed in India, Nepal, Bhutan, Pakistan and Afghanistan. [63] The DMU for the Snow Trout includes the Arkari Gol (stretch of 5 km) and parts of the Lutkho and Mastuj and Chitral Rivers between elevation range of 300 to 2810 m[64] as shown in **Exhibit 4.41**. The fish is widespread and found in rivers in India, Nepal, Bhutan, Pakistan and Afghanistan. Based on expert judgment, the habitat within the DMU does not provide habitat for more than 1 % of the global population of this species. Therefore Critical Habitat is not triggered for the Snow Trout. The DMU for Snow Trout is provided in **Exhibit 4.41.**

Within the Terrestrial Study Area, some migratory and congregatory bird species have been reported including the Northern Pintail, Northern Shoveler, Bar–headed Goose, Common Shelduck, and Gadwall. However, these bird species are widespread. According to expert judgment, the migratory bird populations are small and do not trigger Tier 1 or Tier 2 sub–criteria for Criterion 3 and the Terrestrial Study Area is not a Critical Habitat for migratory birds.

4. *Highly threatened and/or unique ecosystems*

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[63] Vishwanath, W. 2010. *Schizothorax richardsonii*. The IUCN Red List of Threatened Species 2010: e.T166525A6228314. http://dx.doi.org/10.2305/IUCN.UK.2010–4.RLTS.T166525A6228314.en. Downloaded on **27 December 2017**

[64] As outlined in IUCN Red List. Vishwanath, W. 2010. *Schizothorax richardsonii*. The IUCN Red List of Threatened Species 2010: e.T166525A6228314. http://dx.doi.org/10.2305/IUCN.UK.2010–4.RLTS.T166525A6228314.en. Downloaded on **27 December 2017**

There is no information which indicates the Study Areas, or any part of them, are a highly threatened and/or unique ecosystem. Furthermore, there is no information which indicates the Study Areas are a part of a threatened or unique ecosystem.

5. *Areas with unique assemblages of species or which are associated with key evolutionary processes or provide key ecosystem services:*

There is no information which indicates the Study Areas, or any part of them, are associated with key evolutionary processes or provide key ecosystem services. While the species are functioning components of ecosystems, there are no unique assemblages of species or association of key evolutionary processes in the Study Areas.

ADB's Guideline for Critical Habitat Assessment not covered by IFC PS6

6. *Areas with biodiversity that has significant social, cultural or economic importance to local communities.*

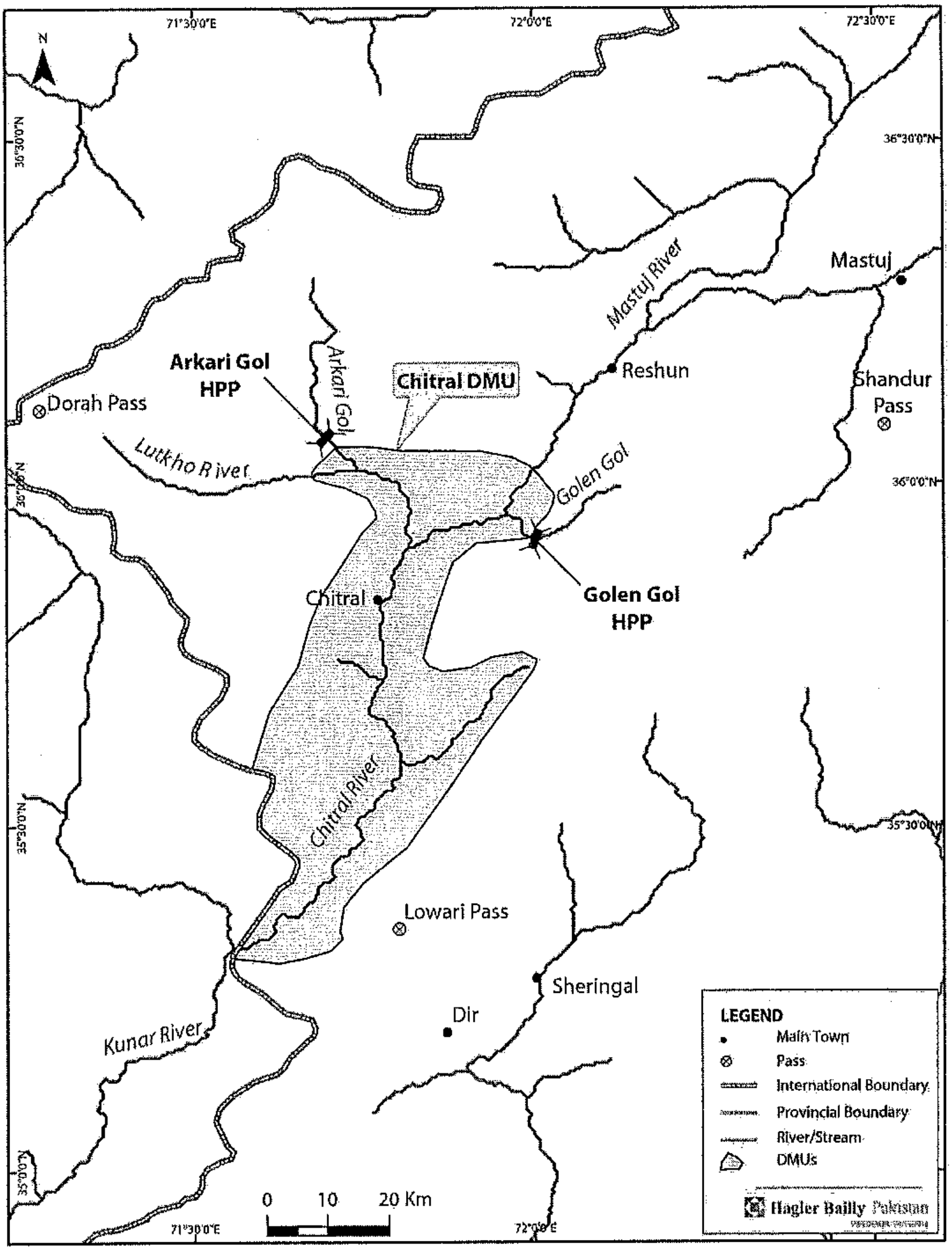
There is some recreational fishing in the Aquatic Study Area but livelihood dependence of the local communities on the fish for subsistence is low. The wider area around the Project provides habitat for Flare–horned Markhor and Himalayan Ibex which are animals for licensed trophy hunting. However, the communities do not depend on the income from trophy hunting for their livelihood and this income is used for developmental projects such as schools or medical units in the area. Project impacts are not likely to have significant impact on trophy hunting.

Therefore, neither the Aquatic Terrestrial Study Area nor the Terrestrial Study Area has biodiversity of significant social, cultural or economic importance for the local communities, and Critical Habitat is not triggered for this criterion.

Determination:

The Aquatic and Terrestrial Study Area do not lie in a Critical Habitat.

Exhibit 4.41: DMU of Snow Trout



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4.1.8 Conclusions

This section provides a summary of the aquatic and terrestrial ecological resources in the Study Area which may be of concern from Project related impacts as outlined in **Section 7**, *Anticipated Environmental Impacts and Mitigation Measures.*

- A total of six fish species have been reported from the Aquatic Study Area including the Snow Trout, Kunar Snow Trout, Chirruh Snow Trout, Chitral Loach, Himalayan Catfish and Khyber Loach. None of these fish species are listed as Endangered or Critically Endangered in the IUCN Red List 2018. Of these, only the Snow Trout is a fish species of conservation importance since it is a long distance migratory fish, has high commercial importance and is listed as Vulnerable in the IUCN Red List. This fish is widespread and has been reported from India, Nepal, Bhutan, Pakistan and Afghanistan. In the Study Area, the Snow Trout is not found above an altitude of 2810 m[65] and in the Arkari Gol the presence of a natural water fall (2.5 km downstream of the proposed dam site) restricts its presence upstream of the waterfall.
- None of the terrestrial plant species reported from the Terrestrial Study Area or surroundings are globally/nationally threatened species, endemic species or protected species. There are some medicinal plants reported from the wider area around the Project such as *Rumex hastatus*, *Pistacia khinjuk*, *Sisymbrium irio* and Artimisia species.[66] No invasive plant species were observed in the terrestrial Study Area but few invasive plant species including Marijuana *Cannabis sativa*, Strumarium *Xanthium strumarium* and Castor Oil Plant *Ricinus communis* were observed in the Aquatic Study Area. It is important that Project activities take preventative measures to avoid spread of invasive species.
- A number of mammalian species of conservation importance have been reported from the wider area around the Project. The Common Leopard, Snow Leopard, and Asiatic Black Bear are listed as Vulnerable, while Pallas's Cat and Flare–horned Markhor are listed as Near Threatened in the IUCN Red List.[67] Both the Flare–horned Markhor and Himalayan Ibex are animals for licensed trophy hunting. Most of these mammals prefer higher altitudes and their occurrence at the Project site and vicinity is rare. Project related impacts are not expected to have a direct impact on these mammals. However, there may be an increase incidence of poaching as a result of influx of Project staff and contractors to the area.
- Of the bird species reported from the Study Area, none are Endangered or Critically Endangered based on the IUCN Red List of Threatened Species.[68] Only

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65 As outlined in IUCN Red List. Vishwanath, W. 2010. *Schizothorax richardsonii*. The IUCN Red List of Threatened Species 2010: e.T166525A6228314. http://dx.doi.org/10.2305/IUCN.UK.2010-4.RLTS.T166525A6228314.en. Downloaded on **27 December 2017**

66 Ali, Haidar, and M. Qaiser. "The ethnobotany of Chitral valley, Pakistan with particular reference to medicinal plants." *Pak. J. Bot* 41, no. 4 (2009): 2009–2041.

67 Ibid

68 IUCN 2015. *The IUCN Red List of Threatened Species. Version 2015–4*. <http://www.iucnredlist.org>, accessed May 29, 2017.

two species, the Lammergeier or Bearded Vulture and Ferruginous Pochard are included in the IUCN Red List as Near Threatened species. Mallard is included in CITES Appendix I while Lammergeier is included in CITES Appendix II. The waterbodies in the vicinity of the Project site provide habitat for a number of migratory birds which can be hunted by obtaining permits from the KP Wildlife Department. These birds are likely to face disturbances during the Project construction phase. During the operation phase, it is important to ensure that Project staff and consultants do not engage in illegal hunting of these birds.

- Of the herpeto-fauna species reported from the Study Area, none are endemic or included in the IUCN Red List. Project construction is likely to have a short-term impact on individual receptors but the basin wide impact or Project on herpeto-fauna is likely to be minor.
- There is no Critical Habitat (according to IFC's Performance Standard 6) in the Project site and vicinity though both the Aquatic and Terrestrial Study Area is considered a Natural Habitat.

4.2 Physical Environment

The physical baseline includes a description of the topography, land use, geomorphology, visual character, climate, air quality, water resources, noise levels, and traffic.

4.2.1 Scope and Methodology

The specific tasks covered under the physical baseline study included:

- Review of the available literature on the physical environment of the Study Area.
- Review of the feasibility study of the Project: Pakhtunkhwa Hydel Development Organization (PHYDO), Government of Khyber Pakhtunkhwa, March 2014, Feasibility Study for the Arkari Gol Hydropower Project, District Chitral, (Lower), Khyber Pakhtunkhwa, referred to as the "Feasibility Study" in this report.
- Analysis of secondary information to characterize baselines, particularly topography, land-use, geology, climate and water resources.
- Field surveys for characterization of Study Area, including:
  - Visual character
  - Ambient air quality
  - Water resources (water quality and domestic water supply and use)
  - Soil Quality
  - Noise levels
  - Traffic

Baseline data is compared to the National Environmental Quality Standards (NEQS), and where relevant, other standards, including the IFC-EHS Guidelines (2007), that are applicable to the Project.

The physical environment survey plan is included as **Appendix F**.

4.2.1 Topography and Land Cover

The Arkari Gol Hydropower Project; including a dam, power tunnel and powerhouse, is proposed along the Arkari Gol in Khyber Pakhtunkhwa, Pakistan. The Arkari Gol is a tributary of the Lutkho River which drains into the Mastuj River – a tributary of Chitral River.

The topography of the Arkari Gol catchment is shown in **Exhibit 4.42**. The area upstream of the Project ranges between 1,830 m and 6,956 m. The cumulative percentage of Project catchment area with elevation classes is shown in **Exhibit 4.43**. The majority (~90%) of the catchment upstream of the Project is below 5,000 m amsl. With the elevation largely below 5000 m, the permanent snow and glacial cover within the catchment is low, particularly relative to other catchments of the higher Himalaya and Karakorum in Pakistan to the east and north east of the Arkari Gol catchment respectively.

A classified land cover map, extracted from the GlobalLand30 dataset[69], is provided in **Exhibit 4.44**. The associated percent-land cover for areas upstream of the Project are provided in **Exhibit 4.45**. Based on the classification, the land cover upstream of the Project includes only minor forest (0.9%) and agricultural land (0.7%). The majority of land cover is barren land (63.1%), followed by shrub land (16.8%), snow and ice (9.8%), and grassland (8.8%). The western side of the Arkari Gol contains most of the shrub land while grasses are mostly found in eastern side. Most of the available snow and ice fraction has been found above 4500 m elevation.

[69] Developed by National Geomatics Center of China (NGCC) using multispectral images at 30 meters spatial resolution of Landsat TM/ETM+ and Chines Environmental Disaster Alleviation Satellite (HJ-1), with an accuracy range for classified land cover types varying between 72.5% and 92%.

Exhibit 4.42: Topography of the Arkari Gol Catchment

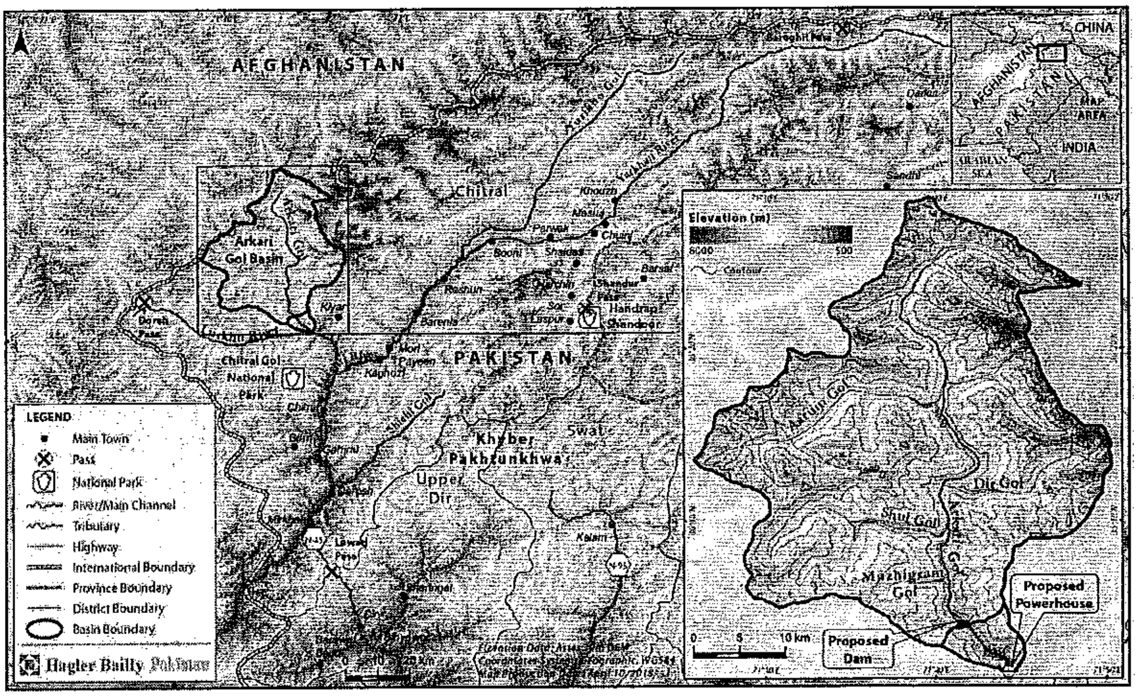

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Exhibit 4.43: Catchment Elevations

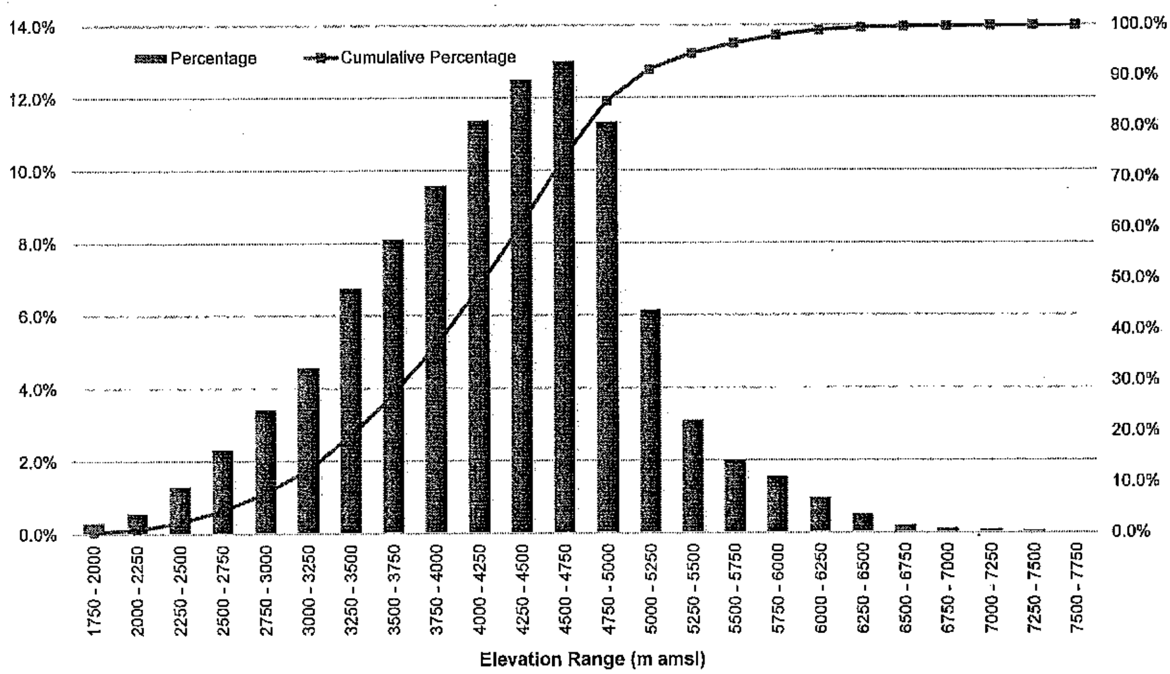


Exhibit 4.44: Land Cover of the Arkari Gol Catchment

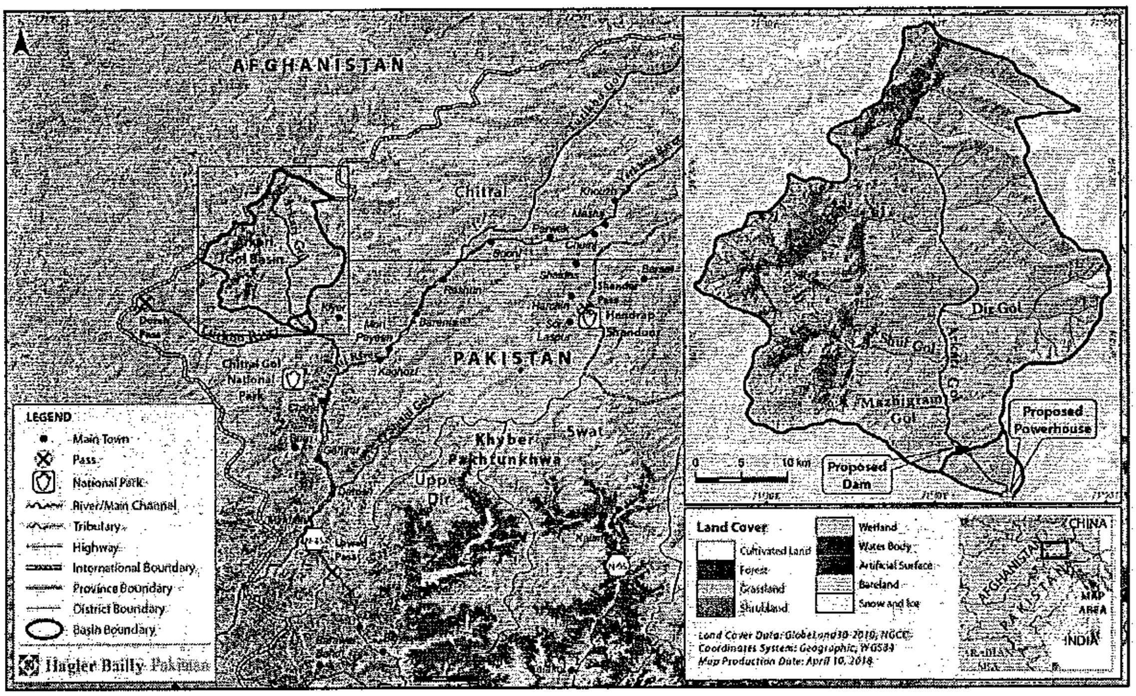
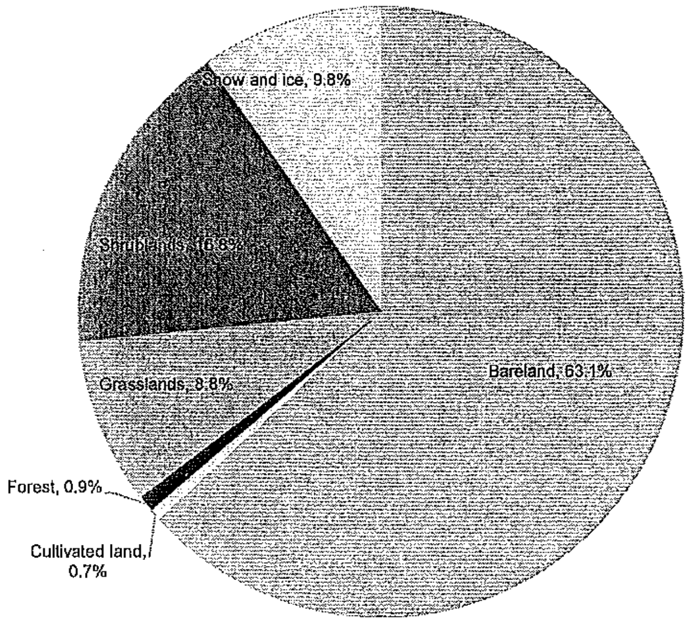


Exhibit 4.45: Land Cover Statistics (Upstream of Project)



4.2.2 Geology, Soils and Seismic Hazards

This section presents information on the geology, soils and seismic hazards within the Study Area. The information is obtained largely from the Feasibility Study and, where specified, other sources.

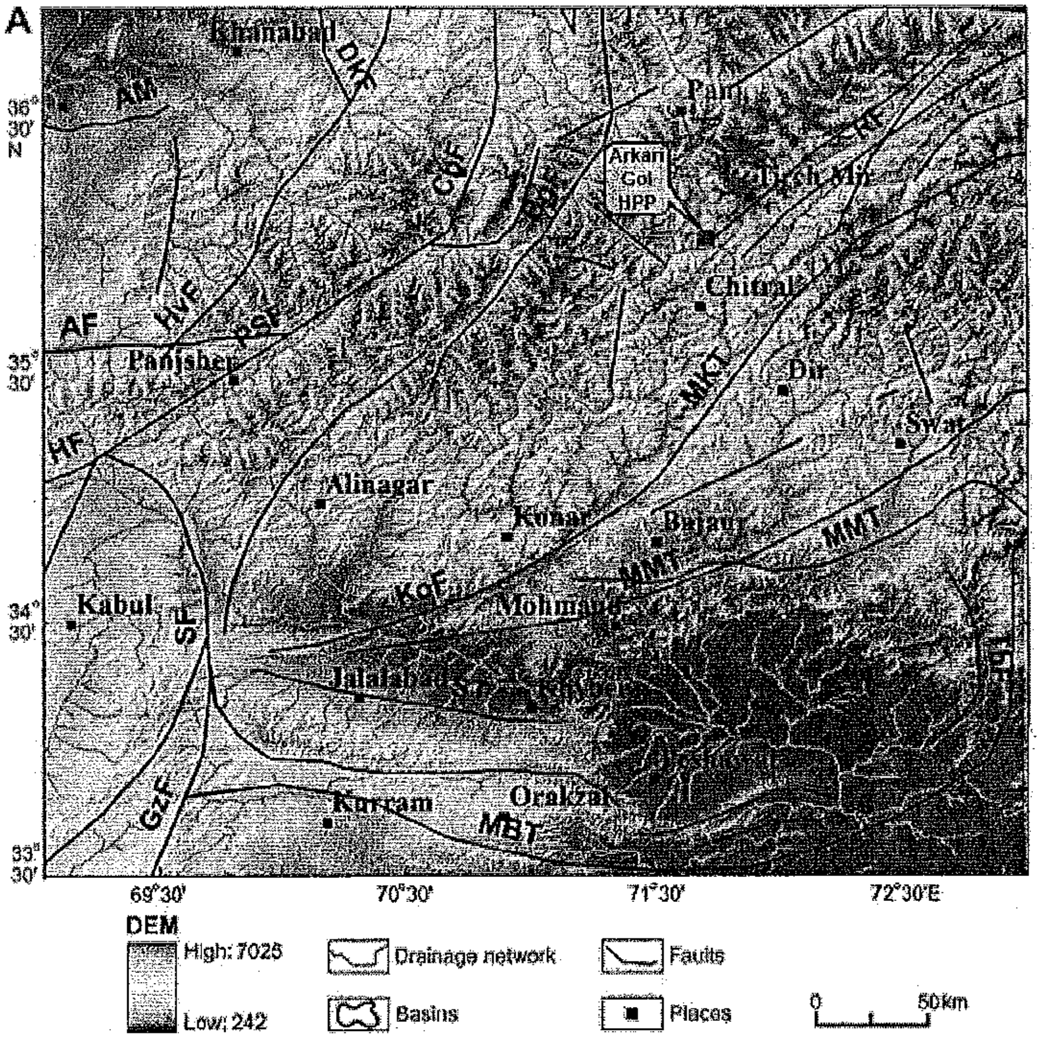
Tectonics

The Project area is part of the continental collision zones between Eurasian and Indian plates and the intervening Kohistan, Ladakh Arc. The intercontinental collision between the Eurasian and Indian plates has resulted in intense deformation with complex folding involving strike-slip and thrust faulting and crustal thickening expressed as a series of thrust faults accompanied by a continental subduction process.

The Chitral district has three main mountain ranges, known as Hindu Kush, Karakoram and Kohistan. The Hindu Kush and Karakoram ranges are located on the Eurasian plate while the Kohistan range is part of Indian plate. The Indian plate is under thrusted and the Eurasian plate is upper thrusted.

Both the plates are separated by the Main Karakoram Thrust (MKT) which trends in NE-SW direction (see **Exhibit 4.46**), through Shishi valley, Rizhun Gol and passes through Harchin from Chitral district. The crushing zone between the MKT and Kohistan is known as Northern Suture Mélange zone (NSM). Other faults shown in Exhibit X include: Reshen Fault (RF), Darvaz Karakul fault (DkF), Alburz Marmul (AM), Central Badakhshan fault (CbF), Henjvan fault (HvF), Herat fault (HF), Gardez fault (GzF), Konar fault (KoF), Main Boundary Thrust (MBT), Main Mantle Thrust (MMT), Sarobi fault (SF); Tarbella fault (TbF), and the Bazgir fault (BgF);

Exhibit 4.46: Major Faults in Relation to Dam Site



Sources: Lawrence et al., 1981; Wheeler et al., 2005; Doebrich and Wahl, 2006; Mahmood and Gloaguen, 2011.

Seismic Hazard

The Northern Areas of Pakistan and AJK are extensive zones of high seismicity and contain several seismo-tectonic features generated by an integrated network of active faults. A telemeter seismic network which operated from 1973 to 1977 has recorded data from approximately 10,000 earthquakes covering the area between longitudes 69° and 75° and latitudes 30° and 35°.

This section presents the calculated earthquake magnitudes to determine baseline conditions. The suitability of these criteria are discussed in the impact assessment presented in **Section 7** (*Anticipated Environmental Impacts and Mitigation Measures*).

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Seismic Hazard Analysis in the Feasibility Study

Seismic hazards may be analyzed deterministically, as when a particular earthquake scenario is assumed, or probabilistically in which uncertainties in earthquakes size, location and time of occurrence are explicitly considered. Both approaches were adopted in the Geological Investigation Report for the Project and are summarized below.

The historical data for the Hindu Kush region was compiled by Amraseys and Biham (2003; 2009) which formed the basis for defining the historical seismicity of the Chitral Region.

The historical data suggests that Konar Fault (KoF in the figure above) and its NE splays like Upper Swat (Kalam) Fault Zone and the MKT have been a focus of several past earthquakes some approaching a magnitude of 7.5 on the Richter scale. There are historical records of extensive damage along the Kunar River as far as Drosh, suggesting that MKT did rupture in these earthquakes. In comparison, the Tirich Mir and Reshun Faults (RF in the above figure) have no historical earthquakes associated with them, except for one at 1842 centered on Chitral-Wakhan border. This apparently indicates lack of seismic activity associated with these faults. However, considering that continued convergence in the Hindu Kush is to the order of 5 cm/yr, the Tirich Mir and Reshun Faults may be more vulnerable in terms of seismic hazard potential as they must be storing strain for the past several hundred years.

Pakistan's PGA (g) contour map with 10% probability of exceeding in 50 years was utilized for the project where PGA contour level of 0.02g had been provided. However, because of lack of strong motion data, attenuation law could not be developed for the Project area. The analysis was based on identification of the nearest faults to the Project area/located within a radius of 100 km. The main tectonic features around the Project area which could be controlling the maximum earthquake are as follows:

a. Reshun Fault

b. Tirich Mir Fault

c. MKT

d. Chitral Fault

e. ShyokSture Zone, Bomb Barat Fault

A summary of the results calculated for the Feasibility Study, together with a brief description of is provided below:

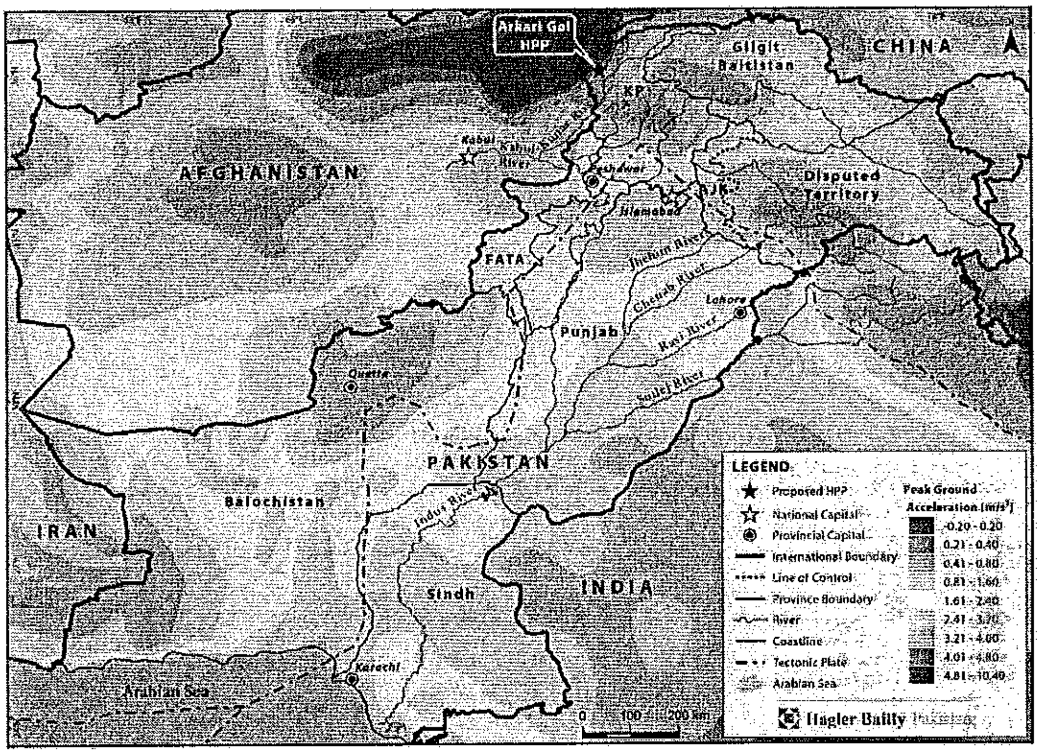
- The Maximum Credible Earthquake (MCE) is the largest reasonably conceivable earthquake that appears possible along a recognized fault or within a geographically defined tectonic province, under the specific tectonic framework governing the region of interest. The value for Peak Ground Acceleration (PGA) for MCE was calculated to be 0.61 g.
- The Maximum Design Earthquake (MDE) is the maximum level of ground motion for which a structure is designed. The MDE value recommended in the Feasibility study is 0.305 g based on a reduction factor of 2 with respect to MCE.

- The Operation Basis Earthquake (OBE) is the level of ground motion the dam shall be capable of resisting, remain operational, and not require extensive repairs. All structural components, which are part of or built within the main dam body, are designed to remain functional during and after an OBE event. For OBE; a value of 0.305 g was recommended. The OBE has probability of 10% of being exceeded in 50 years. However, as the Building Code of Pakistan prescribes a value of 0.34 g (discussed below) the OBE was increased to 0.34g to comply with the building code.

Global Seismic Hazard Assessment Project

The PGA calculated for Pakistan by the Global Seismic Hazard Assessment Project (GSHAP) is shown in **Exhibit 4.47**. The peak ground acceleration (PGA) with 10% probability of exceedance in 50 years (475 year average return interval) is reported and is between 4.01 meter per second squared (m/s^2) and 4.80 m/s^2 (0.41g to 0.49 g) at the Project site.

Exhibit 4.47: Seismic Hazard Map of Pakistan



Source: Adapted from Giardini, D., Grünthal, G., Shedlock, K. M. and Zhang, P.: The GSHAP Global Seismic Hazard Map. Annali di Geofisica 42 (6), 1225-1228, 1999.

Building Code of Pakistan

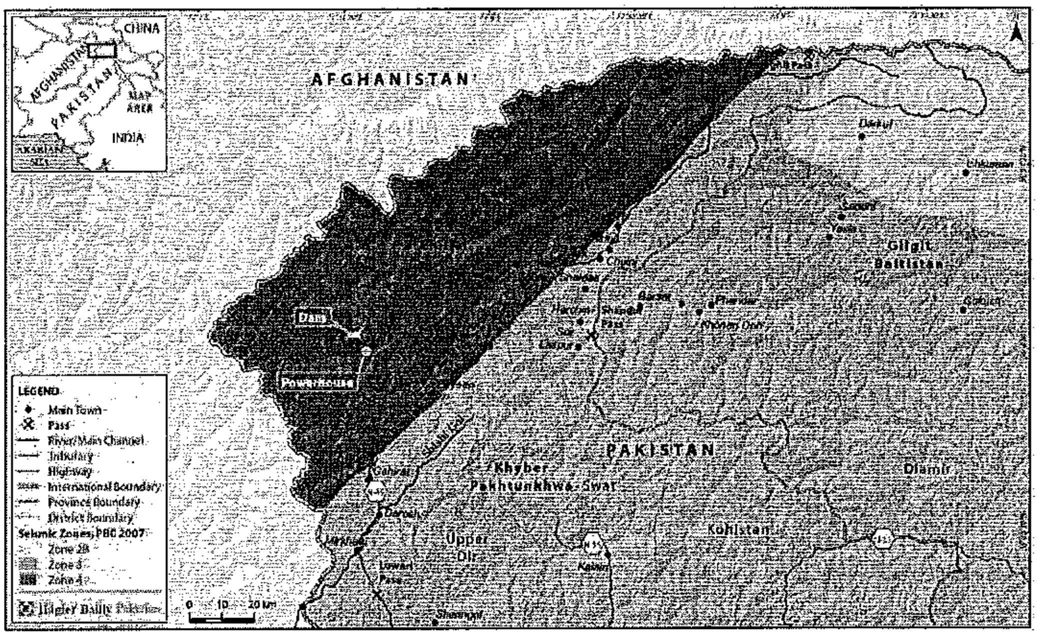
The revised Building code of Pakistan with Seismic Provision categorizes Pakistan into 5 seismic zones (see **Exhibit 4.48**). According to this classification the Project location comes under seismic Zone 4 (see **Exhibit 4.49**) for which the Project is required to withstand a PGA greater than 0.32g (or 3.14 m/s^2).

Exhibit 4.48: Seismic Zone Categorization of the Pakistan Building Code

Seismic Zone	*Peak Horizontal Ground Acceleration*
1	0.05 to 0.08g
2A	0.08 to 0.16g
2B	0.16 to 0.24g
3	0.24 to 0.32g
4	> 0.32g

Source: Building code of Pakistan with Seismic Provision, 2007 Government of Pakistan Ministry of Housing and Works

Exhibit 4.49: Seismic Zones of the Pakistan Building Code



Source: Building code of Pakistan with Seismic Provision, 2007 Government of Pakistan Ministry of Housing and Works

Geology

The geology present at the Powerhouse, Damsite and the Headrace tunnel are described in this section.

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Powerhouse Site

- The rocks at Power house area are gneissic type and phyllite, well bedded, medium to thick bedded, medium to hard, and splintery. The general strike is in the northeast to southwest direction and dipping toward northwest with 40° to 60° angle of dip. Large numbers of big rectangular blocks are lying at the site (see **Exhibit 4.50**) and others are inclined to fall from the ridge. As powerhouse is located at confluence of Arkari Gol and Lutkho river the quaternary deposits like scree and alluvium are present. The whole terrace is covered by cultivated land. The bed rock is covered under these deposits.

Dam Site

- The dam is located in a granitic outcrop. The granite body intrudes along the strike of the Wakhan formation which consists of slate, gneiss and quartzite (see **Exhibit 4.51**). The contact with granite is considered to be faulted but it could be a normal igneous contact as all the granite in Chitral has igneous normal contact in the Karakorum and Hindu Kush range. Tirich Mir granite also has similar origin and may have normal igneous contact with the Wakhan formation in the Project area.

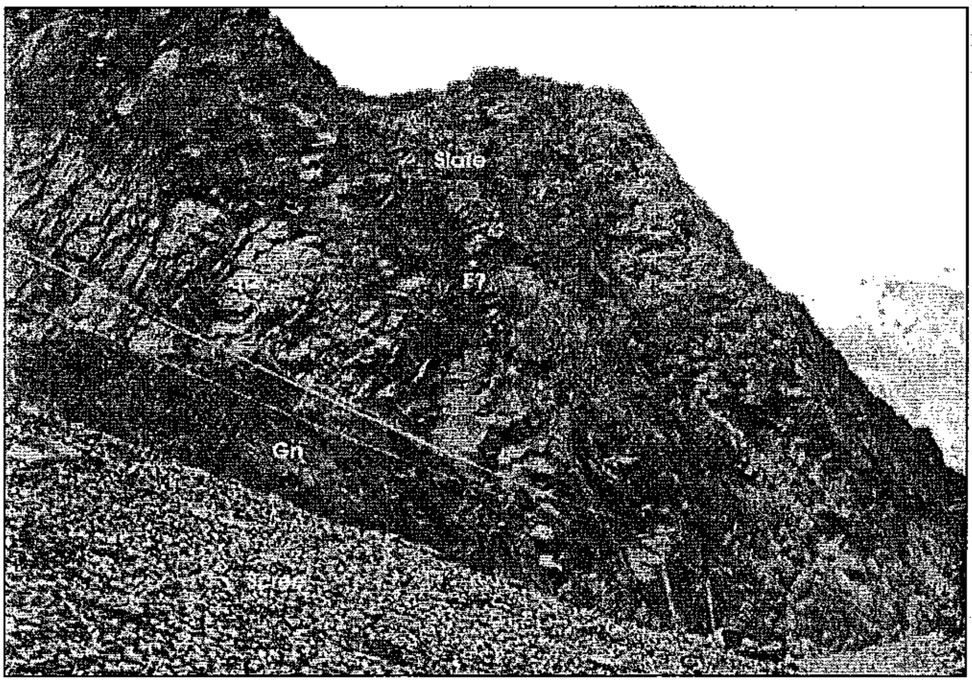
Headrace Tunnel

- From dam to the powerhouse, the tunnel crosses metamorphic and igneous rocks including phyllite, schist, gneisses, quartzite, and granite, which are described further below:
- **Gneiss** is a type of schist but the foliation is interrupted by the granular minerals like quartz, feldspar and garnet. These rocks are exposed in the area of Powerhouse, surge tank and tailrace area exhibiting breaking along the joint and foliation planes.
- **Phyllitic Slates** are dark, exceedingly fine grained, low grade metamorphic rocks. These rocks are exposed as a thick unit in the way of tunnel. The slate unit has white and grey color quartzite and two mapable beds of quartzite have been marked on the geological map. It is very hard, cliff forming, thin to thick bedded, fine to medium grained, well bedded, well jointed, and fractured.
- **Granite** is an acidic plutonic and light color rock. It occurs as major intrusive bodies such as batholiths and blocks. More than 50% of the tunnel length from the dam passes through granite body which the extension of Tirich Mir Granite. It is white color, very course grained and very phenocrystalline.

Exhibit 4.50: Fallen Blocks of Gneissic at the Powerhouse Site

Source: Feasibility Study for the Arkari Gol Hydropower Project, March 2014, PHYDO

Exhibit 4.51: Contact of three types of Rock i.e Gneiss (gn) Quartzite (qtz) and Slate



Source: Feasibility Study

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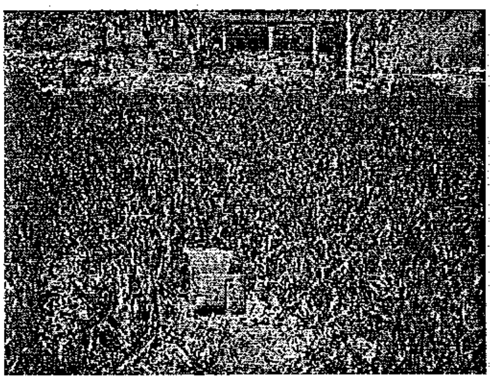
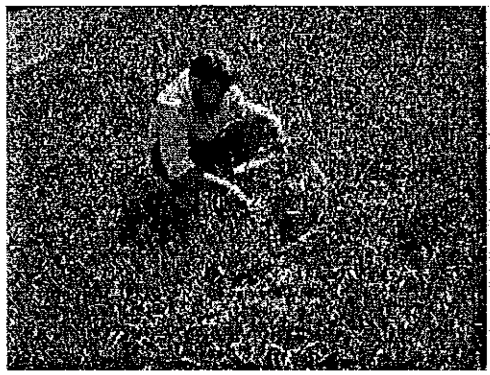
Soil Quality

Soil was tested from the Study Area to document baseline conditions. A soil sample was collected from agricultural land near the Powerhouse site (36° 01' 11.9" N, 71° 44' 15.5" E). **Exhibit 4.52** presents photographs of the site and **Exhibit 4.53** shows the location. pH, EC, and organic parameters were tested at the HBP Lab, and the remaining parameters were tested at PINSTECH. Soil test results are summarized in **Exhibit 4.54** and lab reports are presented as **Appendix G**.

Exhibit 4.52: Soil Sampling Location and Method



Soil sample from agricultural field.



Soil sample collection.

Exhibit 4.53: Soil Sampling Location

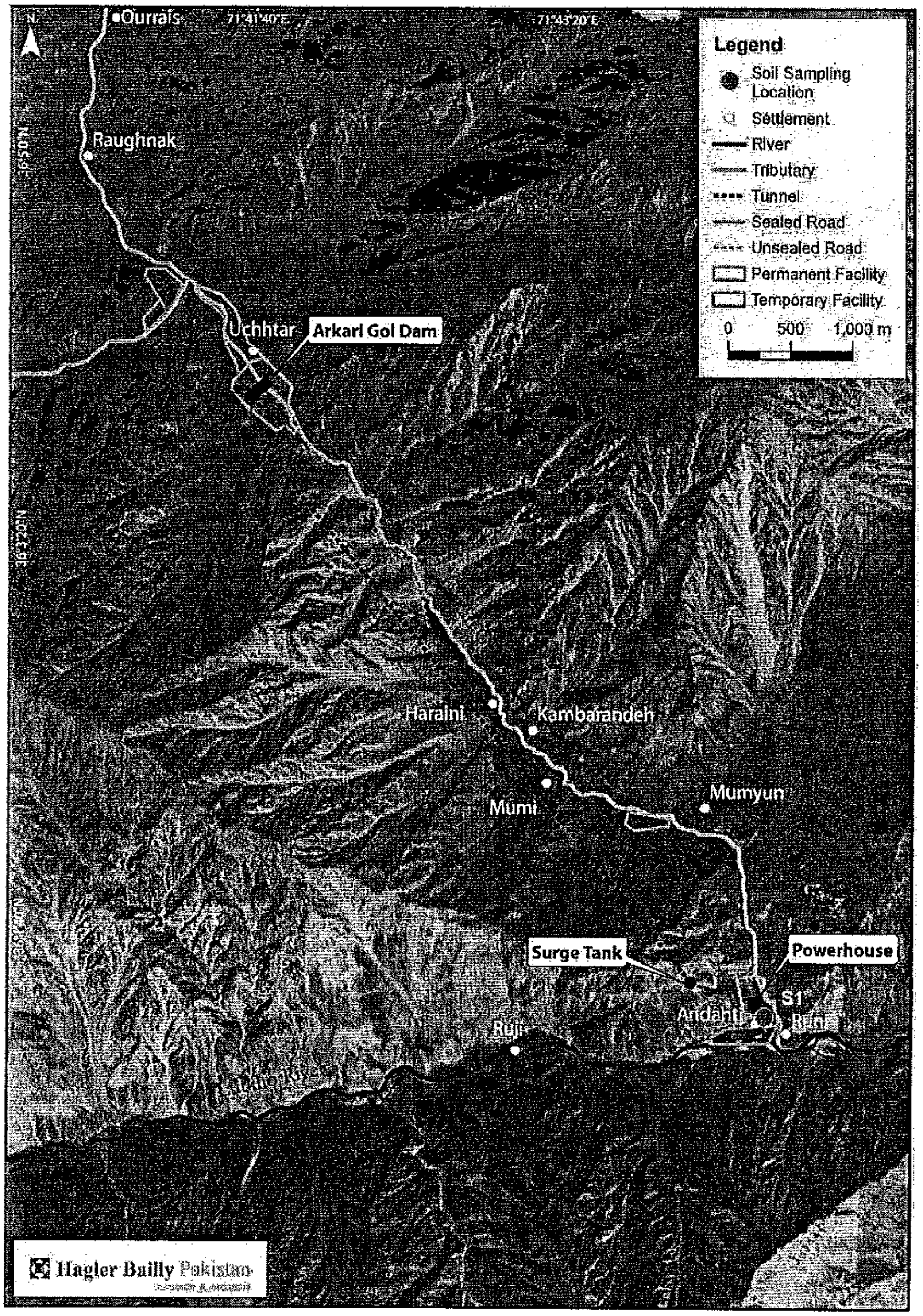


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Exhibit 4.54: Soil Quality at S-1

Parameter	*Analytical Method*	*Unit*	*LOR*	*Analysis Results*
pH	CSSS		0.1	7.08
EC	CSSS	µS/cm	1	343
Organic Matter	CSSS	%	0.1	2.57
Organic Carbon	CSSS	%	0.05	1.48
Silver	ICP-OES	µg/g	4.51	ND
Boron	ICP-OES	µg/g	1.79	5.05
Barium	ICP-OES	µg/g	1.02	90.00
Cadmium	ICP-OES	µg/g	0.24	ND
Chromium	ICP-OES	µg/g	0.44	30.98
Copper	ICP-OES	µg/g	1.02	27.91
Iron	ICP-OES	µg/g	1.70	41639.61
K	ICP-OES	µg/g	1.65	5861.25
Manganese	ICP-OES	µg/g	8.00	633.23
Nickel	ICP-OES	µg/g	0.19	33.24
Phosphate	ICP-OES	µg/g	0.39	2306.06
Lead	ICP-OES	µg/g	2.42	22.41
Zinc	ICP-OES	µg/g	1.31	93.48

CSSS: Canadian Society of the Soil Science
µS/cm: Microsiemens Per Centimeter
EC: Electrical Conductivity
LOR: Level of Reporting
ND: Not detected

4.2.3 Climate Baseline

The objective of the climate baseline is to characterize the climatic conditions in the Study Area. This includes characterization of the monthly trends in weather parameters (temperature, precipitation, relative humidity) and the extreme conditions that occur in the Study Area.

Data Sources

A regional climate overview was established using available data from Chitral weather station. This is the nearest Pakistan Meteorological Department (PMD) weather station to the Project. The description of weather station is presented in **Exhibit 4.55.**

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Exhibit 4.55: Details of Chitral Weather Station

World Meteorological Organization (WMO) Identification Number	41506
Established	1964
Location	71° 50' E, 35° 50' N
Location with respect to dam site	27.5 km southeast
Location with respect to powerhouse site	21 km southeast
Elevation (m amsl)	1499
Data period used in the analysis	1964-1990 (27 Years)

Data Analysis

The climate analysis of Project area was carried out by classifying it into different seasons as below.

Spring (mid-March to mid-June)

Characterized by high temperatures, and high rainfall with moderate humidity and high speed-winds.

Summer (mid-June to mid-September)

The summers are hotand dry, with temperatures reaching highs of 35°C in July and average precipitation of 6-7mm per month..

Autumn (mid-September to mid-November)

Characterized by moderate temperatures and low rainfalls. Daily minimum reaches 5°C in November with moderate humidity, as the humidity again reduces after monsoon and low speed-winds.

Winter (mid-November to mid-March)

Characterized by very low temperatures, with an average daily maximum of 10°C, moderate rainfalls, with an increasing amount of rainfall at the end of the winter

The summary of climate analysis is presented in **Exhibit 4.56**. The parameters are tabulated in **Exhibit 4.57** and graphed in **Exhibit 4.58** to **Exhibit 4.60.**

Exhibit 4.56: Seasonal Variation

Season	Temperature and Humidity	Rainfall
Spring (mid-March to mid-June)	Daily maximum temperature averages between 15°C and 34°C. Daily minimum gradually increases from 9°C in March to 26°C in June. Morning humidity reduces from 67% in March to 47% in June. Same trend was observed in afternoon humidity that also reduces from 36% in March to 14% in June.	31% of total rainfall occur in summers with maximum amount of rainfall observed in April (208 mm). The mean number of rainy days during this period ranges from 0.5 to 7.7 per month.
Summer (mid-June to mid-September)	Daily maximum temperature increases by a few degrees and averages between 31°C and 36°C. Daily minimum temperatures gradually increases and varies between 13.3°C and 17.9°C. Morning humidity increases up to 76% in September. Afternoon humidity increases to 24% in August and then reduces to 21% in September.	Only 5% of total rainfall occur in this season with maximum amount of rainfall observed in September (67.8 mm). The mean number of rainy days during this period are between 0.5 to 0.9 per month.
Autumn *(mid-September to mid-November)*	Daily maximum temperature decreases by about 16°C in November. Daily minimum temperatures start decreasing and drops to 2.9°C by November. Morning humidity decreases to 60% in November. Afternoon humidity gets increased to 28% in November.	By the end of September, the rainfall starts increasing. About 8% of total rainfall occur in post-monsoon summer. Maximum rainfall of 83 mm has been observed in the month of November. The number of rainy days are less than 1.5 during these months.
Winter *(mid-November to mid-March)*	Daily maximum temperature averages between 9°C and 15°C. Daily minimum temperature averages between below 0°C and 4°C. Morning humidity again increases to 67% in March. Afternoon humidity remains almost same (38%) and it starts decreasing in march (36%).	The amount of rainfall starts increasing with the advent of winter. About 56% of the total rainfall occurs during this season with maximum amount in February (281 mm). The mean number of rainy days are between 3.6 and 7.7 per month.

Exhibit 4.57: Weather Parameters

Month	*Temperature (°C)*			*Humidity (%)*		*Rainfall (mm)*	*Number of Rainy days*
	Mean	*Min*	*Max*	*5:00 AM*	*5:00 PM*		
Jan.	4.1	-0.7	8.8	64	38	36.8	3.6
Feb.	5.4	0.6	10.1	65	38	63.4	5.4
Mar.	9.6	4.2	15	67	36	106.7	7.7
Apr.	15.2	8.4	21.9	70	31	88.5	7.1
May.	20.2	12.5	27.8	62	23	44.6	3.5
Jun.	26.2	17.9	34.4	47	14	5.5	0.5
Jul.	28.1	20.2	36	62	19	6.2	0.7
Aug.	26.8	18.8	34.7	73	24	6.5	0.7
Sep.	22.3	13.3	31.2	76	21	7.7	0.9
Oct.	16.2	7.5	25	71	25	16.1	1.7
Nov.	10.7	2.9	18.5	60	28	19.5	1.9
Dec.	5.7	0	11.3	64	38	41.4	3.6

Exhibit 4.58: Mean Monthly Temperatures (°C)

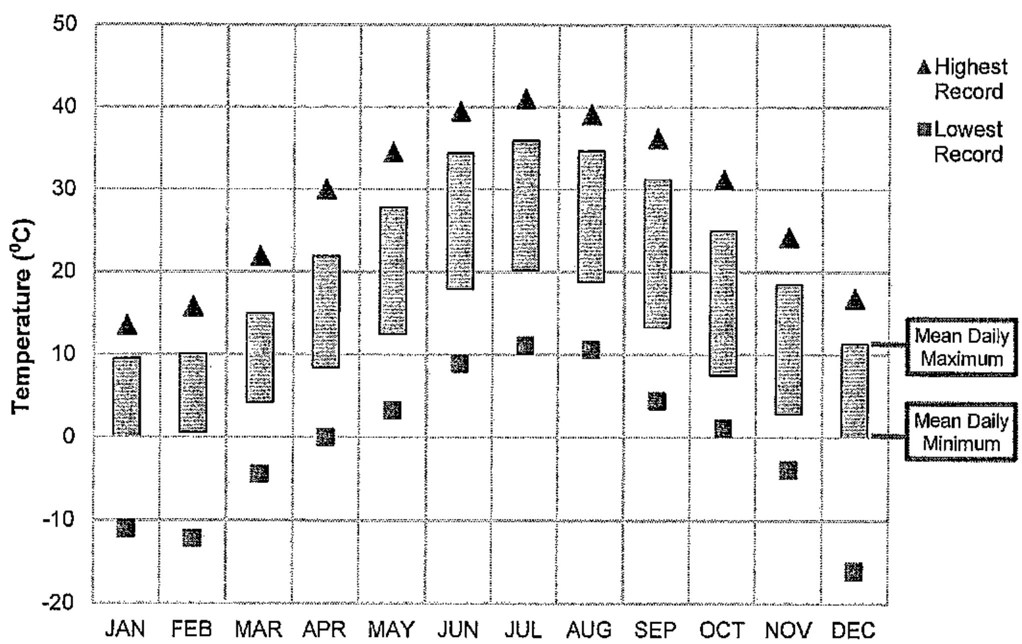


Exhibit 4.59: Mean Monthly Relative Humidity (%)

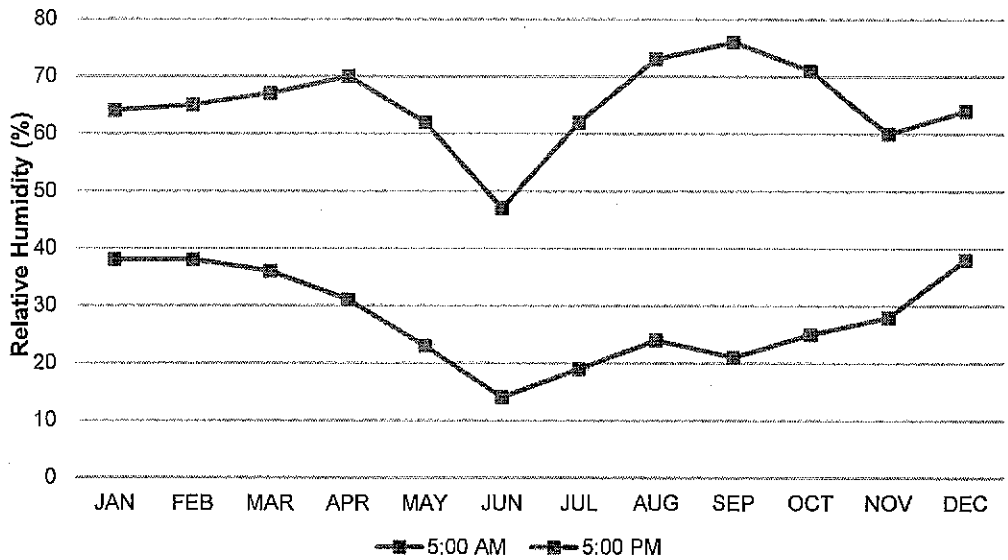
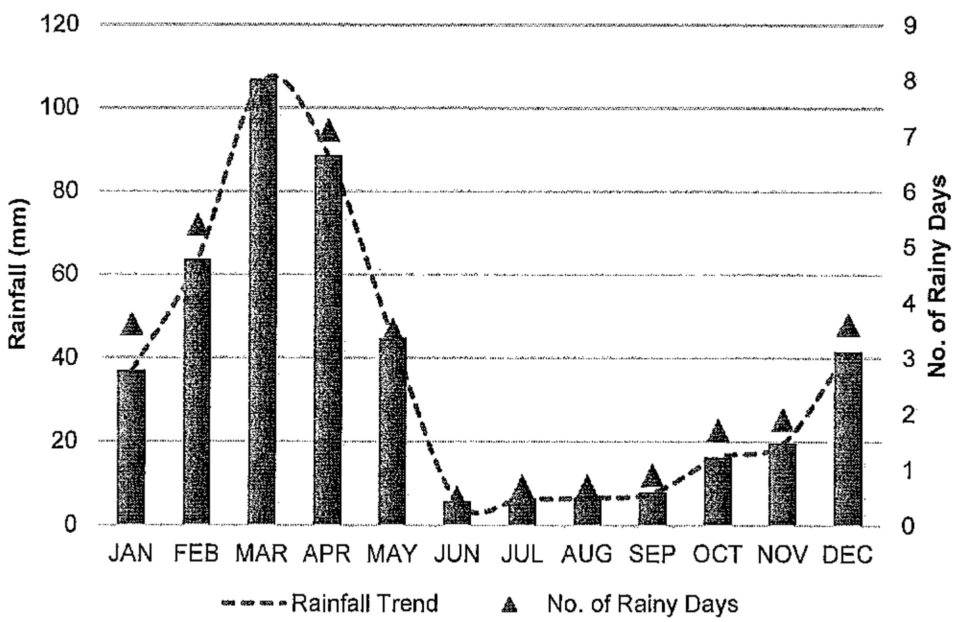


Exhibit 4.60: Mean Monthly Rainfall (mm)



Extreme Events

Weather extremes recorded at the Chitral weather station are given in **Exhibit 4.61** for temperature and in **Exhibit 4.62** for precipitation.

Exhibit 4.61: Temperature Extremes, 1961-1990 (°C)

	Highest Recorded	*Date*	*Lowest Recorded*	*Date*
January	17.2	14/1965	-11	29/1977
February	21	28/1985	-12.2	2/1969
March	28	22/1974	-4.4	18/1966
April	34.3	29/1988	0	7/1975
May	38.3	28/1971	3.3	22/1965
June	42.5	26/1984	8.9	2/1982
July	44.4	10/1971	11.1	6/1989
August	42.8	10/1970	10.6	31/1989
September	39.8	17/1990	4.4	18/1967
October	35	1/1970	1.1	31/1987
November	27.2	7/1970	-3.9	26/1970
December	20.7	4/1990	-16.1	27/1965
Year	44.4	July 10, 1971	-16.1	December 27, 1965

Exhibit 4.62: Extreme Precipitation Conditions, 1961-1990 (mm)

	Wettest Month		*Driest Month*		*Heaviest Rainfall in 24 hours*	
January	94.3	1977	0	1987	37.3	26/1974
February	123.2	1972	9.3	1978	61.7	23/1972
March	281.4	1966	7.4	1974	54.6	17/1966
April	208.3	1965	8.4	1982	64	18/1965
May	176.8	1972	0.3	1971	90.7	22/1965
June	64.5	1987	0	-9	35.4	3/1987
July	36.6	1966	0	-9	15.5	4/1965
August	28.7	1988	0	-6	16	27/1988
September	67.8	1972	0	1988	29.7	19/1972
October	62.5	1987	0.3	1982	44.2	2/1973
November	83.1	1982	0	-5	44	16/1982
December	119.3	1990	1.8	1966	80.5	30/1984
Year	779	1972	110.4	1964	90.7	22 May 1965

4.2.4 Climate Patterns in Arkari Gol Region

A number of different datasets to characterize the climate of the Project area are available. These include weather station data from weather stations operated by the Pakistan Meteorological Department (PMD) and Water and Power Development

Authority (WAPDA) as well as multiple gridded datasets. Chitral station is the nearest station located at a distance approximately of 26 km to the south of Project site. Other weather stations which have been considered are: Drosh station in south of proposed dam site with approximated distance of 56 km and Ashkasham station in Afghanistan at a distance ~ 71 km in north direction of Project site. Chitral and Drosh stations are located at downstream of Project. Precipitation observations are available for all three stations while temperature observations are available for Chitral and Drosh stations only. The mean monthly temperature is provided in **Exhibit 4.63** and **Exhibit 4.64** and mean monthly precipitation data is provided in **Exhibit 4.65** to **Exhibit 4.67.**

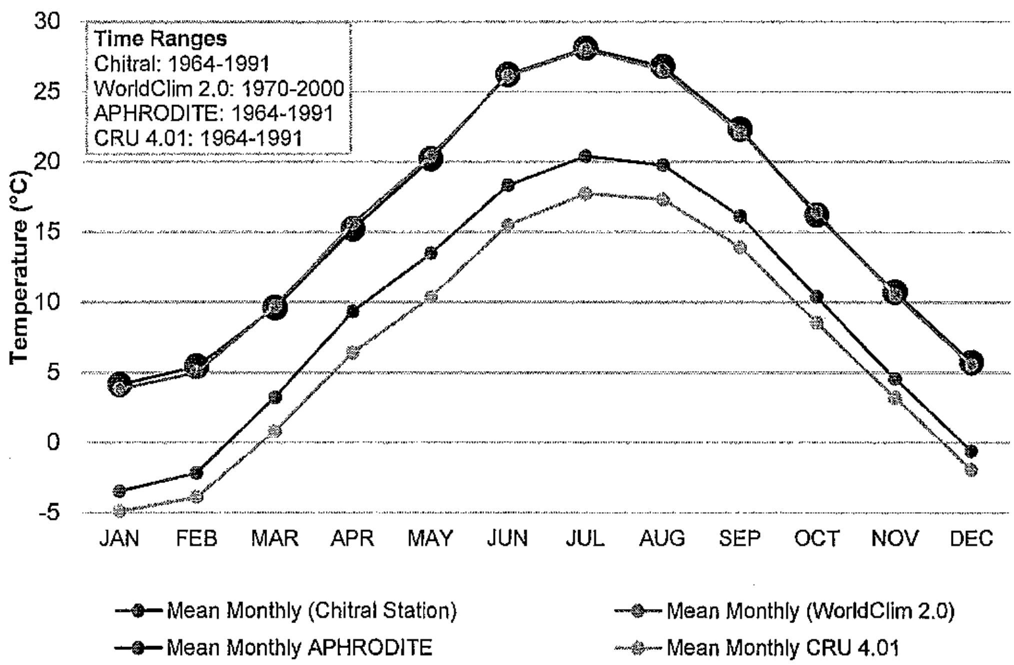
Most of the stations operated by the Pakistan Meteorological Department (PMD) in high altitudes are not representative of the respective catchments, as these are located in the valleys, and there is a positive correlation, particularly between winter precipitation and elevation, in the region. Therefore, point data, i.e. Chitral, Drosh and Ashkasham stations data, is not best to characterize catchment climate characteristics. With respect to any climate change risk assessment for the Project, a gridded dataset is likely to be a requirement to specify the baseline. Gridded datasets that rely solely on station data, typically under-predict the winter rainfall, and in some instances severely under-predict the South Asian Summer Monsoon (SASM). As an example, the Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation (APHRODITE) dataset, which is widely considered to be the best state-of-art dataset available, since it has the largest climate station network and provides very high resolution (spatial) data, severely under-predicts Monsoon rainfall in most regions of Pakistan. The dataset is limited by the sparse gauging station data in Pakistan. Another commonly cited dataset in peer-reviewed journal literature is the Climate Research Unit (CRU) dataset. This is typically utilized as a monthly baseline in peer reviewed literature for climate change as well as for assessment of GCM historic modelled results. However, the CRU dataset has very low spatial resolution, and is only useful for analysis of baseline trends on a larger scale. In contrast to APHRODITE and CRU, the WorldClim dataset has higher spatial resolution, and provides the greatest advantage, particularly for hydrologic modelling aspects, as it uses a large amount of climate station gauging data, covariates (to varying degrees) such as elevation and distance from the coast, and satellite data that offers some improvement.

A comparison of point stations vs gridded datasets has been shown in **Exhibit 4.63** to **Exhibit 4.67.** The comparison suggests that APHRODITE and CRU datasets underestimates temperature throughout the year while WorldClim best approximate temperature with respect to weather stations (**Exhibit 4.63** and **Exhibit 4.64**). On the other hand, in terms of precipitation (**Exhibit 4.65** to **Exhibit 4.67**), CRU overestimates precipitation especially in Monsoon period. Precipitation overestimation by CRU is well expected due to its larger grid cell. Overall, comparison shows that WorldClim 2.0 dataset gives best approximation for temperature and precipitation and thus can be used for climate change patterns analysis.

The mean monthly temperature and precipitation from the gridded WorldClim 2.0 dataset are provided in **Exhibit 4.68** to **Exhibit 4.71.** A comparison at Chitral and Drosh station shows a good match between stations and WorldClim 2.0 temperatures (**Exhibit 4.63** and **Exhibit 4.64**). However, there is a mismatch in precipitation especially at Ashkasham station, where the WorldClim 2.0 dataset over predicts the winter westerly (**Exhibit 4.67**). Thus, where and if a gridded dataset is required for further analysis as part of further studies, bias correction will need to be performed for the precipitation dataset to adjust, based on data from a network of weather stations.

Two contrasting climatic regimes govern in the northern Pakistan including the winter westerlies and the SASM. Based on the WorldClim dataset (**Exhibit 4.70** and **Exhibit 4.71**), the Arkari Gol catchment is totally run by winter westerlies and area does not get any impression of SASM[70] and thus have least precipitation in summer season in contrast to other regions of Pakistan. Arkari Gol region starts getting increase in precipitation in December (winter) and receives maximum amount of precipitation in March and April. Once the winter season sets-off, precipitation starts decreasing and reaches to significantly low value in summer and summer monsoon seasons. September is the month with least precipitation.

Exhibit 4.63: Mean Monthly Temperature Comparisons at Chitral Station



[70] Also known as the South-West Monsoon

Exhibit 4.64: Mean Monthly Temperature Comparisons at Drosh Station

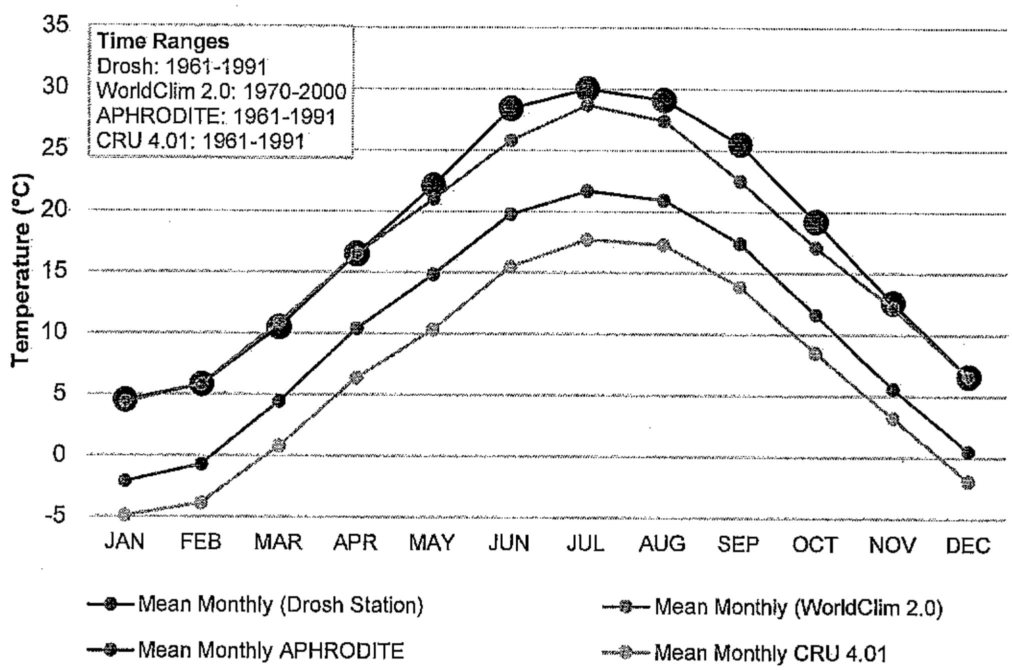


Exhibit 4.65: Mean Monthly Precipitation Comparisons at Chitral Station

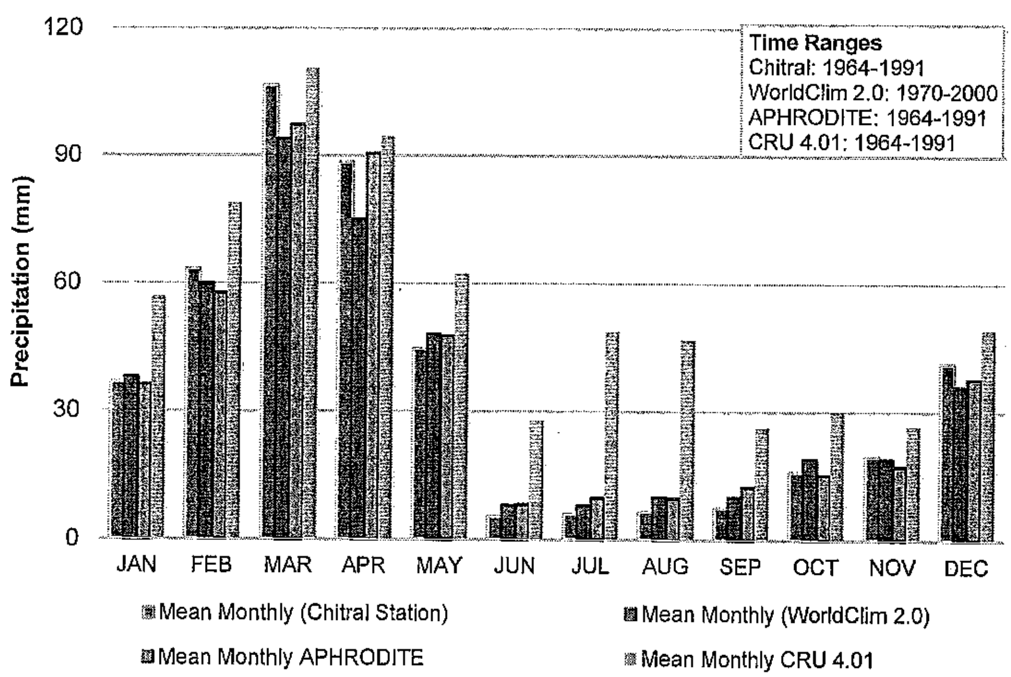


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Exhibit 4.66: Mean Monthly Precipitation Comparisons at Drosh Station

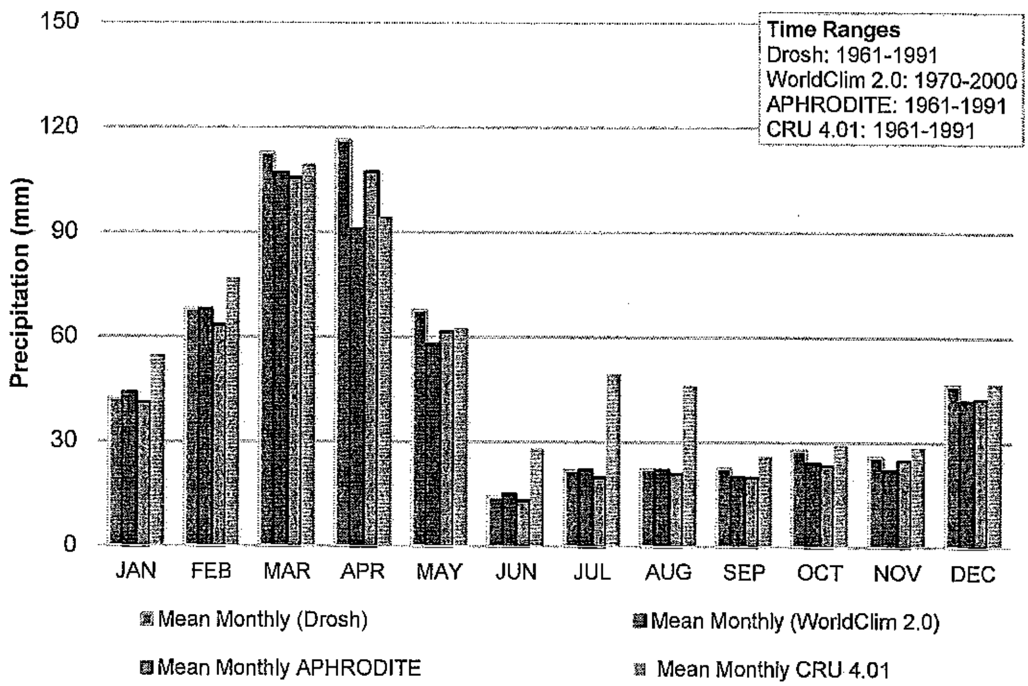

Exhibit 4.67: Mean Monthly Precipitation Comparisons at Ashkasham Station

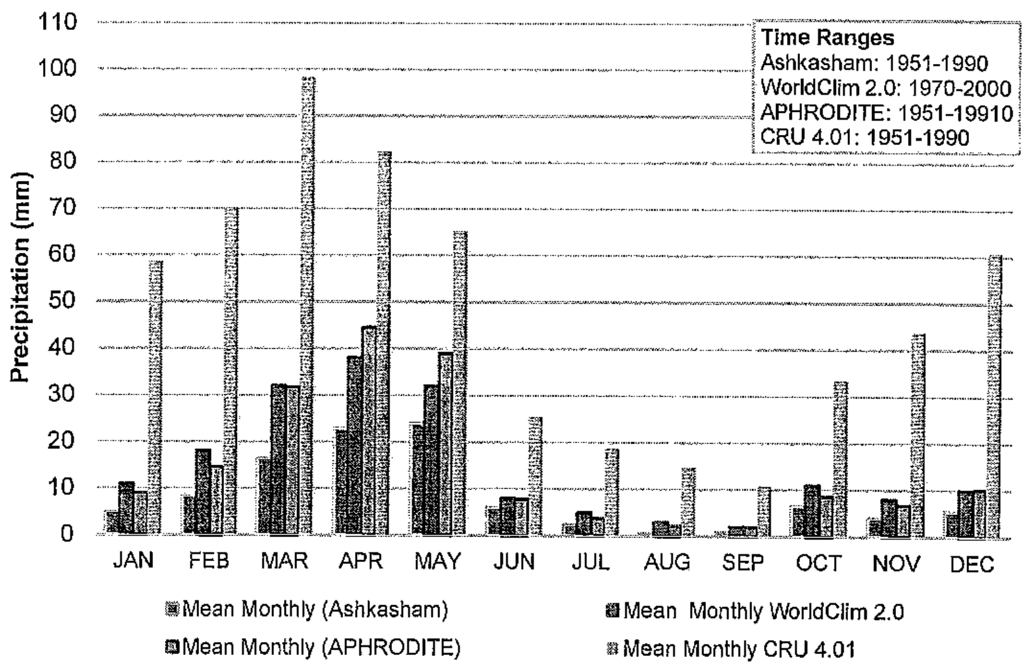

Exhibit 4.68: Mean Monthly Temperature at Larger Scale (WorldClim 2.0)

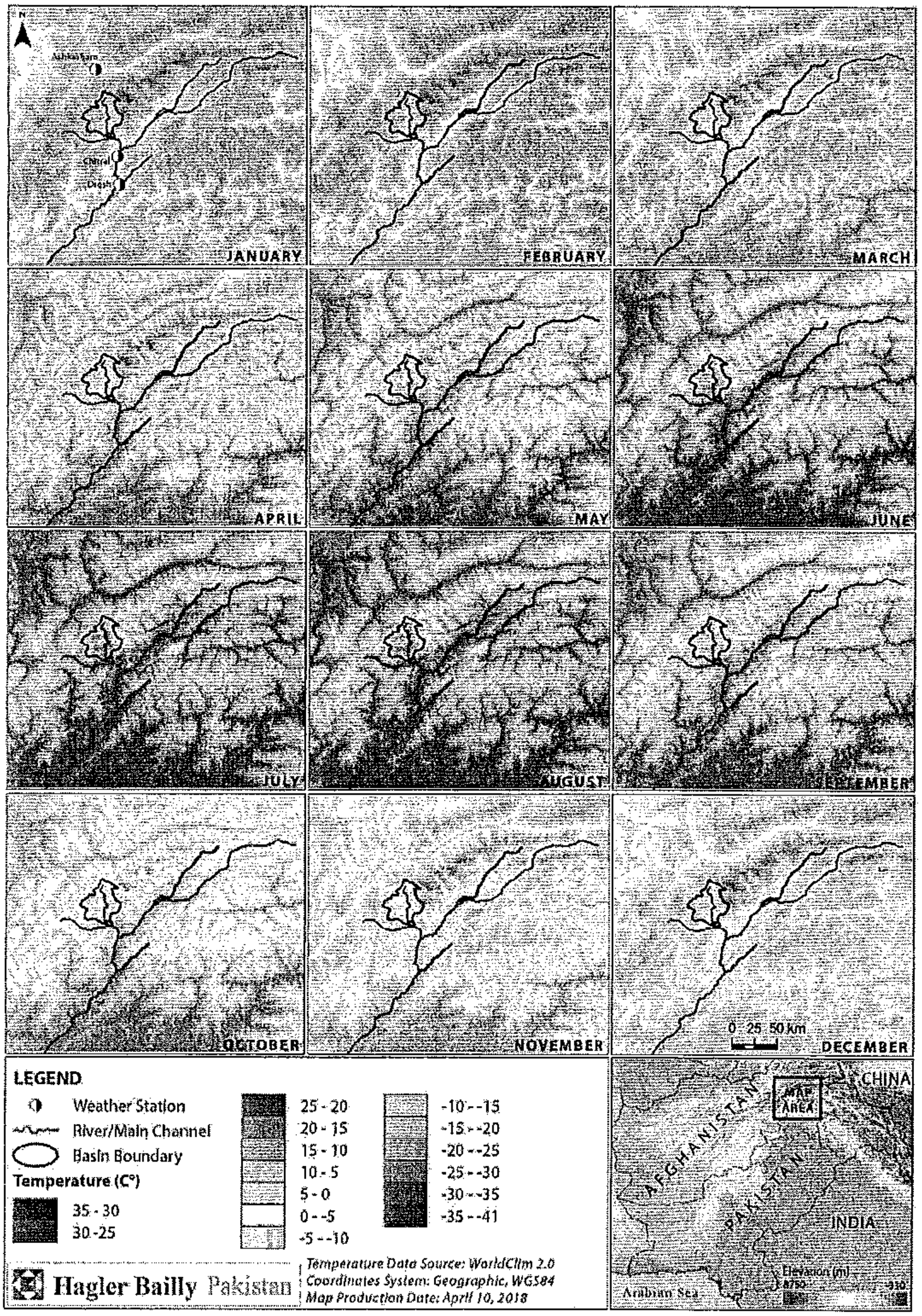

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Exhibit 4.69: Mean Monthly Temperature at Arkari Gol Basin (WorldClim 2.0)

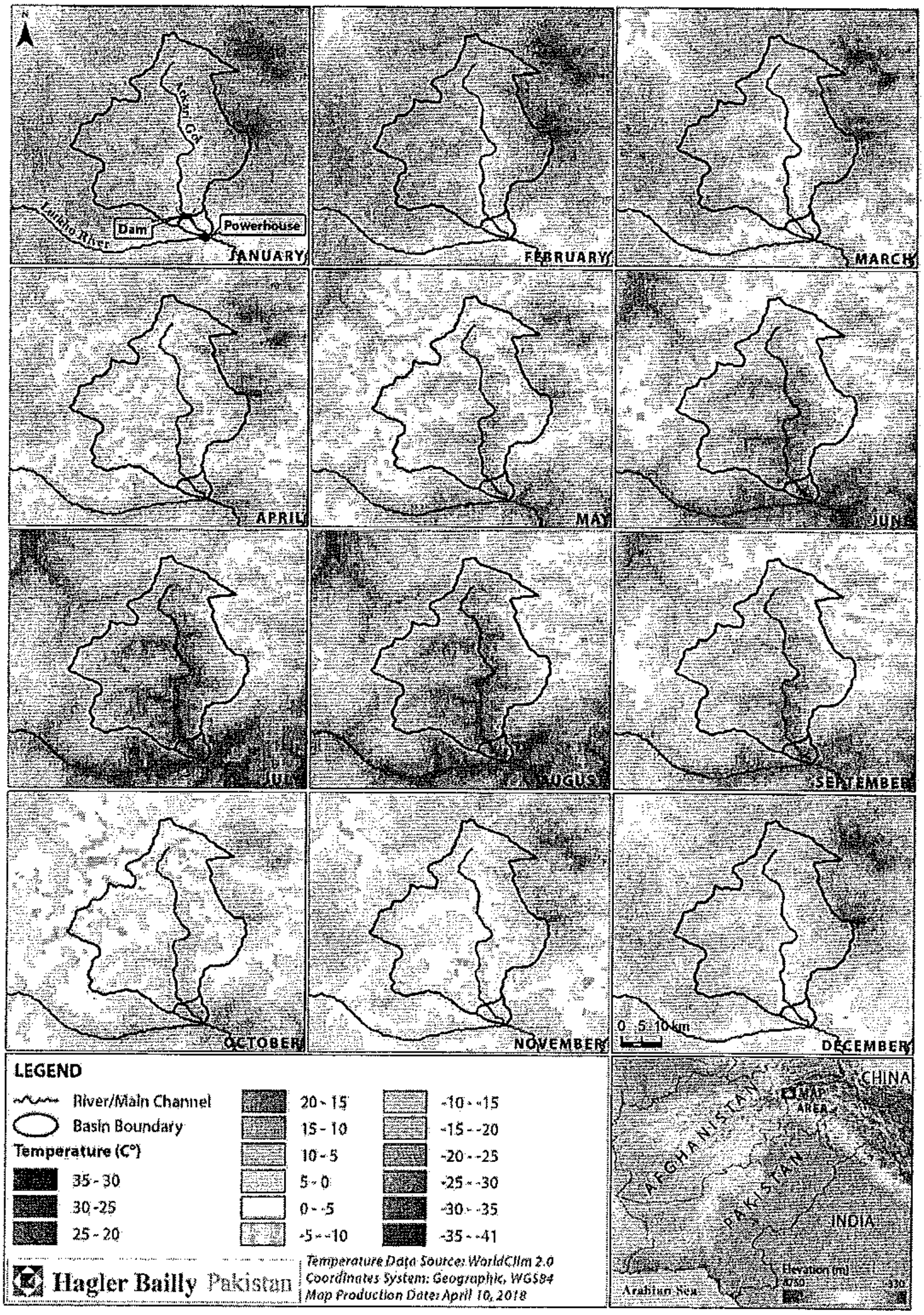

Exhibit 4.70: Mean Monthly Precipitation at Larger Scale (WorldClim 2.0)

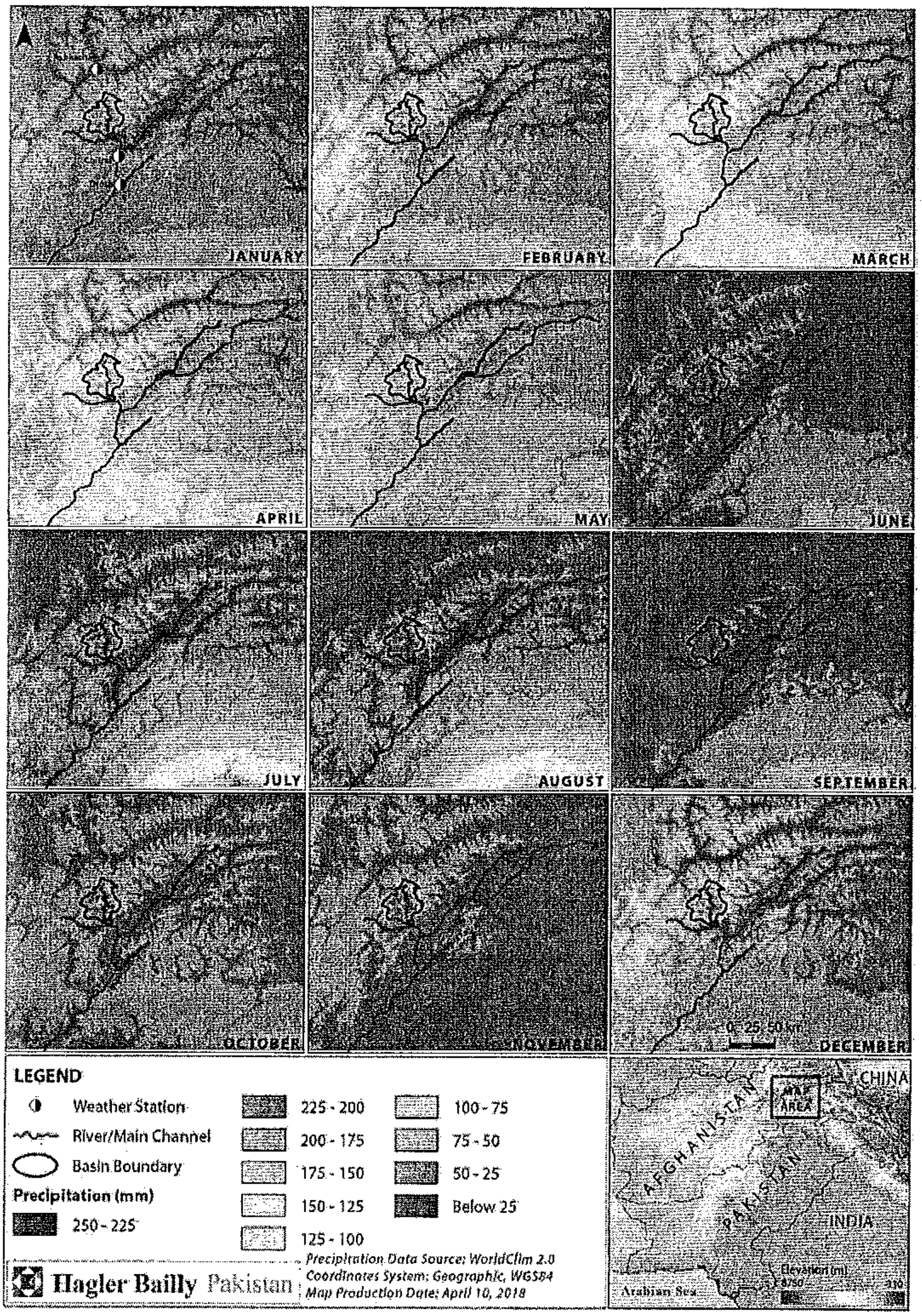

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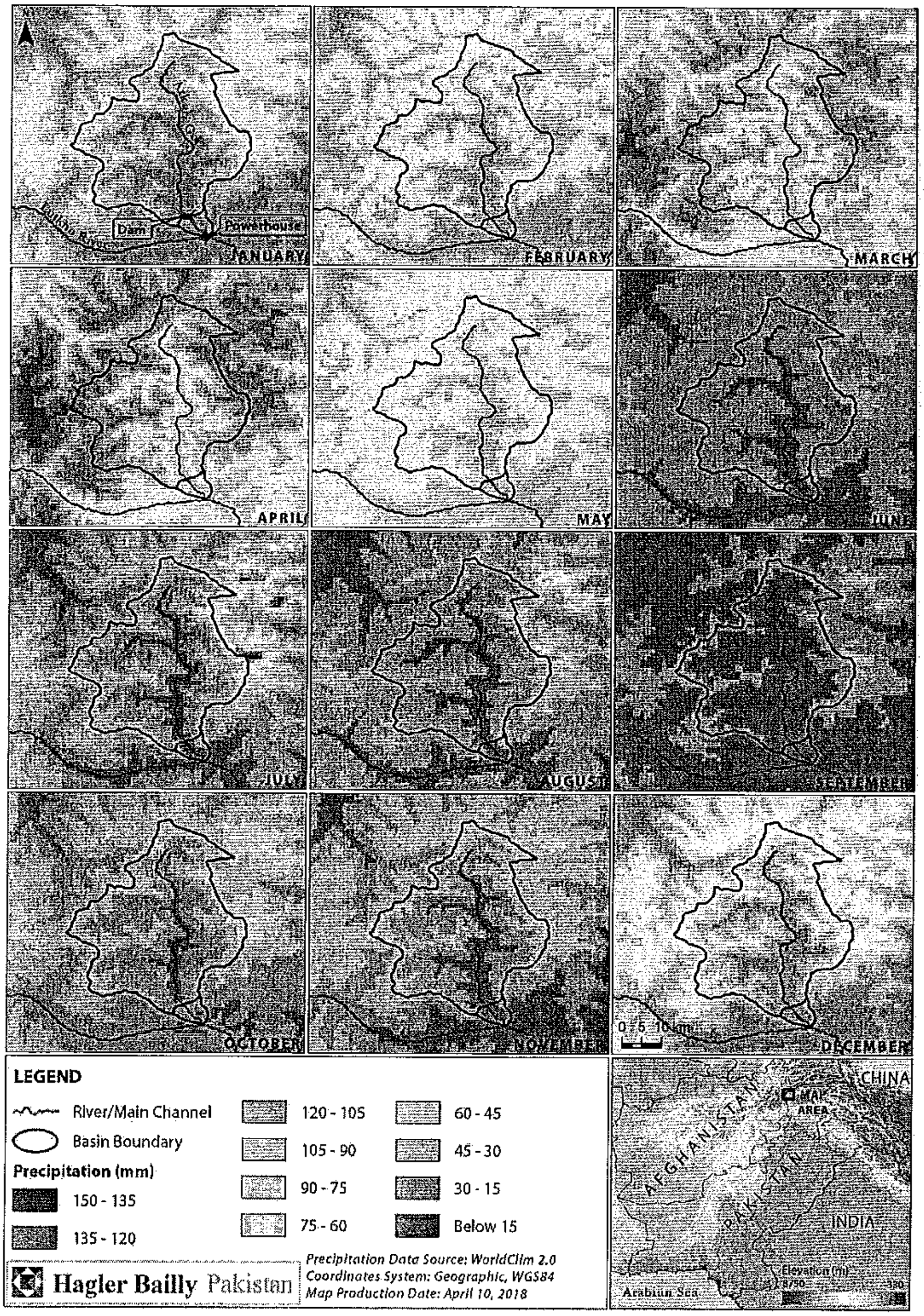
Exhibit 4.71: Mean Monthly Precipitation at Arkari Gol Basin (WorldClim 2.0)



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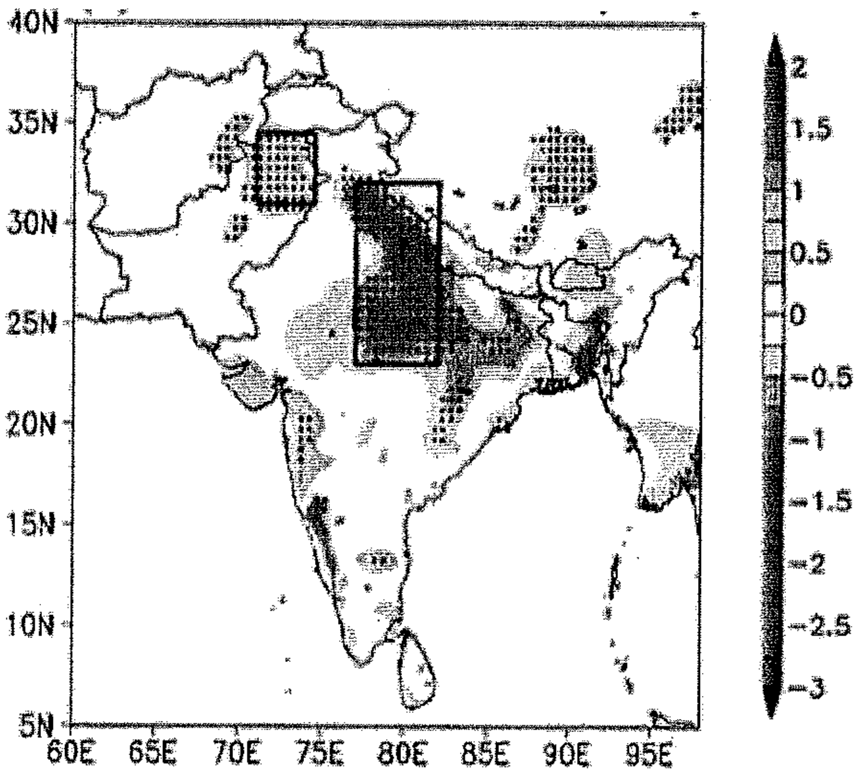
Trends in Precipitation

Observed trends indicate that the annual, as well as June, July, August and September (JJAS) rainfall, i.e. SASM rainfall, over most of India is decreasing.[71] [72] However, the trend in Pakistan shows increasing JJAS rainfall (**Exhibit 4.72**). **Exhibit 4.72** indicates that the Arkari Gol catchment has a consistent status for JJAS precipitation i.e. there is no trend in precipitation.

Analysis of WorldClim 2.0 dataset indicates that the Arkari Gol region receives most of the precipitation in December, January, February, March and April (majority in winter season) due to a phenomena called Western Disturbances. Different studies have shown an increase in temperature in this region but there are no major trends in the winter seasonal precipitation. However, there is a significant increase in the occurrence of extreme precipitation events in recent decades[73].

Exhibit 4.72: Trend in SASM Rainfall - JJAS (1951-2011) using CRU dataset (mm/year)



Source: Latif, M., Syed, F., & Hannachi, A. (2016). Rainfall trends in the South Asian summer monsoon and its related large-scale dynamics with focus over Pakistan. Climate Dynamics, 48(12), 3565-3581.

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71 Latif, M., Syed, F., & Hannachi, A. (2016). Rainfall trends in the South Asian summer monsoon and its related large-scale dynamics with focus over Pakistan. Climate Dynamics, 48(12), 3565-3581.

72 Kumar, V., Jain, S. K. & Singh, Y. (2010) Analysis of long-term rainfall trends in India. Hydrol. Sci. J. 55(4), 484–496.

73 Madhura, R. K., R. Krishnan, J. V. Revadekar, M. Mujumdar, and B. N. Goswami. "Changes in western disturbances over the Western Himalayas in a warming environment." Climate dynamics 44, no. 3-4 (2015): 1157-1168.

4.2.5 Ambient Air Quality

This section describes the current ambient air quality in the area where Project activities are proposed. As traffic volumes are minimal (see **Section 4.2.8**) and housing density is sparse, low levels of anthropogenic sources of air pollutants are expected. Particulate matter, however, is often high in the region due to natural sources.

Therefore, respirable particulate matter (both coarse (PM_{10})[74] and fine ($PM_{2.5}$)[75]), was selected as a pollutant for evaluation, based on baseline emission sources in the area, the expected emissions from the Project activities, and the level of risk to human health.

Methodology and Sampling Locations

Air quality sampling was carried out at three different locations for 24 hours each in the Study Area between March 29 and April 1, 2018. A description of the air quality samples (including locations of sampling) and the rationale of selection of each sampling site is given in **Exhibit 4.73**.

Particulate matter was sampled using Airmetrics MiniVol Portable Air Samplers. This equipment draws an air sample through an inlet by a vacuum pump at a fixed flow rate. The particulates are filtered using an impactor and collected on a filter paper which is dried and weighed after the sampling to obtain the weight of particulates in the sampled volume of air. The samples were analyzed in the HBP Laboratory, Islamabad after collection. Weather data[76] was collected alongside sampling for particulate matter using a Kestrel 5500 weather meter.

Photographs of the sampling sites are shown in **Exhibit 4.74**. The sampling locations, along with nearby settlements and roads are shown in **Exhibit 4.75.**

Exhibit 4.73: Details of Air Quality Samples and Locations

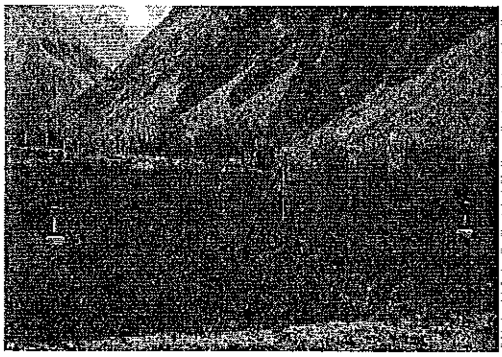
Sample ID	*Coordinates*	*Altitude (m)*	*Location*	*Rationale for Site Selection*
A1	36° 01' 11.6" N 71° 44' 16.1" E	1846	Andahti Village	To document baseline air quality at the Powerhouse construction site.
A2	36° 02' 07.5" N 71° 43' 22.7" E	1922	Mumi Village	To document baseline air quality near the temporary construction facility.
A3	36° 04' 10.5" N 71° 41' 32.9" E	2206	Uchhtar Village	To document baseline air quality near the Dam construction site.

74 PM_{10} is particulate matter 10 micrometers or less in diameter

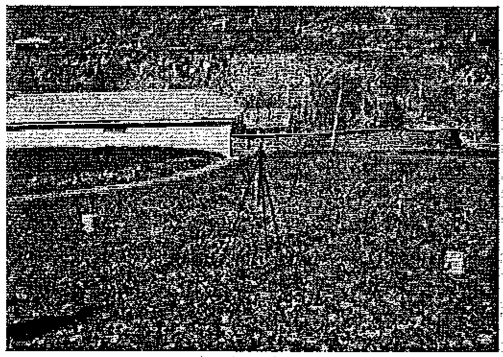
75 $PM_{2.5}$ is particulate matter 2.5 micrometers or less in diameter

76 Weather data includes wind speed and direction, temperature, humidity and barometric pressure.

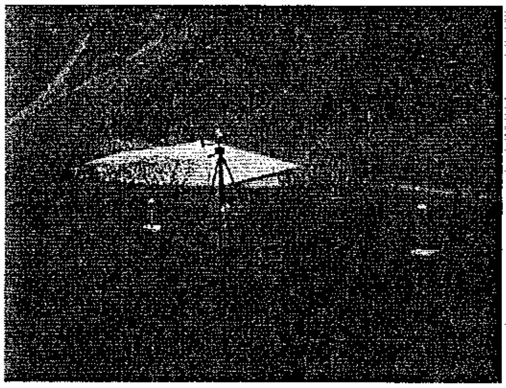
Exhibit 4.74: Ambient Air Quality Sampling Site Photographs



Weather meter and PM samplers at A1



Weather meter and PM samplers at A2



Weather meter and PM samplers at A3

Results and Analysis

The air quality sampling results are summarized in **Exhibit 4.76** and measured weather parameters during sampling in **Exhibit 4.77.** The values exceeding either the NEQS or the IFC-EHS guidelines are highlighted. The complete lab results are provided in **Appendix G.**

The following analysis of results are presented:

- PM_{10} and $PM_{2.5}$ readings were well within the IFC EHS interim target 1 guideline values at all locations.
- The 24-hour PM_{10} concentration comply with the NEQS at all sampling locations. The level of PM_{10} is ranges between about 52-78% of the limit.
- The 24-hour $PM_{2.5}$ concentration does not comply with NEQS at A2 and A3.
- The highest readings for both PM_{10} and $PM_{2.5}$ were recorded at A2 (Mumi village) which is a settlement along the road and near the temporary construction site 2.

Exhibit 4.75: Air Quality Sampling Locations

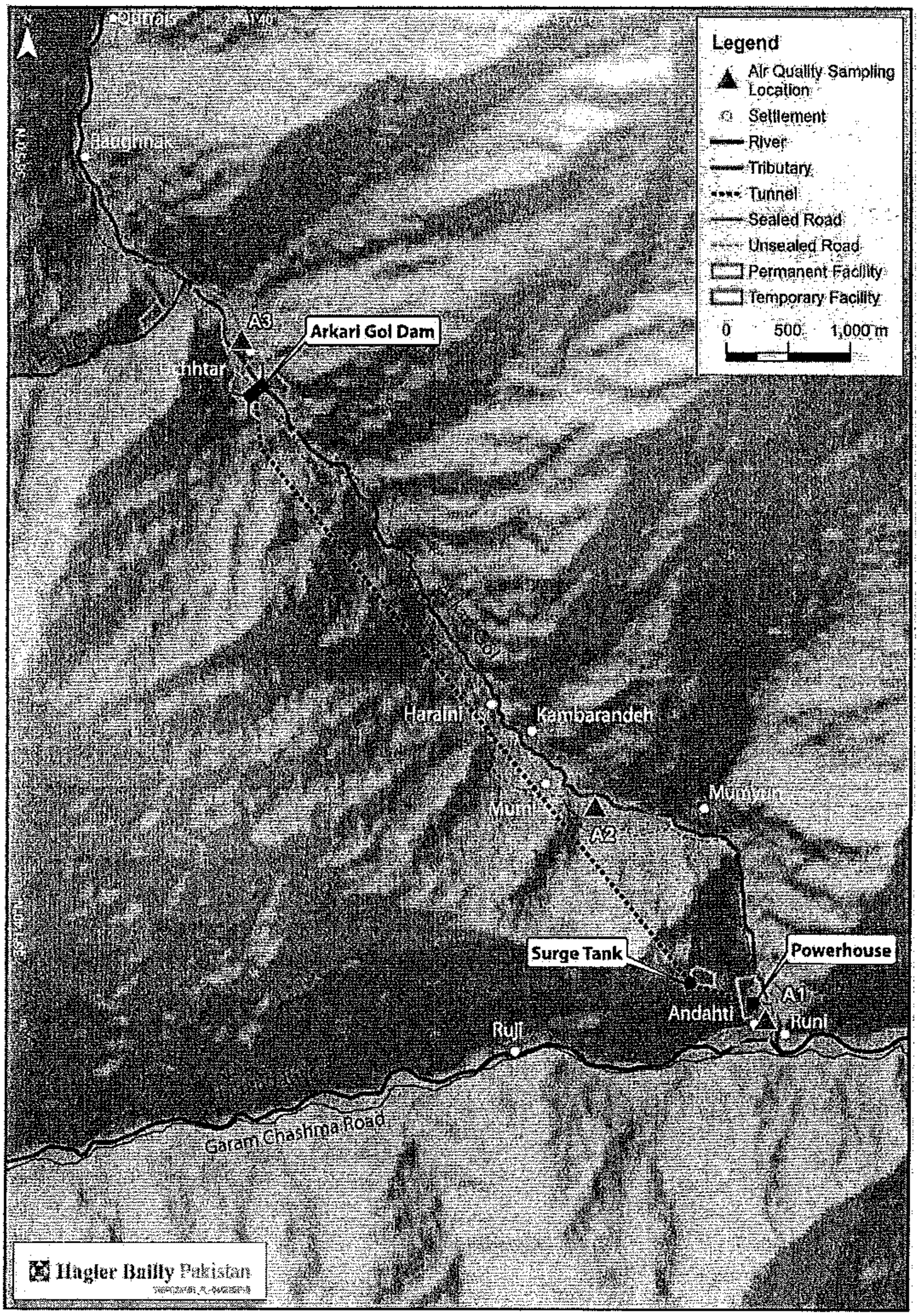


Exhibit 4.76: Results of Ambient Air Quality Sampling ($\mu g/m^3$)

Sample ID	PM_{10}	$PM_{2.5}$
LOR	100 µg	100 µg
A1	77.90	25.96
A2	117.33	65.17
A3	95.21	39.26
NEQS (24-hour)	**150**	**35**
IFC EHS (24-hour – interim target 1)	**150**	**75**

Note: LOR: Level of Reporting

Exhibit 4.77: Results of Weather Parameters during Air Sampling ($\mu g/m^3$)

Sample ID		Temperature (deg C)	Relative Humidity (%)	Barometric Pressure (mb)	Wind Speed (m/s)
A1	Min	5.2	11.8	819.7	0.0
	Mean	13.2	34.1	822.1	1.5
	Max	22.9	58.1	824.5	7.1
A2	Min	7.2	8.5	809.2	0.0
	Mean	15.1	33.0	812.7	0.5
	Max	28.9	64.0	814.7	4.4
A3	Min	11.8	12.7	779.7	0.0
	Mean	18.0	25.3	782.6	0.8
	Max	28.2	35.7	784.5	2.9

4.2.6 Noise Levels

This section defines the baseline ambient noise levels in the Study Area in a manner that can be used for the assessment of the noise impact of the proposed Project.

Noise is defined as a loud, undesired sound that interferes with normal human activities. If it affects the well-being of the surrounding community (environmental noise), it is considered a nuisance and normally has no direct health impacts. Exposure to very high noise levels (exceeding 85 dBA), particularly for prolonged period can cause hearing loss. This level of noise is usually encountered in the workplace around construction sites and is considered an occupational hazard.

In general, human sound perception is such that a change in sound level of 3 dB is just noticeable, a change of 5 dB is clearly noticeable, and an increase of 10 dB is perceived as a doubling of sound level

The following is a brief description of terminology used in this assessment:

- *Sound*: A vibratory disturbance created by a vibrating object, which, when transmitted by pressure waves through a medium such as air, is capable of being detected by a receiving mechanism, such as the human ear or a microphone
- *Noise*: Sound that is loud, unpleasant, unexpected, or otherwise undesirable
- *Decibel (dB)*: A unitless measure of sound on a logarithmic scale, which indicates the squared ratio of sound pressure amplitude to a reference sound pressure amplitude. The reference pressure is 20 micro-pascals
- *A-Weighted Decibel (dB(A))*: An overall frequency-weighted sound level in decibels, which approximates the frequency response of the human ear. The typical human ear is not equally sensitive to all frequencies of the audible sound spectrum. As a consequence, when assessing potential noise impacts on people, an electronic filter is used that de-emphasizes certain frequencies in a manner corresponding to the human ear's decreased sensitivity to low and extremely high frequencies. All of the noise levels reported in this Section are A-weighted.
- *Equivalent Sound Level* (L_{eq}): The equivalent steady state sound or vibration level, which in a stated period of time, typically one hour, would contain the same acoustical or vibration energy.

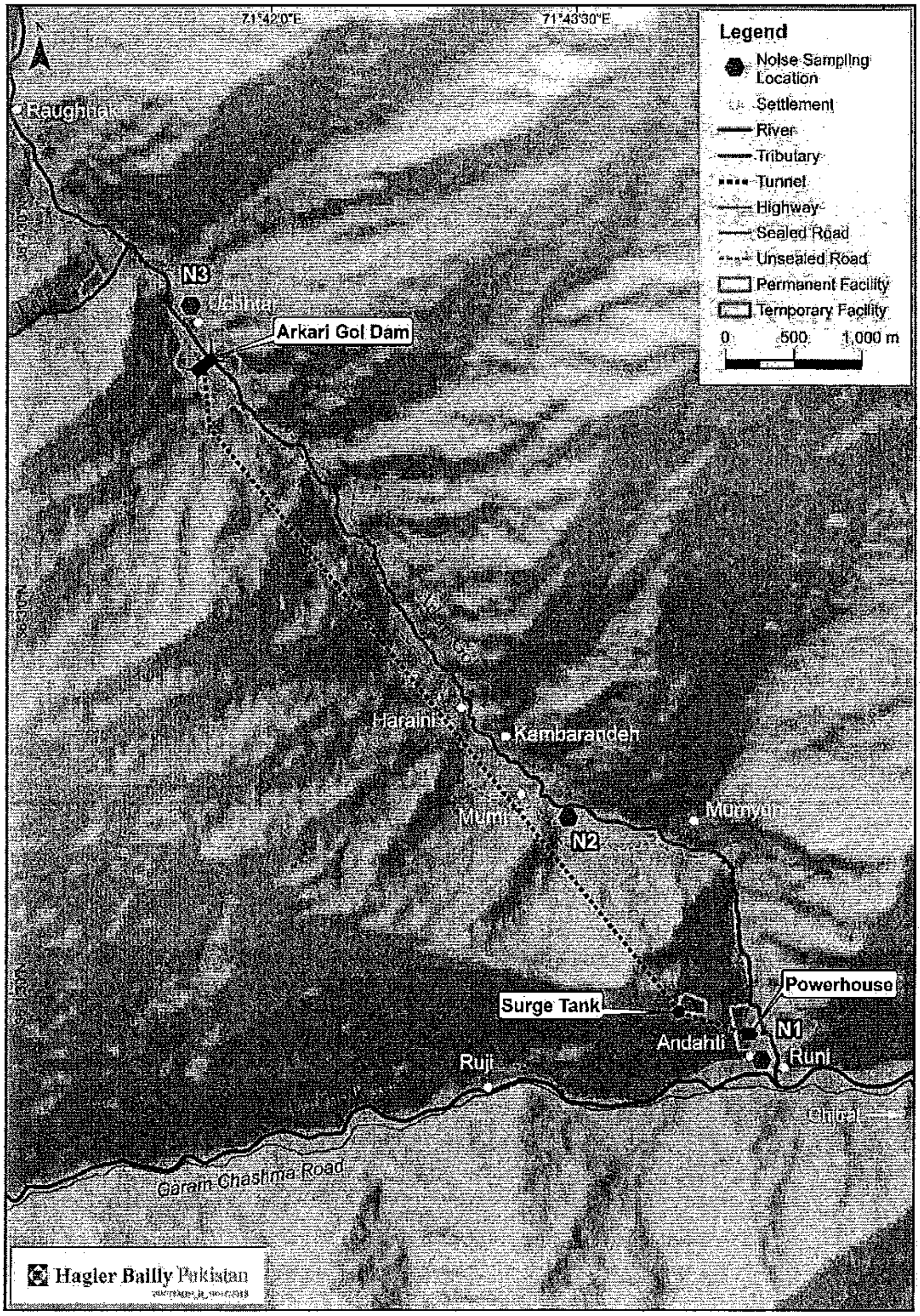
Methodology and Sampling Locations

Noise measurements were taken at three locations listed in **Exhibit 4.78** and shown in **Exhibit 4.79**. Noise readings were taken for 24 hours at each site.

Exhibit 4.78: Noise Sampling Locations

ID	*Location*	*Coordinates*	*Dates of Survey*	*Description*
N1	Andahti Village	36° 01' 09.4" N 71° 44' 15.8" E	March 29 to 30, 2018	Settlement and road near Powerhouse site.
N2	Mumi Village	36° 02' 07.6" N 71° 43' 20.8" E	March 30 to 31, 2018	Settlement and road near temporary construction facility.
N3	Uchhtar Village	36° 04' 11.1" N 71° 41' 33.7" E	March 31 to April 1, 2018	Settlement and road dam site.

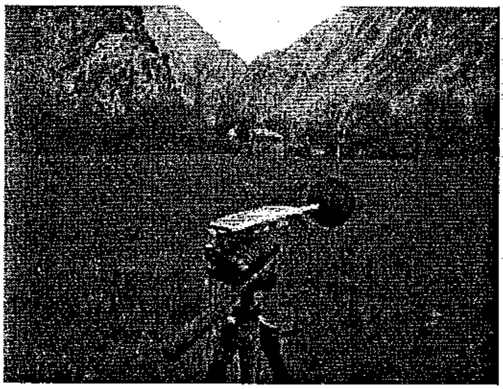
Exhibit 4.79: Noise Sampling Locations



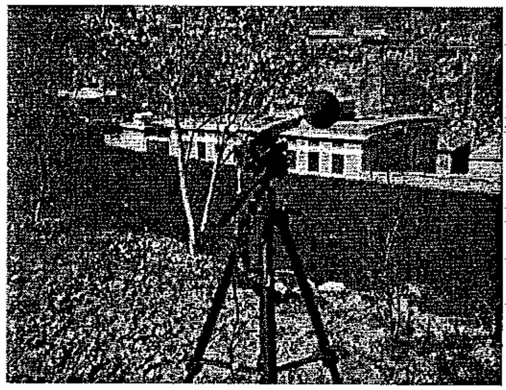
The noise levels were measured using portable Cirrus Research plc.'s sound level meter, Model CR:1720. The instrument meets the International standards IEC 61672-1:2002, IEC 660651:1979, IEC 60804:2001, IEC 61260:1995, IEC 60942:1997, IEC 61252:1993, ANSI S1.4-1983, ANSI S1.11-1986, and ANSI S1.43-1997 where applicable. The instruments have a resolution of 0.1 dB.

The meter was calibrated at the start of measurement at each site, using Cirrus Research plc.'s acoustic calibrator, Model: CR:514. The instrument was mounted on a tripod, to avoid interference from reflecting surfaces within the immediate neighborhood, and a wind shield was used in all measurements. Photographs of the sampling equipment setup are provided in **Exhibit 4.80**.

Exhibit 4.80: Noise Sampling Site Photographs



Sound meter at N1



Sound meter at N2

Results and Analysis

A summary of the results and NEQS are provided in **Exhibit 4.81.** L_{10} and L_{90} refer to percentile noise levels that are exceeded 10% and 90% of the time, respectively. Hourly L_{eq} noise levels are shown in **Exhibit 4.82** and graphed in **Exhibit 4.83** as IFC EHS guidelines require hourly compliance.

The following analysis of results are presented:

- The daytime noise levels at all locations are within limits of PEQS, and for most hours for IFC EHS.
- Nighttime noise levels are higher than the NEQS at N-2 and N-3. However, the background noise levels (L_{90}) are close to the nighttime limit at both these locations. Nighttime average noise levels are only 2.7 and 1.6 dBA higher than the background noise at N-2 and N-3 respectively. Moreover, when analyzed at an hourly level fluctuations of nighttime noise levels were within 1 dBA at N-2 and N-3, further showing that the noise levels are from constant natural sources.
- The highest L_{10} noise level is of 51.3 dBA at N-3. Therefore, it can be concluded that while there is significant natural background noise, which may be caused due

to stream and river flow, insects, animals, and wind there are minor sources of anthropogenic noise in the area.

Exhibit 4.81: Summary Statistics of Noise Levels (dBA)

Sample ID	*24 hour*				*Daytime*	*Nighttime*
	L_{90}	L_{50}	L_{10}	L_{EQ}	L_{EQ}	L_{EQ}
N-1	42.5	44.5	48.8	52.5	54.2	44.6
N-2	46.8	49.2	50.2	49.9	50.1	49.5
N-3	44.8	46.1	51.3	51.3	52.8	46.4
NEQS Limits					**55**	**45**

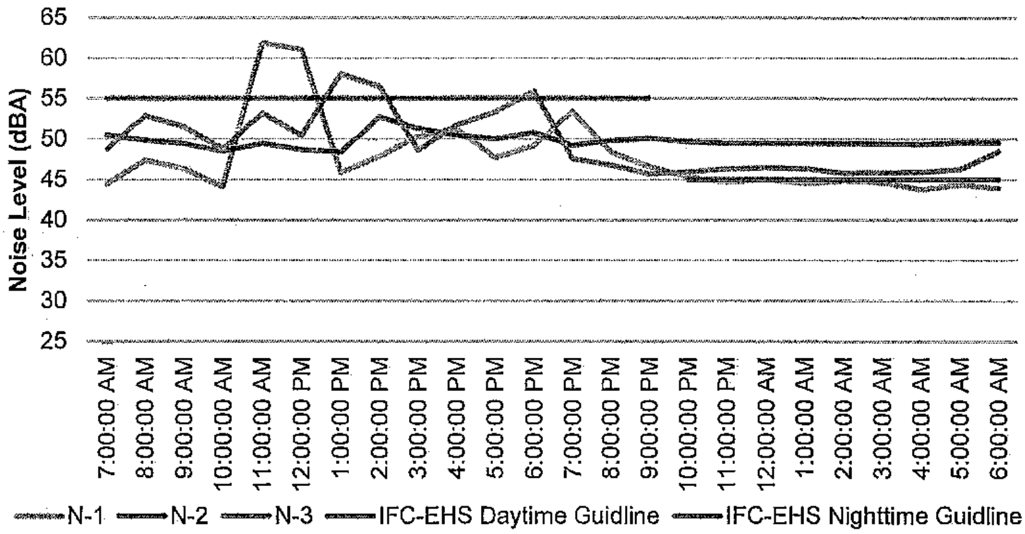
Note: For NEQS daytime hours are from 6 am to 10 pm and nighttime hours from 10 pm to 6 am

Exhibit 4.82: Hourly L_{eq} (dBA) of Noise Levels during the Survey

Time	*IFC-EHS Guideline*	*N1*	*N2*	*N3*
7:00:00 AM	55	44.4	50.5	48.7
8:00:00 AM	55	47.4	49.9	52.9
9:00:00 AM	55	46.3	49.4	51.5
10:00:00 AM	55	44.1	48.5	48.8
11:00:00 AM	55	61.9	49.4	53.2
12:00:00 PM	55	61.0	48.6	50.4
1:00:00 PM	55	45.8	48.4	58.0
2:00:00 PM	55	47.8	52.7	56.5
3:00:00 PM	55	50.3	51.3	48.6
4:00:00 PM	55	51.3	50.4	51.7
5:00:00 PM	55	47.7	50.0	53.3
6:00:00 PM	55	49.2	50.8	55.9
7:00:00 PM	55	53.4	49.2	47.6
8:00:00 PM	55	48.4	49.8	46.8
9:00:00 PM	55	46.6	50.1	45.7
10:00:00 PM	45	45.3	49.6	45.9
11:00:00 PM	45	44.7	49.5	46.3
12:00:00 AM	45	45.1	49.4	46.5
1:00:00 AM	45	44.5	49.5	46.3
2:00:00 AM	45	44.8	49.5	45.8
3:00:00 AM	45	44.6	49.4	45.8
4:00:00 AM	45	43.7	49.3	45.9
5:00:00 AM	45	44.3	49.6	46.3
6:00:00 AM	45	43.9	49.5	48.5

Note: For IFC EHS daytime hours are from 7 am to 10 pm and nighttime hours from 10 pm to 7 am.

Exhibit 4.83: Hourly Leq of Noise Levels during the Survey (dBA)



4.2.7 Water Resources and Sediment

Water resources in the area consist of surface water including rivers and nullahs and groundwater including mountain springs. The information in this section is obtained largely from the Feasibility Study and, where specified, other sources.

Regional Hydrology

The Project reservoir and dam are located on the Arkari Gol, a left bank tributary of the Lutkho River. The Lutkho River drains into the Mastuj/Kunar River. After passing Chitral, the Mastuj River is known as the Chitral River, which on entering Afghanistan is known as the Kunar River, a left bank tributary of the Kabul River. The Kabul River reenters Pakistan near Peshawar, where it combines with the Swat River, and then flows into the Indus River downstream of the Tarbela Dam near Attock City. The route from the Arkari Gol to the Indus River is shown in **Exhibit 4.84**.

Flow Regime at Dam Site

While the Feasibility Study was being conducted, the quality of data available at the Arkari stream gauging station was low, therefore a regional analysis was undertaken to calculate the mean annual flow at the site. Data from gauging stations in the vicinity of the Project was used to generate a 48 year hydrology time series for the Arkari HPP dam site. The resulting generated mean monthly flows at Arkari Gol stream gauging station (1964 – 2011) are shown in **Exhibit 4.85**. A ten-year average (2006 to 2015) of mean monthly flows from the Arkari gauging station is presented in **Exhibit 4.86**.

Exhibit 4.84: Mastuj River and Principal Tributaries

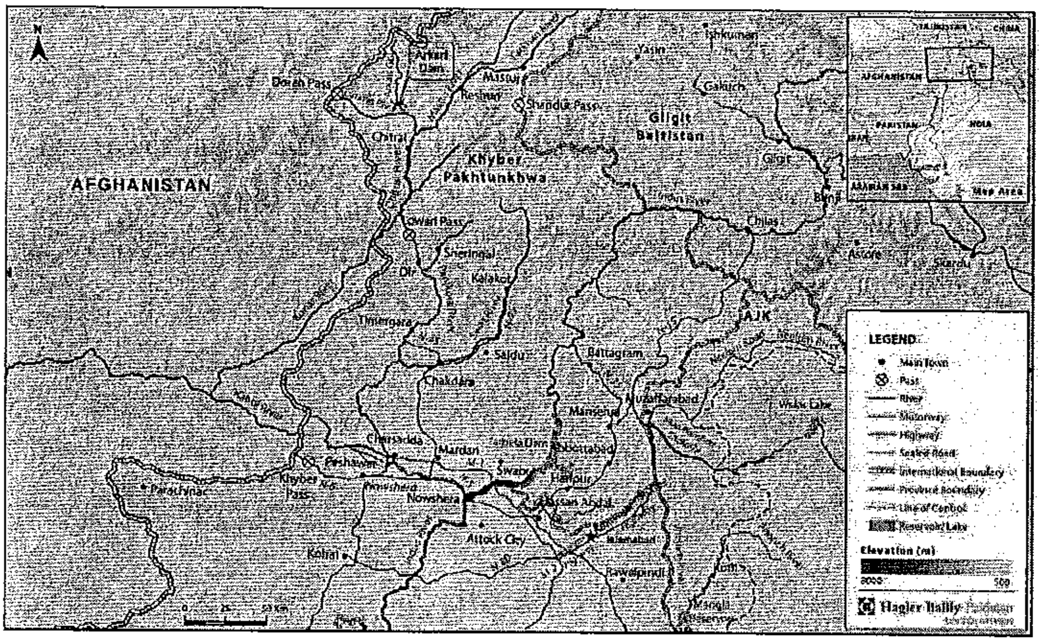


Exhibit 4.85: Generated Average Flow by Month along Arkari Gol (1964 – 2011)

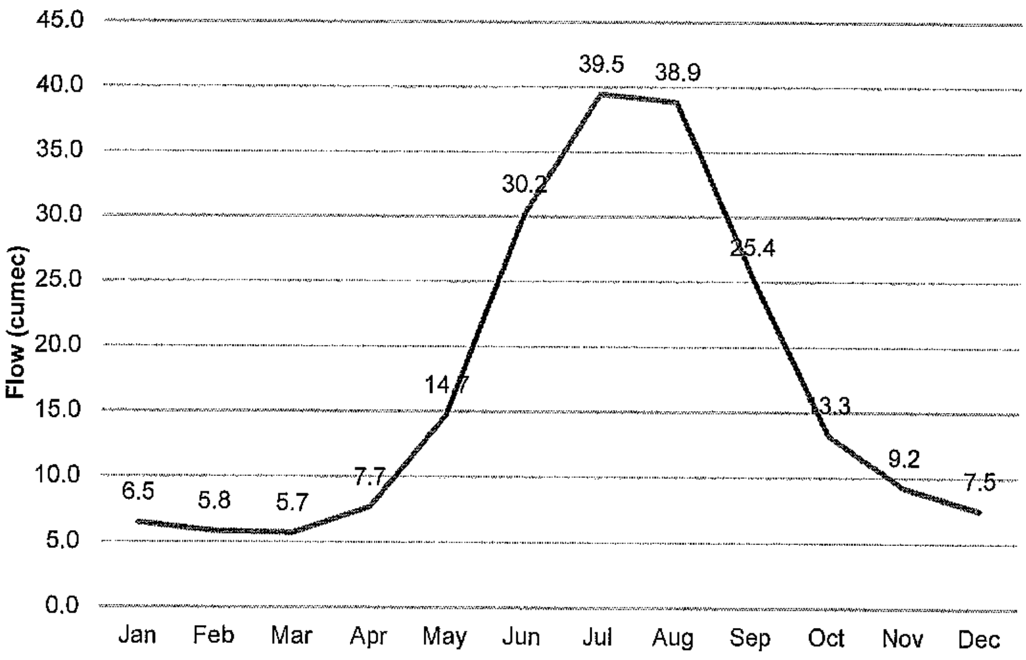


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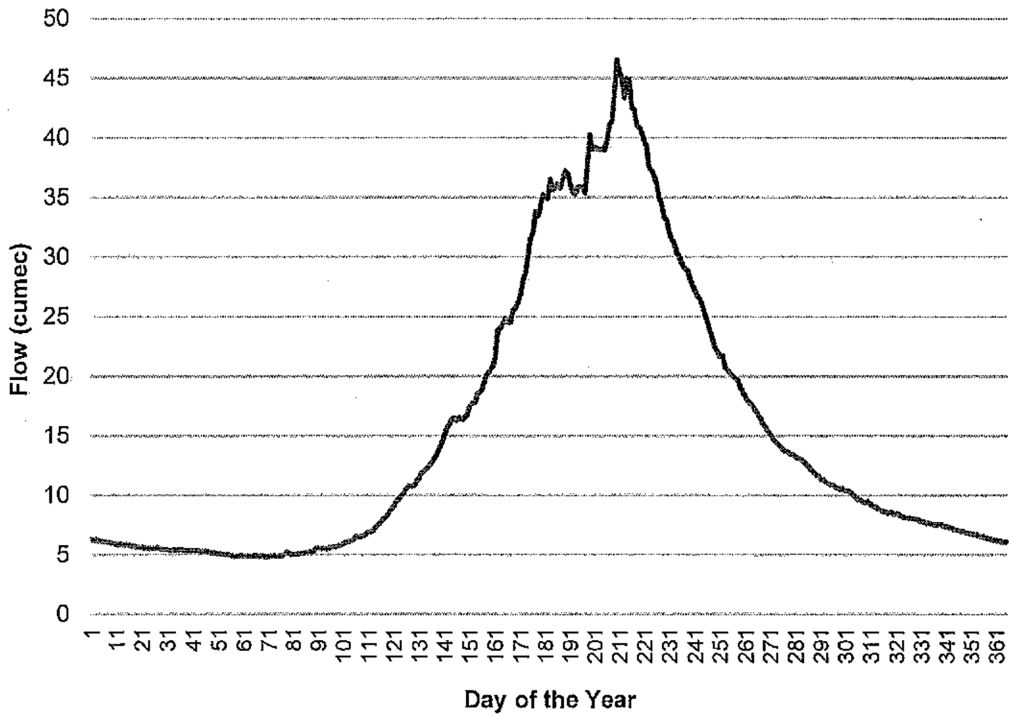
Exhibit 4.86: Average Flow Arkari Gol (2005 – 2015)



The hydrology at the dam site is characterized by:

- Peak flows in the month of July and August associated with melting of snow and ice at higher elevations in the catchment
- Dry or low flow winter season typically extends from December through March when the flows are reduced to the order of one sixth of peak in the month of August.
- Median values of key parameters of the hydrology at the dam site are presented in **Exhibit 4.87.**

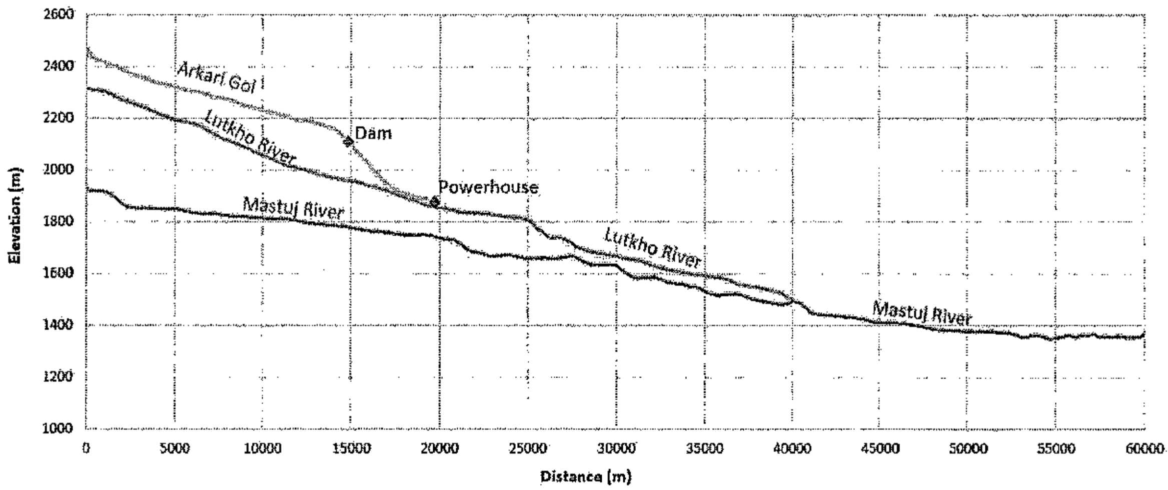
Exhibit 4.88 presents the riverbed elevation of the Arkari Gol as compared to the Lukho and Mastuj rivers. It can be observed that the Arkari Gol flows at a much higher elevation than both the Lutkho and Mastuj rivers.

Exhibit 4.87: Average Flow Arkari Gol G(2005 – 2015)

	Units	*Value*
Mean Annual Runoff	m^3/s	14
Mean flood peak	m^3/s	46
Mean flood volume	Mm^3	271
Dry Season		
Dry season onset	calendar week	42
Dry season relative onset	weeks	0
Dry season duration	days	210
Min 5 day dry season flow	m^3/s	4.2
Wet Season		
Wet season onset	calendar week	24
Wet season duration	days	106
Flood volume	Mm^3	215
Max 5 day flood season flow	m^3/s	35

Based on 10 year hydrology from the Arkari gauging station

Exhibit 4.88: Riverbed Elevation of Mastuj River and its Tributaries



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Sediment at Dam Site

May, June, July, August and September are months of significant amounts of suspended sediment in the Arkari Gol (see **Exhibit 4.89**). In August suspended sediment at the site peaks at 81,605 tons, whereas January has the lowest suspended sediment load at 791 tons. There is little vegetation cover in the watershed as it remains covered with glaciers and snow during the winter. Consequently, the river is fed mostly by snow and glacial melt and flows steadily throughout the year. Additional flow in the river in summer months is from the rainfall runoff flow during monsoon experienced from June to September which causes an increase in sediment.

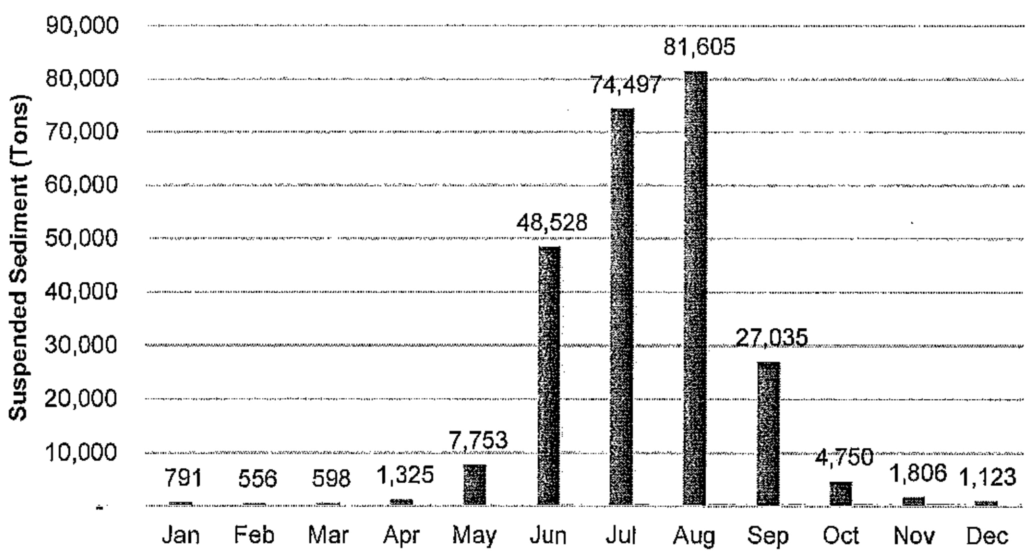
On an annual basis the Chitral River carries 435 times more sediment but only 17 times more water than the Arkari Gol (see **Exhibit 4.90**). The high value of suspended sediment at low elevation (Chitral) is mainly owing to high rainfall runoff erosion and increased sediment transport.

Exhibit 4.89: Mean Monthly Suspended Sediment Load at Arkari Dam Site

River	*Gauging Station*	*Source*	*Duration of Data*	*Watershed (km^2)*	*Annual Suspended Sediment Load (M tons)*	*Mean Annual Flow (m3/s)*
Chitral	Chitral	SWHP	1964-2010	11,400	23.087	280.57
Arkari Gol	Uchhtar	SHYDO	2006-2013	1015	0.053	16.37

Source: Feasibility Study

Exhibit 4.90: Monthly Suspended Sediment Load at Arkari Dam Site



Source: Feasibility Study

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Community Water Supply (Mountain Spring) Census

A census was carried out to map the community water resources for villages near Project facilities. A 500 m buffer around the Project facilities that may need excavation (including the dam and underground tunnels) was demarcated for the survey to account for the distance to which the impact on ground water might possibly extend. All the springs within this buffer have to be sampled irrespective of the distance from the Project facility. This area and the surveyed water resource infrastructure are shown in **Exhibit 4.91**.

The methodology is presented as part of the survey plan attached as **Appendix F**.

Results and Analysis

A total of 13 water resource infrastructure points (9 mountain springs and 4 water supply schemes) were identified (see **Exhibit 4.91**) and characterized within the hydrocensus area. 74 households depend on the springs, whereas 487 households depend on the water supply schemes in the area covered by the hydro-census. Mountain springs in the area are largely undeveloped and have no associated infrastructure. These springs are a major sole potable water supply for the majority of households. 90% of active water sources are used to supply drinking water to humans and all water sources are used for livestock drinking as well. Residents of the area also use the Arkari Gol for drinking, other uses, and for their livestock. Images depicting the water infrastructure are shown in **Exhibit 4.92** and **Exhibit 4.93.**

The four water supply schemes in the area were developed by the government or NGOs as detailed below:

- S-8: This water supply scheme was funded by the Public Health Department, Government of KP in 2017. This scheme supplies water to Mumi and Haraini villages via a 2 inch diameter pipe. It routes water from the Essi Forest 4 km away from Haraini village.
- S-9: This water supply scheme was funded by the Sarhad Rural Support Programme (SRSP) in 2008. This supply line is a second source of water for households in Mumi and Haraini villages. Spring water coming from the Icci Forest 4 km away from Haraini village through a 2 inch diameter pipe.
- S-10: This water supply scheme was funded by Water and Sanitation Extension Programme (WASEP) in 2012 for 60 houses in the villages of Andahti and Ruji. The mountain spring from where the water is sourced is located 5 km away from Andahti village via a 2 inch diameter pipe.
- S-11: This water supply scheme was funded by the Public Health Department, Government of KP in 1992. This scheme supplying water to 47 houses in Ruji village via a 4 inch diameter pipe. The water is sourced from coming from a mountain spring in Kochga, 2 km away from Ruji village.

Identifying characteristics of the community water resources are presented in **Exhibit 4.94** and water quality and water use data provided in **Exhibit 4.95**. Based on the pH and electrical conductivity, the water is fresh and potable.

Exhibit 4.91: Hydro-census Locations

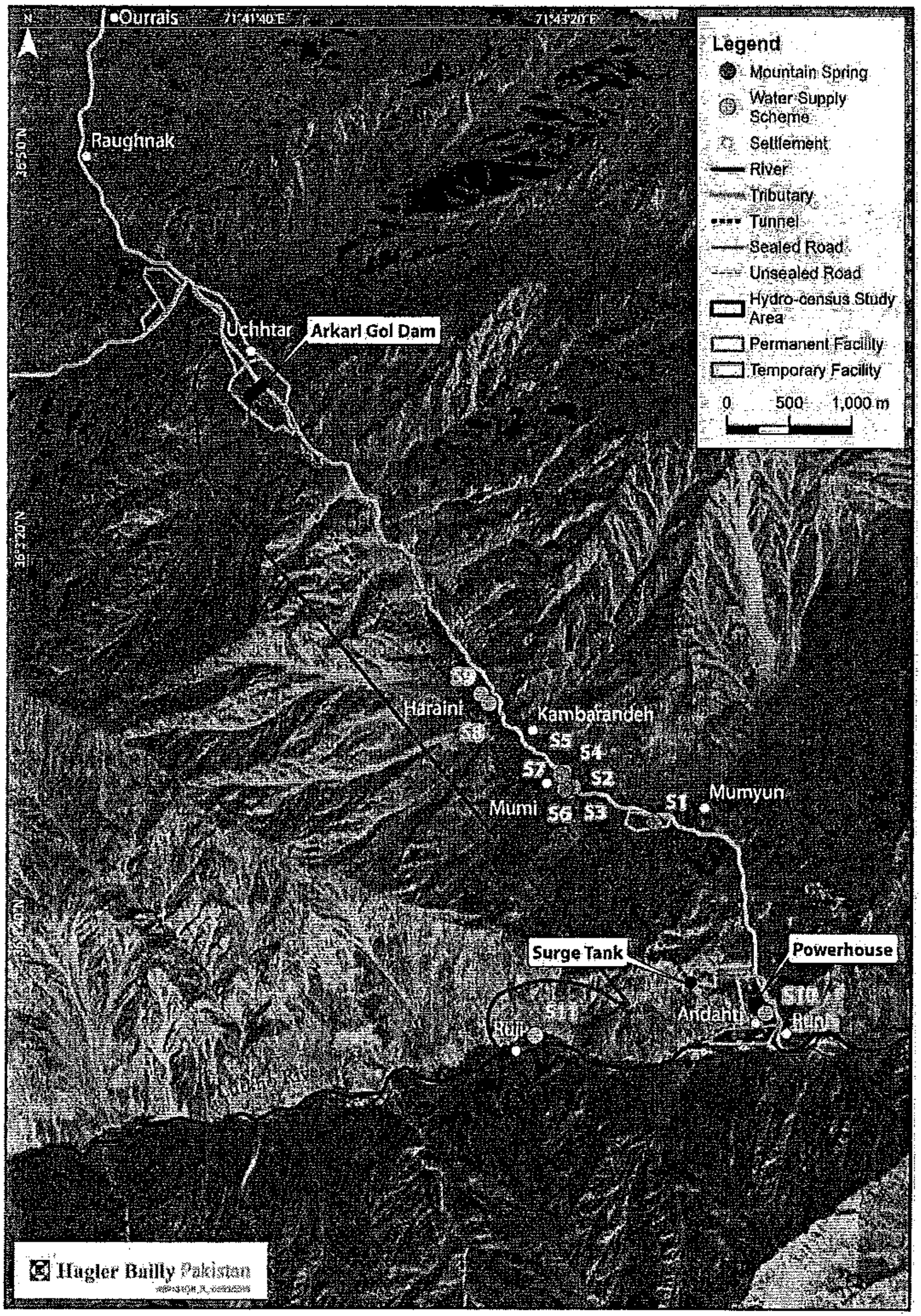

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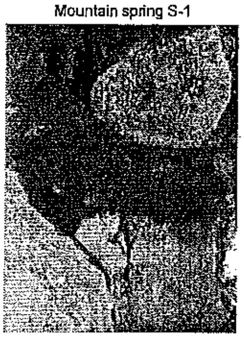
Exhibit 4.92: Photographs of Mountain Springs in the Study Area

Mountain spring S-1

Mountain spring S-2

Mountain spring S-3

Mountain spring S-4

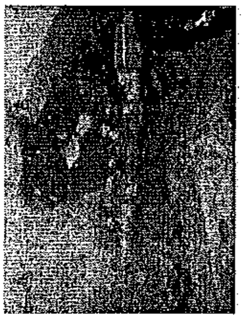


Mountain spring S-5

Mountain spring S-6

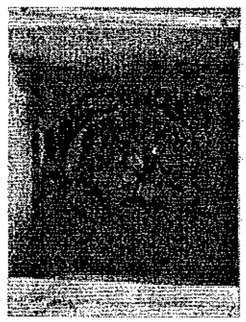
Mountain spring S-7

Exhibit 4.93: Photographs of Water Supply Infrastructure in the Study Area


Water Supply S-8

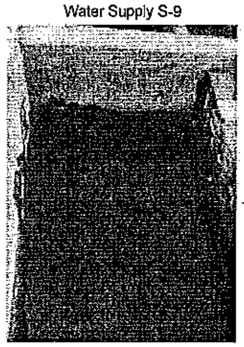

Water Supply S-8


Water Supply S-9


Mountain spring S-10


Mountain spring S-10


Mountain spring S-11


Water storage tank for mountain spring S-11

RAO

Exhibit 4.94: Surveyed Springs in the Study Area

ID	*Date of Survey*	*Time of Survey*	*Coordinates*	*Village*	*Ownership*	*Age*	*Extraction Method*
S-1	April 1, 2018	1310	36° 02' 02.73" N 71° 43' 41.46" E	Mumi	Mustahkam	1968	Manual
S-2	April 1, 2018	1350	36° 02' 12.37" N 71° 43' 15.58" E	Mumi	Ikhlas ud Din	1968	Manual
S-3	April 1, 2018	1410	36° 02' 11.38" N 71° 43' 14.05" E	Mumi	Ikhlas ud Din	1968	Manual
S-4	April 1, 2018	1415	36° 02' 16.14" N 71° 43' 12.64" E	Mumi	Mir Muhammad	1918	Manual
S-5	April 1, 2018	1430	36° 02' 15.41" N 71° 43' 11.74" E	Mumi	Gulazam	1918	Manual
S-6	April 1, 2018	1450	36° 02' 14.66" N 71° 43' 12.40" E	Mumi	Zarmast Khan	1918	Manual
S-7	April 1, 2018	1510	36° 02' 11.78" N 71° 43' 12.86" E	Mumi	Mir Muhammad	1918	Manual
S-8	April 1, 2018	1550	36° 02' 34.58" N 71° 42' 49.04" E	Haraini	Water Supply Scheme	1917	Gravity Pipe
S-9	April 2, 2018	1445	36° 02' 36.95" N 71° 42' 46.67" E	Haraini	Water Supply Scheme	2008	Gravity Pipe
S-10	April 2, 2018	1645	36° 01' 12.89" N 71° 44' 15.82" E	Andahti	Water Supply Scheme	2012	Gravity Pipe
S-11	April 2, 2018	1730	36° 01' 08.75" N 71° 43' 01.39" E	Ruji	Water Supply Scheme	1992	Gravity Pipe

Comments: Water in all springs increase during the summer months.
Water in spring S-1 becomes hot in winter months.

Exhibit 4.95: Water Quality and Water Use Data of Springs in the Study Area

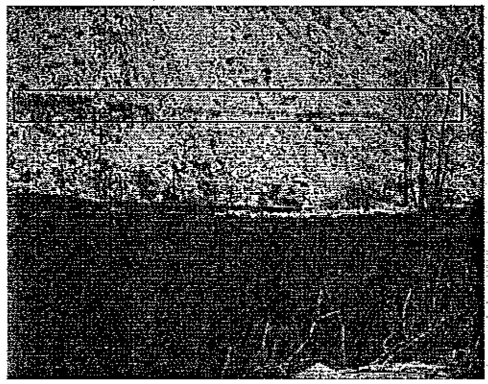
	Altitude (m amsl)	*Temperature (°C)*	*pH*	*Electrical Conductivity (µS/cm)*	*Number of Livestock Using Spring*	*Number of Households Using Spring*	*Water use per Household (liters/day)*	*Total Estimated Usage (liters/day)*
Summary Statistic								
Minimum	1833	13.4	7.5	179	20	4	75	300
Mean	1895	14.6	7.8	301	533	51	216	14,800
Median	1895	14.7	7.7	319	100	15	100	1,500
Maximum	1956	15.8	8.2	353	2,500	250	500	52,000
Individual								
S-1	1895	15.8	7.7	353	20	4	75	300
S-2	1912	14.9	7.8	318	100	14	100	1,400
S-3	1833	15.2	7.7	319	100	16	100	1,600
S-4	1877	14.3	7.6	331	40	10	100	1,000
S-5	1883	14.7	7.8	327	50	5	100	500
S-6	1912	13.4	7.6	333	150	15	100	1,500
S-7	1956	13.7	7.5	337	100	10	100	1,000
S-8			8.2	264	1,300	130	500	52,000
S-9			8.2	298	2,500	250	200	50,000
S-10			8.2	250	800	60	500	30,000
S-11			7.5	179	700	47	500	23,500

Comments: All springs other than S-11 are used for human drinking. All springs are used for livestock drinking and other human uses

Use of River Water for Irrigation

There are four main water channels that are diverting river water for irrigation from near the dam site. These channels have been constructed by the community using locally quarried stone and materials (see **Exhibit 4.96**). Approximately 202 acre of land is irrigated from water diverted by these channels. Crops are grown in both winter (maize crop) and in the summer (wheat crop). Additional discussion on these channels is presented in **Section 4.3** (*Socioeconomic Baseline*).

Exhibit 4.96: Photographs of Water Channels



Water Quality

Water quality samples from the Arkari Gol, Lutkho River, and mountain springs were collected and analyzed for establishing baseline conditions for surface and groundwater.

Methodology and Sampling Locations

Water was sampled on April 2, 2018 from 5 surface water sources and 5 mountain springs. Photographs of collected samples are shown in **Exhibit 4.97.** Samples were sent to the labs listed in **Exhibit 4.98**, and onsite field tests were also carried out. Sampling locations are described in **Exhibit 4.99** and shown in **Exhibit 4.100**.

Exhibit 4.97: Photographs from the Water Sampling

Collection of sample at W-1

Water quality sample W-1

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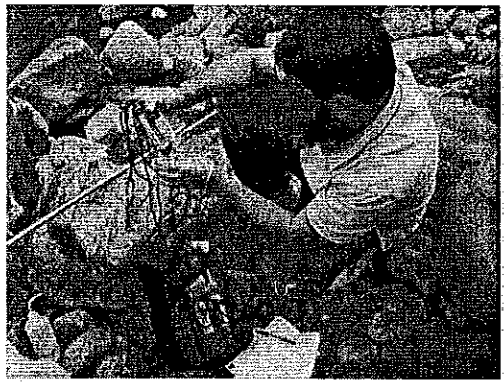
Spring water quality sample W-10 and duplicates



Field testing sample W-6

Exhibit 4.98: Laboratories used for Water Quality Sample Tests

Laboratory	*Parameters*
Field Testing	Physical parameters (pH, Conductivity, Temperature, DO)
HBP Laboratory, Islamabad	General Parameters (TDS, TSS, BOD, COD, Turbidity), major ions (Nitrate, Phosphate), Metals (Manganese, Zinc,)Iron
Pakistan Institute of Nuclear Sciences & Technology , Islamabad	Metals (Arsenic, Mercury, Antimony, Selenium, Silver, Aluminum, Boron, Barium, Cadmium, Chromium, Copper, Nickel, and Lead)
Excel Labs, Islamabad	Microbiology (Coliforms, E Coli)

Exhibit 4.99: Water Quality Sampling Location Details

ID	*Coordinates*	*Description*	*Justification*
W-6	36° 04' 32.6" N 71° 40' 58.3" E	Arkari Gol (upstream of Weir)	To document the baseline water quality of the Arkari Gol.
W-7	36° 03' 11.3" N 71° 42' 25.6" E	Arkari Gol (downstream of Weir)	
W-1	36° 01' 11.0" N 71° 44' 19.7" E	Arkari Gol before confluence with Lutkho River	
W-2	36° 01' 02.0" N 71° 43' 46.4" E	Lutkho River before confluence with Arkari Gol	To document the baseline water quality of the Lutkho River.
W-3	36° 01' 04.0" N 71° 44' 42.6" E	After Confluence of Lutkho River with Arkari Gol	To analyze the effect of dilution by the Lutkho River.
W-4	36° 02' 02.5" N 71° 43' 41.6" E	Mountain spring (S-1)	To document baseline water quality of springs that are used by the community as a source of water
W-5	36° 02' 12.1" N 71° 43' 14.3" E	Mountain spring (S-3)	
W-8	36° 02' 15.0" N 71° 43' 12.1" E	Mountain spring (S-7)	

ID	Coordinates	Description	Justification
W-9	36° 02' 14.5" N 71° 43' 12.3" E	Mountain spring (S-5)	
W-10	36° 02' 13.3" N 71° 43' 11.8" E	Mountain spring (S-6)	
W-10D	36° 02' 13.3" N 71° 43' 11.8" E	Duplicate of W-10	Quality control sample

Results and Analysis

The water quality results are provided in **Exhibit 4.101** and discussed below:

- No bacterial contamination was found in the mountain spring water that was tested and was classified as excellent for drinking based on its microbiology.
- All parameters tested were below the NEQS limits and the water quality is uncontaminated in the area.
- The Lutkho River has lower conductivity and higher pH than the Arkari Gol and the mountain spring water in the Arkari Gol catchment.

Complete water quality lab results are presented in **Appendix G**.

Exhibit 4.100: Water Quality Sampling Locations

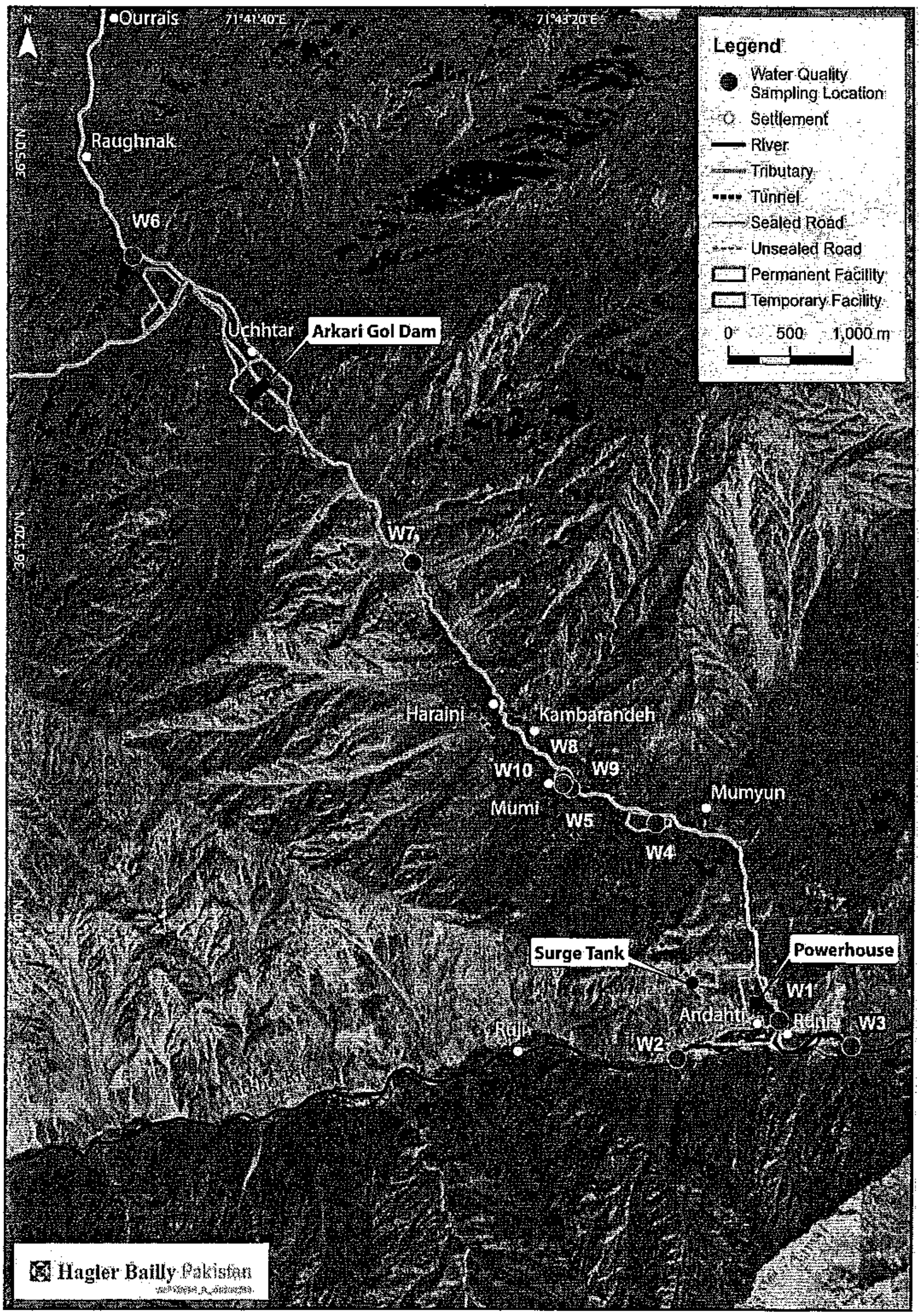


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Exhibit 4.101: Water Quality Results

	Unit	Analytical Method	LOR	NEQS	Arkari Gol			Luthko River		Mountain Springs					
					W–6	W–7	W–1	W–2	W–3	W–4	W–5	W–8	W–9	W–10	W–10D
Field Tests															
pH		US EPA 150.1	0.1	6.0–9.0	7.85	7.91	7.85	8.27	8.09	7.74	7.74	7.79	7.58	7.50	7.50
Conductivity	µS/cm	US EPA 120.1	1	–	399	402	398	189	290	353	319	327	333	337	338
Temperature	°C	US EPA 170.1	1	–	12.3	12.8	12.9	12.0	12.6	15.8	15.2	14.7	13.4	13.7	13.7
DO	mg/l	US EPA 360.1	0.1	–	11.21	11.07	10.54	10.87	11.01	8.43	8.56	8.21	8.45	8.51	8.50
General															
TDS	mg/l	US EPA 160.1	10	3,500	290	294	NT	NT	198	243	220	NT	NT	224	226
TSS	mg/l	US EPA 160.2	4	200	16.66	17	NT	NT	17	ND	ND	NT	NT	ND	ND
BOD	mg/l	US EPA 405.1	5	80	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
COD	mg/l	US EPA 410.2	5	150	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
Turbidity	FAU	HACH 8037	0	–	7	7	NT	NT	12	3	0	NT	NT	3	3
Nitrate	mg/l	US EPA 352.1	0.1	–	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
Phosphate	mg/l	SMEW	0.1	–	ND	ND	NT	NT	ND	ND	ND	–	–	ND	ND
Metals															
Manganese	mg/l	SMEW	0.1	1.5	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
Zinc	mg/l	SMEW	0.1	5	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
Iron	mg/l	SMEW	0.1	8	–	–	NT	NT	–	–	–	NT	NT	ND	ND
Silver	µg/l	ICP	90	0	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
Aluminum	µg/l	ICP	220	200	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
Boron	µg/l	ICP	20	300	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND

	Unit	Analytical Method	LOR	NEQS	Arkari Gol			Luthko River		Mountain Springs					
					W–6	W–7	W–1	W–2	W–3	W–4	W–5	W–8	W–9	W–10	W–10D
Barium	µg/l	ICP	10	700	20	10	NT	NT	10	10	10	NT	NT	10	10
Cadmium	µg/l	ICP	10	10	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
Chromium	µg/l	ICP	20	50	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
Copper	µg/l	ICP	30	500	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
Nickel	µg/l	ICP	10	20	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
Lead	µg/l	ICP	30	50	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
Arsenic	ng/l	ICP	0.64	–	ND	1.95	NT	NT	ND	7.66	14.47	NT	NT	12.89	11.97
Mercury	ng/l	ICP	0.52	–	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
Antimony	ng/l	ICP	0.72	–	ND	2.95	NT	NT	ND	ND	ND	NT	NT	ND	ND
Selenium	ng/l	ICP	0.78	–	ND	ND	NT	NT	ND	ND	ND	NT	NT	ND	ND
Microbiology															
Coliforms	MPN/ 100ml	Internal	0	1 to 3	NT	NT	NT	NT	NT	NT	0 or Excellent	NT	NT	0 or Excellent	NT
E.Coli	MPN/ 100ml	Internal	0	1 to 3	NT	NT	NT	NT	NT	NT	0 or Excellent	NT	NT	0 or Excellent	NT

NT: Not tested
ND: Not detected

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4.2.8 Traffic

The traffic baseline is prepared to assess the current traffic conditions on the road route that will be used for the Project related transportation of services during construction and operation of the Project. The objectives of the traffic study are to document present traffic situation, identify existing road capacity, bottle necks (congestion points) and potential impacts due to the Project traffic during construction and operation. The transport route options are described in **Section 3** (*Description of Project*).

Methodology and Sampling Locations

Traffic counts were conducted at two locations on the transport route, as listed in **Exhibit 4.102** and shown in **Exhibit 4.103**. A team of qualified surveyors was selected and a pilot count was conducted before the actual survey. At the counting site, one person was stationed to separately count traffic for each direction. The traffic count was conducted on April 2, 2018, over a 15-hour period starting at 7 am and ending 10 pm.

Exhibit 4.102: Traffic Count Locations

ID	*Coordinates*	*Location*	*Rationale*
T1	36° 01' 00.2" N 71° 43' 16.0" E	Near Powerhouse	Located on intersection point where traffic diverts towards the Project site.
T2	35° 55' 34.0" N 71° 48' 37.8" E	Near Seen Village and University of Chitral	Along the main transport route from Chitral

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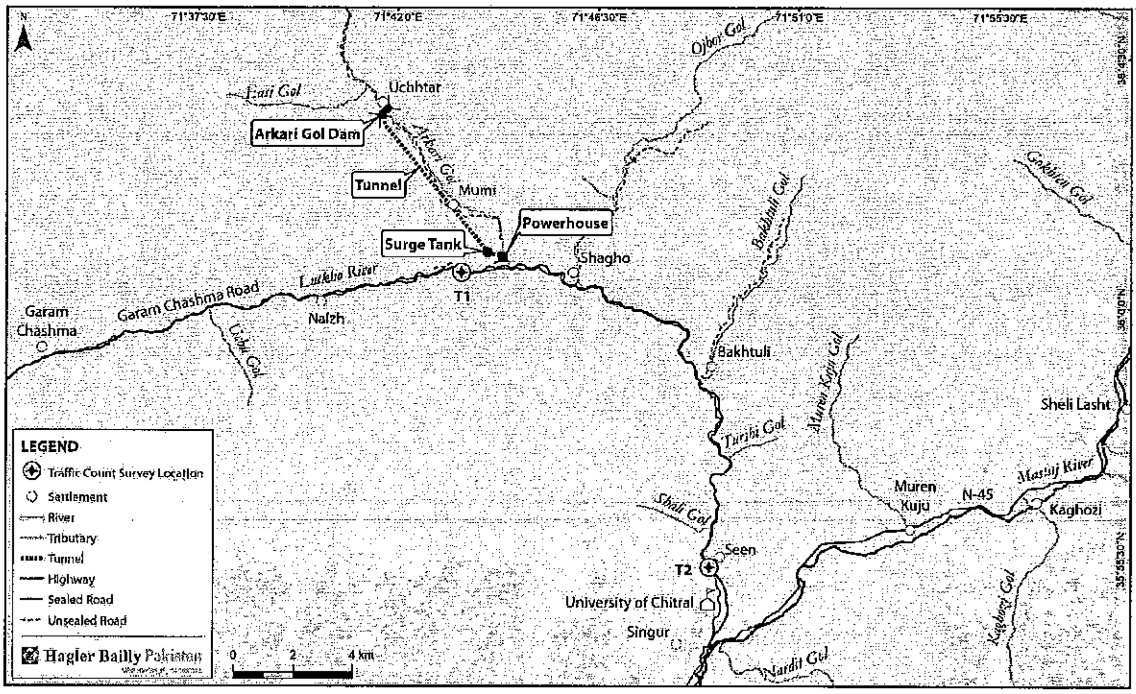
Exhibit 4.103: Traffic Survey Locations



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Passenger Car Equivalent (PCE) or Passenger Car Unit (PCU) is a metric unit used to assess traffic-flow rate.[77] PCU, is a measure of the relative space requirement of a vehicle compared to that of a passenger car under a specified set of roadway, traffic and other conditions. The value assigned to each of the classification of the vehicles may depend on a number of factors such as:

- dimensions, power, speed, acceleration and braking characteristics of the vehicle;
- road characteristics such as geometrics including gradients, curves, access controls, type of road: rural or urban, presence and the type of intersections;
- transverse and longitudinal clearances between vehicles moving on road, which in turn depends upon the speeds, driver characteristics and the classes of other moving vehicles;
- environmental and climatic conditions and;
- Traffic control methods, speed limits, and barriers.

The PCU for different classes of vehicles are not defined universally, however, the values used here are typical for Pakistani road conditions. The PCUs are calculated on the basis of traffic counts. **Exhibit 4.104** shows PCU factor for each vehicle.

Exhibit 4.104: PCU Values for Selected Vehicle Types

Vehicle	*PCU Factor*
Motorcycles	0.50
Auto rickshaws	0.75
Cars (sedans)	1.00
Jeeps/Pickups	1.25
Mini Bus	1.50
Bus	2.00
Truck - 2 axle	2.50
Truck - 3 axle	3.00
Truck - 4 axle	3.50
Truck - 5 axle	4.00

Results and Analysis

Key findings of the survey are presented below. The complete results of the survey are provided in **Appendix H.**

- 94% to 100% of the traffic consists of LTV. HTV observed consisted of buses and two axle trucks.
- At T-2, an early morning peak was observed from Garam Chashma to Chitral, whereas an afternoon peak was observed in the opposite direction. This may

[77] Ahuja, Amanpreet Singh (2004). *Development of passenger car equivalents for freeway merging section*

indicate that people travel into Chitral for work in the morning and return in the afternoon.

- At T-1 the Arkari to Chitral and Garam Chashma to Chitral routes show similar early morning peaks as observed at T2. The remaining routes have minimal traffic on them.

The hourly traffic PCU is graphed in **Exhibit 4.105** to **Exhibit 4.107**. The summary of the two-way traffic count at the sampling locations is presented in **Exhibit 4.108** and graphed in **Exhibit 4.109**.

Exhibit 4.105: Distribution of HTV and LTV in each Direction

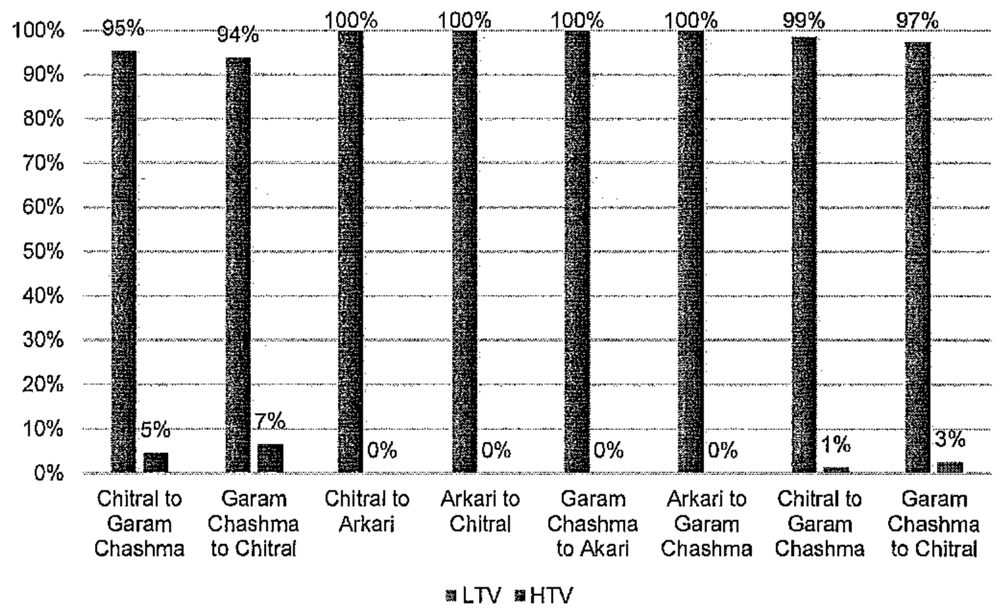

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Exhibit 4.106: Calculated PCU at T-1

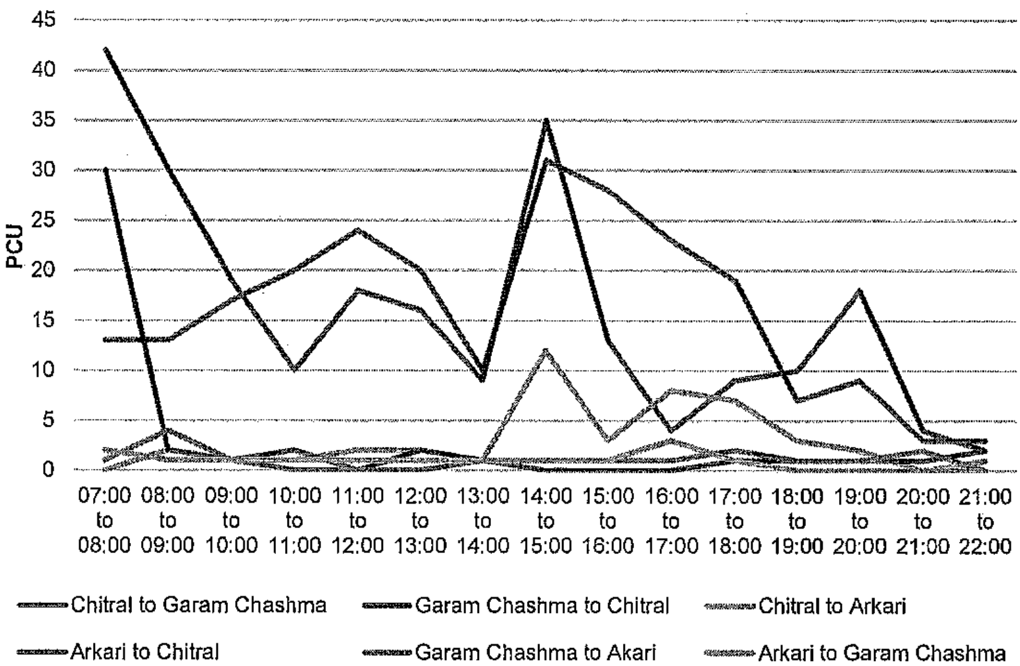

Exhibit 4.107: Calculated PCU at T-2

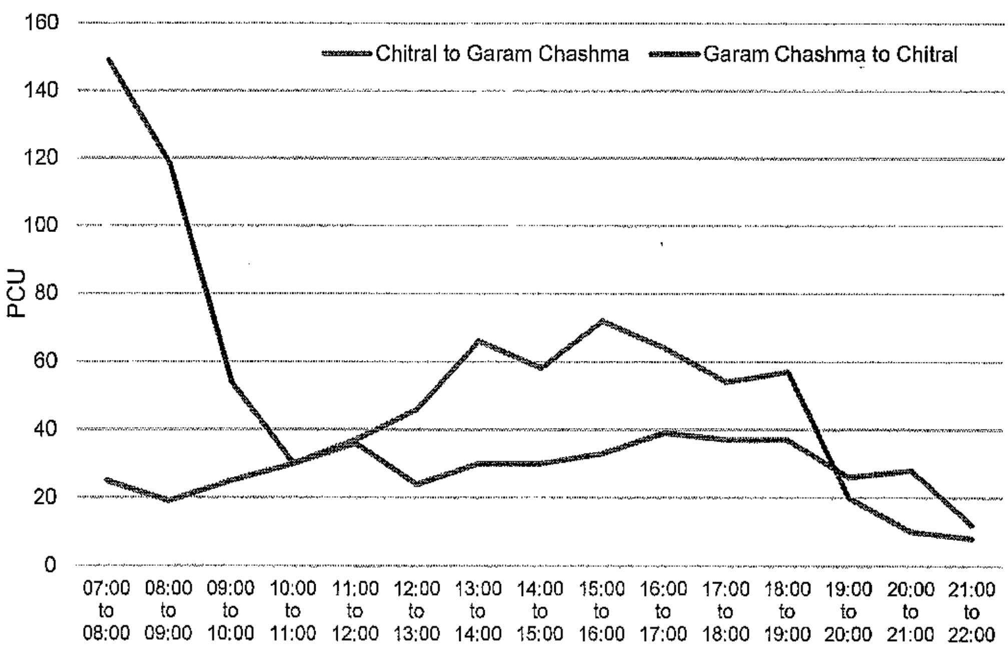

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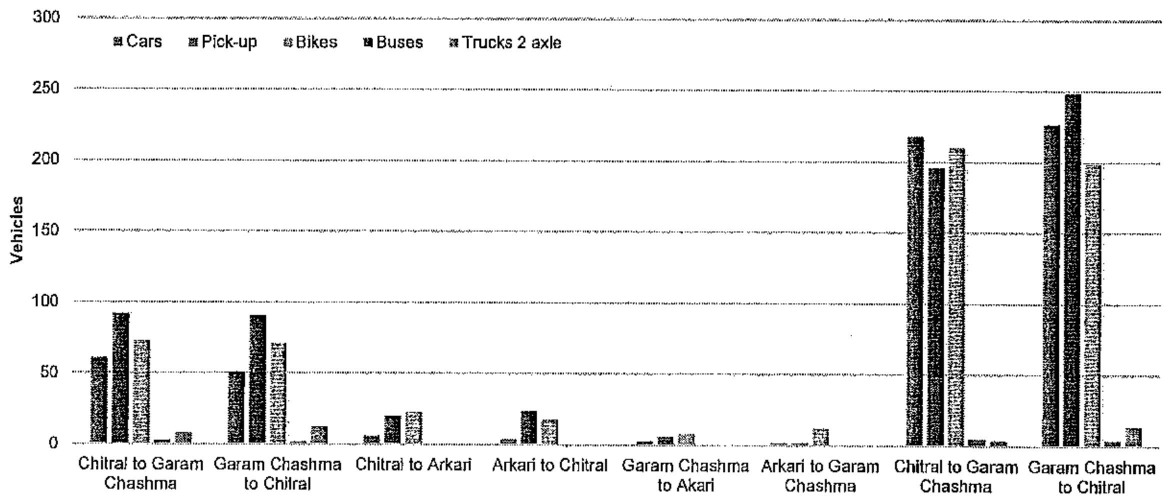
Exhibit 4.108: Two-Way Traffic at each Traffic Count Location

Direction	Cars	Pick-up	Bikes	Buses	Trucks 2 axle	Total	Total LTV	Total HTV	%LTV	%HTV	Total PCUs
Location T-1											
Chitral to Garam Chashma	61	92	73	3	8	237	226	11	95%	5%	239
Garam Chashma to Chitral	51	91	71	2	13	228	214	15	94%	7%	237
Chitral to Arkari	6	20	23	–	–	49	49	–	100%	–	43
Arkari to Chitral	4	24	18	–	–	46	46	–	100%	–	43
Garam Chashma to Akari	3	6	8	–	–	17	17	–	100%	–	15
Arkari to Garam Chashma	2	2	12	–	–	16	16	–	100%	–	11
Total at Intersection T-1	**127**	**235**	**205**	**5**	**21**	**593**	**568**	**26**	**96%**	**4%**	**588**
Location T-2											
Chitral to Garam Chashma	218	196	210	5	4	633	624	9	99%	1%	588
Garam Chashma to Chitral	227	249	199	4	14	693	675	18	97%	3%	681
Total at Intersection T-2	**445**	**445**	**409**	**9**	**18**	**1326**	**1299**	**27**	**98%**	**2%**	**1269**

Note: The survey form contains space for Trucks 3 to 5 axles, Trailors, Tractors and Other. However, no such vehicles were noted during the survey.

Exhibit 4.109: Total Vehicles Counted each Traffic Count Location



4.2.9 Visual Character

The visual baseline documents the current aesthetic and visual conditions of the proposed Project site as seen from the nearby receptors.

Methodology and Sampling Locations

Visual survey locations are listed in **Exhibit 4.110.** The survey to establish the visual baseline was conducted on April 1, 2018, involving the following at each survey location:

- The coordinates of the locations were recorded using a GPS unit.
- A camera and tripod were used to take panoramic photographs spanning 180°.
- A compass was used to record the bearings, in degrees, for the panorama center.

Exhibit 4.110: Visual Survey (Receptor) Locations

ID	*Coordinates*	*Altitude (m)*	*Bearing of Image Center*	*Location*	*Rationale*
V1	36° 01' 01.6" N 71° 44' 19.6" E	1868	Northwest	Powerhouse site	View of Powerhouse site from the main road.
V2	36° 02 '01.5" N 71° 43' 41.7" E	1915	North	Temporary Facility 2	View of temporary facility from the main road.
V3	36° 04' 02.6" N 71° 41' 30.0" E	2224	East	Dam site	View towards area inundated by reservoir and dam site.

Results and Analysis

The visual survey locations are shown in **Exhibit 4.111. Exhibit 4.112** shows the views of proposed Project facility locations from nearby receptors. The mountainous landscape, deep gorges restricts visibility to a maximum of 0.5 to 1.5 km at receptor locations. However, the lack of vegetation and distance between mountains allows for clear visibility within the valley.

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Exhibit 4.111: Visual Survey Locations and Directions

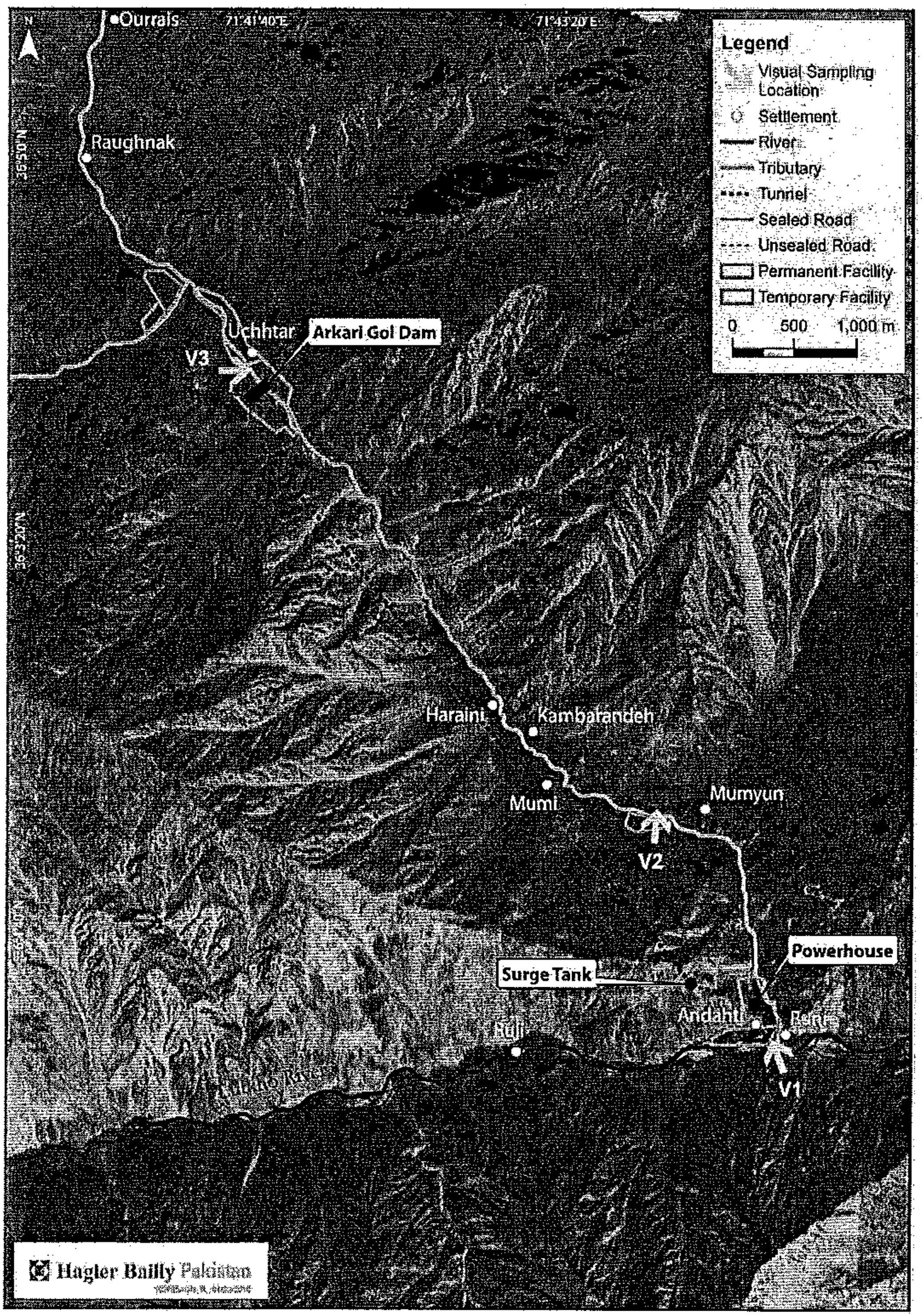

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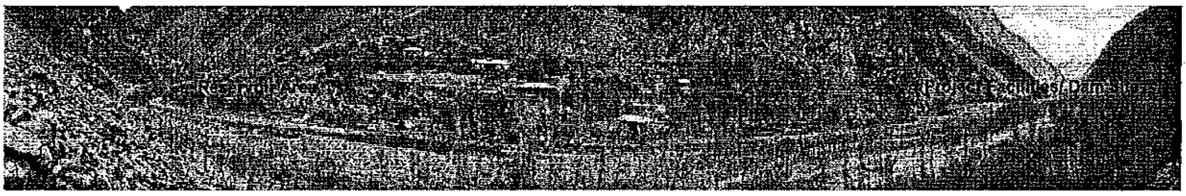
Exhibit 4.112: Visual Survey Photographs

View from V1 on the Garam Chashma Road (180 degree view, at 1868 meters elevation, centered at bearing northeast, right bank Lutkho River). The wide barren valley allows for extensive views of the site.

View from V2 (180 degree view, at 1915 meters elevation, centered at bearing North, right bank Arkari Gol). Agricultural land can be observed at the location of the temporary construction site 2. The Arkari Gol can be seen in the distance.



View from V3 (180 degree view, at 2224 meters elevation, centered at bearing East, right bank Arkari Gol). View of Uchhtar and proposed site for the dam and reservoir.

Note: Locations f Project facilities are approximate and for illustrative purposes.

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4.3 Socioeconomic

Exhibit 4.113 shows the Socioeconomic Study Area. The Socioeconomic Study Area has been delineated using the following buffers and boundaries:

- **1 km buffer around reservoir**: along reaches that may be affected due to the Project, where there is river dependence (i.e., sediment mining, fishing, use of drift wood, or recreational activities).
  - All settlements with a center of the settlement within the 1 km buffer around reservoir.
  - All settlements with more than 50% of their land area within the 1 km buffer.
- **1 km buffer around Project facilities:** for coverage of communities that will be directly affected through either resettlement, or construction related impacts such as disturbance due to noise or dust.
- **1 km buffer around Low Flow Area:** for coverage of communities that will be affected by reduction in water of River.

4.3.1 Methods of Data Collection

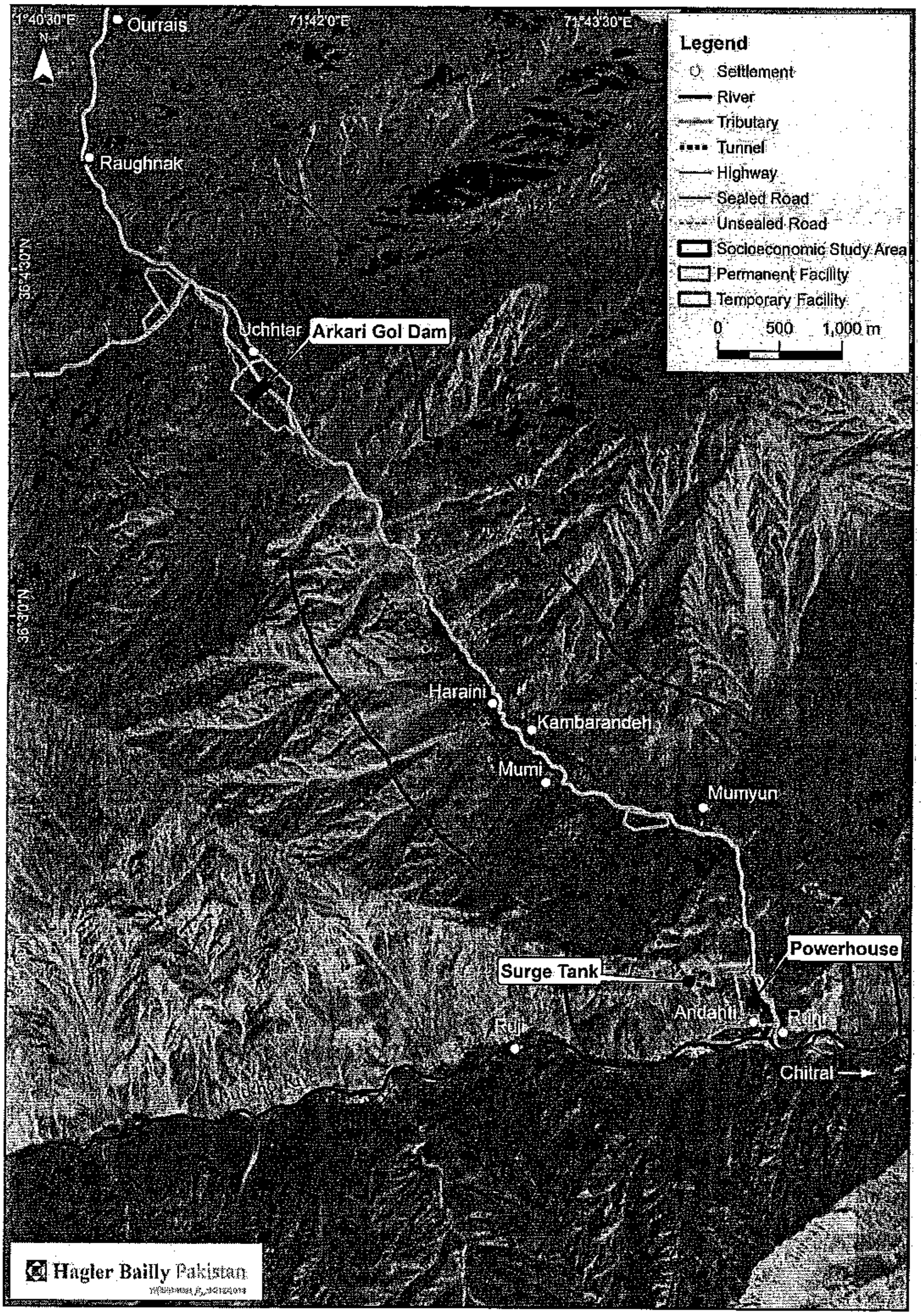
Primary data was collected at the settlement level by administering settlement level questionnaires.

Socioeconomic Aspects of Interest

Socioeconomic aspects of interest include the following:

- **Demography:** a description of the sample population and its characteristics, such as dependency ratio, population pyramid and sex ratio.
- **Infrastructure:** information on existing social and physical infrastructure, such as roads, police facilities, electricity availability, water and sanitation and postal services.
- **Health:** information on key health issues prevailing in the area and access to health facilities.
- **Education:** information on educational institutions and their accessibility.
- **Livelihood:** information on key occupations and income sources.
- **Income and poverty:** discussion on incomes, use of natural resources, expenditures and debts.
- **Dependence on ecosystems services:** dependence on ecological/natural resources (including the river) of the area as a source of livelihood, to meet day to day requirements, or for recreation.
- **Gender:** All socioeconomic information gathered was disaggregated by gender and vulnerability.

Exhibit 4.113: Socioeconomic Study Area



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Surveys

The settlement level survey was completed by a team of social and resettlement experts appointed by HBP, in view of the complex and qualitative nature of information to be obtained in a semi-literate environment. Information was obtained in discussion with a group of 4 to 5 key informants including, but not limited to, the following:

- Union Council (local government) heads
- Educated persons (with Higher School Certificate as minimum level of education attained)
- School teachers
- Local government representatives and leaders
- Community based organization active in the area

Settlement Level Survey was undertaken in all the settlements within Socioeconomic Study Area. A pilot survey was carried out prior to start of the rural settlement survey. Based on the pilot survey results, settlements for rural settlement surveys were selected based on their use of the river (domestic uses and irrigation) and potential impacts of the Project. Detailed interviews were conducted with key informants (male and female) to gather information on selected settlements' social and economic setup including gender issues, with focus on infrastructure and livelihoods;

4.3.2 Overview of the Socioeconomic Study Area

The Socioeconomic Study Area falls within the jurisdiction of Chitral district of KP Province. **Exhibit 4.114** shows administrative boundaries around the Socioeconomic Study Area.

Administration and Governance

The total area of Chitral district is 14, 850 km^2 and it is the largest district of KP province in terms of area.[78] This mountainous district is situated in the northernmost region of Pakistan. It shares borders with Gilgit Baltistan in east, Afghanistan in west, and the narrow Wakhan Corridor of Afghanistan separates it from Tajikistan in north. The districts of Swat and Upper Dir are located in south.

The ex-state of Chitral was transformed into a district in 1969. The Executive Officer of the district is Deputy Commissioner, Chitral. There are two sub divisions of the district namely, Chitral and Mastuj administered by two sub-divisional officers (Assistant Commissioners). Under each sub-divisional officer there are two Extra Assistant Commissioners and one Tehsildar to assist the Assistant Commissioner. For each tehsil there is one Naib Tehsildar working under the Assistant Commissioner for administrative and revenue works. The entire district comprises 24 union councils. The Project is located in village Shaghor and Union Council Shaghor.

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[78] District Profile -Chitral 2014, http://kpbos.gov.pk/files/1432633137.pdf, accessed on April 18, 2018

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History

As mentioned in District Profile-Chitral 2014[79] no authentic account of the history of Chitral State prior to the 100 AD is available. It is recorded in a Sanskrit inscription carved on a rock near Barenis in Mastuj Sub-Division probably by Buddhists and under the rule of Jaipal, King of Kabul. The area has been ruled by Kushan of Peshawar, Chinese and the Iranians. It was inhabited by the Kalash who were Buddhist or followed a religion similar to Buddhism. Alexander the Great also passed through its southern tip while crossing into northern India via east Afghanistan known as little Kashghar, Chitral in the old days was on the trade route between China and Western Asia. In the fourteenth century it was conquered by Torkhoman Prince called Rais who established the Rais Dynasty which flourished for about 275 years. The Raisas subdued the remaining Kalash strong-holds in southern Chitral and conquered the whole country stretching from Gilgit to Asmar. Then the Taimuris, descend, ants of Mirza Hussain of Hirat overthrew the Rais ruler and established the Katura rule. Chitral was then ruled by Katur dynasty from 1590 to 1947.

Demography

As per Pakistan Poverty Alleviation Fund[80] the total population of the Chitral District is 479,000 (2014) with a household size of 7 persons per household and population density of 32 persons/ km^2.

Social Profile and Languages

Original inhabitants of Chitral are said to be *"Khow"*.[81] These people (Khow) accounts for 92 % of the population of Chitral and are spread in many villages.[82] Other tribes of Chitral are Kalass, Shubgali, Wakhi, Madaklashti/ Tajik, Gujars, Dameli, Gawari or Arandui, Sariquli, Kirghiz, Pathan, Dangerik, Afghans and Mukhbani or Yidgha.

Original language of Chitral district is Khowar, made up of words from various tongues and dialects. In some parts such as Lutko, Madaklasht, Kalashgum there are local dialects in which they talk between themselves but they also know Khowar. Other than Khowar some other languages are also spoken in some parts of district Chitral like Warshikwar (Upper Chitral, Warshigum and Yaseen Areas), Dangarik (Ashuret, Kalkatak and Buri), Narsatwar (Arandu), Damariwar (Domel), Kalashwar (Kalashgum) and Persian (Madaklasht and Broghil)

The majority of the people in the district Chitral are Sunni-Muslims whereas there is a sizeable population of Shia Muslims and Ismaili Muslims. The district also home to an indigenous community named the Kalasha tribe. The People of Kalash and various tribes of it are thought to believe in various gods and in very old rituals and religions[83]. Kalasha tribe lives in Kalash Valley located 37 km south of the Project and 22 km away from Chitral City.

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79 Ibid

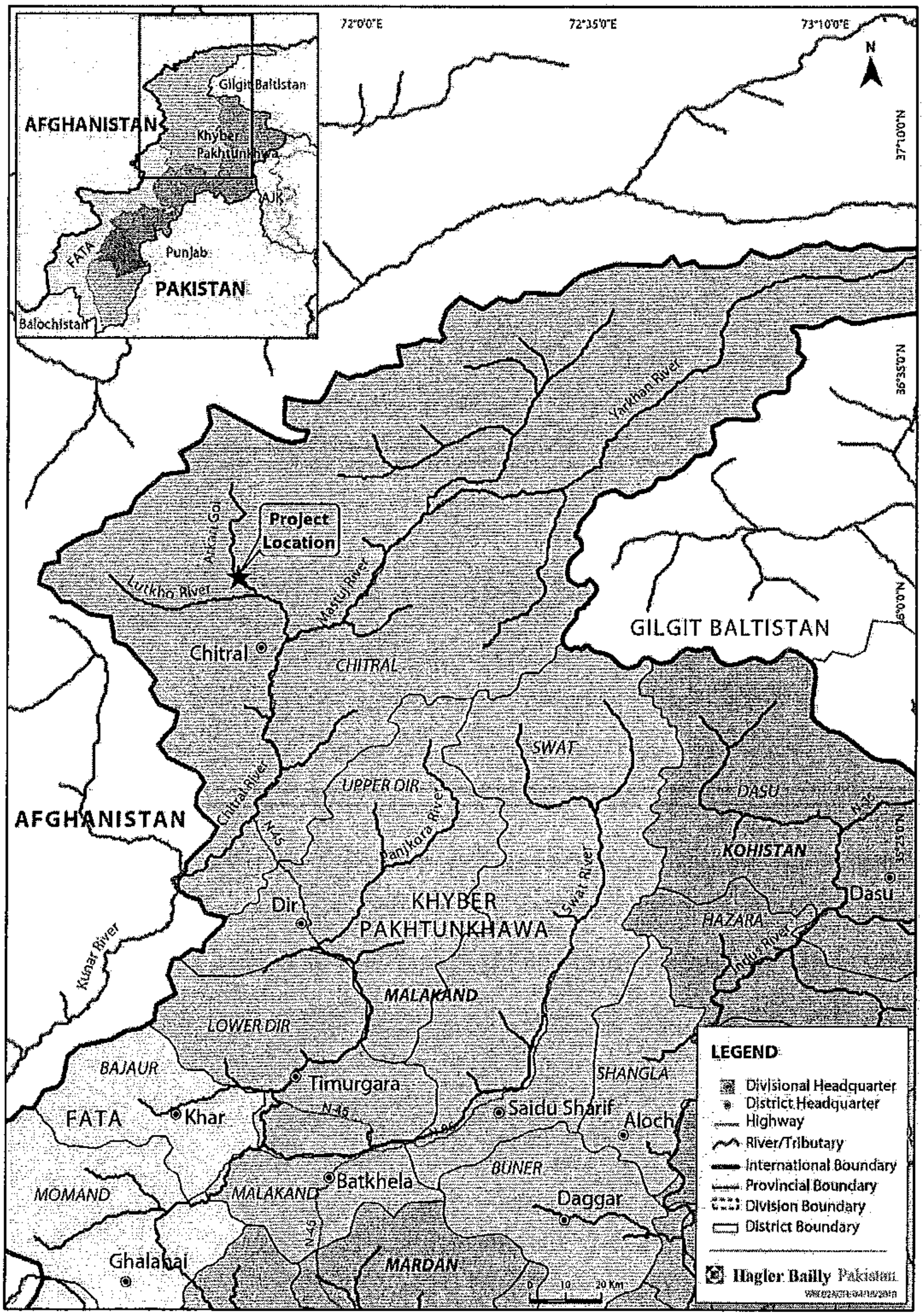
80 Development Profile of Chitral District, Pakistan Poverty Alleviation Fund, January 2015

81 District Profile -Chitral 2014, http://kpbos.gov.pk/files/1432633137.pdf, accessed on April 18, 2018

82 http://merachitral.blogspot.com/2010/05/tribes-of-chitral.html accessed on April 18, 2018

83 http://historypak.com/chitral-a-place-for-tourists accessed on April 19, 2018

Exhibit 4.114: Administrative Boundaries around the Socioeconomic Study Area



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Education

The Chitral district literacy ratio is 77.42%[84] which is comparatively higher than the rest of districts of KP. A study[85] in 2014 shows that there are 641 primary schools, 88 middle schools, 66 high schools, 4 higher secondary schools, 7 community schools, 157 private schools and 4 intermediate/degree colleges in Chitral district.

Agriculture

The total cultivated area in district Chitral is 22,552 hectares.[86] The chief source of irrigation in Chitral district is mountain streams from where water channels have been constructed. Main crops are wheat, maize, barley and paddy. Vegetables and fruits are also grown.

Trade and Industry

As mentioned in District Profile - Chitral 2014[87] the mineral resources of Chitral have never been properly explored. The illiteracy and lack of enterprise of the inhabitants proves an effective bar to the profitable exploitation of her mineral even for internal use. Orpiment or Yellow Arsenic is found in the Lonkhuh valley in Tirich village. It is extracted but in small quantity. Lead is found in various parts in small quantity but is not exported. The best quality of marble stone is available in Chitral. Director of Industries, Commerce, Mineral Development Department have issued a number of licenses for exploration of minerals in some selected areas (see **Exhibit 4.115**).

Exhibit 4.115: Minerals Production 2012-13

Type of Minerals	*Quantity (Tones)*
Antimony	54
Iron Ore	160
Lead	122
Marble	5,625
Soap Stone	317

Indigenous Cultures and People

The Kalasha tribe of Chitral is considered as indigenous people due to their existence from hundreds of years with unique culture, language and ethnicity. As narrated in web based source, the culture and traditions of Chitral[88], in the tenth and eleventh century, the Kalash ruled over Lower Chitral, up till Hurbuns. In 1220, the tribe of Khow defeated Bal Singh, the Kalash ruler, and pushed them to the south western valleys of Chitral. Living

[84] Chitral Today, Basic needs for education in Chitral, https://www.chitraltoday.net/basic-needs-for-education-in-chitral/ cited on April 19, 2018

[85] District Profile -Chitral 2014, http://kpbos.gov.pk/files/1432633137.pdf, accessed on April 18, 2018

[86] Bureau of Statistics, Planning & Development Department, Government of Khyber Pakhtunkhwa and UNICEF. *District Profile: Chitral 2014.*

[87] Ibid

[88] http://merachitral.blogspot.com/2010/05/tribes-of-chitral.html accessed on April 18, 2018

with the Khow, they gradually embraced Islam. Those in the valleys of Bomborate, Birir and Rumbur however have retained their religion and culture.

Until the 1970s, not much was known about this tribe that resided in the south west of Chitral, in the three valleys of Bomborate, Birir and Rumbur. This pagan tribe of 3,000 people follows its own distinct culture and traditions. Their native language is Kalasha or Kalashamun.

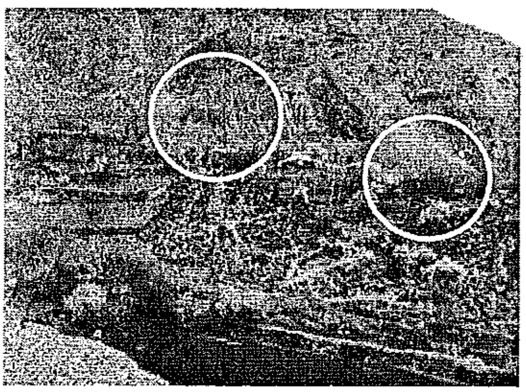
Field survey reveals that none of the culture, religion, ethnic minority and indigenous community is residing in the vicinity of the Project and none of the indigenous household is being affected by the Project.

4.3.3 Socioeconomic Conditions in the Socioeconomic Study Area

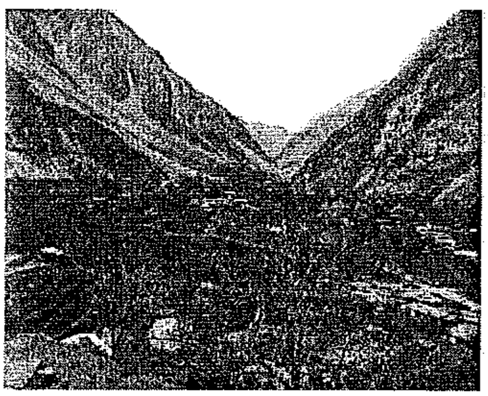
Rural Settlements and Population

There are a total of 8 settlements in the Socioeconomic Study Area. All the settlements in the area are located along the River within a radius of 300 meter from the center of the river. All the settlements are small in terms of number of households (HHs) ranging from 5 to 70 HHs. The area is mountainous and there are small patches of plains therefore, houses in the settlements are scattered with clusters of 3 to 8 houses at a single location. Houses are surrounded by small patches of agricultural lands as well as fruit and non-fruit trees. All settlements are connected to main road (Chitral_Garam Chasma Road) through an un-sealed road. **Exhibit 4.116** shows typical settlements in the Socioeconomic Study Area.

Exhibit 4.116: Typical Settlements in the Socioeconomic Study Area



Uchhtar Settlement



Mumi Settlement

As shown in **Exhibit 4.117**, there are 197 HHs with a population of 1,319 persons in the Socioeconomic Study Area.[89] Average household size in the Socioeconomic Study Area is 6.67 individuals, with a minimum of 5.63 and a maximum of 7.5 individuals. Male to female ratio is 1.01:1.

[89] There are a total of 48 HHs with a population of 350 persons that are affected by resettlement.

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Exhibit 4.117: Average Household Size

Settlement	*Number of HHs*	***Total Population***	*Male Population*	*Female Population*	*Average Household Size*
Uchhtar	22	**147**	78	69	6.68
Mumyun	40	**300**	153	147	7.50
Mumi	70	**450**	225	225	6.43
Haraini	16	**110**	53	57	6.88
Kambarandeh	15	**100**	51	49	6.67
Andahti	13	**90**	46	44	6.92
Raughnak	16	**90**	43	47	5.63
Runi	5	**32**	15	17	6.40
Total	**197**	**1,319**	**664**	**655**	**6.67**

Migration Trends

People in the pastoral communities within the Socioeconomic Study Area have a trend of seasonal migration, with one home close to the river and one at higher elevations. These communities move their livestock herds to higher elevations in the mountains for grazing during the summer.

Migration into and out of the Socioeconomic Study Area was found to be insignificant over the past 7 years. Very little out migration was recorded, whereas no in-migration was recorded in any settlement.

As shown in **Exhibit 4.119** in previous 10 years there is no in-migration reported during the rural settlement survey in any settlement however 7 incidences of out migration were reported which is also insignificant. Households have migrated to Chitral and other main cities of the country for livelihood, education of children and batter living standards. There are also few HHs (less than 5 %) who have two houses one in the Socioeconomic Study Area and one in the main cities (Chitral, Islamabad etc.). These HHs spend summer in Socioeconomic Study Area and winter in their second houses.

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Exhibit 4.118: Average Household Size

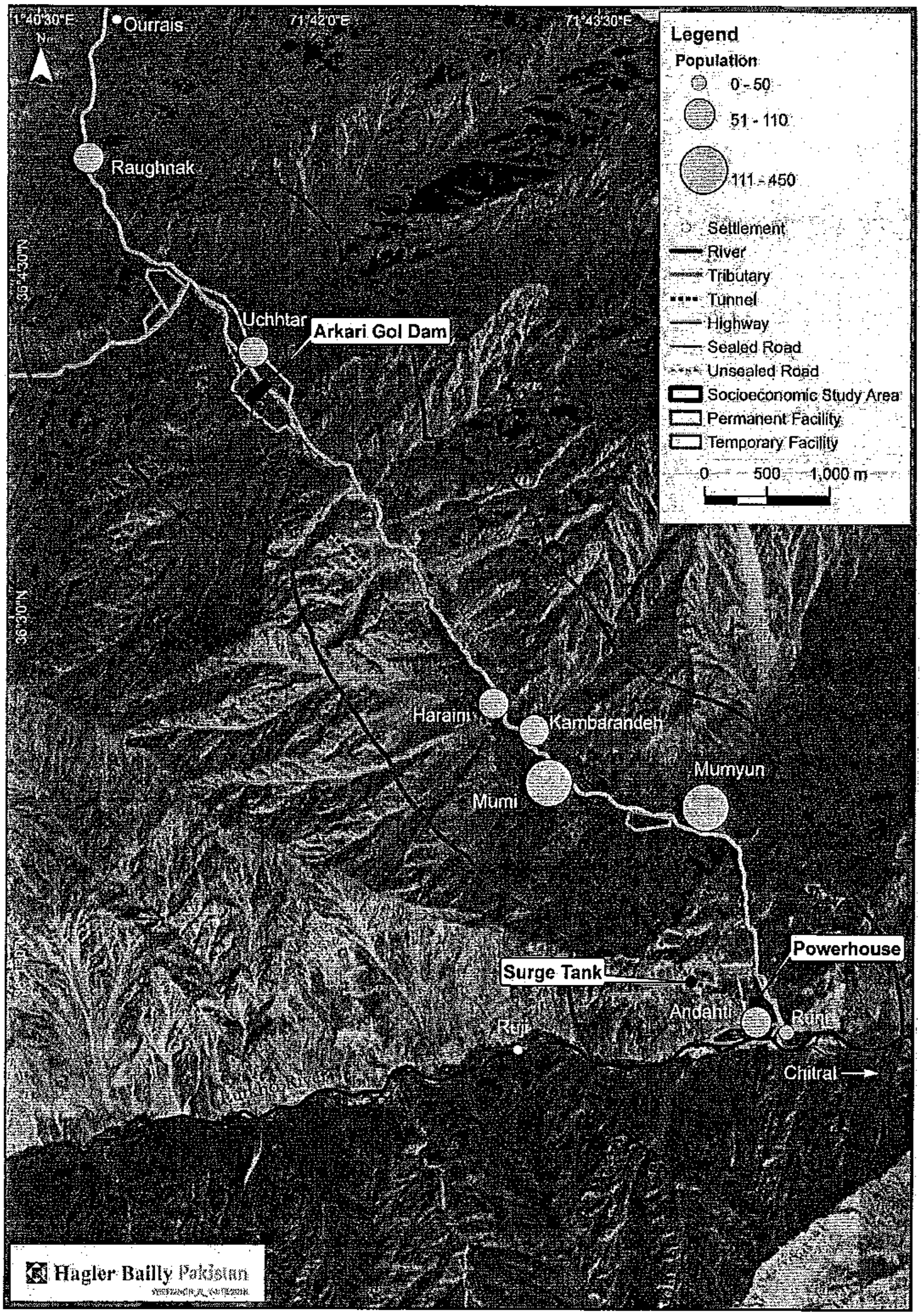

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Exhibit 4.119: Migration Trends and Patterns

Settlement	In Migration	Out Migration
Uchhtar	–	–
Mumyun	–	1
Mumi	–	–
Haraini	–	–
Kambarandeh	–	–
Andahti	–	–
Raughnak	–	6
Runi	–	–
Total	–	7

Castes

A caste is a social group identity which individuals get through their status as close class separated from other classes by distinctions of hereditary status or profession. It is different from the open class system for the reason that in the open class system one may change identity through wealth but in a caste it is forever and hereditary. In settlements in the Socioeconomic Study Area, it not only represents an individual's familial ties, but also political affiliations and social standing. **Exhibit 4.120** shows the cast distribution of the population in the Socioeconomic Study Area. Main castes in the Socioeconomic Study Area are Zondray, Khuja Alanjas and Raees.

Exhibit 4.120: Distribution of Population on Caste Basis

Castes	*Uchhtar*	*Mumyun*	*Mumi*	*Haraini*	*Kambarandeh*	*Andahti*	*Raughnak*	*Runi*	***Total***
Katur	–	–	–	–	–	100%	–	–	**7%**
Zondray	–	100%	–	50%	–	–	–	–	**25%**
Dashmaner	–	–	15%	–	–	–	–	–	**6%**
Raees	–	–	10%	–	–	–	100%	–	**12%**
Mir	–	–	–	–	–	–	–	100%	**3%**
Khuja Alanjas	100%	–	15%	50%	100%	–	–	–	**26%**
Raza Khel	–	–	10%	–	–	–	–	–	**4%**
Quazia	–	–	20%	–	–	–	–	–	**7%**
Shagoria	–	–	15%	–	–	–	–	–	**6%**
Bojongee	–	–	5%	–	–	–	–	–	**2%**
Khorya	–	–	10%	–	–	–	–	–	**4%**

Languages Spoken

Like entire Chitral district the predominant language in the Socioeconomic Study Area is Khwar (100%), with Urdu as the main secondary language. Urdu, the national language is understood everywhere especially among younger people.

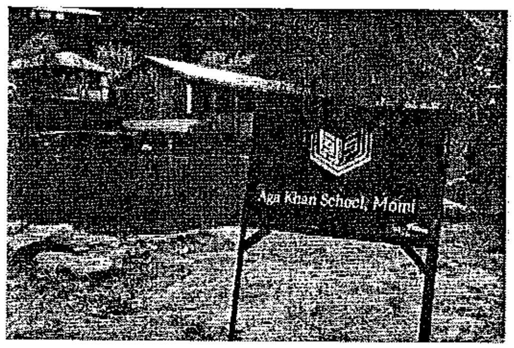
Literacy and Education

There are only three primary schools in the Socioeconomic Study Area, one secondary school (up to level10) and one higher secondary school (up to level 12) are located in Shaghor at a distance of 5 km to 12 km. There is no Degree college and university accessible from Socioeconomic Study Area. This is also evident in **Exhibit 4.121** which shows current school and college enrolment in the Socioeconomic Study Area. The number of students at different educational levels in all settlement is given, and the data is also broken down by gender.

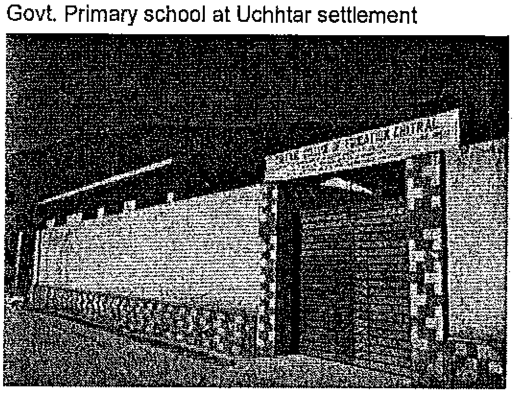
This data indicates that children from the Socioeconomic Study Area are enrolled in primary and high schools and male and female enrolment is almost comparable. However no student from the Socioeconomic Study Area is enrolled in any college or university from the entire Socioeconomic Study Area. **Exhibit 4.121** shows photographs of primary schools available in the Socioeconomic Study Area and higher educational institutions in Chitral city.

Exhibit 4.121: Photographs of Education Infrastructure

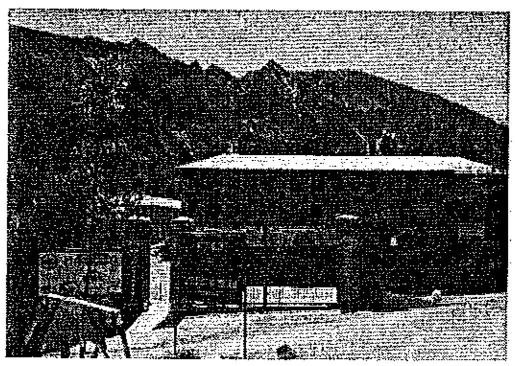
Govt. Primary school at Uchhtar settlement



Agha Khan school at Mumi settlement



Chitral College of Education at Chitral



University of Chitral at Chitral

As provided in **Exhibit 4.122** literacy rate in the Socioeconomic Study Area is 60 % which is less than the 75 % literacy rate of the district. Moreover literacy rate of female is less then literacy rate of male.

Exhibit 4.122: Literacy Rate in the Socioeconomic Study Area

Settlement	*Literacy Rate*		
	Male	*Female*	***Total***
Uchhtar	80%	60%	**71%**
Mumyun	70%	50%	**60%**
Mumi	80%	50%	**65%**
Haraini	50%	10%	**29%**
Kambarandeh	75%	50%	**63%**
Andahti	90%	60%	**75%**
Raughnak	70%	15%	**41%**
Runi	70%	45%	**57%**
Total	**75%**	**45%**	**60%**

Health

There is no health facility available in the Socioeconomic Study Area, only lady health visitors/ workers (LHVs and LHWs) visit the settlements and provide basic health services. LHVs and LHWs also provide polio vaccination service in the Socioeconomic Study Area.

The nearest health facility is a Basic Health Unit (BHU) in Shahgor, while district hospital is located in Chitral city, photograph of BHU Shahgor is shown in **Exhibit 4.124**.

Exhibit 4.125 shows the reported incidence of common diseases in the Socioeconomic Study Area, as a percentage. No disease was reported as an epidemic. As expected, the most common illness reported in the children, adult male and female populations was flu/fever. Other illnesses reported included dysentery, diabetes and jaundice. The prevalence of these is within a negligible proportion of the population.

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Exhibit 4.123: Distribution of Enrolled Population by Gender, Education Levels

Settlement	*Uchhtar*		*Mumyun*		*Mumi*		*Haraini*		*Kambarandeh*		*Andahti*		*Raughnak*		*Runi*	
Gender	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*
Primary (Nursery to Class V) for Boys	12	6	30	25	70	80	20	18	10	6	8	9	8	14	4	7
Primary (Nursery to Class V) for Girls or Co-Ed	–	–	–	–	–	–	–	–	4	4	3	2	–	–	–	–
Middle (Class VI to VIII) for Boys	7	6	12	8	50	50	15	15	–	–	–	–	3	–	1	–
Middle (Class VI to VIII) for Girls or Co-Ed	–	–	–	–	–	–	–	–	1	1	2	2	–	4	–	2
Secondary (Class IX to X) for Boys	–	–	12	8	25	25	12	10	–	–	–	–	8	5	4	3
Secondary (Class IX to X) for Girls	–	–	6	4	–	–	–	–	–	–	–	–	–	–	–	–
Intermediate College for Boys/Girls	–	–	–	–	15	15	5	3	–	–	–	–	–	1	–	1
Degree College for Boys	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Degree College for Girls	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Technical and Vocational Training Institutes for Boys	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Technical and Vocational Training Institutes for Girls	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Madrassah	–	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–
Other	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

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Exhibit 4.124: Basic Health Unit Shahgor

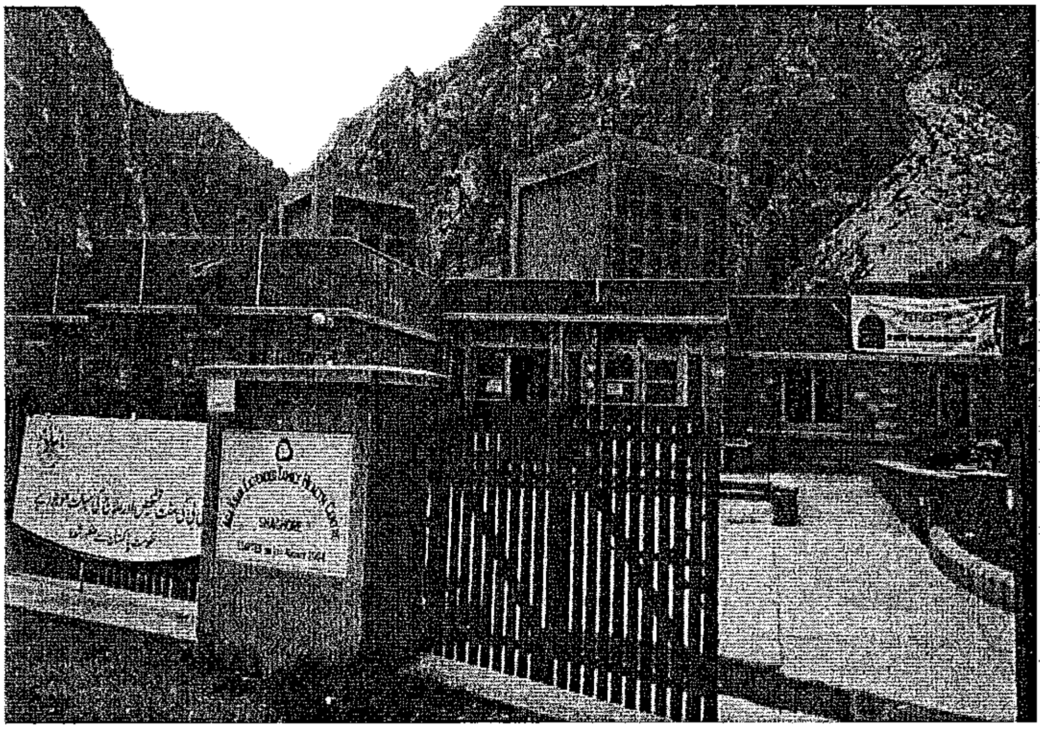

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Exhibit 4.125: Reported Incidences of Diseases in Socioeconomic Study Area, %

Settlements	Uchhtar			Mumyun			Mumi			Haraini			Kambarandeh			Andahti			Raughnak			Runi		
	M	F	C U 15	M	F	C U 15	M	F	C U 15	M	F	C U 15	M	F	C U 15	M	F	C U 15	M	F	C U 15	M	F	C U 15
Flu/Fever	80%	80%	90%	50%	70%	90%	25%	50%	50%	30%	30%	40%	50%	60%	80%	50%	50%	80%	30%	30%	40%	50%	50%	80%
Malaria	5%	5%	10%	50%	60%	60%	20%	30%	30%	30%	30%	40%	10%	40%	50%	10%	10%	20%	–	–	–	10%	10%	20%
Chicken Pox	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Typhoid	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Diarrhea/Dysentery	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Tuberculosis	–	–	–	–	–	–	5%	3%	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Goiter/Thyroid	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Jaundice	–	–	–	10%	5%	–	5%	5%	–	–	–	–	50%	40%	–	5%	3%	–	20%	15%	0%	5%	3%	–
Diabetes	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Other	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	5%	2%	–	–	–	–

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Gender

Generally in affected settlements activities of the women are confined to their houses and nearby areas. Examples of these activities are management of houses, livestock rearing and assisting their men in agricultural activities. Their social contacts are mostly limited to the settlement level. Women in the area are vulnerable, not only economically but also due to their poor educational level and lack of contacts outside their homes. They are also susceptible to risks due to the impacts of Project in terms of resettlement and relocation. This will further increase due to the large influx of in-migrants and construction workers to the area which will affect their privacy and free mobility in the area especially in Harani, Mumi and Mumyun settlements as these settlements are close to the construction activities and movement of workers. Therefore it may be concluded that resettlement will have more effects on women as compared to the men. Starting economic and social activities at new places will be difficult for women.

As detected through resettlement field survey one female-headed HH is being affected by the Project. This HH is considered as vulnerable HH and mitigation measures are included in the RAP of the Project.

Vulnerability

Certain groups of the population, by virtue of their socioeconomic realities, are considered socially vulnerable and thus in need of special consideration so that they can benefit from the development activities of the Project. These groups include; (a) hard core poor HHs (HHs under national poverty line); (b) female–headed HHs (FHH), (c) HHs headed by disabled persons, (d) HHs headed by elderly persons and (e) HHs headed by landless persons. Out of total 48 affected households (AHs), 1 AH is female–headed HH and 14 AHs are below national poverty line. Mitigation measures for affected vulnerable AHs are included in the Resettlement Action Plan (RAP) of the Project.

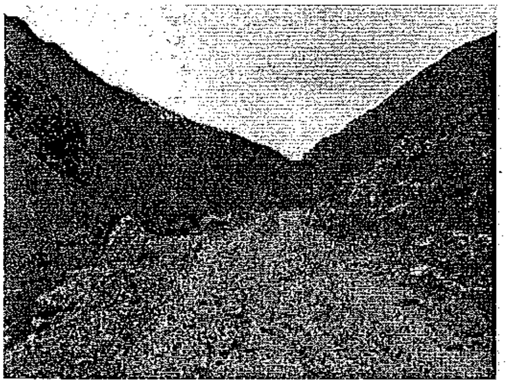
Physical Infrastructure

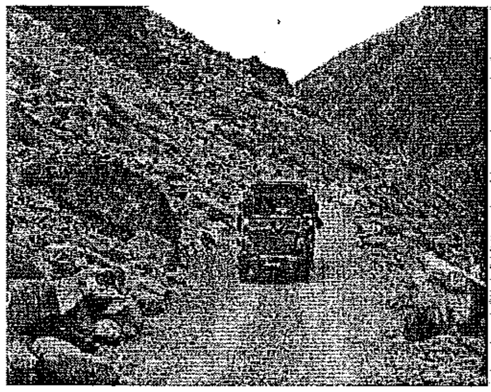
The presence of roads, communication networks and other infrastructure are indicators of development in a region. The survey determined that there is considerable scope for development in the infrastructure, as access to various facilities and infrastructure is low in most parts.

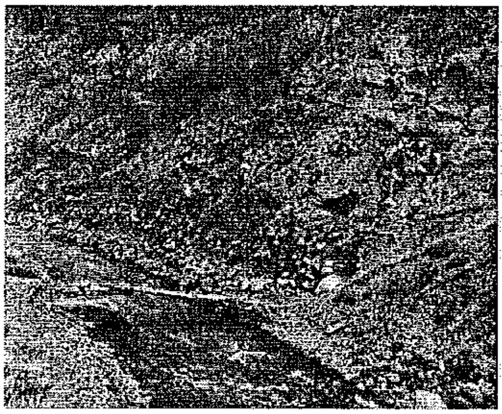
Roads and Transportation

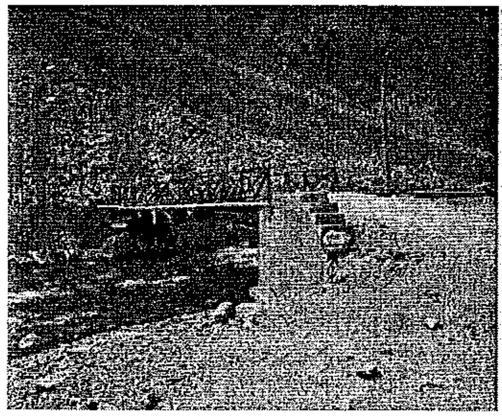
The settlements situated on both side of Arkari Gol in the Socioeconomic Study Area are connected to main towns and cities through Arkari Road which links settlements to Chitral Garam Chashma road on one side and to Arkari town to other side. Arkari Road is an unsealed road in poor condition moreover, it is a landslide area and occasionally land sliding also damages the road. **Exhibit 4.126** shows the conditions of the road.

Exhibit 4.126: Road Network in Socioeconomic Study Area


Unsealed road


Transport


Foot bridge

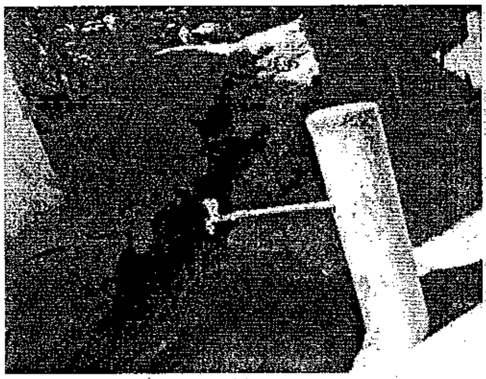

A bridge for vehicles

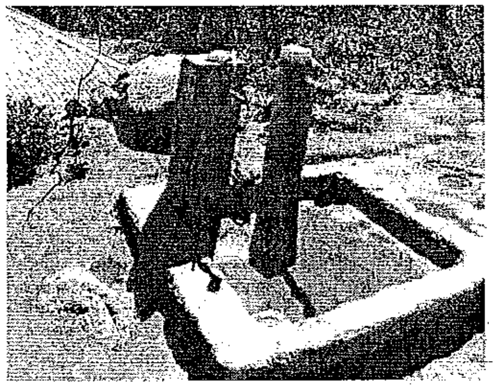
Water Supply Sources

All surveyed settlements are reported having access to a public potable water supply system consisting of a central water storage system, where water collects from a mountain spring and is supplied to the community via a pipeline up to a central point in the community. Distances of the settlements to sources of water ranges from 1 km to 4 km. Almost all surveyed settlements also reported having access to spring water at relatively short distances.

The dependence on the Arkari Gol for drinking is negligible in all settlements, although river water is occasionally used for livestock. **Exhibit 4.127** shows the water supply source

Exhibit 4.127: Pictures of Water Supply Sources





Sanitation and Waste Disposal

None of the settlements surveyed in the Socioeconomic Study Area are connected to a municipal sewage system. Most human waste is disposed of in septic tanks and all other wastewater eventually runs off into the Arkari Gol, affecting water quality However, dilution rates are high as population is low and quality of river water is relatively unaffected.

Most settlements surveyed reported access to pit latrines of some type, although a significant number of households are still using open latrines.

Power and Fuel Source

As shown in **Exhibit 4.128**, three major fuel sources in the Socioeconomic Study Area include electricity, fuelwood and liquefied petroleum gas (LPG). Natural gas is not supplied in the area.

All settlements of the Socioeconomic Study Area are connected to the local micro hydro power project located at settlement Mumi provided by AKRSP. **Exhibit 4.129** shows micro hydro power plant. Electricity is mainly used for lighting purposes and running household electrical appliances. For cooking, water and space heating purposes, fuelwood is used in almost all the HHs however some of the HHs also use. Fuelwood is commonly used as a source of fuel. Communities' source fuelwood from individual lands and communal forests, paying only for the transportation cost.

Exhibit 4.128: Fuel Sources

Settlement	*Uchhtar*	*Mumyun*	*Mumi*	*Haraini*	*Kambarandeh*	*Andahti*	*Raughnak*	*Runi*
Electricity	100%	100%	100%	100%	100%	100%	100%	100%
Fuel wood (Gathered)	100%	100%	100%	100%	100%	100%	100%	100%
Fuel wood (Market)	–	–	–	–	–	–	30%	–
Drift Wood	–	–	–	–	–	–	–	–
LPG	80%	–	–	75%	60%	–	45%	40%

Settlement	Uchhtar	Mumyun	Mumi	Haraini	Kambarandeh	Andahti	Raughnak	Runi
Diesel	–	–	–	–	–	–	–	–
Other	–	–	–	–	–	–	–	–

Exhibit 4.129: Micro Hydro Power Plant in Settlement Mumi

Communication Infrastructure

None of the settlements are connected to the country's landline telephone network, however all the area does receive a mobile phone signal. Post office is also available in Shaghor village and is accessible to all the settlements.

Places of Worship

There are two sects of the religion Islam in the Socioeconomic Study Area including the Ismaili sect of Islam and Ahle Sunat sect of Islam. People belonging to both the sects have their own places of worship. Place of worship of Ismaili sect are called Jamat Khana and those of Ahle Sunat sect are called Mosques. There are a total of six Jumat Khanas and three Mosques in the Socioeconomic Study Area. One Mosque at Andahti settlement and two Jamat Khana at Uchttar settlement will be affected by the Project. These structure will be reconstructed by the Project. Budget for the reconstruction of places of worship is included in the RAP of the Project.Police

The Socioeconomic Study Area and surroundings are generally peaceful, and there are no major law and order problems reported. However, police presence in the entire area is quite low, police check post is available in Shaghor. The police check posts mainly monitors incoming traffic to determine the purpose of visitors to the area.

Other Facilities

There are no banks or markets within the Socioeconomic Study Area. For major purchases the surveyed settlements depend on nearby town Shaghor, Garam Chashma and Chitral city. There were one or two small shops selling basic groceries found in all settlements, mostly belonging to household having vehicles. **Exhibit 4.130** shows nearby villages and cities to the study area. **Exhibit 4.131** shows commercial activities in the Socioeconomic Study Area.

Exhibit 4.130: Micro Hydro Power Plant in Settlement Mumi

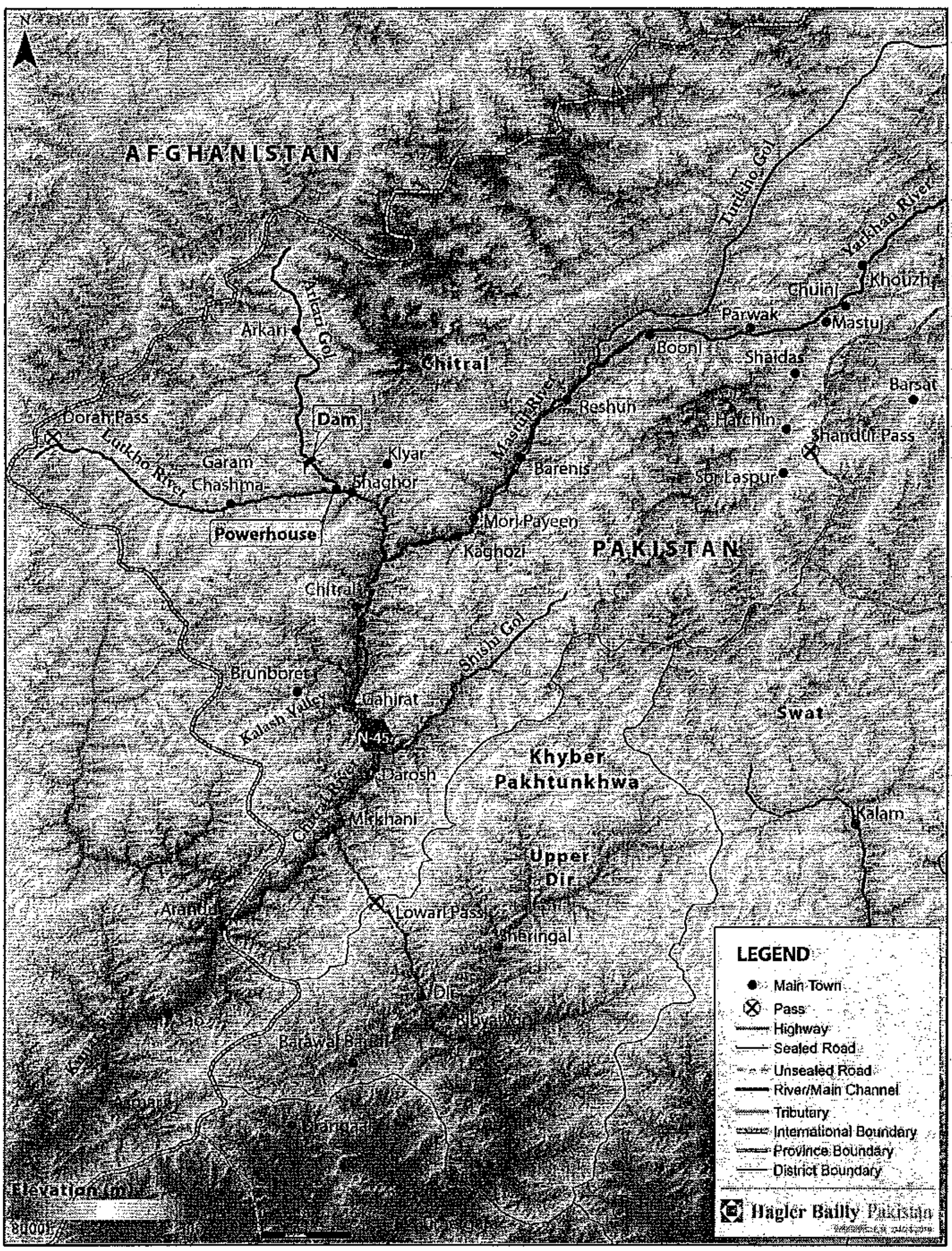


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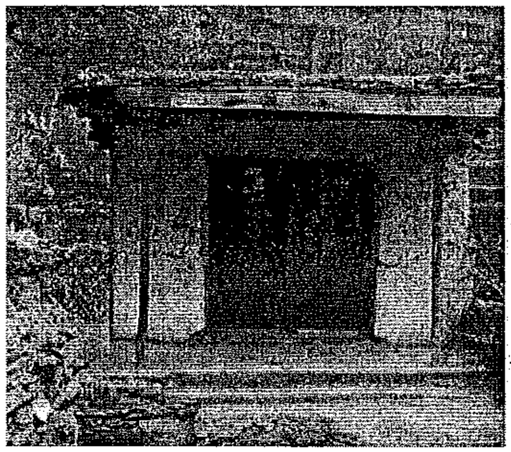
Exhibit 4.131: Commercial Activities in Socioeconomic Study Area



Income and Employment

Sources of income, access to sustainable income sources, diversity of sources and dependence on these sources have a direct impact on poverty, income distribution and economic development. There are certain issues inherent to employment such as literacy skill level and lack of opportunities in the Socioeconomic Study Area. **Exhibit 4.132** shows the sources of livelihood as a percentage by settlement in the Socioeconomic Study Area. The major sources of income are private jobs (23%), Agriculture (22%) Government services (21%) and labor (19%). For women major sources of income are private jobs (33%), Government services (33%), Agriculture (24%) and livestock (10%) Moreover, as mentioned in Exhibit 4.20 average income for male is higher in business sector followed by private sector and government services sector. For women average income is higher for Private services sector followed by government services and agriculture.

Exhibit 4.132: Employment and Livelihoods

Settlement	*Uchhtar*	*Mumyun*	*Mumi*	*Haraini*	*Kambarandeh*	*Andahti*	*Raughnak*	*Runi*	***Percent***
Male									
Private service	8	12	21	2	5	2	5	3	**23%**
Agriculture	–	–	28	6	5	4	12	–	**22%**
Labor	12	6	–	4	12	–	11	2	**19%**
Livestock	–	–	–	5	–	–	8	–	**5%**
Business	–	3	5	1	–	1	–	–	**4%**
Skilled Artisan	–	3	–	1	–	–	2	–	**2%**
Government service	4	22	6	3	5	5	3	3	**21%**

RAP

Settlement	*Uchhtar*	*Mumyun*	*Mumi*	*Haraini*	*Kambarandeh*	*Andahti*	*Raughnak*	*Runi*	***Percent***
Other occupations	–	–	7	–	–	–	–	–	**3%**
Female									
Private. Service	1	3	3	–	–	–	–	–	**33%**
Agriculture	–	–	–	–	–	–	5	–	**24%**
Labor	–	–	–	–	–	–	–	–	**–**
Livestock	–	–	–	–	–	–	2	–	**10%**
Business	–	–	–	–	–	–	–	–	**–**
Skilled Artisan	–	–	–	–	–	–	–	–	**–**
Government service	–	3	2	–	–	–	2	–	**33%**
Other occupations	–	–	–	–	–	–	–	–	**–**

Exhibit 4.133: Average Income from Different Sources

Settlement	*Uchhtar*	*Mumyun*	*Mumi*	*Haraini*	*Kambarandeh*	*Andahti*	*Raughnak*	*Runi*	***Total***
Male									
Private. Service	25,000	45,000	25,000	40,000	20,000	20,000	12,000	25,000	**26,500**
Agriculture	–	–	15,000	25,000	15,000	–	10,000	–	**16,250**
Labor	–	15,000	–	1,500	15,000	–	15,000	15,000	**12,300**
Livestock	–	–	–	10,000	–	–	5,000	–	**7,500**
Business	–	25,000	25,000	50,000	30,000	30,000	20,000	–	**30,000**
Skilled Artisan	–	–	–	10,000	–	20,000	8,000	–	**12,666**
Government service	20,000	30,000	25,000	30,000	25,000	25,000	25,000	24,000	**25,500**
Female									
Private. Service	40,000	25,000	20,000	–	–	–	–	–	**28,333**
Agriculture	–	–	–	–	–	–	5,000	–	**5,000**
Labor	–	–	–	–	–	–	–	–	
Livestock	–	–	–	–	–	–	3,000	–	**3,000**
Business	–	–	–	–	–	–	–	–	
Skilled Artisan	–	–	–	–	–	–	–	–	**–**
Government service	–	20,000	15,000	–	–	–	20,000	–	**18,333**
Other occupations	–	–	–	–	–	–	–	–	

Exhibit 4.134 shows the distribution of households in surveyed settlements by level of income. A significant portion (30%) of households in the Socioeconomic Study Area earn less than PKR 20,000, and can therefore be considered impoverished. A fairly small percentage (12%) of households earn more than PKR 50,000. There is some variation in income across the settlements, however variation appears to be random, with no particular settlement being significantly better or worse off.

Exhibit 4.134: Household Income Levels by Settlement (PKR/month)%

Settlements	*Very Low Income Group less than PKR 10,000 (%)*	*Low Income Group PKR 10,000 – 20,000 (%)*	*Middle Income Group PKR 20,000 – 50,000 (%)*	*High Income Group more than PKR 50,000 (%)*
Uchhtar	–	–	33%	67%
Mumyun	5%	20%	65%	10%
Mumi	5%	15%	75%	5%
Haraini	15%	50%	30%	5%
Kambarandeh	5%	15%	70%	10%
Andahti	10%	25%	60%	5%
Raughnak	80%	15%	4%	1%
Runi	–	–	60%	40%
Total	**12%**	**18%**	**58%**	**12%**

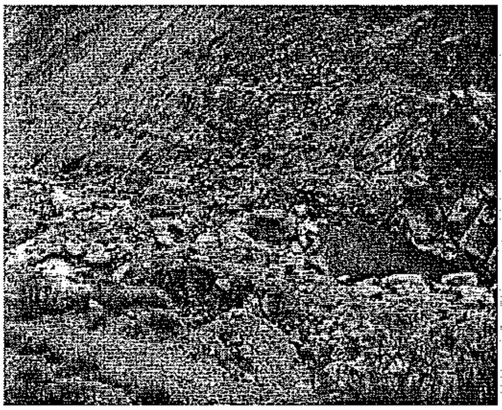
Land Holding and Farming

Exhibit 4.135 shows the average land holding size by settlement in the Socioeconomic Study Area. The average landholding in settlements ranges from 2 to 7 kanals (0.10-0.35 hectares) per household. People grow wheat in winter and maize in summer season vegetables are also grown in the Socioeconomic Study Area. Although the area is mountainous and land holdings are small still people have made water channels up to a length of 3-4 km to irrigate their lands. Therefore, crop yields are good in the Socioeconomic Study Area. Due to small land holdings quantity of crop production is limited and not even sufficient for the households themselves, and no crops are sold in the market. **Exhibit 4.136** shows agriculture in the socioeconomic area and **Exhibit 4.137** shows average crop yield in the Socioeconomic Study Area.

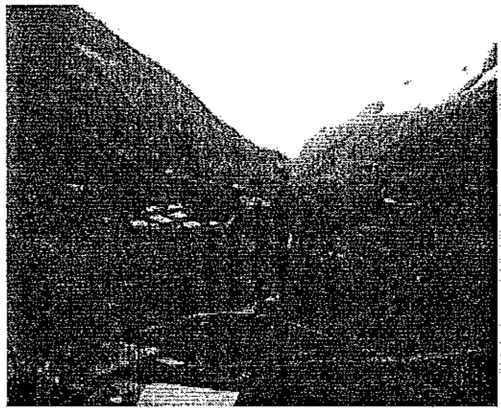
Exhibit 4.135: Average Land Holding by Settlements

Average Land Holding	*Uchthar*	*Mumyun*	*Mumi*	*Haraini*	*Kambarandeh*	*Andahti*	*Raughnak*	*Runi*
Kanal	7	1.5	3	1.5	2	2	6	3
Hectares	0.35	0.08	0.15	0.08	0.10	0.10	0.30	0.15

Exhibit 4.136: Crops Grown by Season



Water channel extracted from Arkari Gol



Wheat crop in Mumi settlement

Exhibit 4.137: Average Yield by Type of Crop by Settlement

Settlements	*Uchhtar*	*Mumyun*	*Mumi*	*Haraini*	*Kambarandeh*	*Andahti*	*Raughnak*	*Runi*
Wheat								
Maund/ Kanal	5	4	4	4	4	5	4	4
Tons /Hectare	4.36	3.49	3.49	3.49	3.49	4.36	3.49	3.49
Maize/Corn								
Maund/ Kanal	6	6	5	4	5	6	4	5
Tons/ Hectare	5.23	5.23	4.36	3.49	4.36	5.23	3.49	4.36
Pulses								
Maund/ Kanal	2	1	1.5	-	-	2	-	1.5
Tons/Hectare	1.74	0.87	1.31	-	-	1.74	-	1.31

Livestock Rearing

People keep cows and goats for milk production and chicken for eggs and meat. A small number of buffalos and sheep was also reported. As previously shown in **Exhibit 4.138**, most of the population is engaged in livestock rearing. Trends in livestock rearing were found to be consistent across the settlements, and animals commonly owned include bullocks/buffalos, cows, goats. Livestock owners often engage herders to rear goats, whereas poultry, cows and buffalo are reared at home. **Exhibit 4.139** below shows photographs of livestock in the Socioeconomic Study Area.

Exhibit 4.138: Distribution of Livestock by Animal Type

Animals	*Uchhtar*	*Mumyun*	*Mumi*	*Haraini*	*Kambarandeh*	*Andahti*	*Raughnak*	*Runi*	***Total***
Buffalo	–	–	–	–	–	–	5	–	**5**
Cow	45	50	300	50	25	60	17	25	**572**

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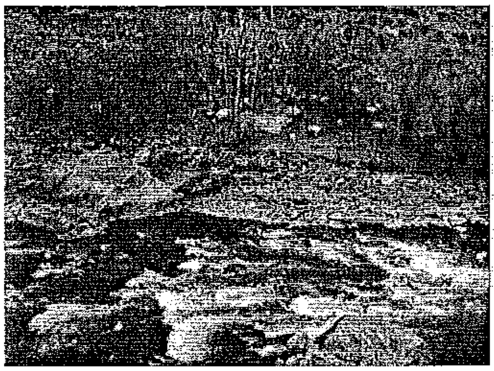
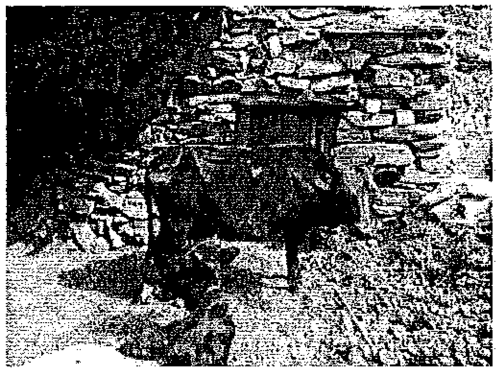
Animals	Uchhtar	Mumyun	Mumi	Haraini	Kambarandeh	Andahti	Raughnak	Runi	Total
Goat	5	–	500	–	2	–	60	–	**567**
Sheep	–	–	–	–	–	–	10	–	**10**
Poultry	100	50	500	–	–	100	80	45	**875**

Exhibit 4.139: Photographs of Livestock in the Socioeconomic Study Area



Goats grazing along Arkari Gol



Cows, Mumi settlement

Exhibit 4.140 shows the average value of livestock by type of animal in the Socioeconomic Study Area. Animals are mostly sent within the settlements for grazing however, animals are also provided fodder especially in winter. Land acquisition for the Project will affect part of the grazing lands however these lands are an insignificant part of total land available for grazing therefore, grazing will not be affected by the Project.

Exhibit 4.140: Average Value of Livestock by Type of Animal, PKR

Animals	Uchhtar	Mumyun	Mumi	Haraini	Kambarandeh	Andahti	Raughnak	Runi
Bullock/Buffalo	–	–	–	–	–	–	60,000	–
Cow	50,000	40,000	50,000	50,000	40,000	40,000	50,000	40,000
Goat	12,000	–	10,000	–	10,000	–	15,000	–
Poultry	1,000	1,000	800	–	–	800	600	800
Other	–	50,000	–	–	–	–	–	–

River-Dependent Socioeconomic Activities

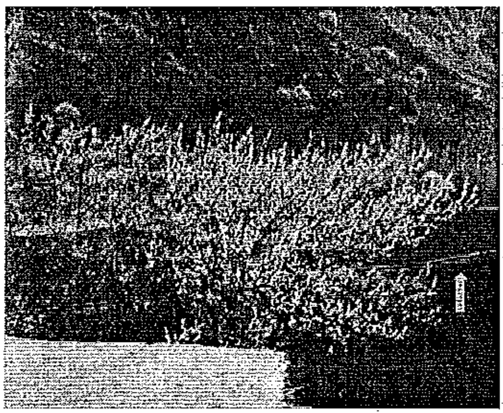
As described earlier, rural settlement surveys were undertaken in selected settlements with river dependence or within one km of Project facilities. Detailed consultations and village profiling were conducted in each settlement to collect data on livelihoods and dependency on natural resources including on the Arkari Gol for the settlements on both river banks. The socioeconomic activities investigated in detail included sediment mining from the river, irrigation, migratory birds hunting, fishing, and recreation and tourism.

On the whole, river dependent socioeconomic activities in the Socioeconomic Study Area were found to be limited mainly to irrigation. Details are given in the following sections.

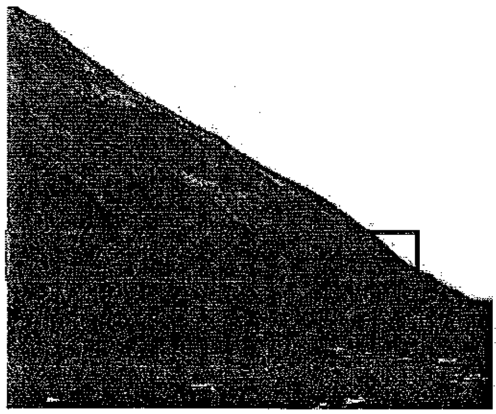
Irrigation

Main River dependent socioeconomic activity is the irrigation of agricultural lands. As reported by the local communities and observed by the survey team more than 150 acres of land is being irrigated by the Arkari Gol in Socioeconomic Study Area. Moreover, four water flour mills and one micro hydro power plant at settlement Mumi are also operating on these water channels. This irrigation system may be affected by the Project and mitigation measures are required. **Exhibit 4.141** provides photographs of irrigation channels.

Exhibit 4.141: Photographs of Irrigation Channels



Irrigation Channel passing through agricultural fields



Irrigation channel passing through mountains

Hunting of Migratory Birds

Hunting of migratory birds is quite common through the entire stretch of the Socioeconomic Study Area. Photographs related to birds hunting in Socioeconomic Study Area are shown in **Exhibit 4.142.** Large size artificial ponds have been constructed near the bank of the river in the Socioeconomic Study Area and decoys ducks are used to attract migratory ducks. A small hunting hide, built from large stones, is used for hunting purposes (**Exhibit 4.142**). Consultations with the local communities and wildlife department confirmed that permits are issued for hunting of migratory ducks. Permits are issued at the rate of PKR 2,000 to each hunter for a specific period of the year. With one permit each hunter can kill 20 waterfowls per day. It was also observed that people hunt birds without permits.

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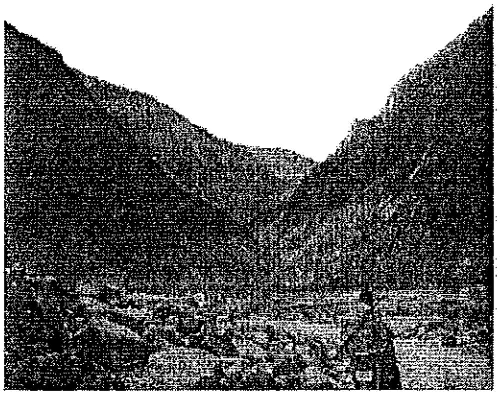
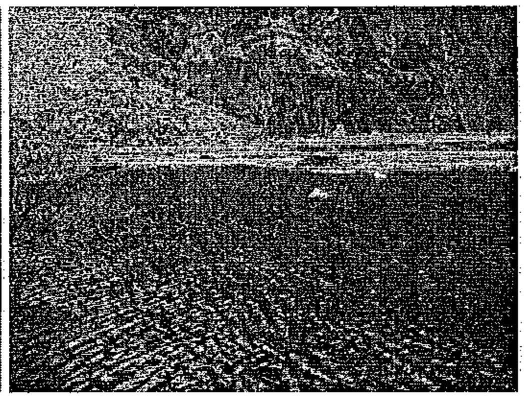
Exhibit 4.142: Photographs of Irrigation Channels


Hunter searching for ducks


Artificial pond and hunting hide near Uchttar

Sediment Mining

As observed during the field survey and consultation with the local communities sediment mining in the Socioeconomic Study Area is limited and insignificant. There is no commercial sediment mining however people collect sand from the river for their own use when required. Moreover as road is in a poor condition commercial sediment miners prefer to extract material from the mountains along the Chitral-Garam Chashma road.

Fishing

As observed during the field survey and consultation with the local communities fishing in the Socioeconomic Study Area is insignificant.

Tourism and Recreational Activities

There is very little tourism in the Socioeconomic Study Area and recreational dependence on the river was reportedly low in all the settlements. During the survey the survey team did not observe riverside fishing, boating or picnics as a recreational activity or source of income along Arkari Gol in Socioeconomic Study Area.

Physical Cultural Heritage

No physical cultural heritage was identified in the Socioeconomic Study Area based on consultation with the local communities and observation of the survey team.

Indigenous Peoples

The IFC's Performance Standard 7 recognizes that "Indigenous Peoples (IP) are social groups with identities that are distinct from dominant groups in national societies and that they are often the most marginalized and vulnerable segments of the society. Their economic, social, and legal status limits their capacity to defend their rights to, and interests in, lands and natural and cultural resources, and may restrict their ability to participate in and benefit from development. Indigenous Peoples are particularly vulnerable if their lands and resources are transformed, encroached upon, or significantly degraded. Their languages, cultures, religions, spiritual beliefs, and institutions may also come under threat. As a consequence, Indigenous Peoples may be more vulnerable to the adverse impacts associated with project development than non-indigenous communities."

In IFC Performance Standard 7, the term "Indigenous Peoples" is usually used in a generic sense to refer to a distinct social and cultural group possessing the following characteristics in varying degrees:

- Self-identification as members of a distinct indigenous cultural groups and recognition of this identity by others;
- Collective attachment to geographically distinct habitats or ancestral territories in the project area and to the natural resources in these habitats and territories;
- Customary cultural, economic social or political institutions that are separate from those of the dominant society or culture; or
- An indigenous language, often different from official language of the country or region.

Keeping in view the above mentioned characteristics no Indigenous Peoples are residing in the Socioeconomic Study Area. More than 90 % of the entire population of the Socioeconomic Study Area belongs to Ismaili sect of Islam and others belong to Ahle Sunat sect. Ismaili sect is in minority in entire Pakistan however, based on the above mentioned characteristics it cannot be categorized as Indigenous Peoples.

5. Analysis of Alternatives

A key component in the ESIA process is the consideration of alternatives. Most guidelines use terms such as 'reasonable', 'practicable', 'feasible' or 'viable' to define the range of alternatives that should be considered. Essentially there are two types of alternatives:

- incrementally different (modifications) alternatives to the project; and
- fundamentally (totally) different alternatives to the project.

Alternatives are essentially, different ways in which the developer can feasibly meet the Project's objectives, for example by carrying out a different type of action, choosing an alternative location or adopting a different technology or design for the project. At the more detailed level, alternatives merge into mitigating measure where specific changes are made to the project design or to methods of construction or operation to avoid, reduce or remedy environmental effects. All ESIA systems also require developers to consider mitigation (i.e. measures to avoid, reduce and remedy significant adverse effects).

Alternatives and mitigation therefore cover a spectrum ranging from a high level to very detailed aspects of Project design. The "No Project" scenario must also be considered as the baseline against which the environmental effects of the Project should be considered.

This section presents an analysis of the following alternatives from the perspective of economic and environmental considerations:

1. No project option
2. Alternative options for power generation
3. Environmental flow and management alternatives
4. Options for transportation of equipment to project site

5.1 No Project Option

The No Project alternative will have the following economic and environmental consequences:

- Pakistan is going through an acute power shortage. The gap between supply and demand was 7,000 MW in May 2017.[1] The GoP is enhancing generation capacity to meet the requirements and at the same time encouraging hydropower both in the public and private sectors. The proposed Project will supply the much needed power to reduce the current gap. Thus in the absence of this project, the gap in power supply and demand will continue to grow.
- Environmentally, this Project will contribute towards reducing the deterioration of air quality, as in the long run it will supply power that would otherwise be generated using coal or fuel oil, which increase the concentrations of pollutants in

[1] Dawn News, https://www.dawn.com/news/1331738, accessed November 7, 2017

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the air in the surrounding areas. The Project will also reduce the volume of greenhouse gases emitted into the atmosphere for the same reason.

- The Chitral District, as compared to other districts, has a shortage of power and is lagging behind other valleys and districts in the Jhelum, Indus and Kaghan in terms of hydropower development. This Project will be the first in the valley. The Arkari Gol HPP will support economic and infrastructure development and will save on transmission costs by generating power in the district itself.
- Anthropogenic pressures on the ecosystem in this valley are limited as compared to other areas such as Jhelum and Poonch. The Project will result in some decline in population of fish species mainly in the 6 km reach of the river in the low flow section downstream of the dam. However, with the recommended modes of operation these declines can be limited. The Project will support the government departments for protection of habitat and illegal exploitation of wildlife which is presently occurring in the area in absence of organized protection. This will not only mitigate the loss due to Project, but in the long term will contribute to improvement in biodiversity as compared to the No Project alternative where protection level is weak.

Considering the pressures and issues described above, unless economically and environmentally more viable options can be found, which appears unlikely, the 'no project' option will have a negative impact on the economy as well as on the environment in Arkari Gol.

5.2 Alternative Technologies and Scale for Power Generation

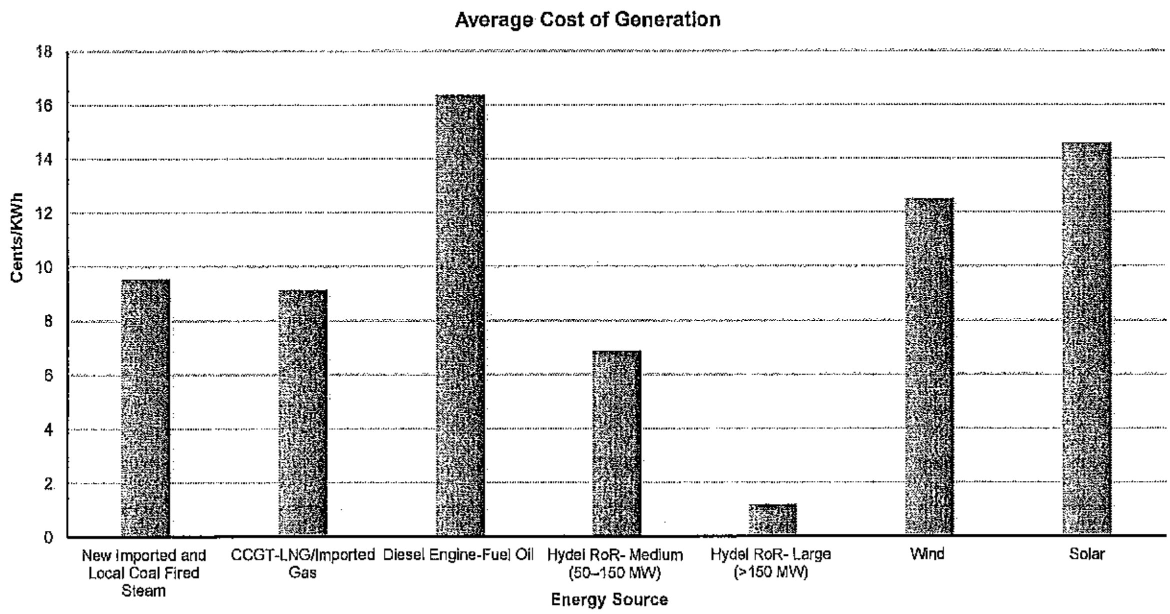
The alternatives to the proposed hydropower project include power generation from LNG/imported natural gas based combined cycle gas turbines (CCGTs), coal fired steam plants, and fuel oil based diesel engines. In addition, other technologies such as nuclear, and wind and solar renewable energy power plants could also be considered as alternatives. An analysis of the life cycle average cost of generation from the competing technologies was carried out to assess the least cost generation alternative of the project.

Exhibit 5.1 shows the comparison of cost of generation from various technology alternatives. The cost of power generation for the proposed large size RoR hydropower project is lower than that for LNG and coal based options. Cost of power generation for the large hydropower projects is also lower than that for wind energy and solar PV projects where power generation is intermittent and weather dependent, and requires back up fossil fuel based power generation capacity to maintain supply in the grid. Larger hydropower projects such as Diamer-Basha Dam that have also capacity for water storage can produce power at a slightly lower cost than the smaller RoR hydropower projects. Such large projects, however, generally involve extensive resettlement and technical studies, tend to be delayed for these reasons and can take 7-12 years to complete, and frequently face cost overruns.[2] In addition, investment is difficult to mobilize in Pakistan at present due to risk rating of the country. Given the risk of delays and cost over runs in larger dams, shortage of power in the country, and investment constraints, the Project as a large capacity RoR that

[2] Should we build more large dams? The actual costs of hydropower megaproject development, Atif Ansara, Bent Flyvbjergb, Alexander Budzierb, Daniel Lunnc, Energy Policy, Volume 69, June 2014

can be completed in four years is an acceptable option amongst currently available alternatives in terms of technology and scale of projects. In terms of socioeconomic impacts the Project is much simpler to implement than a large hydropower project involving large scale resettlement. Environmentally, potential Project impacts will be mitigated and managed through the implementation of the EMP.

Exhibit 5.1: Average Cost of Power Generation from the Project Alternatives



Source: National Electric Power Regulatory Authority, State of Industry Report 2015
National Transmission & Dispatch Company, Power System Statistics 2015 – 2016

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5.3 Environmental Flow Assessment

Environmental flow (EFlow), or flow that has to be released from the dam to meet the requirements of the aquatic ecosystem, is generally of concern when the powerhouse is located at a distance from the dam, which can result in an extended stretch of river drying up. In the case of Arkari Gol HPP the power house is located 7.3 km from the dam. This will be the low flow section over which to maintain flowing conditions. An environmental flow ranging from 0.8-2 m^3/s over different months of the year is recommended. In the case of impacts downstream of the powerhouse due to peaking operations the EFlow Assessment (**Appendix M**) considers three scenarios including run of river operation, peaking and a modified form of peaking and presents the impacts of each operational scenario on indicator fish species. It recommends an approach to power generation which will balance the economic value of peaking power and impacts on river ecology in order to justify "No Net Loss Where Feasible" in Natural Habitats as defined in PS6.

5.4 Offsets to Balance the Impact on Aquatic Ecology

Conversion of lotic river habitat to lentic habitat (lake habitat) in the reservoir created by the Project will not have an impact on fish population as this stretch of the river is very limited in biodiversity. This is because of the presence of a natural barrier (waterfall) 3 km downstream of the dam which prevents fish migration to that part of the river. Losses as a result of creation of a low flow section and peaking downstream of the tailrace will be offset by maintaining an environmental flow as described above as well as by providing support to the Wildlife and Fisheries Departments to improve protection of fish habitat in the Chitral Valley.

5.5 Peaking vs. Non-peaking

Hydropower dams with storage can be operated in the peaking mode in the dry season when the river flow drops. In this mode of operation, water is typically stored in the reservoir during the day, and released through power generation turbines for three to four hours in the evening to meet the peak electricity demand. Environmental issues that are of concern with such a mode of operation include an adequate release of water through the dam when water is being stored in it to support aquatic life (environmental flow), and the impact of sudden changes in flow on aquatic life when the water is released from the dam for peaking purposes.

The powerhouse can also be operated continuously or at baseload without resorting to peaking in the low flow dry season. In other words, the dam can be operated in a true Run of the River mode where water coming into the reservoir can be allowed to flow through the power house without storing it in the reservoir created by the dam. This will minimize the impact of the flow release from project on the river biodiversity downstream of the dam.

The preferred option is to operate the Project as a true run-of-river project as this mode of operation will have minimal impacts on aquatic ecology. However, this is not economically feasible. The other operational scenarios include a peaking operation and a modified form of peaking. In the latter the flow is gradually ramped up to peak level and is then ramped down towards the end of the peaking period which buffers the impact of a full peaking operation. This form of peaking will also result in losses but at a lower level than with full peaking mode. The approach to power generation should be selected in consultation with the power purchaser which provides a balance between economic value of peaking power and impacts of the Project on river ecology to achieve "No Net Loss Where Feasible" in a Natural Habitat as defined in PS6.

5.6 Fish Passages

A fish ladder is not required as fish were not observed upstream of the natural fall in the river located about 2.5 km downstream of the dam.

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6. Information Disclosure, Consultation, and Participation

As part of the ESIA process, consultations are undertaken with communities and institutions that may have interest in the proposed Project or may be affected by it. This section documents the consultation process for the ESIA of the proposed Project and summarizes its results. The consultation process was designed to be consistent with the relevant national legislation and the IFC Guidelines[1] on Stakeholder Engagement.

6.1 Regulatory Requirements

Public consultation is mandated under national environmental law. The Pakistan Environmental Protection Agency, under Regulation 6 of the IEE-EIA Regulations 2000, issued a set of guidelines of general applicability and sectoral guidelines indicating specific assessment requirements. These guidelines have been adopted by the KP-EPA for use in its jurisdiction. This includes Guidelines for Public Consultation, 1997 (the 'Guidelines'), that are summarized below:

- **Objectives of Public Involvement:** 'To inform stakeholders about the proposed project, to provide an opportunity for those otherwise unrepresented to present their views and values, providing better transparency and accountability in decision making, creating a sense of ownership with the stakeholders'.
- **Stakeholders:** 'People who may be directly or indirectly affected by a proposal will clearly be the focus of public involvement. Those who are directly affected may be project beneficiaries, those likely to be adversely affected, or other stakeholders. The identification of those indirectly affected is more difficult, and to some extent it will be a subjective judgment. For this reason it is good practice to have a very wide definition of who should be involved and to include any person or group who thinks that they have an interest. Sometimes it may be necessary to consult with a representative from a particular interest group. In such cases the choice of representative should be left to the group itself. Consultation should include not only those likely to be affected, positively or negatively, by the outcome of a proposal, but should also include those who can affect the outcome of a proposal'.
- **Mechanism:** 'Provides sufficient relevant information in a form that is easily understood by non-experts (without being simplistic or insulting), allow sufficient time for stakeholders to read, discuss, consider the information and its implications and to present their views, responses should be provided to issues and problems raised or comments made by stakeholders, selection of venues and timings of events should encourage maximum attendance'.

1 International Finance Corporation (IFC), 2007, Stakeholder Engagement: A Good Practice Handbook for Companies Doing Business in Emerging Markets

- **Timing and Frequency:** Planning for the public consultation program needs to begin at a very early stage; ideally it should commence at the screening stage of the proposal and continue throughout the ESIA process.
- **Consultation Tools:** Some specific consultation tools that can be used for conducting consultations include; focus group meetings, needs assessment, semi-structured interviews; village meetings and workshops.

Important Considerations: 'The development of a public involvement program would typically involve consideration of the following issues; objectives of the proposal and the study; identification of stakeholders; identification of appropriate techniques to consult with the stakeholders; identification of approaches to ensure feedback to involved stakeholders; and mechanisms to ensure stakeholders' considerations are taken into account'.

6.2 Lender's Requirements

The Project is being developed by MHL which is seeking financing from OPIC. MHL is following OPIC guidelines. OPIC uses the IFC PSs to guide the ESIA including the stakeholder consultation process. IFC PSs are designed to manage social and environmental risks and impacts and to enhance development opportunities. Eight PSs are established which are described in **Section 2.6.2** (*International Finance Corporation's (IFC) Environmental and Social Performance Standards on Sustainability*). Clients of IFC, or other financial institutions electing to apply the Standards to projects that it is financing, are expected to meet these standards throughout the life of an investment by IFC or other relevant financial institution. The Performance Standard 1 (PS1) relevant to information and disclosure is described below.

PS 1 Social and Environmental Assessment and Management System

The PS1 establishes the importance of integrated assessment to identify the social and environmental impacts, risks, and opportunities in the project's area of influence. PS1 requires Social and Environmental Assessment and Management Systems for managing social and environmental performance throughout the life cycle of this Project and runs through all subsequent PSs. Community engagement or stakeholder engagement is one of the seven elements of PS1. The specific requirements of the stakeholder engagement are summarized below.

- **Stakeholder Analysis:** Clients should identify the range of stakeholders that may be interested in their actions and consider how external communications might facilitate a dialog with all stakeholders. Where projects involve specifically identified physical elements, aspects and/or facilities that are likely to generate adverse environmental and social impacts to Affected Communities, the client will identify the Affected Communities.
- **Engagement Planning:** The client will develop and implement a Stakeholder Engagement Plan that is scaled to the project's risks, impacts, and development stages, and will be tailored to the characteristics and interests of the Affected Communities. Where applicable, the Stakeholder Engagement Plan will include differentiated measures to allow the effective participation of those identified as disadvantaged or vulnerable. When the stakeholder engagement process depends

substantially on community representatives, the client will make every reasonable effort to verify that such persons do in fact represent the views of Affected Communities and that they can be relied upon to faithfully communicate the results of consultations to their constituents.

- **Disclosure of Information:** The client will provide Affected Communities with access to relevant information[2] on: (i) the purpose, nature, and scale of the project; (ii) the duration of proposed project activities; (iii) any risks to and potential impacts on such communities and relevant mitigation measures; (iv) the envisaged stakeholder engagement process; and (v) the grievance mechanism.
- **Consultation:** When Affected Communities are subject to identified risks and adverse impacts from a project, the client will undertake a process of consultation in a manner that provides the Affected Communities with opportunities to express their views on project risks, impacts and mitigation measures, and allows the client to consider and respond to them. Effective consultation should: (i) begin early in the process of identification of environmental and social risks and impacts and continue on an ongoing basis as risks and impacts arise; (ii) be based on the prior disclosure and dissemination of relevant, transparent, objective, meaningful and easily accessible information which is in a culturally appropriate local language(s) and format and is understandable to Affected Communities; (iii) focus inclusive engagement on those directly affected as opposed to those not directly affected; (iv) be free of external manipulation, interference, coercion, or intimidation; (v) enable meaningful participation, where applicable; and (vi) be documented. The client will tailor its consultation process to the language preferences of the Affected Communities, their decision-making process, and the needs of disadvantaged or vulnerable groups.
- **Informed Consultation and Participation:** For projects with potentially significant adverse impacts on Affected Communities, the client will conduct an Informed Consultation and Participation (ICP) process that will build upon the steps outlined above in 'Consultation' and will result in the Affected Communities' informed participation. ICP involves a more in-depth exchange of views and information, and an organized and iterative consultation, leading to the client's incorporating into their decision-making process the views of the Affected Communities on matters that affect them directly, such as the proposed mitigation measures, the sharing of development benefits and opportunities, and implementation issues. The consultation process should (i) capture both men's and women's views, if necessary through separate forums or engagements, and (ii) reflect the different concerns of men and women and their priorities regarding project impacts, mitigation mechanisms, and benefits, where appropriate. The

2 Depending on the scale of the project and significance of the risks and impacts, relevant document(s) could range from full Environmental and Social Assessments and Action Plans (i.e., Stakeholder Engagement Plan, Resettlement Action Plans, Biodiversity Action/Management Plans, Hazardous Materials Management Plans, Emergency Preparedness and Response Plans, Community Health and Safety Plans, Ecosystem Restoration Plans, and Indigenous Peoples Development Plans, etc.) to easy-to-understand summaries of key issues and commitments. These documents could also include the client's environmental and social policy and any supplemental measures and actions defined as a result of independent due diligence conducted by financiers.

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client will document the process, in particular the measures taken to avoid or minimize risks to and adverse impacts on the Affected Communities, and will inform those affected about how their concerns have been considered.

6.3 Consultation Methodology

Consultations with the Project stakeholders were undertaken in late April 2018. The main document for distribution to stakeholders during the consultations was the Background Information Document (BID) that informed the stakeholders about the ESIA process and provided a background about the Project. The BID was made available in English and Urdu (**Appendix I**) to suit the language preferences of different stakeholders. The feedback from the communities was recorded and the detailed logs of consultations with the attendees were prepared. Separate meetings with institutional stakeholders were arranged in Chitral.

6.3.1 Stakeholders Consulted

Community Stakeholders

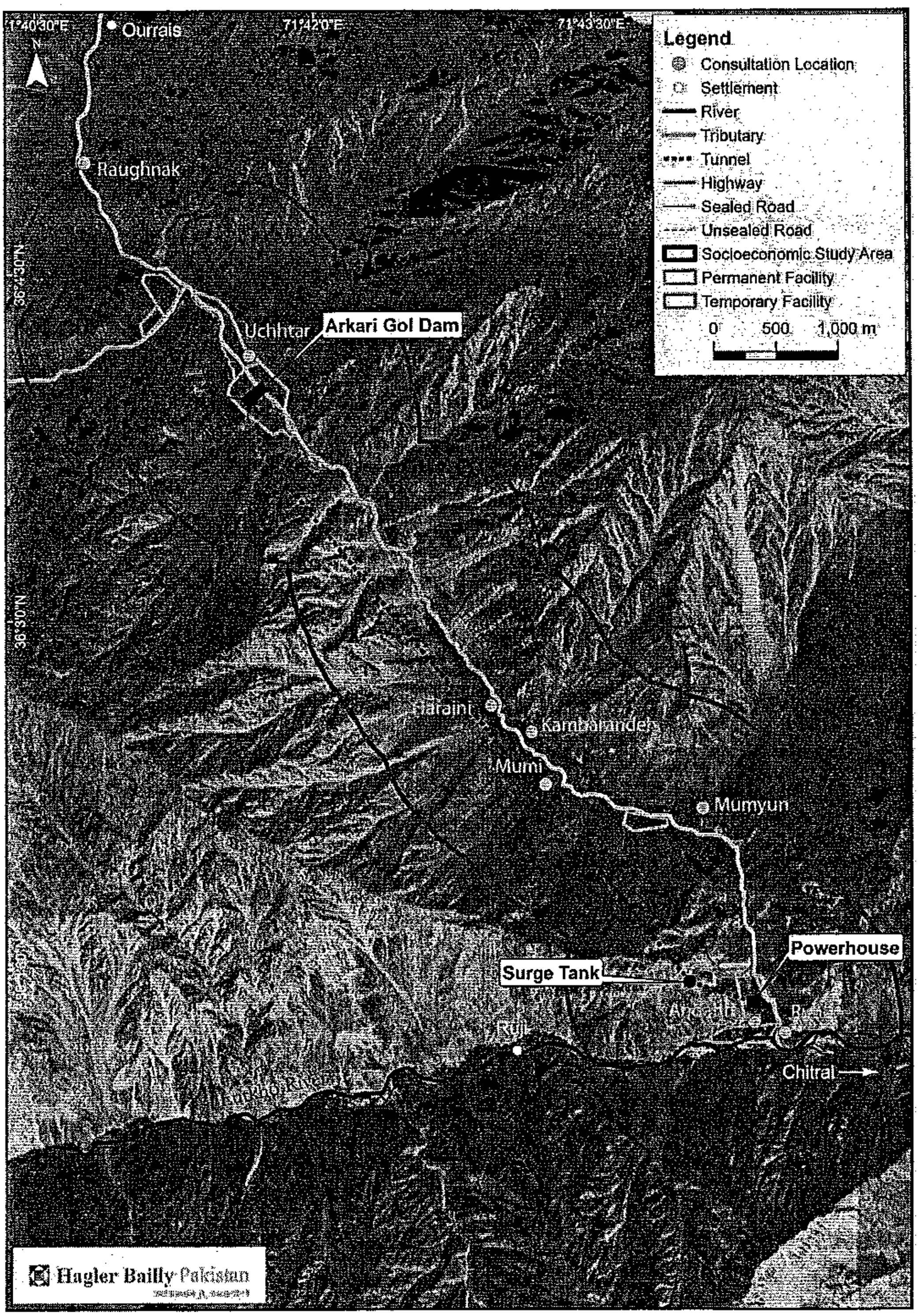
Stakeholders are groups or individuals that can affect or take affect from a project's outcome. Affected Communities include population that is likely to be affected by the Project activities. Potential impacts of the Project on the local environment include disturbances and changes to the physical and biological environment, such as, land transformation, noise disturbances, and air and water quality issues. These disturbances can result in indirect socioeconomic impacts, such as, physical or economic displacement. These impacts are expected to reduce with the increased distance from the Project facilities. A basin wide study approach was used for the ESIA of Arkari Gol HPP; therefore 8 rural communities were consulted along the Arkari Gol River.

Exhibit 6.1 lists the community stakeholders consulted. Consultation were conducted in representative number of communities while ensuring that people from various segments of the society participate in the consultation, to ensure proper coverage of possible stakeholder concerns. **Exhibit 6.2** shows location of stakeholders consulted near Project Site.

Exhibit 6.1: List of Community Stakeholders Consulted

Stakeholders	*Consultation Group*		*Date Consulted*
	No. of Men	*No. of Women*	
Raughnak	4	0	April 5, 2018
Mumyun	8	9	April 7, 2018
Kambarandeh	9	10	April 6, 2018
Haraini	6	11	April 8, 2018
Andahti / Runi	10	13	April 8, 2018
Uchhtar	8	11	April 7, 2018
Mumi 1	8	7	April 6, 2018

Exhibit 6.2: Consultation Locations



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Institutional Stakeholders

The institutional stakeholders consulted for the Project included relevant government agencies. The list of stakeholders consulted is shown in **Exhibit 6.3.**

Exhibit 6.3: List of Institutional Stakeholder

Stakeholders	*Date Consulted*
Wildlife Department, Chitral	April 10, 2018
Forest Department, Chitral	April 10, 2018
DC Office, Chitral	April 11, 2018
Fisheries Department, Chitral	April 11, 2018
Sarhad Rural Support Programme (SRSP), Chitral	April 12, 2018
Aga Khan Rural Support Programme (AKRSP), Chitral	April 12, 2018
Helping Hand, Chitral	April 13, 2018
Justice Aid and Development Foundation (JAD), Chitral	April 13, 2018

6.3.2 Consultations Mechanism

Community Consultation

The Potentially Affected Communities (PAC) were visited and consultations were conducted with the community members within their settlements to encourage and facilitate their participation. Representatives, notables and other interested groups from the Potentially Affected Communities were invited. In most of the consultation, women also participated, however, where required, separate consultations were conducted with community women.

Institutional Stakeholder Consultation

Letters to inform experts/institutional stakeholders about the objective of the consultation process and to arrange meetings with the stakeholders were dispatched in advance. BID and a detailed Institutional Stakeholder Consultation documents were enclosed with the letters for the information of the stakeholders.

For institutional consultation, HBP organized meetings in Chitral district for government departments and agencies. Invitations for the meetings were sent a week before the meeting and these were followed up with phone call to ensure maximum participation.

The key agenda items for the meetings with the communities, experts/institutional stakeholders, fishermen and sand miners communities included:

- An overview of the Project description to the community representatives;
- Description of the ESIA process that will be undertaken for the Project and presentation of a structure of the ESIA report to facilitate understanding of the report;
- A list of the possible environmental and social impacts of the Project.

6.3.3 Consultation Team

An ESIA specialist led the team, which comprised of stakeholder consultation experts and male/female social assistants that were familiar with the area and the local languages.

6.4 Summary of Consultations

6.4.1 Community Consultation

Exhibit 6.4 summarizes the key concerns emerging from community consultations and explains how each concern is addressed in the ESIA. The detailed log of consultations is provided in **Appendix J.** Photographs of the consultation are shown **Exhibit 6.5.**

6.4.2 Institutional Consultation

The key concerns emerging from institutional stakeholder consultations are summarized in **Exhibit 6.7.** The detailed log of consultations is provided in **Appendix K.**

Exhibit 6.4: Summary of Concerns Expressed and Management Measures Recommended

Concerns Expressed by Stakeholders	*How they are Addressed*	*Institution/ Community*
Opportunities		
The locals expressed their interest in jobs that will be available due to the Project.	The ESIA includes preference for locals in jobs.	Community
The locals expressed their interest in the improvements in education and healthcare that may be brought to their communities.	MHL will contribute to the community through Corporate Social Responsibility (CSR).	Community
The community wants the Project to bring improvements in livelihood, for example, access to safe drinking water, education facilities, hospitals etc.	MHL will contribute to the community through Corporate Social Responsibility (CSR) keeping in mind the developments mentioned by the community.	Community
The community wants new roads to be constructed and others to be improved so that land sliding is reduced. Land sliding is a serious risk in the area.	The Project will involve reconstruction of new roads for its implementation. These will benefit the community as well. It should be noted that building new roads for the community is not the responsibility of the Project. MHL will contribute to the community through Corporate Social Responsibility (CSR).	Community
The community requested that the Project supply them with LPG at subsidized rates so that they no longer need to use forest wood for fuel.	Supplying the community with LPG is not the responsibility of the Project. MHL will contribute to the community through Corporate Social Responsibility (CSR).	Community

Concerns Expressed by Stakeholders	How they are Addressed	Institution/ Community
Priority in jobs should be given to those who are most affected.	The ESIA includes preference for locals in jobs.	Community
Electricity should be provided to the affectees free of cost.	The Project proponent cannot take this decision. This is a federal government level consideration.	Community
Job opportunities will increase and infrastructure will improve.	The ESIA includes preference for locals in jobs.	Institutions
Electricity should be provided free of cost.	The Project proponent cannot take this decision. This is a federal government level consideration.	Institutions
Source of water		
The river is a source of water for the locals and the construction of a dam will result in interruption in this water supply. Therefore, their livelihoods will be affected for example impacts on agriculture.	The Project will not use the community water supply. If any local's water supply is affected, the Project will provide alternative supply. This is included in the budget of the EMP in ***Section 9***, Environmental Management Plan.	Community
Irrigation systems depend on river water and may be disrupted due to the Project.	If any irrigation water channel is affected, the Project will provide alternative supply. This is included in the budget of the EMP in ***Section 9***, Environmental Management Plan.	Community
Traffic		
Increased traffic due to the Project will results in difficulties for the locals especially for school-going children.	Impacts due to traffic are considered as part of the ESIA and mitigations for impacts due to increased traffic are provided in **Section 9**, *Environmental Management Plan*.	Community
Increased traffic especially heavy traffic will result in an increase in air and noise pollution.	Impacts due to traffic are considered as part of the ESIA and mitigations for impacts due to increased traffic are provided in **Section 9**, *Environmental Management Plan*.	Community
Graveyards		
If any graveyards and places of worship are affected the Project should provide them with newly constructed places of worship.	The Project is not affecting any graveyard. The places of worship that are being affected will be replaced by the Project.	Community

Concerns Expressed by Stakeholders	*How they are Addressed*	*Institution/ Community*
Resettlement		
Affected households should be properly compensated for the loss of land and property. The government should build homes for them.	A comprehensive Resettlement Action Plan (RAP) has been developed for the resettlement of affected people.	Community
People's homes are very important to them and hold value in terms of family ties.	People will be properly compensated for loss of houses and other assets. A comprehensive Resettlement Action Plan (RAP) has been developed.	Community
Land acquisition should be minimized. Those affected should be properly compensated. This should be done for all assets, not just land.	A comprehensive Resettlement Action Plan (RAP) has been developed for the resettlement of affected people. This includes compensation for loss of assets.	Community
Project developers should build a colony for affectees and provide alternative land.	The majority of affectees have opted for compensation instead of a colony.	Community
Grazing areas		
Grazing areas are watered using river water. A decrease in water in the river will result in a decrease in grazing areas as water will not be available for them.	If any source of water is affected, the Project will provide alternative supply. This is included in the budget of the EMP in **Section 9**, *Environmental Management Plan.*	Community
Springs		
Springs may dry up due to construction activities.	If any local's water supply is affected, the Project will provide alternative supply. This is included in the budget of the EMP in **Section 9**, *Environmental Management Plan.*	Community
Springs may become dry due to construction activities.		Institutions
Tunnel construction		
Construction of the tunnel may result in instability and an increase in landslides.	If there is any damage to community assets due to landsliding caused by tunnel construction, compensation will be provided. The Arkari Road will be upgraded, metaled and maintained. Extensive measures will be taken for stability in spoil disposal areas. These are included in **Section 9**, *Environmental Management Plan.*	Community
Land sliding is a major issue in the area.		Institutions

Concerns Expressed by Stakeholders	*How they are Addressed*	*Institution/ Community*
Influx of outsiders		
Due to influx of outsiders mobility of women will be affected.	A code of conduct will be included in the workers agreement to ensure that the locals' way of life is not affected.	Community
Fish fauna		
Fish may be affected and their populations may decrease due to dam construction.	An assessment of impacts on fish fauna is presented in **Section 7**, *Anticipated Environmental Impacts and Mitigation Measures* are included as well. These mitigation measures are made part of the **Section 9**, *Environmental Management Plan.*	Institutions
Flow-related issues		
River as well as the major tributaries with a significant perennial flow that support breeding of fish also affects due to dam construction	An assessment of impacts on fish fauna is presented in **Section 7**, *Anticipated Environmental Impacts and Mitigation Measures* and mitigation measures are included as well. These mitigation measures are made part of the **Section 9**, *Environmental Management Plan.*	Institutions

Exhibit 6.5: Photographs of Community Consultations

Consultation with men at settlement Andahti

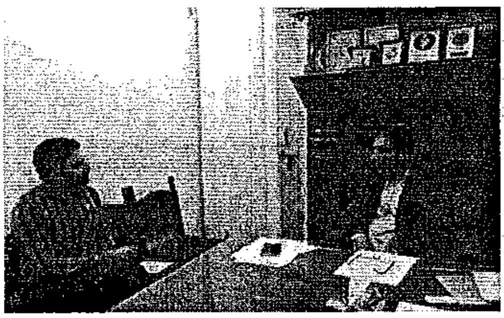
Consultation with men at settlement Mumyun

Consultation with women at settlement Uchhtar

Consultation with women at settlement Mumi 1

Exhibit 6.6: Photographs of Stakeholder Consultations

Consultation with DFO, Wildlife Department, Chitral



Consultation with RPM, AKRSP, Chitral

Consultation with DPM, SRSP, Chitral

6.5 Future Consultations

Further consultations to be undertaken as part of the Project ESIA process have been outlined in the **Stakeholder Engagement Plan** in **Appendix L.**

The Project management will continue community engagement activities throughout the life of the Project. Visits will be undertaken in all the communities twice or more times in a year, depending on the number of concerns raised under each consultation. Ongoing community engagement activities relevant to the ESIA include:

- Ongoing reporting on progress on the implementation of environmental and social management measures identified during the ESIA process and recording of comments on the effectiveness of these measures;
- Updating communities about new project developments and recording comments on these; and,
- Ongoing operation of the grievance redress mechanism (**Appendix L**).

An overview of Stakeholder Engagement Plan is provided in **Exhibit 6.7**.

Exhibit 6.7: List of Stakeholders and their Relevance for the ESIA and the Project

Stakeholder Group	*Stakeholders*	*Engagement Method*	*Frequency*
Government Institutions	Fisheries Department, KP Forest Department, KP Wildlife Department, KP Deputy Commissioner Office (DCO), Chitral	▶ Face-to-face meetings. ▶ Periodic reports	▶ Annually or earlier, if required
Non-Government Organizations	Aga Khan Rural Support Programme (AKRSP), Chitral Sarhad Rural Support Programme (SRSP), Chitral Helping Hand, Chitral Justice Aid and Development Foundation (JAD), Chitral	▶ Face-to-face meetings. ▶ Periodic reports	Annually or earlier, if required
Communities being relocated	Communities with river-dependent livelihoods and being relocated/resettled	▶ Meetings with the communities ▶ Visit to homes ▶ Group meetings ▶ Sharing of documents in Urdu	On an ongoing basis during resettlement process
Communities within a 500 m buffer of the river	Communities with river-dependent livelihoods	▶ Meetings with the communities ▶ Group meetings	At least once every year
Communities within 1 km of the Project infrastructure	Communities that may be directly impacted by the Project	▶ Meetings with the communities ▶ Group meetings ▶ Sharing of documents in Urdu	At least once every six month

7. Anticipated Environmental Impacts and Mitigation Measures

During the scoping stage of the ESIA process, several potential environmental and social impacts of the Project were identified. The baseline surveys were conducted keeping in consideration the potential impacts. In this section, the potential environmental and social impacts are evaluated. The impacts have been identified based on consideration of the information presented in previous sections. To avoid unnecessary repetition of supporting information, cross referencing to previous sections is given where necessary. Following the impact assessment, the mitigation measures related to each impact category is presented.

7.1 Introduction

The general methodology used for impact assessment is described in this section. It describes the process of impact identification and definition, significance rating, the mitigation, management and good practice measures.

7.1.1 Impact Identification and Definition

There are several guidelines and textbooks on identification and description of environmental and social impacts. These documents use various tools in an attempt to define a comprehensive and consistent method to capture the potential impacts of a proposed Project. However, it is now widely recognized by ESIA practitioners that impact evaluation is not a purely objective and quantitative exercise. It has a subjective element; often based on judgment and values as much as scientific criteria. Recognizing this, a uniform system of impact description is used to enable the reviewers to understand how impacts have been interpreted. The description of each impact will have the following features:

- a definition of the impact using an **impact statement** identifying the Project activity or activities that causes the impact, the pathway or the environmental parameter that is changed by the activity, and the potential receptors of the impact (aspect-pathway-receptor)
- **description of the sensitivity and importance value** of the receiving environment or receptors (based on the stakeholder consultations undertaken)
- **extent of change** associated with the impact
- **rating of the significance** of the impact
- description of appropriate mitigation and management measures and potential effectiveness of the proposed measures
- characterization of the level of uncertainty in the impact assessment

The significance of an impact is determined based on the product of the consequence of the impact and the probability of its occurrence. The consequence of an impact, in turn, is a function primarily of three impact characteristics:

- magnitude
- spatial scale
- timeframe

Magnitude is determined from quantitative or qualitative evaluation of a number of criteria including:

- sensitivity of existing or reasonably foreseeable future receptors
- importance value of existing or reasonably foreseeable future receptors, described using the following:
  - inclusion in government policy
  - level of public concern
  - number of receptors affected
  - intrinsic or perceived value placed on the receiving environment by stakeholders
  - economic value to stakeholders
- severity or degree of change to the receptor due to impact, measured qualitatively or quantitatively, and through comparison with relevant thresholds:
  - legal thresholds—established by law or regulation
  - functional thresholds—if exceeded, the impacts will disrupt the functioning of an ecosystem sufficiently to destroy resources important to the nation or biosphere irreversibly and/or irretrievably
  - normative thresholds—established by social norms, usually at the local or regional level and often tied to social or economic concerns
  - preference thresholds—preferences for individuals, groups or organizations only, as distinct from society at large
  - reputational thresholds—the level of risk a company is willing to take when approaching or exceeding the above thresholds

Spatial scale is another impact characteristic affecting impact consequence. The spatial scale of impacts can range from localized (confined to the proposed Project site) to extensive (national or international extent). They also may vary depending on the component being considered.

The impact **timeframe** is the third principal impact characteristic defining impact consequence and relates to either its duration or its frequency (when the impact is intermittent). Impact duration can range from relatively short (less than four years) to long (beyond the life of the Project). Frequency ranges from high (more than 10 times a year) to low (less than once a year). These timeframes will need to be established for each Project based on its specific characteristics and those of the surrounding environment.

Once the impact consequence is described on the basis of the above impact characteristics, the **probability of impact** occurrence is factored in to derive the overall impact significance. The probability relates to the likelihood of the impact occurring, not the probability that the source of the impact occurs. For example, a continuous Project activity may have an unlikely probability of impact if there are no receptors within the area influenced by that activity.

The **reversibility of each impact** at the end of construction and operation are important, as these impacts may need on-going management after operation. The reversibility of each impact at the end of construction and operation will be noted and described alongside the three primary characteristics of magnitude, spatial scale and duration. The characteristics are outlined in **Exhibit 7.1**.

Exhibit 7.1: Characteristics Used to Describe Impact

Characteristics	*Sub-components*	*Terms used to describe the impact*
Type		Positive (a benefit), negative (a cost) or neutral
Nature		Biophysical, social, cultural, health or economic Direct, indirect or cumulative
Phase of Project		Construction, operation, decommissioning or post closure
Magnitude	Sensitivity of receptor	High, medium or low capacity to accommodate change High, medium or low conservation importance Vulnerable or threatened Rare, common, unique, endemic
	Importance or value of receptor	High, medium or low concern to some or all stakeholders High, medium or low value to some or all stakeholders (for example, for cultural beliefs) Locally, nationally or internationally important Protected by legislation or policy
	Severity or degree of change to the receptor	Gravity or seriousness of the change to the environment Intensity, influence, power or strength of the change Never, occasionally or always exceeds relevant thresholds
Spatial scale	Area affected by impact - boundaries at local and regional extents will be different for biophysical and social impacts.	Area or Volume covered Distribution Local, regional, transboundary or global

Characteristics	*Sub-components*	*Terms used to describe the impact*
Timeframe	Length of time over which an environmental impact occurs or frequency of impact when intermittent	Short term or long term Intermittent (what frequency) or continuous Temporary or permanent Immediate effect (impact experienced immediately after causative project aspect) or delayed effect (effect of the impact is delayed for a period following the causative project aspect)
Probability - likelihood or chance an impact will occur		Definite (impact will occur with high likelihood of probability) Possible (impact may occur but could be influenced by either natural or project related factors) Unlikely (impact unlikely unless specific natural or Project related circumstances occur)
Reversibility/Sustainability		Potential for recovery of the endpoint from a negative impact Reversible or irreversible Sustainability for positive impacts
Effectiveness of management measures (will management measures reduce impact to an acceptable level)		Indication of what could occur in the absence of management measures Effectiveness of proposed measures
Confidence in impact evaluation (degree of certainty in the significance ascribed to the impact)		Scientific uncertainty – limited understanding of ecosystem (or community) and processes governing change Data uncertainty – restrictions introduced by incomplete or incomparable information, or by insufficient measurement techniques Policy uncertainty – unclear or disputed objectives, standards or guidelines

7.1.2 Impact Significance Rating

The impact significance rating process serves two purposes: firstly, it helps to highlight the critical impacts requiring consideration in the approval process; secondly, it serves to show the primary impact characteristics, as defined above, used to evaluate impact significance. The impact significance rating system is presented in **Exhibit 7.2** and described as follows:

- **Part A:** Define impact consequence using the three primary impact characteristics of magnitude, spatial scale and duration.
- **Part B:** Use the matrix to determine a rating for impact consequence based on the definitions identified in Part A; and
- **Part C:** Use the matrix to determine the impact significance rating, which is a function of the impact consequence rating (from Part B) and the probability of occurrence.

Using the matrix, the significance of each described impact is rated.

Exhibit 7.2: Method for Rating the Significance of Impacts

PART A: DEFINING CONSEQUENCE IN TERMS OF MAGNITUDE, DURATION AND SPATIAL SCALE *Use these definitions to define the consequence in Part B*			
Definition		Criteria	
MAGNITUDE		Negative	Positive
	Major	Large number of receptors affected Receptors highly sensitive and/or are of conservation importance Substantial deterioration, nuisance or harm to receptors expected Relevant thresholds often exceeded Significant public concern expressed during stakeholder consultation Receiving environment has an inherent value to stakeholders	Large number of receptors affected Receptors highly amenable to positive change Receptors likely to experience a big improvement in their situation Relevant positive thresholds often exceeded
	Moderate	Some receptors affected Receptors slightly sensitive and/or of moderate conservation importance Measurable deterioration, nuisance or harm to receptors Relevant thresholds occasionally exceeded Limited public concern expressed during stakeholder consultation Limited value attached to the environment	Some receptors affected Receptors likely to experience some improvement in their situation Relevant positive thresholds occasionally exceeded
	Minor	No or limited receptors within the zone of impact Receptors not sensitive to change Minor deterioration, nuisance or harm to receptors Change not measurable or relevant thresholds never exceeded Stakeholders have not expressed concerns regarding the receiving environment	No or limited receptors affected Receptors not sensitive to change Minor or no improvement in current situation Change not measurable Relevant positive thresholds never exceeded No stakeholder comment expected
TIMEFRAME (determine specific to each Project)		Duration of continuous aspects	Frequency of intermittent aspects
	Short term/ low frequency	Less than 5 years from onset of impact coinciding with the active construction period	Occurs less than once a year
	Medium term/ frequency	More than 5 years from onset of impact up to 15 years	Occurs less than 10 times a year but more than once a year
	Long term/ high frequency	Impact is experienced during and beyond 15 years	Occurs more than 10 times a year
SPATIAL SCALE (determine specific to each project)		Biophysical	Socio-economic
	Small	Within the project fence line or within 200 m of unfenced facilities, or to less than a 6 km reach of a river on which the project is located	Within the 200 m of the Project footprint in which the activity occurs

	Intermediate	Within 3 km of the area in which the facilities are located, or to more than 6 km reach of the river on which project is located, but not extending beyond the sub basin	Within 15 km of the Project activities		
	Extensive	Beyond 3 km of the area in which the facilities are located, or extending basin wide in the river system	Beyond 15 km of the Project activity		
PART B: DETERMINING CONSEQUENCE RATING *Rate consequence based on definition of magnitude, spatial extent and duration*					
MAGNITUDE		TIMEFRAME	SPATIAL SCALE		
			Small	Inter-mediate	[illegible]
Minor		Short term / low frequency	Low	Low	Medium
		Medium term / frequency	Low	Low	Medium
		[illegible]	Medium	Medium	Medium
Moderate		Short term / low frequency	Low	Medium	Medium
		Medium term / frequency	Medium	Medium	[illegible]
		[illegible]	Medium	[illegible]	[illegible]
[illegible]		Short term / low frequency	Medium	Medium	[illegible]
		Medium term / frequency	Medium	Medium	[illegible]
		[illegible]	[illegible]	[illegible]	[illegible]
PART C: DETERMINING SIGNIFICANCE RATING *Rate significance based on consequence and probability*					
			CONSEQUENCE		
			Low	Medium	High
PROBABILITY (of exposure to impacts)		[illegible]	Low	Medium	[illegible]
		Possible	Low	Medium	[illegible]
		Unlikely	Low	Low	Medium

7.1.3 Mitigation, Management and Good Practice Measures

Using the matrix, the significance of each described impact is initially rated. This initial rating assumes the management measures inherent in the Project design and described in the Project description (**Section 3**, *Description of the Project*) are in place. For example, if a fuel store has secondary containment, the initial impact rating takes this into account.

Wherever the Project is likely to result in unacceptable impact on the environment, additional mitigation measures are proposed (over and above the inherent design measures included in the Project description). In addition, good practice measures may be proposed however these are unlikely to change the impact significance. In the case of positive impacts, management measures are suggested to optimize the benefits to be gained. Where mitigation measures are required the impact will be rated again to show the residual impact after implementation of management controls.

The following mitigation hierarchy will be utilized in selecting practical mitigation measures for unacceptable impacts as follows (in order of preference):

- avoid the impact wherever possible by removing the cause(s)
- reduce the impact as far as possible by limiting the cause(s)
- ameliorate the impact by protecting the receptor from the cause(s) of the impact
- providing compensatory measures to offset the impact, particularly where an impact is of high significance and none of the above are appropriate.

A rating of impact considering mitigations will be carried out to highlight the effectiveness of proposed management measures designed to mitigate or enhance the impact, and by characterizing the level of confidence or uncertainty in the assessment.

For each of the impacts identified, a table will be filled in **Exhibit 7.3**.

Exhibit 7.3: Impact Assessment Template

Impact 01: Changes in ecological conditions downstream of the dam i.e. creation of a flow section								
Applicable Project Phase				*Construction*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Long Term	Extensive	High	Definite	High	-	High
Mitigation Measures:								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Major	Long Term	Extensive	High	Definite	High	+	High

7.1.4 Impact Grouping

The impacts in this Section are grouped as follows:

- Ecology
  - 7.2 Aquatic Ecology
  - 7.3 Terrestrial Ecology
- Physical Environment
  - 7.4 Ambient Air Quality
  - 7.5 Blasting and Vibration
  - 7.6 Construction Noise
  - 7.7 Water Availability and Quality
  - 7.8 Soil, Topography, Land Stability
  - 7.9 Aesthetics
  - 7.10 Traffic and Road
- Socioeconomic Environment
  - 7.11 Livelihood and Well-being
  - 7.12 Socio-cultural Impacts
- Cross-thematic Aspects
  - 7.13 Greenhouse Gas Emissions
  - 7.14 Climate Change
  - 7.15 Cumulative Impact Assessment

7.2 Aquatic Ecology

An overview of the aquatic ecological resources in the Study Area is given in **Section 4.1.4**, *Aquatic Ecology*.

Project impacts on aquatic ecology are assessed within the river and tributaries where the aquatic ecological resources are likely to be impacted by the Project, called the Area of Impact (AoI). Details are presented in **Appendix M** (*Environmental Flow Report*). The AoI (**Exhibit 7.4**) considers the Project footprint including the reservoir, the changes it will make to the hydrology and connectivity of the river, including the major tributaries that drain into the stretch of Jhelum River affected by the Project. The AoI can be divided into three distinct segments. The segments which the Project will impact are described below:

- Arkari Gol, upstream of its confluence with Lutkho River: the riverbed in this segment has a relatively higher slope resulting in higher water velocities and frequent rapids and falls. The valley is V shaped with relatively steep and narrow. The migratory Snow Trout was not recorded in this section. No fish were recorded above the water fall (Segment 1 in **Exhibit 7.4**) which presents a barrier to upstream movement of the Snow Trout. Relative abundance of fish is apparently low (see **Section 4.1.4**) downstream of the waterfall (Segment 2 in **Exhibit 7.4**), and the habitat is least conducive to supporting fish populations relative to that in other segments in the Aquatic Study Area (see **Section 4.1.1**).

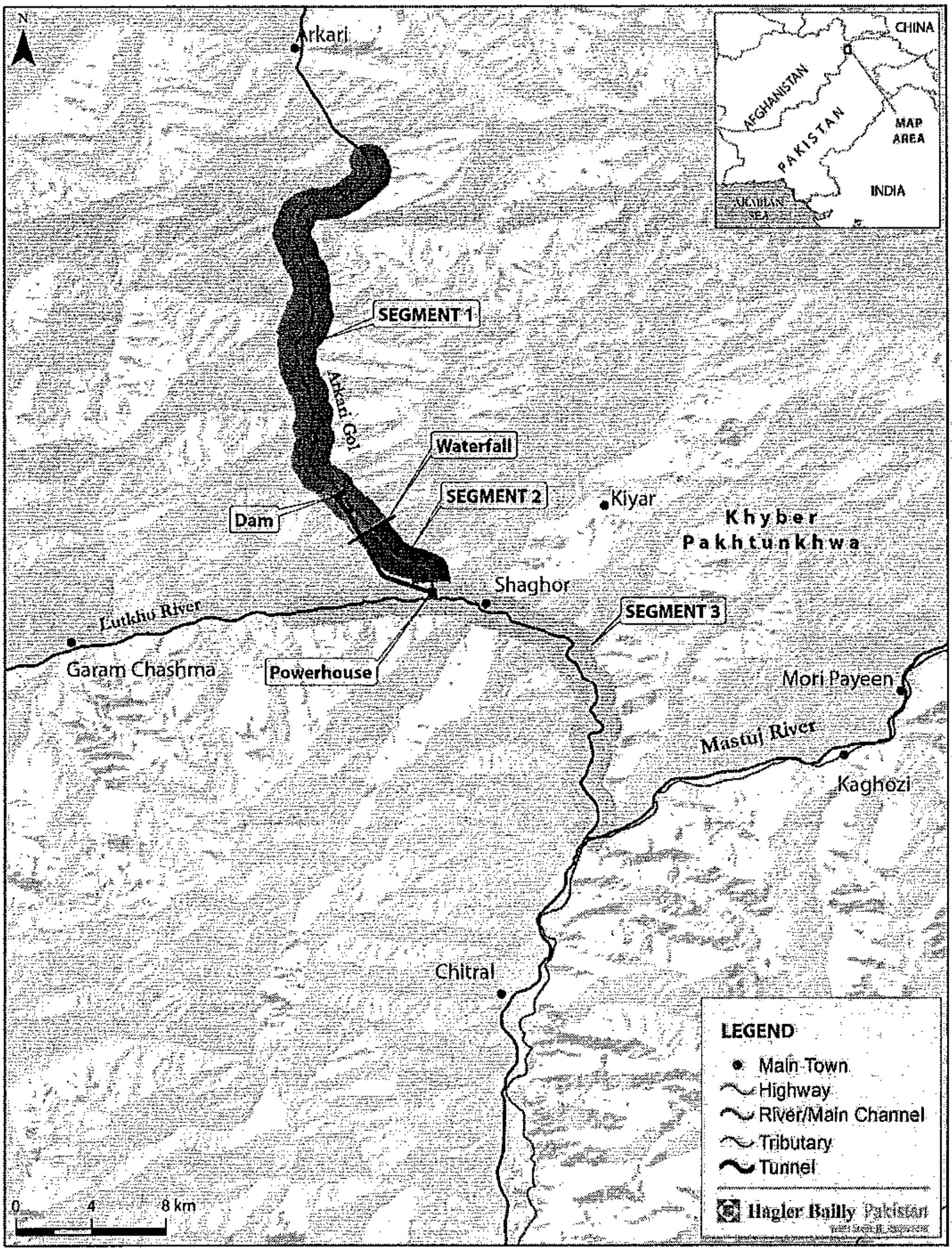
- Lutkho River: With a slope of the riverbed that is lower in comparison to that in Arkari Gol, the habitat in this segment (Segment 3 in **Exhibit 7.4**) is comparatively stable with sequences of pools and rapids. The valley is U shaped with gentle slopes. Diversity and abundance of fish is relatively higher with existence of the three species namely the Snow Trout, the Himalayan Catfish, and the Chitral Loach, and breeding of Snow Trout (**Exhibit 4.10**). A flow downstream of confluence with Arkari Gol also increases, increasing the extent of habitats. Sediment loads are low (about 4% of sediment in Chitral River), and abundance of macro-invertebrates is relatively high due to well armored cobble beds.

Flow as well as sediment loads are substantially higher in Mastuj/Chitral River (**Exhibit 7.4**). Suitable fish habitats exist in side channels where flow is moderate. Diversity is expected to be higher as there are number tributaries that feed into this river. Habitat conditions are not likely to be suitable for breeding as compared to those in Lutkho River, and food availability for fish, mainly macroinvertebrates, is also likely to be lower as the river bed would consist of sand and boulders as compared to predominantly cobbles in the Lutkho River and Arkari Gol. During summer months the river carries a very large amount of silt in suspension giving the water a distinctly reddish color on account of the color of the soil over which it flows. The impact of the Project on this section associated with variations ion flow will be limited by attenuation of the peaking flows from the Project by the flow of Mastuj/Chitral River. There will be some residual impact associated with the impact the Project flow alterations due to the project will have on the breeding of the Snow Trout in the Arkari Gol and Lutkho Rivers, and its consequential impacts on its population in the Mastuj/Chitral River. This impact will also be very limited as there are a number other tributaries of Mastuj/Chitral River that provide breeding grounds for the Snow Trout, in addition to the main river itself. The ecological impacts of the Project on Segment 4, i.e. Mastuj/Chitral River, are therefore not discussed further in this section.

The construction of the Project will result in the formation of a reservoir upstream of the dam. A segment of the river of length 1.3 km upstream of the dam will be inundated by the creation of the reservoir, where the river will cease to exist. As there is a natural barrier (waterfall) about 2.5 km downstream of the dam, there are no species in the waters upstream of the dam. Therefore, the reservoir will not have significant impacts on the fish fauna of Arkari Gol. While production of macroinvertebrates in the impoundment will be severely affected, the areas downstream of the dam are also productive for macroinvertebrates. The impact of loss of macroinvertebrates which are a food source for the fish was considered in the EFlow assessment for the Project.

The river downstream of the dam will be exposed to lower flows due to diversion of the river flow. The low flow section will be 7.3 km. Environmental flow ranging from 0.8-2 m^3/s over different months of the year is recommended (see **Appendix M,** *Environmental Flow Report*).

Exhibit 7.4: Area of Impact



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The impacts of the proposed Project on the aquatic biodiversity are summarized below and described in detail in **Appendix M** (*Environmental Flow Report*). These include:

- Impact 01: Changes in ecological conditions downstream of the dam i.e. creation of a low flow section leading to loss of aquatic biodiversity
- Impact 02: Changes in ecological conditions downstream of the powerhouse due to release of water leading to loss of aquatic biodiversity

7.2.1 Loss of Aquatic Biodiversity due to Creation of a Low Flow Section Downstream of the Dam

Impact 01: Loss of Aquatic Biodiversity due to Creation of a Low Flow Section Downstream of the Dam								
Applicable Project Phase				*Construction and Operation*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Long Term	Small	Moderate	Definite	Medium	-	High
Mitigation measures: 1. Maintain environmental flow as recommended in Project design 2. Regulate activities of the staff so that they do not engage in illegal exploitation of wildlife such as illegal fishing and poaching 3. Construction activities should be carried out whilst ensuring that there is no run-off of silt into the river and that the river is not contaminated to ensure that water quality is not affected 4. Illegal fishing activities will be curtailed by providing support to the government in implementation of river protection. 5. The Project will help the Wildlife and Fisheries Departments by providing one field office, three motor cycles, 5 guards and 1 inspector to protect river biodiversity and terrestrial wildlife, subject to an agreement in which the responsibilities of the Project and the Departments are clearly defined and performance of the protections activities is independently monitored. Improvement in aquatic and terrestrial biodiversity through protection will partly offset the residual impacts of the Project on aquatic ecology. 6. Limited subsistence fishing using rods and cast nets could be allowed through a permitting system.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Long Term	Small	Moderate	Definite	Medium	-	High

Details of impacts on aquatic ecology are provided in **Appendix M** (*Environmental Flow Report*). Fish were not observed to be present in the 3 km segment of the river above the waterfall in the low flow section (**Exhibit 7.4**), which presents a natural barrier to movement of the fish upstream. Impacts on fish fauna will therefore be limited to the 6 km reach of the river in the low flow segment downstream of the waterfall. Here there will be a degradation of ecological habitat due to reduction in flow. The impacts on the riverine biodiversity in the low flow section will mainly be on macro-invertebrates, Snow Trout and Chitral Loach. The abundance of all three is expected to decrease to 56%, 58% and 20% of their present day populations respectively over a period of 31 years.

For macro-invertebrates represented by Ephemeroptera, Plecoptera and Tricoptera (EPT) abundance, this will be due to reduction in the wet season duration and the delay in the onset of wet season will not provide sufficient time for eggs to mature and hatch. Similarly, the Snow Trout will decline in abundance in the low flow section due to reduction in the maximum flood season flows and the barrier to migration created by the Project.

The Snow Trout is a long distance migratory fish therefore cues and suitable habitat during migration and breeding are key factors for its survival. The delay in the onset of the wet season, (and a lack of wet season in years where there are little to no spills) will affect migration and breeding in this reach. Similarly, due to reduction in the maximum flood season flows, inflow to pools will be less and water levels will be lower in this reach. Flood peaks also scour pools and with a reduction in flood peak, the pools will become shallower. Therefore, smaller flood peaks will lead to a degradation in overall yearlong habitat for the fish over time in this reach. More details are provided in **Appendix M** (*Environmental Flow Report*).

The Chitral Loach is a more sensitive species as compared to the Snow Trout in terms of food sources, summer and winter habitat and breeding cues. It feeds exclusively on aquatic invertebrates and therefore, a decline in EPT abundance will have a greater impact on it relative to impacts on the Snow Trout which is a more opportunistic feeder with an omnivorous diet.

While impacts on aquatic ecology in the low-flow section are expected to be significant, the basin-wide impacts on the aquatic ecological resources will not be high. This is because all the fish species reported from the Aquatic Study Area are widespread. There are no endemic fish species and the only fish of conservation importance is the Snow Trout which is a long distance migratory fish, has high commercial importance and is listed as Vulnerable in the IUCN Red List. This fish is widespread and has been reported from India, Nepal, Bhutan, Pakistan and Afghanistan. In the Study Area, the Snow Trout is not found above an altitude of 2,810 m and in the Arkari Gol the presence of a natural water fall (2.5 km downstream of the proposed dam site) restricts its presence upstream of the waterfall.

7.2.2 Loss of Aquatic Biodiversity due to Changes in Ecological Conditions Downstream of the Powerhouse as a Result of Release of Water

Impact 02: Loss of Aquatic Biodiversity due to Changes in Ecological Conditions Downstream of the Powerhouse as a Result of Release of Water								
Applicable Project Phase				*Construction and Operation*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Long Term	Small	Moderate	Definite	Medium	-	High

Mitigation measures:

1. Design peaking operation to reduce impacts on aquatic ecology as recommended in the EFlow Assessment (see **Appendix M**)
2. Regulate activities of the staff so that they do not engage in illegal exploitation of wildlife such as illegal fishing and poaching
3. Construction activities should be carried out whilst ensuring that there is no run-off of silt into the river and that the river is not contaminated to ensure that water quality is not affected
4. Illegal fishing activities will be curtailed by providing support to the government in implementation of river protection.
5. The Project will help the Wildlife and Fisheries Departments by providing one field office, three motor cycles, 5 guards and 1 inspector to protect river biodiversity and terrestrial wildlife, subject to an

agreement in which the responsibilities of the Project and the Departments are clearly defined and performance of the protections activities is independently monitored. Improvement in aquatic and terrestrial biodiversity through protection will partly offset the residual impacts of the Project on aquatic ecology. 6. Limited subsistence fishing using rods and cast nets could be allowed through a permitting system.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Long-term	Small	Moderate	Definite	Medium	-	High

Downstream of the tailrace the impacts on aquatic ecology depend on the operational scenario selected. Under true run of river conditions where no peaking is carried out populations of the Snow Trout and Chitral Loach will not decline due to the Project. However, under peaking conditions their populations will decline to 40% and 50% of present day baseline levels, respectively, over a period of 31 years. A modified peaking scenario is an option in which the peak is reduced to 24 m^3/s and flow is gradually ramped up to peak level and is then ramped down towards the end of the peaking period. This will buffer the impact of a peaking operation. Under this operational scenario the Snow Trout will decline to 70% of baseline while the Chitral Loach will not be significantly impacted downstream of the powerhouse. More details are provided in **Appendix M** (*Environmental Flow Report*).

As mentioned above, the fish species of the Aquatic Study Area are widespread. No endemic fish species have been reported and the only fish of conservation importance is the Snow Trout. While the fish fauna immediately downstream of the powerhouse will decline as a result of water release, the basin-wide impacts on the fish will not be high.

7.3 Terrestrial Ecology

The Project is a run-of-river hydropower project and will require construction of a dam on the Arkari Gol which is a tributary of the Lutkho River. The Project, with design capacity of 99 MW, will use the water resources of the Arkari Gol for power generation.

The major structures associated with the Project include the dam and spillway, headrace tunnel and tailrace channel, workshop building, diversion tunnels, powerhouse, construction camps, waste disposal areas and quarry areas. A detailed description of the Project is provided in **Section 3** (*Description of the Project*). The permanent footprint of the proposed Project includes the area that will be acquired for the dam, reservoir, powerhouse and other facilities. A temporary footprint includes the land that will be required or disturbed due to the facilities that will be developed during the construction phase.

The Area of Habitat Loss is defined as the areas that will be occupied due to construction and operation of Project infrastructure.[1] It has been demarcated taking into consideration the footprint of each Project facility and a 50 m zone around each facility, as well as the area that will be submerged under water due to formation of the reservoir (**Exhibit 7.5**). The Area of Habitat Loss is estimated at 1.03 km^2.

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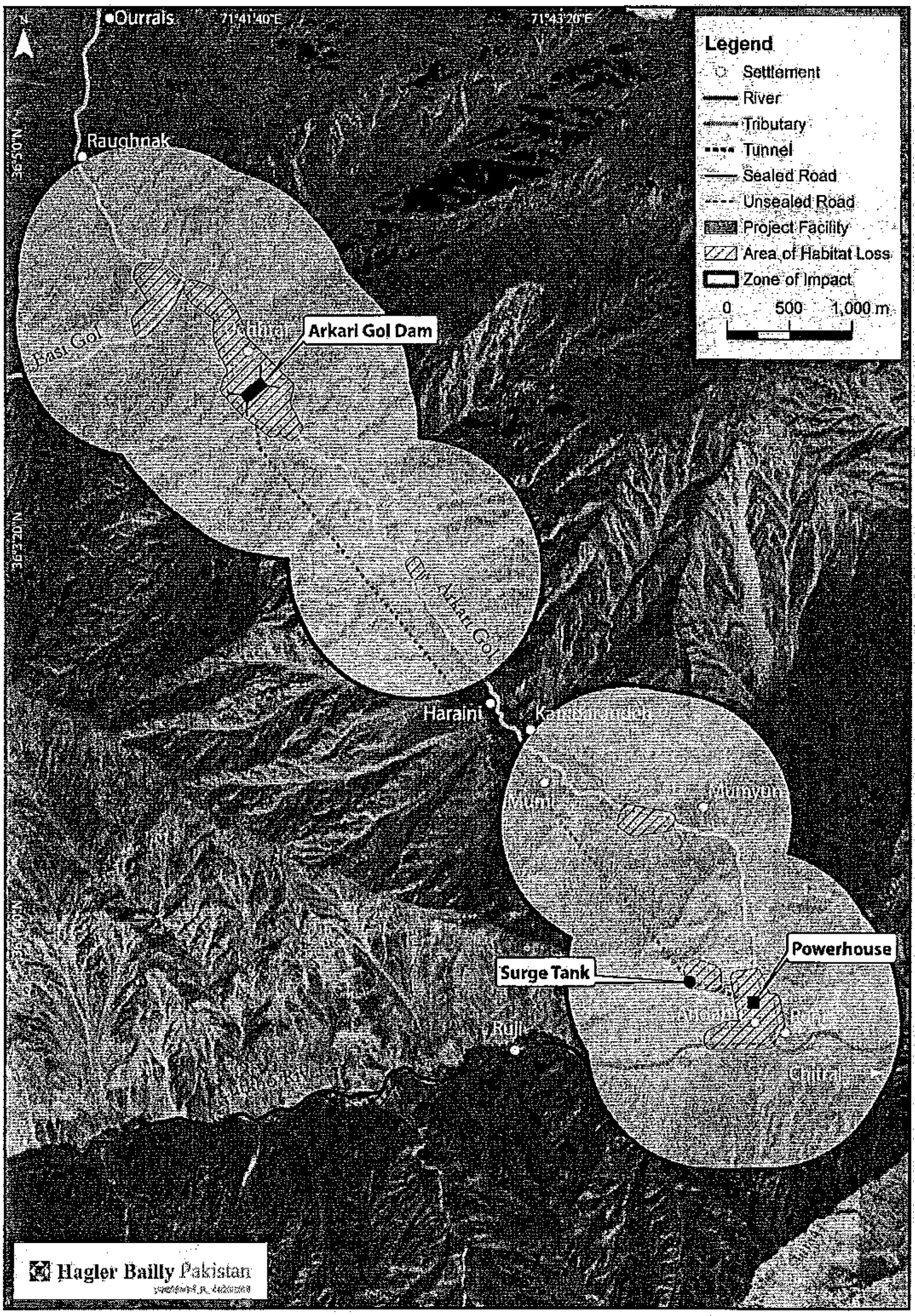
1 This includes temporary facilities

The Zone of Impact for Terrestrial Ecological Resources (referred to in this section as the Zone of Impact) consists of the Project facilities and a 1 km potential impact zone around these facilities to account for an area in which the ecological resources may be impacted by Project-related disturbances such as sound, light and vibrations during construction and operations (**Exhibit 7.5**).

The terrestrial ecological resources of the Study Area are described in **Section 4.2.7** (*Terrestrial Ecology*). The aspects affecting ecology and biodiversity in the Terrestrial Study Area are discussed below:

- Impact 03: Terrestrial habitat loss caused by construction related activities.
- Impact 04: Decline in abundance and diversity of terrestrial flora and fauna caused by construction related activities.
- Impact 05: Project operation leading to animal disturbance, displacement and decline.

Exhibit 7.5: Zone of Impact and Area of Habitat Loss



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7.3.1 Terrestrial Habitat Loss

Impact 03: Terrestrial habitat loss caused by construction of Project infrastructure								
Applicable Project Phase					*Construction*			
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Possible	Low	-	High
Mitigation measures:								
1. Minimize the Project footprint, clearly delineate and restrict access beyond work sites and other areas to be disturbed. 2. Minimize disturbance to, or movement of, soil and vegetation; Prevent soil damage and erosion; retain as much natural vegetation as possible. 3. Prevent Alien Invasive Species (AIS) establishment on exposed stored soil (do not store bare soil near known sources of AIS). Invasive plant species was not observed in the Terrestrial Study Area, however few invasive species like Marijuana, Strumarium *Xanthium strumarium* and Castor Oil Plant *Ricinus communis* were observed in the lower parts of the Aquatic Study Area. 4. Train and raise awareness regarding AIS among Project staff and contractors. 5. Solid waste should only be disposed of at designated sites and a Waste Management Plan developed and implemented. 6. Within the quarry areas, activities will be restricted to areas at a distance from perennial water channels so as to avoid disturbances to them including the risk of siltation.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Possible	Low	-	High

Site clearance and construction of Project infrastructure such as the powerhouse, dam, and the inlets and outlets of the tunnels will result in immediate and direct modification of land and loss of approximately 0.373 km^2 (37.3 hectares) of terrestrial habitat leading to loss of plants and displacement of animals in this area. There will be a permanent modification of land within the footprint of specific Project facilities and its ancillaries but the loss will be less severe in the areas that lie adjacent to and immediately outside the Project facilities. In addition, once the Project begins operations, an area of approximately 0.12 km^2 (12 hectares) will become submerged due to formation of a reservoir upstream of the dam (**Section 3**, *Project Description*). The submerged terrestrial habitat will be converted into aquatic habitat. The habitat loss and fragmentation resulting from Project infrastructure will lead to displacement of terrestrial species.

The Area of Habitat Loss (total of 7.5 km^2) consists largely of Barren Land, Vegetation Cluster and Riparian habitat. Common plant species found in the area of habitat loss include *Artimisa maritima, Rumex hastatus, Sisymbrium irio, Robinia pseudoacacia* and *Salix acmophylla.* Of these *Artimisa maritima* is a medicinally important plant.

All these species are common and abundant in the wider area. Habitat loss caused by construction of Project infrastructure will not have any significant impact on the overall population of these vegetation species though individual plants are likely to suffer harm.

7.3.2 Impacts on Biodiversity due to Construction Activities

<table>
<tr><td colspan="9">Impact 04: Decline in abundance and diversity of terrestrial flora and fauna caused by construction related activities.</td></tr>
<tr><td colspan="5">Applicable Project Phase</td><td colspan="4">Construction</td></tr>
<tr><td rowspan="2">Initial Impact</td><td>Magnitude</td><td>Duration</td><td>Scale</td><td>Consequence</td><td>Probability</td><td>Significance</td><td>+/-</td><td>Confidence</td></tr>
<tr><td>Minor</td><td>Short Term</td><td>Small</td><td>Low</td><td>Possible</td><td>Low</td><td>-</td><td>High</td></tr>
<tr><td colspan="9">Mitigation measures:
1. Provide awareness training to staff and contractors on: prevention of injury of animals; identification of likely species found on site (Snow Leopard, Grey Wolf, Red Fox, Asiatic Jackal, Flare-horned Markhor and Himalayan Ibex); identifications of animal hazards (such as venomous snakes); what to do if dangerous animals are encountered; report kills of large mammals and other migratory water fowls particularly designated species of conservation concern.
2. Provide adequate knowledge to the workers on relevant government regulations and punishments for illegal poaching and trade in animals and plants; incorporate in contract documents regulations for Project staff and contractors to avoid illegal poaching of wild animals (Flare-horned Markhor and Himalayan Ibex); MHL to report incidents of poaching and illegal fishing to concerned government departments.
3. Large flood lights should not be installed outside 50 m of the Project fence. The lights should be directed towards Project facilities and not towards the natural habitats
4. Enforce speed limits in ecologically sensitive areas if identified.
5. The Contractor shall prepare an Environmental Training Plan for all construction workers and all Contractor's employees shall be required to provide evidence that they attended the training sessions detailed in the Plan. The Plan should include information about the following issues: fire arm possession, traffic regulations, illegal logging and collection of non-timber forestry products, non-disturbance of resettlement communities, hunting and fishing restrictions, waste management, erosion control, health and safety issues, the Code of Conduct requirements and disciplinary procedures, and general information on the environment in which they will be working and living;
6. Coordinate with the government departments (Fisheries and Wildlife Departments)
7. Facilitate government department staff when they arrive at the site for example provide them accommodation and vehicles.
8. Equipment emitting excessive noise in comparison with other similar equipment will not be allowed to operate. Equipment under use will be regularly maintained, tuned, and provided with mufflers to minimize noise levels;
9. Blowing of horn will be prohibited on all sensitive areas except under emergency conditions.
10. Source goods/materials locally where possible.
11. Minimize disturbance to, or movement of, soil and vegetation; prevent soil damage and erosion;
12. Prevent AIS establishment on exposed stored soil (do not store bare soil near known sources of AIS).
13. Plant compensatory trees for those damaged during construction
14. Train and raise awareness regarding AIS among Project staff and contractors (see Section 4.2.7).
15. Solid waste should only be disposed of at designated sites.</td></tr>
<tr><td rowspan="2">Residual Impact</td><td>Magnitude</td><td>Duration</td><td>Scale</td><td>Consequence</td><td>Probability</td><td>Significance</td><td>+/-</td><td>Confidence</td></tr>
<tr><td>Minor</td><td>Short Term</td><td>Small</td><td>Low</td><td>Possible</td><td>Low</td><td>-</td><td>High</td></tr>
</table>

Construction of Project infrastructure such as the powerhouse, dam and tunnels will result in disturbance to the floral and faunal species in the Zone of Impact around the Project facilities (**Exhibit 7.5**) due to blasting, noise, vibrations, illumination, and introduction of alien species. Pollution may increase due to vehicles and machinery, spillage of fuels or chemicals, emissions and noise. Increased movement of vehicles will increase the risk of incidences of vehicle collisions with wildlife.

Habitat loss, habitat fragmentation and sensory disturbances may result in a decrease in species abundance and possibly change species diversity within the Zone of Impact. In addition, the spatial and temporal distribution of species will also be affected as a result of loss of habitat integrity due to habitat fragmentation and degradation. Habitat alteration and disturbance may increase the likelihood of introduction of alien invasive species such as Marijuana, Castor Oil Plant and Strumarium. The three habitat types (**Section 4.1,** *Ecology Baseline*) found in this Zone of Impact will be affected. However, no terrestrial Critical Habitat was identified in the Zone of Impact and it does not contain any threatened or unique ecosystem. Moreover, the habitats found in this Area of Habitat Loss are homogenous and widespread. Therefore, at a local scale, a decrease in biodiversity and ecological function caused by construction-related disturbances is of minor magnitude near the Project facilities. Moreover, because of the homogenous and widespread distribution of species, the area-wide impact on biodiversity is also minor.

The wider area around the Project provides habitat to the terrestrial mammals of conservation importance including the Himalayan Ibex and Flare-horned Markhor which are animals licensed for trophy hunting. The Flare-horned Markhor and Grey Wolf are listed as Endangered in Pakistan National Red List. Snow leopard is also known to inhabit the area and is listed as Critically Endangered in the Pakistan National Red List and Vulnerable in the IUCN Red List. Improved access to the site as a result of the Project may indirectly increase the incidence of poaching or trade in animal parts. Even though rules to regulate hunting exist, it is important that project staff and contractors abide by these regulations.

The wider area around the Project provides habitat to the terrestrial mammals of conservation importance. The Common Leopard, Snow Leopard, and Asiatic Black Bear are listed as Vulnerable, while Pallas's Cat and Flare–horned Markhor are listed as Near Threatened in the IUCN Red List. In addition, the waterbodies in the vicinity of the Project site provide habitat for a number of migratory birds which can be hunted by obtaining permits from the KP Wildlife Department. Improved access to the site as a result of the Project may indirectly increase the incidence of poaching or trade in animals and their parts. Even though rules to regulate hunting exist, it is important that project staff and contractors abide by these regulations.

7.3.3 Impacts on Terrestrial Biodiversity due to Project Operation

Impact 05: Project operation leading to animal disturbance, displacement and decline.								
Applicable Project Phase	*Operations*							
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Long Term	Small	Medium	Possible	Medium	-	High

Mitigation measures:

1. Large flood lights should not be installed outside 50 m of the Project fence; these lights should be directed towards Project facilities and not towards the natural habitats.
2. Provide awareness training to staff and contractors on: prevention of injury of animals; identification of likely species (Snow Leopard, Grey Wolf, Asiatic Jackal, Red Fox, Flare-horned Markhor, Himalayan Ibex and other migratory water fowls) found on site; identifications of animal hazards (such as venomous snakes); what to do if dangerous animals are encountered; report kills of large mammals particularly designated species of conservation concern.

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3. Provide adequate knowledge to the workers on relevant government regulations and punishments for illegal poaching of wildlife species (Snow Leopard, Flare-horned Markhor, Himalayan Ibex and other migratory water fowls); report any wildlife law violations to concerned government departments; incorporate in contract documents regulations for Project staff and contractors to avoid illegal poaching
4. Facilitating government department staff when they arrive at the site for example providing them accommodation and vehicles.
5. Close coordination with the government departments (Fisheries and Wildlife Departments);
6. Train and raise awareness regarding AIS among Project staff and contractors (see **Section 4.1.5**).
7. The Contractor shall prepare an Environmental Training Plan for all construction workers.
8. Solid waste should only be disposed of at designated sites.

Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	[illegible]	Small	Low	Possible	Low	-	High

The operation of the hydropower plant and associated activities will result in some potential disturbances to species, which may exacerbate the effects of habitat loss and decreased species abundance. In addition, the spatial and temporal distribution of species will also be affected as a result of loss of habitat integrity due to habitat fragmentation and degradation. These disturbances include noise and light. As plant operation will be continuous, the disturbances will also be continuous and affect both diurnal and nocturnal wildlife. The lighting required for operation and safety at the Project site can influence nocturnal foraging behaviors as well as disrupt sleep patterns of crepuscular and nocturnal species. However, considering the fact that no threatened ecosystem or species of conservation importance is reported from the Zone of Impact, the magnitude of this impact is considered minor.

7.4 Ambient Air Quality

Ambient air quality will be affected by construction activities. The air quality baseline (**Section 4.2.5** *Ambient Air Quality)* shows that the baseline concentration of particulate matter (PM_{10} and $PM_{2.5}$) is within IFC EHS guideline values. PM_{10} is also within NEQS whereas $PM_{2.5}$ exceeds the PEQS limits in 2 out of 3 cases. As the construction activities could be a significant source of particulate matter emission, the potential impact of the construction activities on the particulate matter levels is considered a risk and is discussed in this section.

Although the construction equipment will be a source of gaseous emissions, the total emission from them will be small and is unlikely to increase the concentration of these gases in the ambient air significantly. Therefore, gaseous emissions are not considered a risk and are not discussed further. The only exception could be the power generators if they are located close to any settlement. A mitigation measure is proposed requiring keeping a safe distance from settlements.

The impacts are identified and rated below:

Impact 06: Increase in ambient concentration of air pollutants from construction activities and vehicular movement may cause health impacts on the community.								
Applicable Project Phase					*Construction*			
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Short Term	Intermediate	Medium	Possible	Medium	-	High

Mitigation measures:

Management

1. Develop and implement an Air Pollution Control Plan.
2. Prepare a Site Specific Environmental Management Plan (SSEMP) for each construction site that must outline areas to be cleared, vegetated areas to be protected or fenced, solid waste disposal locations, and sprinkling locations.

Fugitive and exhaust emissions from transport vehicles

3. Cover all trucks hauling soil, sand, and other loose materials or require all trucks to maintain at least two feet of freeboard (i.e., the minimum required space between the top of the load and the top of the trailer).
4. Install and maintain appropriate emission control equipment on vehicles and machinery.
5. Regularly maintain vehicles and equipment to keep a check on emissions.
6. Ensure that smoke from internal combustion engines is not visible for more than ten seconds.
7. Use new and low emission equipment and vehicles to the extent possible.
8. Purchase best quality fuel and lubes and where possible use lead free oil and lubes.
9. Sprinkle water on all unsealed roads used by Project vehicles that are within 200 m of any settlement.
10. Cover loads and long-term piles of friable material to reduce fugitive dust emission.
11. Reduce traffic speeds on all unpaved surfaces to 30 km/hr or less to avoid dust emissions from vehicular movement.
12. Absolute prohibition on soil or mud accumulation on public roads. Public and Project access roads should be frequently cleaned and visually inspected daily to prevent any soil or mud accumulation.
13. Install wheel washers where vehicle exit onto the paved road from unpaved and prior to each trip.

Fugitive dust emissions from blasting

14. Indicate the limits of a clearing land with highly visible markers.
15. Leave a layer of about 5 m of undisturbed softs above the top of the overburden blasts. This will act as a blanket to contain air blast, dust and fly rock.
16. Sprinkle water on the area where blasting is done to settle down the particulate matter emissions.

Fugitive dust emissions from quarry areas

Indicate the limits of a clearing land with highly visible markers.

17. Avoid earth stripping or moving in periods of dry and windy weather.
18. Carry out dust generating activities where maximum protection can be obtained through topography or in areas where prevailing winds will blow dust away from sensitive areas/uses.
19. Suspend dust generating when wind speed exceeds 20 km/hr in areas within 500 m of any settlement.
20. Sprinkle water on conveyors/conveyor transfer points, stockpiles, and roads.
21. Cover fine dry loads or spray water on loads prior to exiting the site, and if necessary regular cleaning of public roads in the vicinity of the entrance.

Fugitive dust emissions from concrete batching plants

22. Suspend earthwork operation when wind speed exceeds 20 km/hr in areas within 500 m of any settlement.
23. Perform weighing and mixing process in a fully enclosed environment.
24. Install dust collectors to the mixers to avoid dust emissions.
25. Ensure that bunkers and conveyors are sited in the leeward direction to minimize the effects of the wind.
26. Consider the natural wind barriers such as trees and landforms to help control the emission of dust from the batching plant.

Fugitive dust emissions from aggregate production and handling system								
27. Suspend operation when wind speed exceeds 20 km/hr in areas within 500 m of any settlement. 28. Consider prevailing wind direction to ensure that aggregate handling systems located in the leeward direction to minimize the effects of the wind. 29. Sprinkle water on all exposed surfaces, particularly those close and up-wind of settlements.								
Wind-blown dust from exposed surfaces such as bare land, stockpiles, and waste dumping sites								
30. Cover all exposed surfaces, particularly those close and up-wind of settlements. 31. Suspend all grading operations on a Project when winds exceed 20 km/hr. 32. Minimize disturbance to, or movement of, soil and vegetation. 33. Sprinkle water on all exposed surfaces, particularly those close and up-wind of settlements. 34. Retain as much natural vegetation as possible. 35. Cover on-site dirt piles or other stockpiled areas. 36. Install windbreaks and employ water and/or soil stabilizers to reduce wind-blown dust emissions. 37. Adequately wet, cover with plastic, or provide with wind shield all stockpiles to reduce dust emission								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Intermediate	Low	Possible	Low	-	High

7.4.1 Emission Sources

The construction of the Project will result in number of emission sources including emissions from:

- movement of vehicles
- blasting and quarrying operations
- operation of concrete batching plants and aggregate production systems
- exposed surfaces

The above sources are identified and appropriate mitigations for each source are discussed in **Exhibit 7.6**

7.4.2 Identification of High Risk Areas and Mitigation Measures

The housing density in the area near the Project facilities is low, and much of the existing households near the Project will be relocated (see **Resettlement Action Plan**). The village of Runi is 310 m from the Powerhouse site, whereas there are a few settlements near the temporary construction site along the tunnel including Mumi and Haraini villages. These two areas are considered at risk of deterioration in air quality. At the Dam site after resettlement the nearest residence is at a distance of 1790 m and therefore while all mitigation measures are applicable at the Dam site, it is at risk to impacts due to changes in air quality.

The potential air quality impacts and appropriate mitigation measure for each construction activity is presented in **Exhibit 7.6.** Based on the zone of air quality impact buffers around each source to identify the high-risk areas that are falling under the buffer.

The locations of the following Project facilities were not described in the Feasibility Study and therefore, sensitive receptors near these facilities could not be identified:

- Quarry Areas
- Batching Plants

- Aggregate Production Plants
- Waste Dumping Sites
- Adit Mouths

Before the start of construction, the location of these facilities should be identified and sensitive receptors near these sites should be documented to supplement the information provided below. Air quality monitoring should be conducted based on the location of these receptors. Receptors that are within the Zone of Impact are prone to be affected by the possible increase in pollutant levels due to the construction activities.

The Project access road and 50 m buffer is presented in **Exhibit 7.7**.

Exhibit 7.6: Inventory of Emission Sources, Zone of Impact and Mitigation and Monitoring Measures

Source/Activity	*Zone of Impact*	*Mitigation/Monitoring Measures*
Fugitive and exhaust emissions from transport vehicles Transport emissions include emissions from vehicles moving on roads and from their exhausts. As vehicles move on the road, due to friction between vehicle's tire and road, the dust particles come in suspension which causes dust (PM_{10} and $PM_{2.5}$) emissions. Exhaust emissions include emissions attributable to engine related processes such as fuel combustion and particles that exit the tailpipe.	**General Guidelines:** ▶ A buffer of 50 meters (m) along the route(s) used by construction vehicles as given in Guidance on the Assessment of Dust from Demolition and Construction document by Institute of Air Quality Management, 2014.[2] **Project Specific Zone:** ▶ Transport of material will come to the Project site from different areas of Pakistan (see **Section 3** *Project Description*). From here the material will go to the construction sites through access roads. ▶ The access road to the site is currently unpaved. It will be paved and upgraded to facilitate traffic movement. This will have the added benefit of reducing fugitive emissions during transport. ▶ The material generated on-site both as raw material and as waste material will go to their final destination through access roads to dam site and waste dumping sites. ▶ The buffer around the proposed access roads is shown below.	▶ Pave the access route to the Project site. ▶ Cover all trucks hauling soil, sand, and other loose materials or require all trucks to maintain at least two feet of freeboard (i.e., the minimum required space between the top of the load and the top of the trailer). ▶ Install appropriate emission control equipment on vehicles and machinery. ▶ Regularly maintain vehicles and equipment to have a check on emissions. ▶ Monitor smoke from internal combustion engines that should not be visible for more than ten seconds. ▶ Use new and low emission equipment and vehicles to the extent possible. ▶ Purchase best quality fuel and lubes and where possible use lead free oil and lubes. ▶ Sprinkle water on all unsealed roads used by Project vehicles that are within 200 m of any settlement. ▶ Reduce traffic speeds on all unpaved surfaces to 30 km/hr or less to avoid dust emissions from vehicular movement.

[2] Guidance on the Assessment of Dust from Demolition and Construction document by Institute of Air Quality Management, 2014. http://www.iaqm.co.uk/text/guidance/construction-dust-2014.pdf

Source/Activity	Zone of Impact	Mitigation/Monitoring Measures
		► Absolute prohibition on soil or mud accumulation on public roads. Public and Project access roads should be frequently cleaned and visually inspected daily to prevent any soil or mud accumulation. ► Install wheel washers where vehicles exit onto paved road from unpaved and prior to each trip.
Fugitive dust emissions from blasting Tunnels, adits and underground powerhouse will be excavated through drilling and blasting. Air quality due to blasting will be degraded near the mouth of these sites where the blasting will be near the surface. Along the length of the tunnel and the underground powerhouse etc. air quality will not be affected as this is far underground.	**General Guidelines:** A buffer of 200 m from the point of blasting where there is a high risk of dust emissions according to the Impact Evaluation of Blasting, 2009.[3] **Project Specific Zone:** The locations of tunnels are identified however adit mouths are not identified in the Feasibility Study.	► Indicate the limits of a clearing land with highly visible markers. ► Leave a layer of about 5 m of undisturbed soils above the top of the overburden blasts. This will act as a blanket to contain air blast, dust and fly rock. ► Sprinkle water on the area where blasting is done to settle down the particulate matter emissions.
Fugitive dust emissions from quarry areas Quarry areas are used to excavate stones, rocks, sand, gravel, and aggregate from the ground. This includes stripping of topsoil, blasting of the area, crushing and screening of aggregates and loading of excavated material from quarries to stockpiles.	**General Guidelines:** ► A buffer of 500 m from the quarry areas where there is a high risk of dust emissions as discussed in the Guidelines for Planning Authorities for Quarries and Ancillary Activities, 2004.[4] **Project Specific Zone:** ► The locations of quarry areas are not identified in the Feasibility Study.	► Indicate the limits of a clearing land with highly visible markers. ► Avoid earth stripping or moving in periods of dry and windy weather. ► Suspend dust generating activities when wind speed exceeds 20 km/hr in areas within 500 m of any settlement.

[3] Impact Evaluation of Blasting, Vlakfontein Opencast Project, 200

[4] Guidelines for Planning Authorities for Quarries and Ancillary Activities, Department of the Environment, Heritage and Local Government, 2004. http://www.housing.gov.ie/sites/default/files/migrated-files/en/Publications/DevelopmentandHousing/Planning/FileDownLoad%2C1606%2Cen.pdf

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Source/Activity	Zone of Impact	Mitigation/Monitoring Measures
Wind erosion from exposed surfaces also leads to dust emissions.		► Sprinkle water on conveyors/conveyor transfer points, stockpiles, and roads. ► Cover fine dry loads or spray water on loads prior to exiting the site, and if necessary regular cleaning of public roads near the entrance.
Fugitive dust emissions from concrete batching plants Concrete batching plants are where ingredients such as sand, cement, water, and aggregate are mixed to form concrete. This consists of various activities such as storage of raw materials in bunkers and stockpiles, transfer of raw materials by front-end loaders, conveyors, hoppers and loading of materials to the trucks.	**General Guidelines:** ► A buffer of 100 m between batching plants and sensitive land uses as included in the Recommended Buffer Distances for Industrial Residual Air Emissions, 1990.[5] **Project Specific Zone:** ► The locations of batching plants are not identified in the Feasibility Study.	► Suspend the plant operations when wind speed exceeds 20 km/hr if the plant is near settlements. ► Perform weighing and mixing process in a fully enclosed environment. ► Install dust collectors to the mixers to avoid dust emissions. ► Ensure that bunkers and conveyors are sited in the leeward direction to minimize the effects of the wind. ► Consider the natural wind barriers such as trees and landforms to help control the emission of dust from the batching plant.
Fugitive dust emissions from aggregate production and handling system Sand and gravel are typically mined in a moist or wet condition by open pit excavation or dredging. After mining, the materials are transported to the processing plant where the material is dried, screened and crushed which is a source of particulate matter emissions.	**General Guidelines:** ► A buffer of 1000 m between the point of operations and sensitive land uses. **Project Specific Zone:** ► The locations of aggregate production plants are not identified in the Feasibility Study. ► Fine aggregate production should be minimized and directly extracted where possible.	► Suspend operation when wind speed exceeds 20 km/hr. ► Consider prevailing wind direction to ensure that aggregate handling systems located in the leeward direction to minimize the effects of the wind. ► The prevailing wind direction should be considered to ensure that aggregate handling systems located in the leeward

[5] Environmental Guidelines for the Concrete Batching Industry, http://www.epa.vic.gov.au/~/media/Publications/628.pdf

Source/Activity	Zone of Impact	Mitigation/Monitoring Measures
Typically, the dust associated with aggregate operations consists of particles from exposed soil and rock.	► Final aggregate handling and production systems should be located further than 1000 m of sensitive receptors such as homes, schools, mosques etc. ► In case the above is not possible, then homes within this zone should either be temporarily relocated or mitigation measures strictly implemented in this zone.	direction to minimize the effects of the wind. ► Sprinkle water on all exposed surfaces, particularly those close and up-wind of settlements.
Wind-blown dust from exposed surfaces such as bare land and waste dumping sites Waste dumping sites are not themselves an emission source but unloading the waste (dumping) onto dump sites results in dust emissions.	**General Guidelines:** ► A buffer of 250 m between waste dumping sites and residential development as given in IFC-EHS Guidelines Waste Management Facilities, 2007.[8] **Project Specific Zone:** ► The locations of waste dumping sites are not identified in the Feasibility Study.	► Cover all exposed surfaces, particularly those close and up-wind of settlements. ► Suspend all grading operations on a Project when winds exceed 20 km/hr. ► Minimize disturbance to, or movement of, soil and vegetation. ► Sprinkle water on all exposed surfaces, particularly those close and up-wind of settlements. ► Retain as much natural vegetation as possible. ► Cover on-site dirt piles or other stockpiled areas. ► Install windbreaks and employ water and/or soil stabilizers to reduce wind-blown dust emissions. ► Adequately wet, cover with plastic, or provide all stockpiles with wind shields to reduce dust emission.

[8] IFC-EHS Guidelines Waste Management Facilities, 2007, http://www.ifc.org/wps/wcm/connect/1cd72a00488557cfbdf4ff6a6515bb18/Final+-+Waste+Management+Facilities.pdf?MOD=AJPERES

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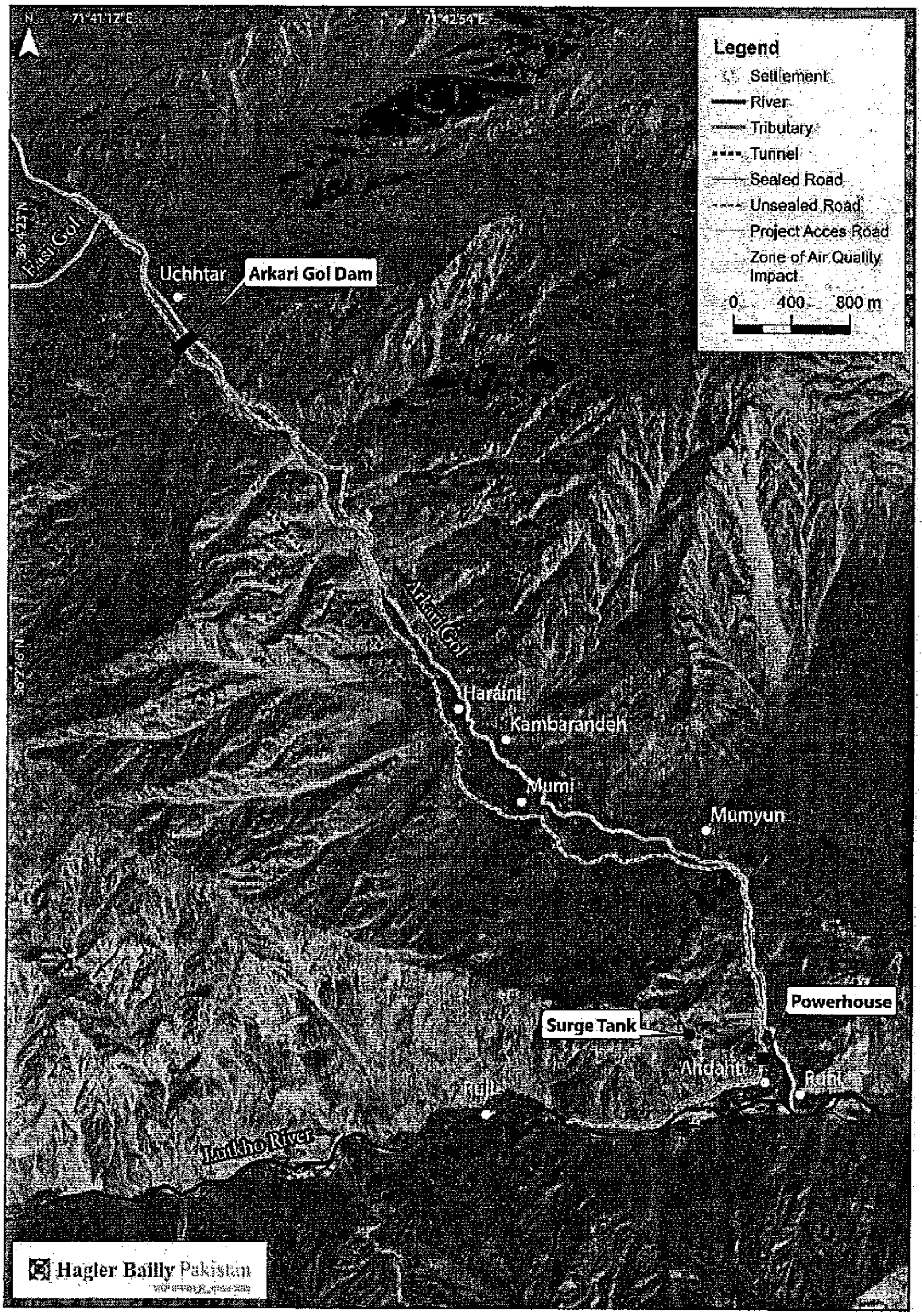
Exhibit 7.7: Zone of Air Quality Impact



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7.5 Vibration from Blasting

Blasting will be undertaken at the quarry site and for the tunnel boring. The key impacts of blasting include vibration, noise and dust, hazards due to flying debris, and disturbance to underground water channels. Dust impacts are discussed in **Section 7.4** the risk from flying debris in **Section 7.6** noise impacts in **Section 7.7**. The potential impacts due to vibration are considered here.

Potential impacts from blasting in mountain springs are discussed in **Section 7.6**

Impact 07: Vibration from blasting during the construction phase may disturb local communities.								
Applicable Project Phase	*Construction*							
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Short Term	Small	Low	Possible	Low	-	High

Mitigation measures:

1. Develop a Blasting and Explosives Management Plan.
2. Conduct a pre-construction survey of structures at risk of vibration impacts households.

- In the initial stages, the blasting induced vibration shall be measured as a function of maximum instantaneous charge and distance from the blasting site. This data shall be then used to refine the Blasting Induced Vibration Risk Zones on the basis of the adopted criteria.
- Using, the refined Blasting Induced Vibration Risk Zones maps and the tunnel boring schedule, the Supervision Consultant in consultation with the MPCL and the Construction Contractor, shall identify the houses that will be affected and the impact duration and schedule.
- For the houses that will fall in the Structural Damage Risk Zone, a temporary relocation plan will be developed. An amendment to the Resettlement Action Plan (RAP) will be commissioned for this purpose. Before the start of blasting, all residents of houses in the Structural Damage Risk Zone will be relocated as per the RAP.
- A survey will be undertaken in both zones, to determine the pre-blasting conditions of the buildings. The survey will be commissioned by the Supervision Consultant and will identify and record any existing damage to the structures. The survey will cover the following aspects:
  - Overall condition of the structures, both exterior and interior.
  - Documentation of defects observed in the structure using digital imagery along with notes, measurements and sketches.
  - Documentation of pre-existing cracks using digital imagery along with notes, measurements, and sketches.

3. Following completion of the blasting, the survey will be repeated in the Structural Damage Risk Zone to determine the condition of the buildings and verify that they are safe for re-occupation. If the buildings are safe, the residents will be allowed to return to their houses following any necessary damage repairs. If the buildings are damaged beyond repair, compensation will be paid to the owners as per the RAP. If there are any claims or reports of damage in the Cosmetic Damage Risk Zone, the affected house will be surveyed against the pre-Project survey and repairs will be undertaken as appropriate.
4. Following are key mitigation measures for the management of blasting:

- Blasting will be scheduled during the day only.
- Local communities will be informed of blasting timetable in advance and will be provided adequate notice of when blasts are required outside of the planned schedule.
- A Blasting and Explosives Management Plan will be developed by the Construction Contractor. The Plan will be reviewed and approved by the Supervision Contractor before the initiation of the blasting work.

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▶ Throughout the blasting activity, vibration sensors will be installed at strategic locations to monitor the impact of blasting and to ensure that the vibration levels are within the adopted criteria. The monitoring plan will be part of the Blasting and Explosives Management Plan. ▶ Unscheduled blasting will be strictly prohibited in any case. 5. Meaningful contact with the community shall be maintained and their grievance shall be attended to in a timely manner. In this regard: ▶ A meaningful community engagement plan will be developed. The plan will cover identify the affected community; the key contact persons; frequency of engagement; the information to be shared; the responsibilities to manage the plan; and the notice period to be giving to the community for various blasting related generating activities. ▶ The Grievance Redress Mechanism will be used to record, investigate, and respond to any complaints. Investigation of the complaints will be undertaken by the Supervision Consultant. 6. Develop a Noise and Vibration Control Plan that will include monitoring of vibration levels and frequency around the blasting sites. The objectives of the monitoring will be to: ▶ Ensure that vibration levels in the communities are within the adopted criteria levels; ▶ Maintain record of vibration to settle any potential conflicts; and ▶ Monitor changes in the vibration levels due to possible changes in the rock formation and take appropriate corrective actions.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Medium Term	Small	Low	Possible	Low	-	High

Sources of vibration include construction equipment movement, pile driving, compaction, hammering (hydraulic or pneumatic), the operation of batching plant and generators. Another source of vibration will be the blasting to be undertaken for tunneling and blasting at the quarry sites. The propagation of vibration from construction activities is different in nature from the vibration from blasting. The construction activities are undertaken essentially on the ground surface and spread as two-dimensional waves. In contrast, the tunneling is undertaken below the surface and spreads in three-dimension. For this reason, the impact of the two is assessed separately.

In the case of ground vibrations, the level of vibration is measured by the Peak Particle Velocity (PPV) with units of millimeters of movement per second. The proposed criteria for damage to buildings are shown in **Exhibit 7.8.** These are derived from British Standard BS 6472 and are German Standards DIN 4150-3:1999

Exhibit 7.8: Criteria for Structural Damage Due to Vibration

Risk Zone	*PPV Range*
No damage likely	PPV < 5 mm/s
Cosmetic damage risk zone	PPV 5 to 15 mm/s
Structural damage risk zone	PPV > 15 mm/s

7.5.1 Vibration Impact of Construction Activities on the Surface

Exhibit 7.9 provides an indication of the approximate vibration levels that may be expected for various vibration sources.

These levels are well below the threshold of any possibility of damage to structures due to vibrations from typical construction activities related to roller, compactors, and movement of construction equipment.

Exhibit 7.9: Approximate Vibration Levels for Various Sources

Activity	*Typical levels of ground vibration*
Vibratory rollers	Up to 1.5 mm/s at distances of 25 m Higher levels could occur at closer distances; however, no damage would be expected for any building at distances greater than approximately 12 m (for a medium to heavy roller)
Hydraulic rock breakers (levels typical of a large rock breaker operating in hard sandstone)	4.50 mm/s at 5 m 1.30 mm/s at 10 m 0.4 mm/s at 20 m 0.10 mm/s at 50 m
Compactor	20 mm/s at distances of approximately 5 m, 2 mm/s at distances of 15 m. at distances greater than 30 m, vibration is usually below 0.3 mm/s
Bulldozers	1 to 2 mm/s at distances of approximately 5 m. at distances greater than 20 m. vibration is usually below 0.32 mm/s
Air track drill	4 to 5 mm/s at a distance of approximately 5 m, and 1.5 mm/s at 10 m. at distances greater than 25 m, vibration is usually below 0.6 mm/s and at 50 m or more, vibration is usually below 0.1 mms
Truck traffic (over normal (smooth) road surfaces)	0.01 to 0.2 mm/s at the footing of buildings located 10 to 20 m from a roadway
Truck traffic (over irregular surfaces)	0.1 to 2.0 mm/s at the footings of buildings located 10 m to 20 m from a roadway

Source: Northern Expressway Environmental Report: Noise and Vibration technical Paper. 2007. http://www.southroad.sa.gov.au/_data/assets/file/0019/13780/Noise_and_Vibration_Technical_Paper.pdf

7.5.2 Vibration Impact of Tunnel and Underground Powerhouse Construction

Blasting for construction results in noise as well as ground vibrations that cannot be confined to the site. As blasting is an occasional activity it does not affect the ambient noise limits evaluated but can be disturbing to local communities with short-term noise exceeding 10 dBA. Single noisy events such as blasting can be audible over a large area.

Although each incident is short-term in nature, the repetitiveness of the noise may give rise to complaints if not managed sensitively. The subjective reaction to a single disturbing noise event will depend on the activities being undertaken by the receptor and the manner in which the program for noisy events is communicated to identified receptors. For example, a large noise event at nighttime may give rise to complaints, where at any other time it would be accepted.

The Project will conduct construction blasting consistent with Pakistan and international safety standards. Open pit blasting will be conducted using standard mining industry practices and procedures for securing personnel and equipment. This includes evacuating

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the blast area to a distance of at least 500 m to avoid any damage from fly rock (**Section 7.6** discusses impacts of fly rock exclusively). The PPV is directly related to the size of the blast and the distance from the blast—the closer to the blast the greater the vibration.

PPV is calculated as follows:

$$PPV = K\ (R/Q^{0.5})^{B},$$

where:

PPV = peak particle velocity (mm/s);

K = site constant (1140)

R = distance to point of concern (m);

B = rock properties constant (-1.6); and

Q = maximum instantaneous charge weight (see **Exhibit 7.10**)

Exhibit 7.10: Instantaneous Charge Weight Calculation

Parameter	*Tunnel Type*		*Explanation*
	Headrace	*Pressure Shaft*	
Diameter (m)	3.8	4.5	From design drawings
Tunnel cross-Section (m^2)	6	8	Assumed as circular
Borehole depth (m)	5	5	Assumed, based on personal communication with construction engineer.
Rock removed in one blast cycle (m^3)	28.35	39.76	Depth times area.
Rock type	Hard	Hard	
Powder factor (kg/m^3)	0.8	0.8	For hard rock.
Total charge weight (kg)	22.68	31.81	Powder factor multiplied by rock removed in one blast.
Maximum instantaneous charge weight (kg)	3	5	Estimated from typical borehole pattern and personal communication with construction engineer.

Exhibit 7.11 shows the PPV value with distance caused by blasting in the various tunnels. For a conservative approach the largest values (for the diversion tunnel) are adopted and therefore, a PPV of 15 mm/s is calculated to occur of a distance of 40 m (or the Structural Damage Risk Zone) from the edge of the blasting source (in all directions) and a PPV of 5 mm/s is calculated to occur about 70 m (or the Cosmetic Damage Risk Zone) from the edge of the blasting. The boundaries of risk zones are drawn without

taking into consideration the variation in elevation of the terrain. The actual boundaries are likely to be closer to the tunnels

Exhibit 7.11: Calculated PPV as Function of Distance from Blast Site

Orange: PPV ~ 15 mm/s, Green: PPV ~5 mm/s

R (m)	*PPV (mm)*	
	Headrace Tunnel	*Penstock*
10	77.8	102.0
20	25.7	33.6
30	13.4	17.6
40	8.5	11.1
50	5.9	7.8
60	4.4	5.8
70	3.5	4.5
80	2.8	3.7
90	2.3	3.0
100	2.0	2.6

In **Exhibit 7.12** there are no houses within the risk zones that are and not included in the RAP. The structures closest to the blasting locations (and not included within the RAP) are at a distance of 150 m. It is possible that after the construction is started and these zones are reassessed no structures will fall within the zone then either. However, in case the design of the tunnel is adjusted, or if vibrations are high due to the rock structure, or large singe explosives are used, these measures are kept.

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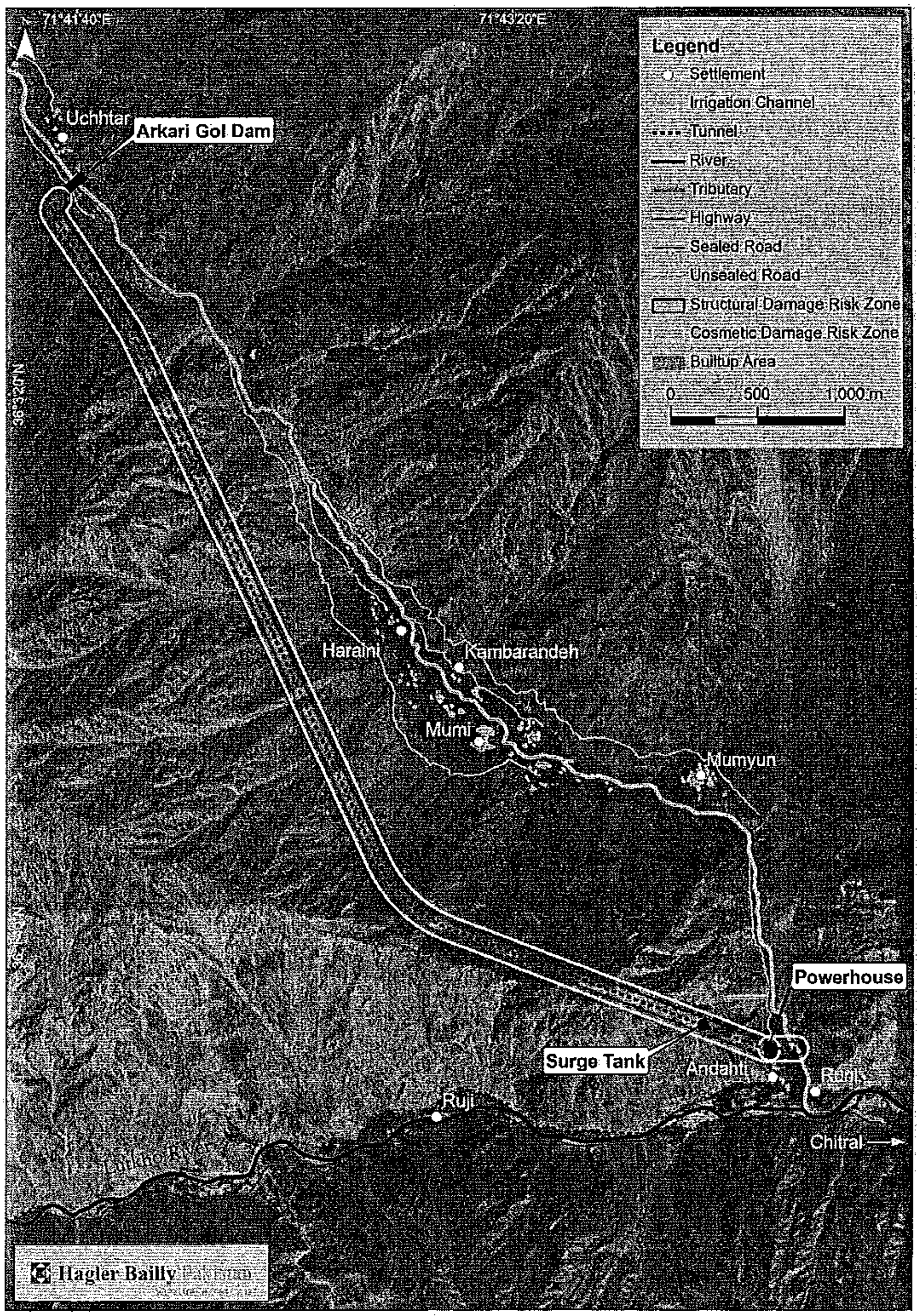
Exhibit 7.12: Blasting Induced Vibration Risk Zones – Powerhouse Site



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7.5.3 Vibration Impact of Blasting at Quarry Sites

Most quarrying will consist of the excavation of loose materials, however, in some case blasting may be used. The vibrations produced by quarry blasting can be a source of concern and frustration for neighboring communities. The vibration that is felt by people living near a quarry is a combination of ground vibration and air over pressure). A well-executed blast uses as much energy as possible in the fracturing of the rock and leaves very little room to escape into the surrounding environment. Energy that isn't used for breaking rock travels either through the remaining rock or through the air.

Escaping energy from a blast that travels through the air produces a temporary increase in air pressure much like a clap of thunder or a jet engine from aircraft traveling overhead. This increase in air pressure, called air overpressure, is measured in decibels. Air overpressure travels in a wave form and much like wind pushes on anything in its path.

Ground vibration is produced by energy escaping through the remaining solid rock, so it tends to be more discernable behind the blast. Unlike air overpressure, the intensity of ground vibration tends to be more predictable since it travels through a more solid medium.

During construction, the actual ground vibration and air blast overpressure will be measured and should meet the criteria set forth in **Exhibit 7.8** and **Exhibit 7.13** at the nearest sensitive receptor of the blast site. The criteria given in **Exhibit 7.13** is taken from the Australian Standards ABN 46 640 294 485.

Exhibit 7.13: Air blast Overpressure Limits for Surface Blasting

Limits	*Criteria for Sensitive Locations*
Air blast overpressure	115 dB (Linear) Peak for 9 out of 10 consecutive blasts initiated and not greater than 10 mm/second peak particle velocity at any time

7.5.4 Mitigations Measures

Overall Approach

The PPV is predicted using a semi-empirical model which is the best alternate in the absence of measured field data. Although there is reasonable confidence in the predicted value, the norm is to measure field data to assess vibration levels. In the initial stages, the blasting induced vibration shall be measured as a function of maximum instantaneous charge and distance from the blasting site. This data shall be then used to refine the Blasting Induced Vibration Risk Zones on the basis of the adopted criteria.

Early during the construction phase, the construction contractor shall develop a detailed blasting and explosives management plan as part of the overall construction schedule. The plan shall also specify, to a reasonable level of accuracy, the schedule for quarrying.

Using, the refined Blasting Induced Vibration Risk Zones maps and schedule, the Supervision Consultant in consultation with MHL and the Construction Contractor, shall identify the houses that will be affected and the impact duration and schedule.

If any houses fall in the Structural Damage Risk Zone, a temporary relocation plan will be developed. An amendment to the RAP will be commissioned for this purpose. Before the start of blasting, all residents of houses in the Structural Damage Risk Zone will be relocated as per the amended RAP. Temporary relocation means relocation while blasting is being conducted while too close to the houses, and depends on the blasting schedule. It is likely that no houses are near enough to be classified as within the Structural Damage Risk Zone due to the low population density in the area.

Following are key mitigation measures for the management of blasting:

- Blasting will be scheduled during the day only.
- Local communities will be informed of blasting timetable in advance and will be provided adequate notice of when blasts are required outside of the planned schedule.
- A Blasting and Explosives Management Plan will be developed by the Construction Contractor. The Plan will be reviewed and approved by the Supervision Contractor before the initiation of the blasting work.
- Throughout the blasting activity, vibration sensors will be installed at strategic locations to monitor the impact of blasting and to ensure that the vibration levels are within the adopted criteria. The monitoring plan will be part of the Blasting and Explosives Management Plan.

Unlike other construction activities, it is recognized that the impact of blasting on the community can be significant or can be perceived as significant by the community. It is therefore vital that regular and meaningful contact with the community shall be maintained and their grievance shall be attended to in a timely manner. In this regard:

- A meaningful Community Engagement Plan will be developed. The plan will cover identify the affected community; the key contact persons; frequency of engagement; the information to be shared; the responsibilities to manage the plan; and the notice period to be giving to the community for various blasting related generating activities
- The Grievance Redress Mechanism will be used to record, investigate, and respond to any complaints. Investigation of the complaints will be undertaken by the Supervision Consultant.

Vibration Monitoring

Noise and Vibration Control Plan will include monitoring of vibration levels and frequency around the blasting sites. The objectives of the monitoring will be to:

- Ensure that vibration levels in the communities are within the adopted criteria levels;
- Maintain record of vibration to settle any potential conflicts; and
- Monitor changes in the vibration levels due to possible changes in the rock formation and take appropriate corrective actions.

Vibration data will be documented, reviewed, and preserved. It will be regularly shared with OPIC, MHL and KP-EPA as part of the quarterly progress report.

7.6 Hazards of Fly Rock from Blasting

Fly rock is an unplanned projection of material from the blast site to any area beyond the designated safety area. These rocks, if not controlled, may result in damage to the surrounding structures and may also pose a safety hazard.

Impact 08: Blasting may pose a safety hazard due to flying debris.								
Applicable Project Phase				*Construction*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Short Term	Intermediate	Medium	Possible	Medium	-	High
Mitigation measures: 1. Provide a minimum buffer of 500 m between the settlements and point of blasting. If not possible then households falling within this buffer should be temporarily evacuated when blasting is done at the quarry. 2. Leave a layer of about 5 m of undisturbed softs above the top of the overburden blasts. This will act as a blanket to contain air blast, dust and fly rock. 3. Ensure that the holes are correctly collared with respect to the back-break/inclination of the face and that digging alongside the initiation face well controlled. 4. Inadequate forward displacement of the front row burden arising out of the under charging of these holes will result in fly rock from vertical catering of the rear holes. 5. Where fly rock pose a serious problem, the stemming length should not be less than the hole burden. Also, an effective stemming material like crushed angular rock should be used to prevent premature venting of explosion gases through the stemming column. 6. The forward fly rock could be fairly controlled to the commonly used 'inline open loop' pattern. The maximum inter-row delay interval consistent with the absence of cut off helped in minimizing the fly rock formation. As a thumb rule, an inter-row delay of 4-8ms/m of burden could be used for this purpose. 7. Adequate care should be taken while connecting the delay devices in the holes/rows and the initiation sequence properly checked before firing to avoid initiation of blast holes out of sequence. 8. Blasts designed on a face length to width ratio in the range of 3 to 4 produces minimum fly rock.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Possible	Low	-	High

Fly rock occurs when the amount of explosive energy is greater than that required to break the mass of rock between the blast position and the free face, the excess energy projects the rock debris beyond the safety area. Uncontrolled fly rock from blasting can travel hundreds of meters, with known cases up to 1000 m. This range is for extreme cases where very little blasting control is applied and is due to over-charging of holes or under-burdening of holes.

Use of large diameter blast holes for small benches, variation in burden due to over break of toe or back crack that results in uneven face, drilling deviation, inadequate burden and too closing spacing are the possible causes of fly rock.

Even though fly rock consumes only 1% of the explosive energy used in a blast it is more serious in nature than any other damage caused by blasting.

Residents should be temporarily evacuated from the homes that fall within the 500 m buffer during blasting at these quarries. An evacuation plan should be developed for temporary evacuation if blasting is required in the quarries.

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Temporary relocation means relocation while blasting is being conducted while too close to the houses, and depends on the blasting schedule. It is likely that no houses are near enough to be classified as within the Risk Zone due to the low population density in the area.

7.7 Construction Noise

Construction noise is a component of environmental noise associated with construction activities. Construction noise arises from an activity at a construction site. It includes:

- noise from operation of construction machinery and equipment for the construction activities including excavation and demolition work, site preparation work, foundations and concrete placement, erection of metal structures, installation of mechanical and electrical equipment and building maintenance or repair work;
- noise from movement of vehicles within, entering or leaving a construction site; and
- noise from blasting.

The noise generated through these activities can be categorized as follows:

- Airborne noise: Noise that travels through air and caused by general construction and construction traffic.
- Ground borne noise: Noise that is generated through rumbling sound caused by vibration due to impact-induced construction activities such as blasting, pile driving and tunneling and movement of heavy transportation such as trucks.
- Air blast noise: Noise generated through blasting, also known as blast overpressure, which is the pressure wave (or pulse) transmitted through the air as the result of an explosion. Air blast may have both acoustic effects in terms of overpressure and vibration effects in terms of airborne and ground borne vibration.

Construction noise emanates from the source and propagates through the atmosphere. There are numerous factors influencing the noise level received at a sensitive receptor including:

- The degree to which the radiation emitted is concentrated in a single direction.
- Atmospheric absorption (i.e. attenuation which is a function of temperature, humidity, and frequency within the atmosphere).
- Meteorological influences (attenuation or enhancement due to surface temperature and humidity, vertical temperature profile, wind speed, and direction).
- Ground absorption (influence of hard or soft ground types on propagation).
- Topography and structures (attenuation due to intervening buildings and terrain features.

Impact 09: Increase in ambient noise levels due to the operation of construction equipment, movement of construction traffic and blasting may create a nuisance for nearby communities and visiting tourists.								
Applicable Project Phase				*Construction*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Short Term	Intermediate	Medium	Possible	Medium	-	High

Mitigation measures:

1. Develop a Noise and Vibration Control Plan.

Noise generated from construction sites from construction activities

2. Select the quietest available plant and equipment that can economically undertake the work required.
3. Undertake maintenance of the equipment as simple maintenance can reduce noise levels by as much as 50%. Parts may become loose, creating more noise because of improper operation or scraping against other parts. Grinding noises may also occur as the result of inadequate lubrication.
4. Maintain equipment under use regularly.
5. Install mufflers on the equipment to minimize noise levels.
6. Use visual alarms in preference to audible alarms.
7. Enclose noisy equipment.
8. Provide noise attenuation screens, where appropriate.
9. Build an enclosure around the noise source so that noise is contained. The enclosure should be free from gaps and made of dense material and be lined with noise-absorbing material like glass or polyester batts.
10. Locate noisy equipment behind parking lots or parks.
11. Close liaison with the community and regular monitoring of the noise levels in the community are key to the successful implementation of the above mitigation measures. Specifically, inform communities of all major construction activities three days in advance.

Construction noise from traffic

12. Install residential class mufflers and silencers to the mobile plants such as excavators, front-end loaders, and other diesel-engine equipment as applicable.
13. Construct paved Project access roads and locate where the gradient is low.
14. Implement special noise reduction measures, such as erecting purpose-built acoustic barriers, restricting opening hours and maintaining transport vehicle.
15. Prepare and implement a Traffic Management Plan including, timing of traffic through communities, route planning to avoid sensitive locations, etc.

Construction noise from on-site plant operations and equipment

16. Select plant equipment appropriately that required minimal mitigation.
17. Install mufflers and silencers on the equipment and provide acoustical enclosures.
18. Modify the equipment or the work area to make it quieter by substituting existing equipment with quieter equipment; retro-fitting existing equipment with damping materials, mufflers, or enclosures; erecting barriers; and maintenance.
19. Shift to a quieter construction process for example pile driving is very loud as compared to boring which is a much quieter way to do the same work.
20. Combine noisy operations to occur in the same time period. The total noise level produced will not be significantly greater than the level produced if the operations were performed separately.
21. Maintain and monitor plant and equipment regularly.
22. Move static plant and equipment as far as possible from sensitive boundaries, as work allows. A distance of four times further away lowers the noise by 12 dBA. A reduction of 10 dBA will sound half as loud.
23. Provide baffles and specialized mufflers, and acoustic enclosures to the plant and equipment.
24. Design and built acoustic barriers if needed. Vegetated buffer zones can also be planted to mitigate noise from operations using suitably selected native plantings local to the area.

25. Reduce workers' exposure to high noise levels by keeping moving workers away from the noise source; restricting access to areas; rotating workers performing noisy tasks, and shutting down noisy equipment when not needed.								
26. Use earplugs to reduce workers' exposure to high noise levels.								
Noise generated from the blasting in quarry areas								
27. Use vibratory piling instead of impact piling.								
28. House conveyor belts and crushing/screening equipment to provide acoustic screening.								
29. Ensure that the noise-reduction equipment fitted to machinery is used and maintained properly.								
30. Erect earth mounds around the site boundary can provide acoustic as well as visual screening.								
Noise emissions from concrete batching								
31. Locate noisy equipment behind sound barriers or sound absorbers – for example, gravel stockpiles or constructed barriers.								
32. Install silencing devices to all pressure operated equipment.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Possible	Low	-	High

7.7.1 Existing Conditions

There is no continuous major anthropogenic source of noise in the communities. Noise baseline conditions at the Project construction sites in the villages are around 50-54 dBA for daytime and 44-50 dBA for nighttime. The detailed noise levels are presented in **Section 4.2.6** (*Noise Levels*).

7.7.2 Criteria for Determining Significance

The IFC EHS guidelines and NEQS for noise require that the sound level in residential areas should not exceed 55 dBA during the day and 45 dBA during the night as presented in **Exhibit 7.14.** IFC EHS guidelines also state that noise impacts should not exceed the levels presented in **Exhibit 7.14** or result in a maximum increase in background levels of 3 dB at the nearest receptor location off-site. The Project site will be considered residential as there are no designated industrial or commercial zones in the area.

Exhibit 7.14: NEQS and IFC Guidelines on Ambient Noise Levels

Specific Environment	*Maximum Allowable Log Equivalent (Hourly Measurements), in dB A*			
	IFC-EHS limit Day (7:00-22:00)	*IFC-EHS limit Night (22:00-7:00)*	*NEQS Day (6:00-22:00)*	*NEQS Night (22:00-6:00)*
Residential, institutional, educational	55	45	55	45
Industrial	75	65	70	70
Commercial	65	55	70	70

7.7.3 Impact Analysis

The analysis presented in this section is based on the approach recommended by Federal Highway Administration of the US Department of Transportation for assessment of construction noise.[7]

Precise prediction of noise due to construction activity at given location at a given time requires the list of all equipment that is operational at the time and the following information regarding each piece of equipment:

- The maximum and minimum noise levels, measured at a reference distance from the equipment, during a work cycle
- The fraction of time it operates at maximum level during a work cycle
- The usage factor, i.e., the number of hours during the day when the equipment is operational
- The distance of the equipment from the receptor
- Potential noise barriers and other topographic features that attenuate the sound.
- Atmospheric conditions—the wind speed and direction, humidity and barometric pressure—also affect the propagation of sound, however, for short distances the effect of these is insignificant compared to other variables.

Construction noise levels at the nearest receptor in the nearby village, would fluctuate depending on the type, number, distance from receptor, and duration of use of various pieces of construction equipment. In this analysis, first, the noise level due to each piece of equipment, which is likely to be used in the construction, is calculated. The peak noise levels of construction equipment mainly used at a typical construction site, are shown in **Exhibit 7.15**. The list includes all equipment except vehicles and some minor pieces of equipment. Using this data, the expected noise level, $L_{eq(8\text{-}hr)}$, is calculated. The predicted noise levels are shown in **Exhibit 7.16**. It shows that the highest equivalent noise level for an 8-hour shift due to a single piece of equipment at a receptor 500 m from the source will be about 52 dBA. This is under no-mitigation conditions and assuming no attenuation due to ground features.

When more than one piece of equipment are working simultaneously, the noise level at the receptor will increase. Generally speaking, the noise level will increase by 3 dBA due to the first equipment. Increase due to subsequent addition of equipment will gradually decrease from 3 dBA. So if five equipment, each producing 52 dBA at the receptor, are working simultaneously, the resulting noise level will be around 59 dBA. The attenuation due to topographic factors could be up to 5 dBA. Good maintenance of equipment with the installation of noise mufflers can reduce the noise by another 5 dBA.

[7] Highway Construction Noise: Measurement, Prediction, and Mitigation, Reagan, J. A. and C. A. Grant, Special Report. US. Department of Transportation, Federal Highway Administration.

Exhibit 7.15: Construction Equipment Noise Ranges (dBA)

Equipment	*Peak Noise Range at 15.2 m*	*Typical Peak Sound Level in a Work Cycle*[a]	*Typical 'Quieted Equipment' Sound Level*[b]	*Construction Phase*		
				Earthworks	*Structures*	*Installation*
Batching plant	82-86	84	81		Y	
Concrete mixers	76-86	85	82		Y	
Cranes	70-94	83	80		Y	Y
Excavators	74-92	85	82	Y		
Tractors and trolleys	77-94	88	85	Y	Y	Y
Water bowsers	85-93	88	85	Y	Y	Y
Graders	72-92	85	82	Y		
Bulldozers	65-95	80	75	Y		
Paver	87-89	88	80	Y		
Pumps	68-72	76	75	Y	Y	Y
Diesel generators	72-82	78	75	Y	Y	Y
Vibrators	68-82	76	75	Y	Y	
Drilling machines	82-98	90	87		Y	Y
Compressors	74-84	81	71		Y	
Dumpers	77-96	88	83	Y	Y	Y
Road rollers	73-77	75	72	Y		

Sources: Noise from Construction Equipment and Operations, Building Equipment, and Home Appliances. USEPA; Bolt, Beranek, and Newman, 1971.

Notes:

[a] Where typical value is not cited in literature, mean of the peak noise range is assumed

[b] Quieted equipment can be designed with enclosures, mufflers, or other noise-reducing features. Where data is not available, a 3 dB reduction is assumed

Exhibit 7.16: Predicted Noise Level for Construction Equipment (dBA)

Equipment	*Equivalent Noise Level in an 8-hr Shift at Receptor 250-500 m from Source*	*Individual Compliance*	
		Daytime	*Nighttime*
Batching plant	59	No	No
Concrete mixers	59	No	No
Cranes	54	Yes	No
Excavators	54	Yes	No
Tractors and trolleys	49	Yes	No

Equipment	Equivalent Noise Level in an 8-hr Shift at Receptor 250-500 m from Source	Individual Compliance	
		Daytime	Nighttime
Water bowsers	49	Yes	No
Graders	45	Yes	Yes
Bulldozers	45	Yes	Yes
Paver	45	Yes	Yes
Pumps	45	Yes	Yes
Diesel generators	43	Yes	Yes
Vibrators	43	Yes	Yes
Drilling machines	43	Yes	Yes
Compressors	43	Yes	Yes
Dumpers	43	Yes	Yes
Road rollers	43	Yes	Yes

It can be seen that some equipment is in compliance with the NEQS and IFC-EHS limits when they are operated on an individual basis. Nighttime construction activities may exceed the limits for certain construction equipment as shown in **Exhibit 7.16**. It is, therefore, predicted that the resultant noise levels at the receptors when the construction work is carried out at a distance of the 350 m from the receptor could be in the range 50-55 dBA. As the noise levels of construction equipment vary considerably, the community can easily notice the variation. However, the overall noise level, L_{eq}, is likely to be within the predicted limited.

In addition to inherent fluctuation in equipment, the other factors that can increase the noise levels at the community include, simultaneous operation of a very large number of equipment, equipment working in close vicinity of the dwellings, receptors located on elevated area thus eliminating attenuation due to topography, and receptors located downwind of the equipment.

7.7.4 Mitigation

Noise mitigation measures for each construction activity are presented in **Exhibit 7.17**.

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Exhibit 7.17: Mitigation Measures for Controlling Noise

Source/Activity	*Mitigation Measures*
Noise generated from construction sites from construction activities Construction activities include removal of topsoil and overburden, excavation with machinery, drilling and blasting of rock, crushing and screening of aggregates, transport of raw materials and finished products within the site and on public roads, etc.	**Source Mitigation** ▶ Select the quietest available plant and equipment that can economically undertake the work required. ▶ Undertake maintenance of the equipment as simple maintenance can reduce noise levels by as much as 50%. Parts may become loose, creating more noise because of improper operation or scraping against other parts. Grinding noises may also occur as the result of inadequate lubrication. ▶ Maintain equipment under use regularly. ▶ Install mufflers on the equipment to minimize noise levels. ▶ Use visual alarms in preference to audible alarms **Pathway Mitigation** ▶ Enclose noisy equipment. ▶ Provide noise attenuation screens, where appropriate. ▶ Building an enclosure around the noise source so that noise is contained. The enclosure should be free from gaps and made of dense material and be lined with noise-absorbing material like glass or polyester batts. ▶ Locate noisy equipment behind parking lots or parks. **Receiver Mitigation** ▶ Close liaison with the community and regular monitoring of the noise levels in the community are key to the successful implementation of the above mitigation measures. Specifically, ▷ Inform communities will of all major construction activities three days in advance, ▷ Discuss noise control measures with the community through informal and formal meetings, and ▷ Implement a complaint registering, tracking and redressal mechanism and undertake on-demand monitoring also in case of any complaints.
Construction noise from traffic Heavy vehicles on access routes can create disturbing noise entering and exiting the facility. The siting of such facilities need to consider the traffic routes the vehicles will travel,	**Source Mitigation** ▶ Install and maintain residential class mufflers and silencers to the mobile plants such as excavators, front-end loaders, and other diesel-engine equipment as applicable. **Pathway Mitigation** ▶ Construct paved Project access roads if practicable and locate where the gradient is low.

Source/Activity	Mitigation Measures
preferably not through built-up residential areas.	**Receiver Mitigation** ▶ Implement special noise reduction measures, such as erecting purpose-built acoustic barriers, restricting opening hours and maintaining transport vehicle. ▶ Prepare and implement a Traffic Management Plan including, timing of traffic through communities, route planning to avoid sensitive locations, etc.
Construction noise from on-site plant operations and equipment The extent to which plant and equipment may disturb neighboring properties will depend on local circumstances and on the nature, level or frequency of the sound emitted, its duration and the time at which it is made.	**Source Mitigation** ▶ Select plant equipment appropriately that required minimal mitigation. ▶ Install mufflers and silencers on the equipment and provide acoustical enclosures. ▶ Modify the equipment or the work area to make it quieter by substituting existing equipment with quieter equipment; retro-fitting existing equipment with damping materials, mufflers, or enclosures; erecting barriers; and maintenance. ▶ Shift to a quieter construction process for example pile driving is very loud as compared to boring which is a much quieter way to do the same work. ▶ Combine noisy operations to occur in the same time period. The total noise level produced will not be significantly greater than the level produced if the operations were performed separately. ▶ Maintain and monitor plant and equipment regularly. **Pathway Mitigation** ▶ Move static plant and equipment as far as possible from sensitive boundaries, as work allows. A distance of four times further away lowers the noise by 12 dBA. A reduction of 10 dBA will sound half as loud. ▶ Provide baffles and specialized mufflers, and acoustic enclosures to the plant and equipment. ▶ Design and built acoustic barriers if needed. Vegetated buffer zones can also be planted to mitigate noise from operations using suitably selected native plantings local to the area. **Receiver Mitigation** ▶ Reduce workers' exposure to high noise levels by keeping moving workers away from the noise source; restricting access to areas; rotating workers performing noisy tasks; and shutting down noisy equipment when not needed. ▶ Use earplugs to reduce workers' exposure to high noise levels.

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Source/Activity	*Mitigation Measures*
Audible noise generated from the blasting in quarry areas Blasting (which occurs at quarries, but not in sand and gravel pits) can give rise to vibration, audible noise, fly rock and dust. Nonetheless, vibration transmitted through the ground and pressure waves through the air ("air overpressure") can shake buildings and people and may cause a nuisance. Audible noise accompanies overpressure.	**Source Mitigation** ▶ Use vibratory piling instead of impact piling. ▶ House conveyor belts and crushing/screening equipment to provide acoustic screening. ▶ Ensure that the noise-reduction equipment fitted to machinery is used and maintained properly. **Pathway Mitigation** ▶ Erect earth mounds around the site boundary can provide acoustic as well as visual screening.
Noise emissions from concrete batching Concrete batching plants are where ingredients such as sand, cement, water, and aggregate are mixed to form concrete. This consists of various activities such as storage of raw materials in bunkers and stockpiles, transfer of raw materials by front-end loaders, conveyors, hoppers and loading of materials to the trucks.	**Source Mitigation** ▶ Locate noisy equipment behind sound barriers or sound absorbers – for example, gravel stockpiles or constructed barriers ▶ Install silencing devices to all pressure operated equipment

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7.8 Water Availability and Quality

The key impacts on water availability and quality due to the Project include:

- Impact 10: Alterations of natural passage of springs due to tunnel construction may disrupt the water availability at mountain springs for local community.
- Impact 11: Use of local water resources for construction activities may reduce the water availability for local communities.
- Impact 12: Contamination of surface and groundwater due to discharge from the construction activities and sewage from the construction camps may affect agricultural productivity and human health.

7.8.1 Changes to Groundwater Patterns

Impact 10: Alterations of natural passage of springs due to tunnel construction may disrupt the water availability at mountain springs for local community.								
Applicable Project Phase				*Construction*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Major	Long-term	Intermediate	High	Possible	High	-	Medium
Mitigation measures: 1. Record location of the springs close to the Project construction site. 2. Monitor flow for located springs and maintain records and ensure the availability of water to the communities and the access of the communities to the water resources being used by them is not adversely affected. Provide water to communities where needed to offset any disturbance. 3. Support the community in development of alternate water supply schemes through local NGOs.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Medium Term	Intermediate	Low	Possible	Low	-	Medium

Heavy construction activities especially the blasting activities for underground construction of the headrace tunnel and powerhouse (see **Section 7.5** *Vibration from Blasting*) and excavation may cause alterations to the groundwater flow patterns in areas proximal to the Project construction site.

The construction area is in the valley, and there are limited households near it. Furthermore, the springs (and households) that have a possibility to be affected fall into the scope of the land acquisition plan. Lastly, these changes will only cause negative impacts when they occur where people or ecological systems are using the water, and for three of the nearby springs nobody uses the spring water.

An inventory of mountain springs and other community water resources is developed in **Section 4.2.7** *(Water Resources and Sediment)*. Mountain springs do not lie proximity to the headrace tunnel or other areas where blasting is expected.

7.8.2 Disturbance to Surface Irrigation Channels

Surface irrigation channels have been constructed by the local residents to divert water from the river into their farms. The channels on the right bank of the Arkari Gol pass in

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close proximity of the headrace tunnel at several locations. Some of the intake structures of these channels fall within the Dam construction site and will be relocated.

Impact 11: Damage to community irrigation channels may occur during construction especially during blasting of the headrace tunnel								
Applicable Project Phase				*Construction*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Major	Long Term	Intermediate	High	Possible	High	-	Medium
Mitigation measures: 1. Document the current status of the irrigation channels. Record location of the springs close to the Project construction site. 2. Engage local communities through GRM for periodic monitoring of the status of the channels. 3. If the channel is damaged, then provide support for fast and complete repair.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Medium Term	Intermediate	Low	Possible	Low	-	Medium

7.8.3 Water Resource Depletion

Impact 12: Use of local water resources for construction activities may reduce the water availability for local communities.								
Applicable Project Phase				*Construction*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Short Term	Intermediate	Medium	Possible	Medium	-	High
Mitigation measures: 1. Develop a Water Sourcing and Abstraction Plan. 2. Source water for construction from authorized abstraction sources agreed between the local communities, local government and EPC contractor. 3. Develop and implement water conservation techniques through the EPC contractor. 4. Keep clear access routes of the community to water sources so that their water requirements are not compromised. 5. Exercise care while moving heavy machinery to avoid damage or blockage of natural waterways and channels. 6. Maintain records of water usage in all Project activities. 7. Incorporate the above measures in the Construction Site Environmental Management Plan..								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Unlikely	Low	-	High

The main source of drinking water in the area is spring water indicated as part of the hydro census (see **Section 4.2.7**, *Water Resources and Sediment*). Water demand for the construction site and camp may take water away from other users if not controlled. Unauthorized abstraction from shallow springs could reduce the yield available or block access for other users, leading to resentment and increasing the risk of hardship.

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7.8.4 Contamination of Surface and Groundwater from Construction Activities

Impact 13: Contamination of surface and groundwater due to discharge from the construction activities and sewage from the construction camps may affect agricultural productivity and human health.

Applicable Project Phase	Construction							
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Short Term	Small	Low	Possible	Low	-	High

Mitigation measures:

1. Develop and implement a Water Quality Management Plan.
2. Develop and implement a Hazardous Material Management Plan.
3. Prepare and implement a Waste Management Plan.
4. Septic treatment facility will be developed at each camp and construction site to manage waste generated on-site.
5. Prepare and implement a Spill Prevention and Response Plan and inducted to the staff for any incident of a spill.
6. Provide and use spill prevention trays at refueling locations.
7. Collect runoff from maintenance workshops using impervious channels and pass through oil water separators (OWS) before final disposal. Properly dispose of the sludge and oil collected at the OWS.
8. Build separate impervious pits (with concrete walls and proper shed) at the construction sites for temporary handling and storage of contaminated soil and water if encountered during construction such as sludge from OWS.
9. Keep all fuel storage tanks and lubricating oil drums in secondary containment impervious pits with impervious shed walls.
10. Avoid on-site maintenance of construction vehicles and equipment, as far as possible.
11. Regularly inspect construction vehicles and equipment to detect leakages.
12. Store fuels and lubricants in covered and dyked areas, underlain with impervious lining.
13. Spill control kits (shovels, plastic bags, and absorbent materials) will be available near fuel and oil storage areas, vehicle parking, and vehicle maintenance areas as well as at construction sites.
14. Remove contaminated soil from the site and dispose of in a manner to ensure the protection of water sources.
15. Construct the bottom of any soak pit or septic tank at least 100 m away from springs and water bores.
16. Maintain records of spills and volume of removed contaminated soil.
17. Maintain a record of remedial measures taken.
18. Use silt traps to prevent contamination of river and streams.
19. Mechanical works and shops, secondary containment (>110% of volume) for storage and use of paints and other hazardous materials should be done over impermeable surfaces.
20. Incorporate the above measures in the Construction Site Environmental Management Plan.

Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Unlikely	Low	-	High

Major risks to water bodies during construction are accidental spills of fuels, lubricants, reagents and other potentially hazardous chemicals.

7.9 Soil, Topography, Land Stability

The impacts associated with soil topography and land stability are discussed in this section. A detailed description of the geology, land use and soil quality is provided in

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Section 4.2.2 (*Geology, Soils and Seismic Hazards*). The potential impacts are as follows:

- Impact 13: Contamination of soil as a result of accidental release of solvents, oils, and lubricants can degrade soil fertility and agricultural productivity.
- Impact 14: Land clearing, excavation, tunnel boring and other construction activities may loosen the top soil in the Project area resulting in loss of soil, accelerated soil erosion, and landslides, especially in the during summer Monsoon.
- Impact 15: Increased erosion and sediment load entering the river from bunds and sediment ponds during the construction phase and as a consequence of the failure of spoil dumping sites.

7.9.1 Soil Quality

Impact 14: Contamination of soil as a result of accidental release of solvents, oils, and lubricants can degrade soil fertility and agricultural productivity.								
Applicable Project Phase				*Construction*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Medium	Small	Medium	Possible	Medium	-	High

Mitigation measures:

1. Develop and implement a Hazardous Material Management Plan.
2. Prepare a Spill Prevention and Response Plan and inducted to the staff for any incident of spill.
3. Provide and use spill prevention trays at refueling locations
4. Appropriately mark fuel tanks by content and store in dyked areas with an extra 10% of the storage capacity of the fuel tank. The area will be lined with an impervious base.
5. Install grease traps on the site, wherever needed, to prevent the flow of oily water.
6. Ensure availability of spill cleaning kit (shovels, plastic bags, and absorbent materials) near fuel and oil storage areas, vehicle parking, and vehicle maintenance areas as well as at construction sites.
7. Carry cleanup kits in all fuel trucks.
8. Carry out fueling and store and use other hazmats only over impermeable surfaces.
9. Ensure the bottom of any soak pit or septic tank at least 10 m above the groundwater table. The distance can be reduced, based on the soil properties, if it is established that distance will not result in contamination of groundwater.
10. The runoff from maintenance workshops will be collected by impervious channels and be passed through oil water separators (OWS) before final disposal. The sludge and oil collected at the OWS will be disposed of properly.
11. Build separate impervious pits (with concrete walls and proper shed) at the construction sites for temporary handling and storage of contaminated soil and water if encountered during construction such as sludge from OWS.
12. Keep all fuel storage tanks and lubricating oil drums in secondary containment impervious pits with impervious shed walls.
13. Avoid on-site maintenance of construction vehicles and equipment, as far as possible.
14. Regularly inspect construction vehicles and equipment to detect leakages.
15. Remove contaminated soil from the site and dispose in a manner to ensure protection of water sources
16. Maintain records of spills and volume of removed contaminated soil.
17. Use silt traps to prevent contamination of river and streams.

18. Mechanical works and shops, secondary containment (>110% of volume) for storage and use of paints and other hazardous materials should be done over impermeable surfaces. 19. Incorporate the above measures in the Construction Site Environmental Management Plan.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Medium	Small	Low	Unlikely	Low	-	High

Oil spills during construction process will result in contamination of soil as well as groundwater. Due to hilly nature of the Project area, soil contamination on the construction site has the potential to travel to surrounding areas and contaminate the soil. Such spills can occur during construction process when tankers will access the area for refueling of excavation and other construction machinery.

Improper handling of oils, lubricants, and other such solvents may result during machinery refueling. Storage in areas with no lining and low-quality storage containers poses another threat of soil contamination. The impact will be minimized by adopting mitigation measures and extra caution during refueling and machinery maintenance at on-site workshops.

7.9.2 Soil Erosion

Impact 15: Land clearing, excavation, tunnel boring and other construction activities may loosen the top soil in the Project area resulting in loss of soil and possible acceleration of soil erosion and land sliding, especially in the wet season.								
Applicable Project Phase					*Construction*			
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Medium Term	Intermediate	Medium	Definite	Medium	-	High
Mitigation measures: 1. Develop a Surface Runoff, Site Restoration and Erosion Control Plan. 2. Limit vegetation loss to demarcated construction area. 3. Cover areas such as muck disposal area, batching plant, labor camp and quarry sites after the closure shall with grass and shrubs. 4. Adopt slope stabilization measures such as adequate vertical and horizontal drains, drainage along roadsides, cross drainage and retaining walls. 5. Monitor slope movements around excavation work areas. 6. Salvage, store, and reuse all topsoil at all construction sites. 7. Minimize height and increase surface area for the stockpile to the extent possible to minimize emissions. 8. Ensure careful stripping of topsoil to avoid its mixing with subsoil. 9. Revegetate the stockpiles to minimize loss of soil quality and weed infestation, maintain soil organic matter levels, soil structure, and microbial activity. 10. Clearly, signpost the topsoil stockpiles for easy identification and minimization of any inadvertent losses. 11. Monitor the establishment of declared plants on the stockpiles and implement control programs as required. 12. Treat topsoil with temporary soil stabilization and erosion control measures. 13. Gradually remove the topsoil in layers (less than 0.5 m thick) in Project affected areas where restoration needs to be done. 14. Mix the top layer with the remainder of the stockpile to ensure that living organisms are distributed throughout the topsoil material at the time of final placement. The use of micro-organism inoculates may be necessary to re-establish micro-organisms in topsoil material. 15. Select local species for plantation to restore the biodiversity of the area in consultation with Forest Department after completion of respective activities.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Possible	Low	-	High

Any excavation work during the construction activities, whether permanent or temporary, would lead to loss of soil. Excavated material collected during boring of the diversion tunnels will be used for the construction of a cofferdam to divert water. Furthermore, construction will require excavation for the powerhouse, tunnels and other Project associated facilities. Erosion of soil can also occur from the removal of vegetation cover, runoff from unprotected excavated areas, muck disposal and quarry sites. Excavations on slopes would also decrease its stability. Given the topography of the area, unprotected excavations on sloping grounds may lead to landslides, especially during the rainy season. Major landslides will disturb the slopes of the area and may also alter the bed of Arkari Gol.

Topsoil from the Project site will be stockpiled for use during the restoration process therefore, it is important that it must retain its advantageous chemical, physical, and biological properties. Generally, the soil is adversely affected during storage if the depth of the stockpile is more than 3 m. Otherwise, anaerobic conditions are created in the deeper depths, which results in a decrease in microbial activity in the stockpiled soil and consequently adversely affect the biological properties. The mitigation measures proposed for ensuring the regeneration of biological activity in the topsoil are provided and will be followed.

7.9.3 Spoil Disposal Areas

Impact 16: Increased erosion and sediment load entering the river from bunds and sediment ponds during the construction phase and as a consequence of the failure of spoil dumping sites.								
Applicable Project Phase				*Construction and Operation*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Long Term	Intermediate	High	Possible	High	-	High

Mitigation measures:

1. Design sedimentation ponds and dumping sites to a have a flood prevention design for a 20-year flood since the dumps will be left in place permanently.
2. Periodically remove sediments from bunds and sedimentation ponds before monsoon and after each large flood.
3. Maintain and monitor the sedimentation ponds to avoid sediment introduction in the river.
4. Undertake vegetation restoration works at all dumping sites including surface leveling, covering and forest/grass planting or agricultural land rehabilitation
5. Monitor slope movements excavation work areas.
6. Restore to the maximum extent possible the hydrological regime and reinstate natural drainage of the land (including provisions to maintain the water balance of the site and protect from flooding where appropriate)
7. Reinstate topsoil (in case it was stripped before construction activities)
8. Revegetate sites with suitable native plant species
9. Drain spoil piles to prevent the concentration of flow and to prevent rill and gully erosion
10. Separate organic material (e.g., roots, stumps) from the dirt fill and store separately. Place this material in long-term, upland storage sites, as it cannot be used for fill.
11. Store "clean" material in a short-term disposal site (stockpile) if it will likely be re-used for fill.
12. Recycle asphalt material in embankments and shoulder backing, where possible. Place these materials where they will not enter the stream system. Asphalt that is 5 years old is considered "inert" (that is, all oils washed off).

13. Do not add excess unusable material to permanently closed sites. 14. Spread material not to be re-used in compacted layers, generally conforming to the local topography. 15. Design the final disposal site reclamation topography to minimize the discharge of concentrated surface water and sediment off the site and into nearby watercourses. Cover the compacted surfaces with a 6-inch layer of organic or fine-grained soil, if feasible. 16. After placement of the soil layer, track walk the slopes perpendicular to the contour to stabilize the soil until vegetation is established. Track walking creates indentations that trap seed and decrease erosion of the reclaimed surfaces. 17. Revegetate the disposal site with a mix of native plant species. Cover the seeded and planted areas with straw compost, mulched with straw at a rate of 1 to 1 ½ tons per acre. Apply jute netting or similar erosion control fabric on slopes greater than 1:2 if site is erosive. 18. Locate stockpiles away from drainage lines, at least 10 meters away from natural waterways and where they will be least susceptible to wind erosion. 19. Ensure that stockpiles and batters are designed with slopes no greater than 1:2 (vertical\ horizontal). 20. Regularly rehabilitate areas not in use for Project activities during construction to minimize erosion. This includes regrading and immediate revegetation (using fast-growing species and different functional groups of plants for keeping soil in place) of slopes to minimize erosion. 21. Install erosion and sediment control measures, if possible before construction commences. Identify drainage lines and install control measures to handle predicted storm water and sediment loads generated in the mini-catchment. 22. Establish an adequate inspection, maintenance and cleaning program for sediment runoff control structures. Ensure that contingency plans are in place for unusual storm events. 23. Continually assess the effectiveness of sediment control measures and make necessary improvements. 24. Keep temporary disposal sites out of wetlands, adjacent riparian corridors, and ordinary high water areas as well as high risk zones, such as 100-year floodplain and unstable slopes. 25. Anticipate sufficient storage area with no risk for sediment delivery for piles that may slump. Stress cracks indicate that the pile is at risk of slumping. 26. Incorporate the above measures in the Spoil Disposal Plan.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Medium Term	Intermediate	Medium	Unlikely	Low	-	High

In the event of failure of a waste dumping site, there can be a danger to downstream communities due to release of sediment into the river impacting the ecology. Sites not revegetated or rehabilitated can be a constant source of fugitive dust emissions due to wind erosion from the surface. Critical mitigation measures listed above ensure spoil units are stable for the coming decades and centuries.

7.10 Aesthetics

The landscapes of remote mountainous areas of northern Pakistan are a source of enjoyment for residents, as well as for the tourists visiting the area.

Although the environmental laws of Pakistan, [8] do not mention visual impacts explicitly, the definition of the environment[9] clearly implies that visual impacts need to be

8 For example, the Punjab Environmental protection Act 199 and the AJK Environmental Protection Act 2000.

9 Section 2(x) of the Punjab Environmental Protection Act 1997 defines "environment" as "(a) air, water and land; ... (e) buildings, structures, roads, facilities and works; (f) all social and economic conditions

considered. Accordingly, Pakistan Guideline[10] recognizes visual impacts of development projects and requires them to be assessed.

A scenic area is any area or landscape that is visually appealing to the observer. It may be an asset to the residents of the area who may have chosen the place of residence because of the scenic beauty or it may be an asset to the businesses in the area who depend on the tourist visiting the area due to the scenic beauty. A visual impact assessment (VIA) is undertaken to ascertain whether the proposed Project will affect the aesthetic value of the area and hence potentially impact the homeowners and tourism industry. The impact on the aesthetic value of an area is inherently subjective in nature. However, reasonably consistent results can be followed, if a standard procedure is used for assessment.

A VIA simulates, in perspective view, the visual effects of proposed Project. The effects could be permanent or temporary. Visual impacts are not necessarily negative. A well-designed project can actually improve the visual experience of observers, hence the Project may have important opportunities to for homeowners and tourism industry in the area. The visual impact to nearby receptors of the Project include:

- Impact 16: Deterioration of aesthetic value of the area due to construction activities may affect tourists, businesses, and nearby homeowners.
- Impact 17: Permanent change in the aesthetic value of the area due to the reservoir and dam.

Section 4.2.9 (*Visual Character*) describes the existing visual (aesthetic) character of the site. The mountainous landscape and deep gorges greatly restricts visibility to a maximum of 0.5 to 1.5 km at receptor locations.

7.10.1 Degradation of Aesthetic Value

Impact 17: Deterioration of aesthetics and visual amenity of nearby receptors due to construction activities, including vehicular movement on roads, may cause a disturbance in aesthetics for nearby communities.								
Applicable Project Phase				*Construction*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Possible	Low	-	High
Mitigation measures: 1. Minimize disturbance to, or movement of, soil and vegetation. 2. Back fill to original levels. 3. Reshape to match in with surrounding topography. 4. Reinstate vegetation around construction sites.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Possible	Low	-	High

affecting community life; and (g) the inter-relationships between any of the factors in sub-clauses (a) to (f);

10 Guidelines for the Preparation and Review of Environmental Reports. Pakistan Environmental Protection Agency, November 1997.

The construction phase visual impact will be local and temporary. The construction will take place at the powerhouse site and dam site. The activities during construction that will affect the aesthetics of the area include excavation, stacking of material onto stockpiles and dumping at the waste disposal areas. Borrow pits and quarry areas will be excavated, useful material will be stacked to stockpiles whereas waste and spoils will be dumped to waste disposal areas.

Quarries and borrow areas may leave a permanent scar on the hillsides as once they are opened, will likely to continue to stay in use and as a result, change the surrounding landscape. Access roads, tunnel faces[11], and adits will necessitate the clearing of vegetation for their construction. Some of the access roads to construction sites will be entirely new and permanent and some will be reconstructed to accommodate the additional construction traffic load which will also alter the landscape of the area. The tunnel faces and adits during the construction phase will be obvious cuts into the mountainsides, many of which will be likely to be visible to residents, especially those on opposing sides of the valleys. For all of these features during the construction phase, there will be an impact on vegetation, as additional areas will be cleared around the feature to provide a working area. These activities will result in the creation of artificial and unnatural features in the landscape. Localized light pollution will also be an issue during construction

7.10.2 Permanent Change in Visual Character

Impact 18: Permanent impact on aesthetics due to proposed developments.								
Applicable Project Phase				*Operation*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Long-term	Small	Low	Possible	Low	-	High
Mitigation measures: 1. Develop and implement a Site Rehabilitation and Landscaping Plan for quarry areas, spoil disposal sites, construction camps and dam site. 2. Use colors that better integrate with the landscape. 3. Disguise elements with vegetation where possible. 4. Retain as much natural vegetation as possible.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Long-term	Small	Low	Possible	Low	-	High

There will be a long-term visual impact due to the construction of the dam and the formation of the reservoir. The Arkari Gol HPP consists of a 20 m high dam wall and a 1.3 km long reservoir. The impact due to the reservoir is subjective as it may be argued that a reservoir is visually appealing and the land use is compatible with the surroundings. Natural lakes in the northern areas of Pakistan are popular tourist

11 Working face of tunnels

attractions, and the reservoir created will offer similar opportunities. The diversion tunnels and powerhouse will be underground limiting their visual impact

7.11 Traffic and Road

There are two categories of roads that will be used to transport material and equipment to the Project facilities, namely Project external roads and Project access roads. Roads will be required to service the site during construction and for the operational life of the scheme.

7.11.1 Project External Roads

It is anticipated that the large mechanical equipment, metal structure, electromechanical device and special steels, that cannot be sourced locally, will be imported. After arriving at port of Karachi it will be transported to the Lahore through the national highway (N5) and then onwards Rashakai, Dargai, and Chakdara. From Chakdara the material will be transported to Dir and then to Drosh via the Lowari tunnel and then onwards to Chitral. Transport route options are further discussed in **Section 3** (*Project Description*).

Certain section of the external roads from Chakdara to Chitral will require widening, upgradation and rehabilitation to support Project transport. Heavy vehicular traffic is already present on roads up till Chitral and, therefore, the incremental impact of Project traffic will be marginal.

7.11.2 Project Access Roads

From Chitral to Uchhtar village, where the Dam site is located, is a 37 km, whereas the powerhouse site is 29 km from Chitral. Current access to the dam site is limited via a jeepable track shown in **Exhibit 7.18.** This track branches of from the Chitral Garam Chashma Road 2 km upstream of the confluence of the Arkari Gol and the Lutkho River as shown in **Exhibit 7.19.**

Exhibit 7.18: Access Road near Dam Site

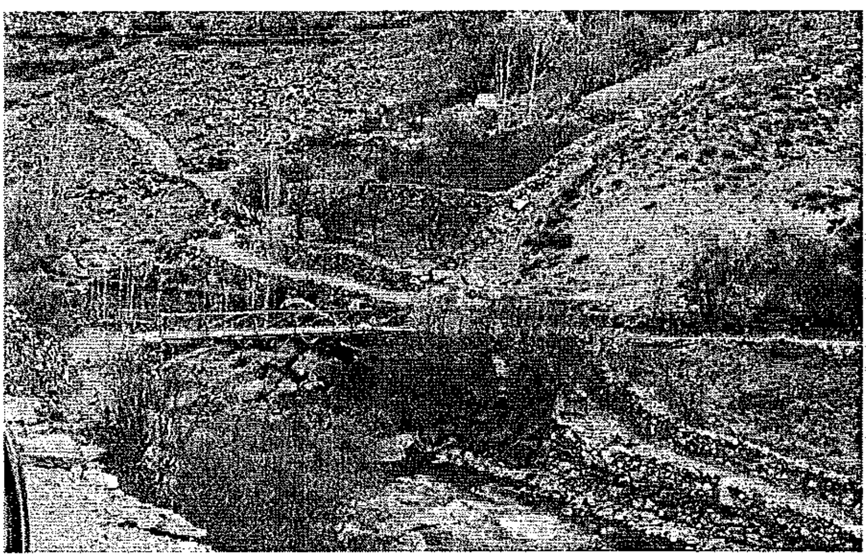

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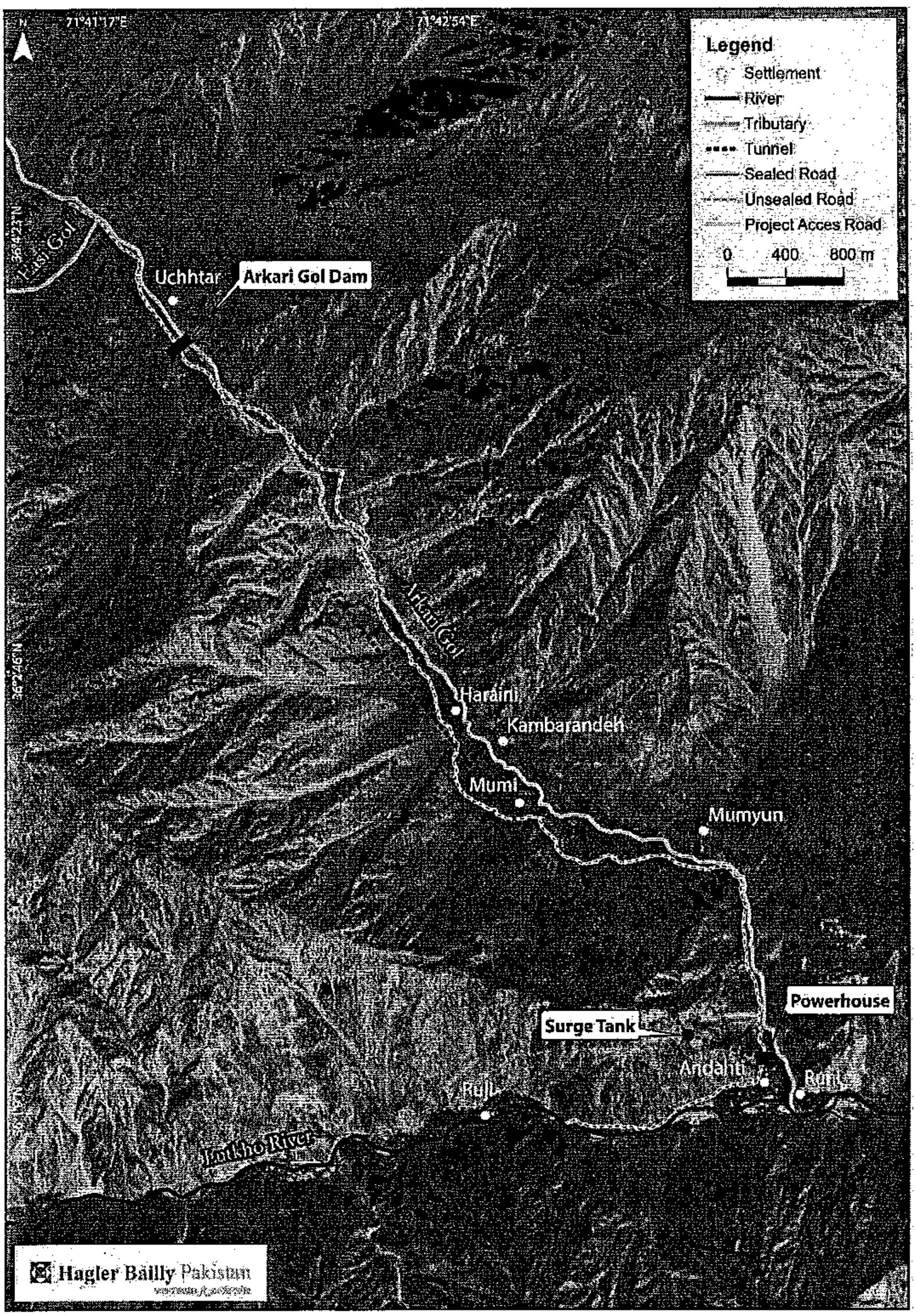
Exhibit 7.19: Project Access Roads



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7.11.3 Impact Analysis for Project Access Roads

The key potential impacts of traffic on Project access roads are:

- Impact 19: Improved accessibility for locals due to the construction of Project access roads.
- Impact 20: Increase in congestion, due to increased traffic during construction will cause delays.
- Impact 21: Increased risk to community safety due to increased traffic volume during the construction phase near communities.
- Impact 22: Degradation of the pavement due to use by heavy construction traffic.

Accessibility

Impact 19: Improved accessibility of locals due to construction of Project access roads.								
Applicable Project Phase				*Construction and Operation*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Medium Term	Small	Low	Possible	Low	+	High
Mitigation measures: 1. Construct Project access roads considering the community connectivity with each other. 2. Allow communities use of new Project access roads.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Medium Term	Small	Low	Definite	Low	+	High

Accessibility for people, living close to the roads, will be improved by the construction of Project access roads. Mountainous terrain in the area is difficult to traverse and construction of new site access roads will improve connectivity in the area.

Congestion

Impact 20: Increase in congestion, due to increased traffic during construction will cause delays.								
Applicable Project Phase					*Construction*			
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Possible	Low	-	High
Mitigation measures: 1. Prepare and implement a Traffic Management Plan. 2. Retain as much natural vegetation as possible to reduce the impact of smoke due to vehicles. 3. Completely cover the vehicles going on the spoil routes and passing through the communities to avoid dust emissions. 4. Strictly implement speed limits and defensive driving policies.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Possible	Low	-	High

Traffic congestion is a condition that results as road use increases and is characterized by slower speeds, longer trip times, and increased vehicular queuing. The Project will upgrade public roads for use as access roads for transporting materials to the Project facilities. There is minimal existing traffic on these roads which may also benefit from the upgradation resulting in faster travel times.

Total external traffic during construction period will carry construction material of ~ 0.2755 million tonnes (see **Section 3.2.2,** *Construction Material*). This will be transported via dump trucks with a capacity of 10-20 tonnes over a 4 year construction period. As a worst case scenario, the capacity of one truck is assumed to be 10 tonnes and 310 active working days[12] are considered. On average, there will be 22 trucks per day. As a worst case-scenario, 40% peaking factor was used that will result in 32 trucks per day.

Community Safety

Impact 21: Increased risk to community safety due to increased traffic during the construction phase near communities.								
Applicable Project Phase				*Construction*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	[illegible]	Short Term	Small	Medium	Possible	Medium	-	High
Mitigation measures: 1. Develop and implement a Traffic Management Plan. 2. Route planning to avoid sensitive areas (mosques, hospitals, schools) during peak activity hours 3. Identify suitable times to transport equipment. 4. Road safety awareness education will also be included during community visits or information sessions so that communities can be familiarized with common road signs and the types of vehicles and equipment that will be moving through the area. 5. Train drivers to move along long transport route to keep their vehicle speed in limits and consider traffic signs and boards. 6. Keep speeds slow (30 km/hr) where there is traffic exchange between roads. 7. Make roundabouts for the congestion points. 8. Designate traffic wardens at roads on the transport route to manage traffic during school hours. 9. Construction traffic will not travel during school starting and ending hours on designated road segments in front of schools on the transport route. 10. Strictly implement speed limits and defensive driving policies. 11. Maintain vehicles, especially brakes.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Possible	Low	-	High

12 Considering that transportation activity will be done for 85% of a year

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Pavement Condition

Impact 22: Degradation of the pavement due to use by heavy construction traffic.								
Applicable Project Phase				Construction				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Possible	Low	-	High
Mitigation measures:								
1. Promptly and properly repair and maintain roads that are subject to damage by Project activities.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Small	Low	Possible	Low	-	High

Heavy transport vehicles in use by the Project during the construction phase may damage the local roads. In case of any damage by Project activities, these roads should be promptly and properly repaired and maintained.

7.12 Seismic and Flood Hazard

Owing to limited availability of flow data (2006-2011) and Arkari Gol largely being a snowy (non-tropical) watershed, Regional Analysis approach was adopted to calculate flood magnitudes at Arkari Gol HPP dam site and powerhouse as shown in **Exhibit 7.20.**

Exhibit 7.20: Flood Magnitudes for Various Return Periods

Return Period	*Flood magnitude at Arkari Gol HPP Dam Site*	*Flood magnitude at Arkari Gol HPP Powerhouse*
10 Years return	158	161
100 Years return	247	252
1000 Years return	333	340
10000 Years return	419	428

The 64 km Arkari Gol runs in a narrow valley with average river gradient of 3.4%. The housing density in the area near the Project facilities is low, and much of the existing households near the Project will be relocated (see **Resettlement Action Plan**).

It is estimated that the diversion facilities will presumably be in service for approximately three construction years. The river diversion facilities will be designed for a flood according to 10-years return period of 284 m^3/s and the design flood for the Project will be selected according to a 1000 years return period with the peak discharge value of 562 m^3/s as per international practice (see **Exhibit 7.20**). In case of floods with higher frequency, the cofferdams would be over spilled and flushed downstream.

Projected Maximum Credible Earthquake (MCE) for Arkari Gol HPP falls between 0.60-0.61g. The Project structure will be designed for Operational Basis Earthquake (OBE) of 0.305 g (which is half of MCE). However, as the Pakistan Building code specifies a PGA of 0.34 g where the Project is located, therefore OBE is set at 0.34 g in compliance with the Pakistan Building Code. The Maximum Design Earthquake (MDE) is also set at the same value as the OBE. Lastly, the GHSAP values are 0.41g to 0.49 g which are much higher than the ones selected for the OBE or the MDE.

The design criteria set for the Project while consistent with the building code is less than the values prescribed in GSHAP and the MDE is the same as the OBE, which is normally set at a higher PGA rating.

The following safety concerns are important for concrete dams[13]:

- **Instability:** The most important safety concern of concrete dams subjected to earthquakes is excessive cracking, which can lead to potential instability from sliding or overturning. Although no concrete dam has failed as a result of earthquake loadings, failure modes can be postulated and tested on shake tables. In general, instability of gravity and arch dams caused by excessive cracking of the concrete is most likely to occur in the upper half of the dam.
- **Importance of Foundation:** Historical experience shows that foundation (abutment) induced failure is the chief source of concern for concrete dams. In contrast to the dam itself, the supporting medium consists of natural materials of varying composition, irregular joints, and planes of weakness. The strength of this medium is generally estimated from exploratory borings and tests on only a small fraction of the material present. Key zones of weakness are critical and often difficult to detect.
- **Field Performance:** No major concrete dam is known to have failed due to earthquake-induced ground motion, although some have experienced strong ground motion and some damage.

Impact 23: A potential flood and seismic hazard under natural extreme conditions for which the dam is not designed, albeit very unlikely, has potential to cause loss of life and damage to property.

Applicable Project Phase					*Operation*			
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Major	Short Term f	Extensive	High	Unlikely	Medium	-	High

The recommended mitigation and management measures include:

- Prepare an emergency preparedness and response plan for the Project that includes consideration of flooding, earthquake, evacuation procedure, co-ordination with local administration and communities.
- Maintain network of climate gauges in the Arkari catchment to monitor potential floods through WAPDA or in conjunction with other hydropower developers.
- Automated telemetric flow gauges can be installed upstream of the reservoir. This will allow the Arkari Hydropower operators to be well aware of any potential flooding conditions using upstream flow data, in addition to climatic conditions recommended above.
- Where climatic data and flow data indicate eminent floods, appropriate measures for management of reservoir level can be undertaken by the dam operators. This includes full opening of gates (including low level outlets) with aim of reducing water levels to below Normal Operating Level at Arkari reservoir.
- Design Basis Earthquake included in the structural design for Powerhouse and weir.

[13] Federal Guidelines for Dam Safety, Earthquake Analyses and design of Dams Maye 2005 FEMA

▶ Design the river diversion facilities according to 10-years return period flood as per international practice. ▶ The design of the Project to be based on 1000 years return period flood.								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Moderate	Short Term	Extensive	Medium	Unlikely	Low	-	High

7.13 Greenhouse Gas Emissions

The Project will result in Greenhouse Gas (GHG) emissions. Increases in greenhouse gas concentrations in the atmosphere results in global warming which has adverse impacts including climate change and ocean acidification. However, the Project has far fewer emissions as compared other power generation methods such as from the combustion of fossil fuels.

The Project will result in the following sources of GHG emissions mainly due to the embodied GHG emissions from construction materials and due to emissions from Project transport. GHG emissions (methane) due to biomass loss and decay due to inundation by Arkari Gol HPP's Reservoir will be minor due to the small reservoir and low vegetation density in the area (see **Exhibit 7.21**). These will further be reduced by the implementation of a Reservoir Clearing Plan.

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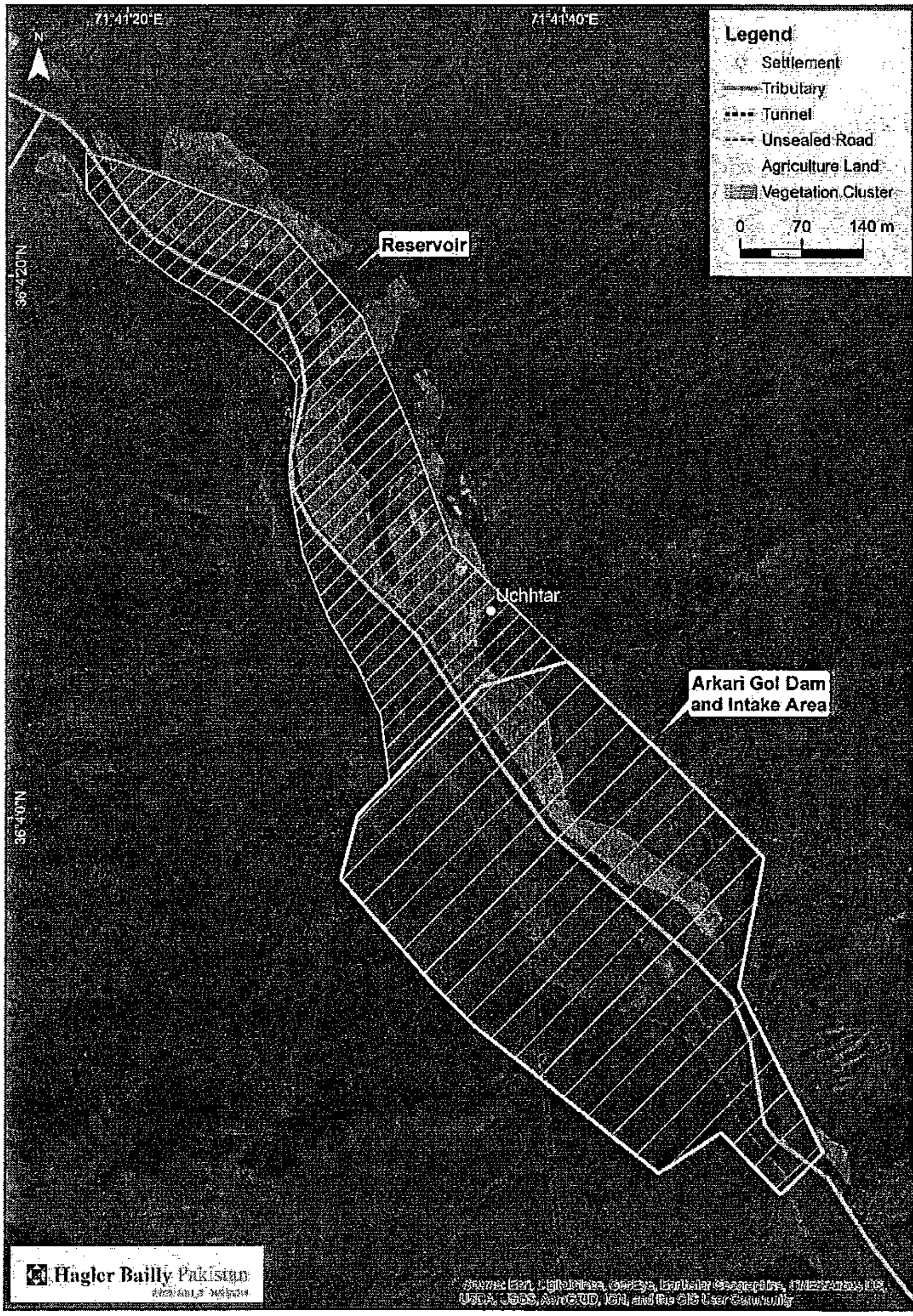
Exhibit 7.21: Vegetation within the Arkari Gol HPP Reservoir



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It is possible that the power generation by the hydropower project will offset more carbon-intensive generation such as that through coal-based thermal power plants. However, due to the complexities in calculating GHG offsets this analysis is not presented in this section

Impact 24: GHG emissions from dam construction will increase GHG concentration in the atmosphere thereby contributing to climate change.								
Applicable Project Phase				*Construction*				
Initial Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Intermediate	Low	Definite	Low	-	High
Mitigation Measures: 1. Implement a Reservoir Clearing Plan 2. Offsets for emissions from vehicles include: a) Make sure vehicles are maintained b) Regular inspection of vehicle exhaust emissions to meet required NEQS standard for exhaust emissions								
Residual Impact Rating	Magnitude	Duration	Scale	Consequence	Probability	Significance	+/-	Confidence
	Minor	Short Term	Intermediate	Low	Definite	Low	-	High

Much of the embodied emissions are contained within concrete production. The Project is a 20 m concrete gravity type dam with an 0.494 km headrace tunnel. The steel and concrete requirements for the Project, as estimated from the Bill of Quantities, is presented in **Exhibit 7.22.**

Exhibit 7.22: Embodied Emission from Materials used in Construction

	Mass (tonnes)	*Emission Factor (tonnes of CO_2/ tonnes of material)*[14]	*Emissions (tonnes of CO_2 e)*
Concrete	240,000	0.228	54,720
Steel	8,000	2.89	23,120
Total			**77,840**

An approximate total of 80 thousand tonnes of CO2 are emitted due to the production of concrete and steel for the Project. Assuming a 30-year lifetime and 378 GWh of electricity production per year the contribution of emissions to the emissions intensity is 0.007 kg per kWh. For comparison an average bituminous coal based thermal power plant has an emission intensity of 0.9 kg per kWh.[15]

14 Ibid.

15 https://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11

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7.14 Livelihood and Well-being

During community consultation conducted for this ESIA community members expressed a desire for the provision of transparent and merit based employment to locals, and investment in community infrastructure. There was a concern that the Project would result in a loss of livelihoods due to inundation of a significant area of productive agricultural land and unavailability of water for irrigation due to the construction of the Project.

A summary of the possible impacts on livelihoods and the well-being of communities in the Study Area is as follows:

- Impact 25: Direct, indirect and induced employment at the local level, resulting in increased prosperity and wellbeing due to higher and more stable incomes of people.
- Impact 26: Increase in the stock of skilled human capital due to transfer of knowledge and skill under the Project resulting in enhanced productivity of local labor.
- Impact 27: Decrease in productivity of agricultural fields due to unavailability of irrigation water for agricultural fields.
- Impact 28: Loss of assets and livelihood as a result of land acquired for the Project.

7.14.1 Employment

Impact 25: Direct, indirect and induced employment at the local level, resulting in increased prosperity and wellbeing due to higher and more stable incomes of people.								
Applicable Project Phase		*Construction and Operation*						
Initial Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Minor	Long-term	Extensive	Medium	Possible	Medium	+	High
Enhancement measures: 1. Ensure preferential recruitment of local candidates provided they have the required skills and qualifications. 2. Include an assessment of the contractor's demonstrated commitment to domestic and local procurement and local hiring in the tender evaluation process. 3. Coordinate recruitment efforts related to non-skilled labor, including for non-skilled labor positions required by contractors. **Good practice measures:** 4. Determine what is considered to be 'fair and transparent' in recruitment and in distribution of jobs between different community groups, in consultation with local communities and their leaders.								
Residual Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Moderate	Long-term	Extensive	High	Definite	High	+	Medium

A large portion of the local population is dependent on agriculture, livestock rearing, small businesses and daily wage labor and government employment.

In the Study Area, education levels of the population are lower than that of the district, as demonstrated by a literacy level of 60% which is less than the literacy rate of the district

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at 75%, (**Section 4.3.3**, *Socioeconomic Conditions in the Study Area*) however is more than that of Pakistan's national average of 56%.[16] The skill set of the local community will need to be developed through vocational training programs run in conjunction with the Project.

As part of data analysis the households were distributed by level of income. A significant portion (30%) of households in the Socioeconomic Study Area earn less than PKR 20,000 per month. This equates to approximately National Poverty line of PKR 3030[17] per person per month. . A small percentage (12%) of households earns more than PKR 50,000 per month. There is some variation in income across the different settlements however this appears to be random, with no particular settlement being significantly better or worse off.

The increased incomes of people employed by the Project are likely to lead to improved nutritional status, better housing, access to education and an improvement in overall well-being of the local. Poverty cycles in poor families can be broken if children become better educated and have better livelihood options than their parents.

The Project will provide employment to a significant number of people during the construction phase, and a more limited number during the operation phase. The Project will directly and through indirect and induced mechanisms (such as more economic activity resulting from improved infrastructure) contribute towards alleviating poverty and vulnerability in the area, and towards increasing prosperity and well-being of the people employed by the Project.

7.14.2 Skill Development

Impact 26: Increase in the stock of skilled human capital due to transfer of knowledge and skill under the Project resulting in enhanced productivity of local labor.

Applicable Project Phase			*Construction and Operation*					
Initial Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Minor	Long-term	Intermediate	Medium	Possible	Medium	+	Low

Enhancement measures:

1. Support a 'vocational training program' to assist local people to qualify for semi-skilled positions focusing on issues such as procurement, involvement of vulnerable groups in Project opportunities and continual professional development of staff.

Good practice measures:

2. Assist local people having practical skills but lacking qualifications to obtain certificates and thus increase their employment opportunities.
3. Support initiatives promoting a culture of learning in local communities.
4. Plan and implement training programs for vulnerable groups to encourage their participation in economic opportunities created by the Project.
5. Assist employees and local communities in improving basic personal financial life skills through training and awareness campaigns.
6. Consider further training programs to prepare retrenched workers to seek employment in sectors not related to dam construction.

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16 http://www.sciencedirect.com/science/article/pii/S2405883116300247 cited on June 2017

17 Dawn <http://www.dawn.com/news/1250694> accessed on April 27,2018.

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Residual Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Moderate	Long-term	Extensive	High	Possible	[illegible]	+	Medium

The Project will result in training and skill development of local and domestic labor, especially during the construction phase. Financial and technical investment by foreign companies is generally seen as a positive opportunity for developing countries as the technology used is usually more advanced compared to locally available technology.

The knowledge and skills acquired by the local community will be of value to the labor-force of the country at national and local levels. The creation and injection of highly trained workers, qualified in multiple skills, into the economy will improve the productivity of the workforce and the benefits will extend to other firms and industries. This impact can therefore stretch to micro- and macro-economic levels.

For enhancement of employment benefits at the local and domestic levels, various training programs will be implemented by MHL. The training programs will focus on maximization of participation of members of the local community in both the construction and operational phases of the Project.

7.14.3 Unavailability of water for irrigation

Impact 27: Decrease in productivity of agricultural fields due to unavailability of water for irrigation								
Applicable Project Phase					*Operation*			
Initial Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Major	Long-term	Extensive	High	Definite	[illegible]	-	High
Mitigation measures: 1. Rehabilitation of Watercourses damaged or affected by the project..								
Residual Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Minor	Short	Small	Low	Definite	Low	-	High

The main river-dependent socioeconomic activity is the irrigation of agricultural lands. As reported by the local communities and observed by the survey team more than 150 acres of land is being irrigated by Arkari Gol in the Socioeconomic Study Area. Moreover, four water flour mills and one micro hydro power plant at settlement Mumi are also working on these water channels. This irrigation system may be affected by the Project during construction.

MHL as a part of the RAP will be responsible to rehabilitate all the watercourses damaged or affected by the Project, in order to minimize the impact of the Project and the extraction of water by the community for their land in the long term while meeting the requirements of the community.

7.14.4 Land Acquisition

Impact 28: Loss of assets and livelihood as a result of land acquired for the Project.								
Applicable Project Phase				*Design and Construction*				
Initial Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Major	Long-term	Extensive	High	Definite	High	-	Medium
Mitigation Measures: 2. See Resettlement Action Plan.								
Residual Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Minor	Medium	Small	Low	Possible	Low	-	High

Land acquired for the Project can potentially have serious effects on the well-being of the community. It is estimated that as about 27 households may have to be relocated as a result of the Project. The Resettlement Action Plan prepared for the Project identifies the potential social issues and proposes measures to avoid adverse impacts. Socio-Cultural Impacts

Project stakeholders expressed concerns about the potential sociocultural changes that could result from Project activities, including the enhancement or possible degradation of the social and economic landscape, and hindrance in mobility of local people due to the location of Project facilities such as the construction camp. Key impacts are listed below and discussed in this section:

- Impact 29: Increase in population due to in-migration of job seekers (in-migrants) leading to pressure on existing social infrastructure and services.
- Impact 30: Disputes over distribution of Project employment within and between Study Area inhabitants and the in-migrants resulting in social unrest.
- Impact 31: Potential social unrest in the Study Area due to conflicting socio-cultural norms amongst the inhabitants and in-migrants.
- Impact 32: Religious conflicts due to different religious beliefs of workers and locals.

7.14.5 Pressure on Social Infrastructure and Services

Impact 29: Increase in population due to in-migration of job seekers (in-migrants) leading to pressure on existing social infrastructure and services in the Study Area.								
Applicable Project Phase	*Construction*							
Initial Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Moderate	Medium	Intermediate	Medium	Possible	Medium	-	Medium
Good practice measures: 1. Development of a Grievance Redressal Mechanism 2. Encourage local communities to use the grievance procedure for concerns related to deterioration of local services. 3. Support local government in the implementation of infrastructure projects. 4. Support NGOs specializing in development of local infrastructure.								
Residual Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Minor	Medium	Intermediate	Low	Possible	Low	-	High

There is a potential for an influx of job seekers into the Study Area due to the jobs created by the Project. The influx will increase pressure on the availability of infrastructure and services, such as those pertaining to education, health care and medication, water and communication in the Project area. The development and implementation of a Grievance Redress Mechanism will help to identify any issues at an early stage so that they can be dealt with effectively.

7.14.6 Conflicts Due to Provision of Employment to Outsiders

Impact 30: Disputes over the distribution of Project employment within and between Study Area inhabitants and the in-migrants resulting in social unrest.								
Applicable Project Phase	*Construction*							
Initial Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Moderate	Medium	Intermediate	Medium	Possible	Medium	-	Medium
Good practice measures: 1. Implement Stakeholder Engagement Plan including: a. maintaining regular communication with local communities and other stakeholders to minimize tensions arising from Project activities; b. maintaining a grievance procedure, and encourage and facilitate stakeholders to use the mechanism to express concerns; and c. providing sufficient resources to the community relations officers to enable them to monitor negative perceptions and associated tensions, and to address them in a timely fashion.								
Residual Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Minor	Short term	Intermediate	Low	Possible	Low	-	High

A potential source of conflict is the real or perceived unequal access to Project opportunities such as employment and small contracts. Complaints can be expected from local communities residing in the Study Area if the distribution of jobs among local communities is perceived to be unfair. Objections can also be expected if people from outside the Study Area are seen to usurp opportunities created by the Project, as the Study Area inhabitants may consider themselves as the rightful owners of Project benefits owing to their vicinity to the Project. This increases the need for open communication between MHL and the various community heads, as well as within the community heads themselves.

7.14.7 Conflicting Socio-Cultural Norms

Impact 31: Potential social unrest in the Study Area due to conflicting socio-cultural norms amongst the inhabitants and in-migrants.								
Applicable Project Phase	*Construction*							
Initial Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Minor	Short term	Small	Low	Possible	Low	-	Medium
Enhancement measures: 1. Refer to measures under Impact 30.								

The Project is likely to result in an influx of job seekers (mainly men) into the Study Area, which could result in disputes of an ethnic or cultural nature in the Study Area. There could be conflicts between the in-migrants and Study Area inhabitants due to their conflicting traditions and norms. It will also affect women's privacy and mobility in the area. The likelihood of this impact is low given that Project facilities are not located in immediate vicinity of local communities and where the facility borders local communities, proper fencing and barriers will be provided to avoid unnecessary interaction.

7.14.8 Religious Conflicts

Impact 32: Religious conflicts due to different religious beliefs of workers and locals.								
Applicable Project Phase	*Construction*							
Initial Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Moderate	Medium	Intermediate	Medium	Possible	Medium	-	Medium
Good practice measures: 1. Refer to measures under Impact 30.								
Residual Impact Rating	*Magnitude*	*Duration*	*Scale*	*Consequence*	*Probability*	*Significance*	+ /-	*Confidence*
	Minor	Short term	Intermediate	Low	Possible	Low	-	High

More than 90% of the entire population of the Socioeconomic Study Area belongs to Ismaili sect of Islam and others belong to Ahl-e-Sunat sect. Sectarian violence is low in the Socioeconomic Study Area, therefore, the risk of such conflicts is low. Moreover, development and implementation of a Grievance Redress Mechanism will help to identify any issues at an early stage so that they can be dealt with effectively.

7.15 Cumulative Impact Assessment

7.15.1 Development Scenarios

The cumulative impact assessment presented in this section assumes the following development scenario:

Completed Projects

- 106 MW Golen Gol Hydropower Project on Golen Gol

Feasibility Stage

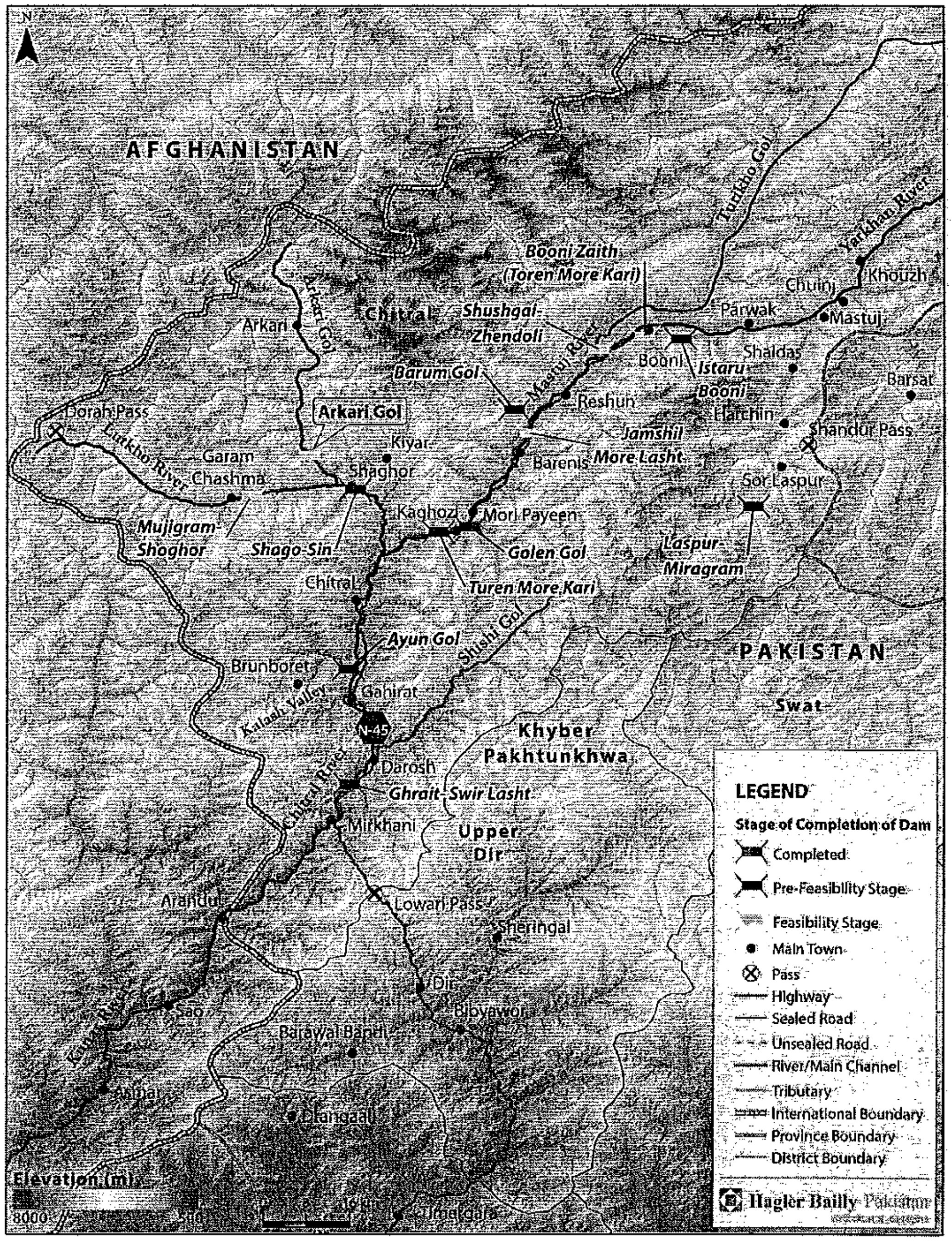
- 99 MW Arkari Gol Hydropower Project on Arkari Gol
- 64 MW Mujigram-Shoghore Hydropower Project on Lutkho River
- 144 MW Shushghai Zandholi Hydropower Project on Tirich Gol
- 350 MW Booni Zaith (Toren More Kari) Hydropower Project on Booni Gol

Prefeasibility of Conceptual Stage

- 230 MW Laspur Murigram Hydropower Project on Laspur River
- 350 MW Turen More – Kari Hydropower Project on Mastuj River
- 370 MW Ghrait-Swir Lasht Hydropower Project (location not known)
- 25 MW Barum Gol Hydropower Project on Barum Gol
- 72 MW Istaru Booni Hydropower Project on Turkuho River

Exhibit 7.23 shows the location of these projects.

Exhibit 7.23: Hydropower Projects in Chitral Valley



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The discussion of cumulative impacts is structured in the following manner:

1. The impacts of proposed hydropower projects on Arkari Gol and Lutkho River is in the catchment of Lutkho River or the Lutkho-Arkari sub-basin that is of immediate concern for this ESIA are first discussed. This discussion draws on the results of the EFlow assessment conducted for the Arkari Hydropower Project for purposes of this study, and extending the results to include the impacts of the proposed Mujigram-Shoghore Hydropower Project located in the catchment of Lutkho River.
2. This is followed by a discussion of cumulative impacts of projects in the catchment of Mastuj/Chitral River in the feasibility or conceptual stage. This discussion is primarily a high level assessment of probable impacts of developments, as modeling of impacts of these projects is not in the scope of this study.

7.15.2 Impact on River Ecology in the Lutkho-Arkari Sub Basin and Management

The recommendations for EFlow management presented in **Appendix M** are based on acceptance of an environmental release from the dam that can be justified on the basis of low level of diversity and abundance in the Arkari Gol, and a barrier to migration of fish upstream of a waterfall located in the low flow section. For impacts downstream of the powerhouse due to peaking operations the EFlow Assessment (**Appendix M**) considers three scenarios including run of river operation, peaking and a modified form of peaking and presents the impacts of each operational scenario on indicator fish species. It recommends an approach to power generation which will balance the economic value of peaking power and impacts on river ecology in order to justify "No Net Loss Where Feasible" in Natural Habitats as defined in PS6. The impacts of full peaking can be mitigated using a modified form of peaking in which the flow is ramped up and ramped down to reduce impacts on fish whilst reducing power generation to about two thirds of the capacity of the powerhouse.

In case the 64 MW Mujigram-Shoghore HPP on Lutkho River is constructed, fish populations and breeding areas in the low flow section created in Lutkho River will be affected. The affects will be severe if an appropriate level of EFlow is not maintained in the low flow section. Similarly, impacts downstream of the powerhouse in the Lutkho River on the fish populations and the aquatic ecosystem will be serious if peaking operations are not managed with due attention to river ecology. In view these potential impacts which will extend to the entire Lutkho-Arkari sub basin, the same EFlow management principles will have to be applied for the Mujigram-Shoghore HPP as recommended for the Arkari Gol HPP. This will imply:

1. Selecting an operational mode in consultation with the power purchaser which provides a balance between the economic value of peaking power and impacts on river ecology in order to justify "No Net Loss Where Feasible" in Natural Habitats as defined in PS6. The operational modes presented include a modified form of peaking in which peak power generation is curtailed to about two-thirds of capacity combined with a ramp up and ramp down of flow around the peak.

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2. Adjusting the release from the dam to levels higher than those set for the Arkari Gol HPP to account for more productive habitats in the Lutkho River where the low flow river section of the Project will exist.
3. Staggering the time of the peak in relation to that for Arkari Gol HPP to avoid imposition of a combined peak flow from the two projects on Lutkho River downstream of its confluence with the Arkari Gol. A 'morning peak' can be considered for the Mujigram-Shoghore HPP to avoid a coincidence with the 'evening peak' for the Arkari Gol HPP.
4. Assessing the feasibility of a fish ladder if the migratory Snow Trout is found upstream of the dam.

In case another project is planned on the Lutkho River downstream of its confluence with Arkari Gol, then the above principles will have to be extended to that project as well. Holistic EFlow assessments would be warranted following the World Bank Group's Good Practice Handbook for Environmental Flow Assessment for Hydropower Projects.

7.15.3 Impacts on River Ecology in the Chitral Basin and Management

The impacts on river ecology predicted in the previous section for the Lutkho sub-basin will be replicated and extended if the hydropower development is extended to other sub-basins in Chitral Basin. The impacts of basin-wide hydropower development will be most severe on the migratory Snow Trout, which will be confined to sections of tributaries. Loss of connectivity will lead to stress on populations of this fish as it may not be able to migrate downstream in winters to avoid colder waters upstream. In-breeding will also follow as populations get isolated and fish is not able to travel to the main stem Mastuj/Chitral River from where it an move to other valleys. Other non-migratory fish that are adapted to river habitats will be at risk from impoundments where lotic or river habitat will be lost and will be converted to lentic or lake habitat. Peaking flows from power houses will substantially reduce the extent of wet riverbed and will result in loss of habitat for the loaches that survive in cobbles and boulders in shallow waters. The following good practice measures are suggested to manage the impacts of hydropower projects in the Chitral Basin:

1. Given the topographic relief in Chitral Basin, the projects generally have shorter impoundments, of the order of 2-3 km, and longer power generation tunnels to benefit from high heads that can be utilized in Pelton turbines. As suggested for the Mujigram-Shoghore HPP in **Section 3.5**, release from the dam to levels higher than those set for the Arkari Gol HPP will have to be considered to account for more productive habitats.
2. The planned projects in the basin are generally located in tributaries, some of which flow through U shaped valleys that provide habitats for breeding of Snow Trout and do not present natural barriers to migration of fish such as that present in Arkari Gol. Depending on the location of the dams, the dams will also present barriers to migration of fish. Feasibility of fish ladders will therefore have to be examined on a case to case basis.

3. The timing of peaking for the projects in a single sub-basin will have to be adjusted to avoid overlapping of peaks and compounding of impact of peaking operations on river ecology for projects located in the same sub-basin.
4. Holistic EFlow assessments would be warranted following the World Bank Group's Good Practice Handbook for Environmental Flow Assessment for Hydropower Projects.

7.15.4 Other Impacts

Ecosystem services such as sand and gravel mining, and recreational and subsistence fishing which are somewhat significant in sub-basins such as Poonch in Jhelum Basin[18] are of comparatively lower significance in Chitral Basin (see **Section 4.3**). Supported by the geology which is different for the Jhelum Basin where sand stone is dominant (see **Section 4.2**), alternatives for mining of sediment are available in the Chitral Basin at locations other than those in or adjacent to the riverbeds. Socioeconomic impacts of hydropower developments are therefore not expected to be significant in the Chitral Basin. The projects will help in improving socioeconomic conditions in the basin through employment generation and infrastructure development.

The impacts on terrestrial ecology will be low and limited to project footprints. Given the design of the projects with limited impoundments, terrestrial habitats inundated by project reservoirs will be limited. Mammals such as the Ibex and Snow Leopard are found at higher elevations where they can shelter and are less at risk from hunting. The basin is located in the shadow of the South Asian Monsoon System with precipitation rates lower than those in the Himalayas, and vegetation cover is lower in comparison the adjacent Jhelum Basin located to the east of the Chitral Basin. Construction of transmission lines located on right of ways closer to roads along the rivers are therefore not expected to impact the terrestrial habitats significantly.

The locals are already hunting migratory birds that stop for resting in the ponds in the Arkari and Lutkho rivers. Presence of migratory birds will increase after the reservoirs are created by the dams, which is likely to result in increase in hunting pressures. The precautionary approach of hiring guards for protection of the river and reservoirs as suggested in **Section 7.2.1** and **Section 7.2.2** will help in management of such pressures, and should be extended to other hydropower projects in the basin as well as suggested in the next section.

The reservoirs created by the projects will provide an attraction for tourists and recreational activities. However, in absence of basic planning and environmental management, degradation of the reservoir banks due to tourism related impacts such as littering, erosion, and pollution from vehicles can damage the tourism potential of the reservoirs. The local governments can work with the project owners in management of tourism activities at the reservoirs to enhance the incomes of the locals while preserving landscape value.

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[18] Hagler Bailly Pakistan, 2018, Draft Strategy Report, Basin-wide Studies in the Jhelum-Poonch Basin for Sustainable Hydropower. International Finance Corporation.

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7.15.5 Recommendations for Basin-Wide Management

This section outlines some recommendations for management of basin-wide impacts to reduce the environmental and social impacts from development of multiple HPPs. It draws from lessons learnt for developing a Strategy for Sustainable Hydropower Development in the Jhelum Poonch Basin.[19]

Prepare Guidelines for ESIAs for Hydropower Projects Following Accepted International Best Practices

A review of available ESIAs (Environmental and Social Impact Assessment) shows that some sub-standard ESIAs have been approved by the provincial EPAs. Since these ESIAs were unable to completely identify the valued ecosystem components (VECs) or predict environmental impacts, project implementation has led to unmanaged and unmitigated environmental and social impacts.

It is recommended that every hydropower project also consider cumulative impacts of other hydropower projects in the basin in their EIAs/ESIAs. In this context, the cumulative impacts of projects should be incorporated in the Terms of Reference for carrying out full EIA studies [20] including identification of valued ecosystem components (VECs) and an assessment of how they will be impacted as a result of cumulative impacts.

To conform to international best practices, it is also recommended that ESIAs for projects in the basin follow the guidelines and standards set in the IFC Performance Standards[21] and ADB's Safeguard Policy Statement[22].

Prepare and Implement Guidelines for EFlow Assessments

Environmental flows describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems. Through implementation of environmental flows, water managers strive to achieve a flow regime, or pattern, that provides for human uses and maintains the essential processes required to support healthy river ecosystems.[23]

It is recommended that provincial Environmental Protection Agencies (EPAs), KP EPA in this case, develop guidelines for hydropower projects for selecting the appropriate environmental flow in line with the principles outlined in the World Bank's Good

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[19] Hagler Bailly Pakistan, 2018, Draft Strategy Report, Basin-wide Studies in the Jhelum-Poonch Basin for Sustainable Hydropower. International Finance Corporation.

[20] Arikan, Esra; Dieterle, Gerhard; Bouzaher, Aziz; Ceribasi, Ibrahim Haluk; Kaya, Dundar Emre; Nishimura, Shinya;Aramullaoglu,Ulker; Kahraman, Bilgen. 2012. Sample guidelines: Cumulative environmental impa ct assessment for hydropower projects in Turkey. Washington DC; World Bank. http://documents.worldbank.org/curated/en/2012/12/17671936/sample-guidelines-cumulative-environmental-impact-assessment-hydropower-projects-turkey

[21] International Finance Corporation, 2012, Performance Standards

[22] Asian Development Bank, 2009, Safeguard Policy Statement, Policy paper.

[23] Postel, S., and Richter, B. 2003. Rivers for Life: Managing Water for People and Nature. Island Press, Washington, D.C.

Practice Handbook.[24]This Good Practice Handbook provides guidance to practitioners on taking rigorous and consistent approaches to assess and manage hydropower project impacts on downstream river ecosystems and people through the assessment and provision of environmental flows (EFlows).

Increase Protection Efforts to Conserve Ecological Resources

The KP Fisheries and Wildlife Departments have a clear mandate for protecting ecological resources. The wider area around the Project provides habitat to migratory birds as well as large mammals of conservation importance such as Himalayan Ibex and Markhor. With improved access to the area, as a result of the development of the hydropower project/s, poaching, illegal fishing and trade in plant and animal species is likely to increase. There is a need to step up protection efforts to minimize anthropogenic impacts, particularly illegal hunting and fishing.

It is recommended that increased budget and man-power be allocated towards these government departments tasked with protecting the river and terrestrial habitats. The individual hydropower projects can play a role in this by either directly supporting the government departments or hiring an Implementing Organization which can support the government departments in conservation efforts.

Become a Member of Hydropower Developers Working Group (HDWG).

The International Finance Corporation (IFC) of the World Bank has created a platform called the Hydropower Developers Working Group (HDWG) which includes members from the existing and planned HPPs in the Jhelum basin. The objective of the HDWG is to make sure that HPPs in the Jhelum basin have a common understanding of the issues related to hydropower development so that they can work jointly to redress these issues and problems. It is recommended that HPPs in the Lutkho-Arkari sub-basin and Chitral/Mastuj basin become a member of the HDWG.

Design HPPs to Balance Power Generation Benefits and Environmental Impacts

Large hydropower projects designed to harness a s much as possible of the river's energy to generate electricity, to maximize power generation and financial benefits. However, they also lead to significant negative environmental and social impacts. This is because dams modify the river's flow regime, and in doing so they impact this fundamental driving force of the river ecosystem, leading to knock-on effects on the sediment, chemical and thermal regimes of the river, the river's biota and all the ecosystem services valued by people. It is important for hydropower project proponents to balance power generation benefits and consider the loss of ecological resources, ecosystems, ecosystem services and livelihoods in the design, construction and operation of projects.

Maximize Synergistic Project Development

Where more than one project is being built in close proximity on the same tributary or river section, developers have the opportunity to coordinate with each other and redesign projects based on a synergistic approach. This can help maximize positive impacts and mitigate adverse environmental impacts. Coordinated mitigation measures can be

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24 World Bank Group, February 2018, Good Practice Handbook, Environmental Flows for Hydropower Projects Guidance for the Private Sector in Emerging Markets

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incorporated into the design and operation plans to mitigate expected cumulative impacts at the watershed level. These measures include maintaining adequate downstream flow regimes, coordinated design of fish ladders, contribution to native fish hatcheries, open water re-stocking, and designing fish diversion structures at intakes to avoid entrapment.[25] The same approach towards synergistic project development can be adopted when planning the transmission lines.

Promote Research on River Ecology

There is a need to carry out research on a number of issues related to river ecology including development of a comprehensive baseline of ecological resources of Lutkho and Mastuj River; assessment of impacts of construction of multiple hydropower projects on migratory fish; techniques for captive breeding and stocking of fish of conservation importance that are impacted by projects; fish passages suited to local species, river conditions, and dam designs; genetic studies to determine risk of in-breeding and actions to reduce the risks; use of holistic environmental flow models to assess cumulative impacts of projects.

The establishment of an Institute for Research on River Ecology (IRRE) in the Jhelum Basin has been recommended in the Biodiversity Management Plan (BMP) of Karot HPP. The same approach has been incorporated into the BAP prepared for the Kohala HPP, Mahl and Azad Pattan HPP, all of which are located on the Jhelum River (subject to approval of the associated costs in the electricity tariff by NEPRA). The IRRE is proposed as a basin wide institution in which all the developers of HPPs in the Jhelum basin contribute to establishment and operation of the institute, and jointly benefit from the research outputs.

HPPs in the Lutkho and Chitral basin can either promote small scale research in the basin, or preferably, contribute towards the research conducted at the IRRE in Jhelum Basin, or set up an independent research institute in the Chitral Basin following the model of IRRE.

Increase Environmental Management Capacity

The KP Wildlife and Fisheries Departments are the custodians of the terrestrial and aquatic ecological resources in the basin. Capacity building of the staff of these government departments is imperative for implementing any conservation measures. In addition, it is equally important for hydropower project proponents to increase their environmental management capacity so that HPPs consider environmental protection at the design, construction and operation stage of HPP development.

7.16 Summary of the Project Impacts

In this section, a summary of the impacts of the Project are provided. The summary is provided in the form of a table (**Exhibit 7.24**).

[25] Hagler Bailly Pakistan, 2013, Strategic Environmental Assessment of Hydropower Plan for Azad Jammu and Kashmir for International Union for Conservation of Nature (IUCN), Islamabad

Exhibit 7.24: Summary of Impacts

ID	*Aspect*	*Impact*	*Phase*	*Stage*	*Magnitude*	*Timeframe*	*Spatial Scale*	*Consequence*	*Probability*	*Significance*	*+/-*
1	Aquatic Ecology	Loss of Aquatic Biodiversity due to Creation of a Low Flow Section Downstream of the Dam	C, O	Init	Moderate	[illegible]	Small	Moderate	[illegible]	Medium	-
				Res	Moderate	[illegible]	Small	Moderate	[illegible]	Medium	-
2	Aquatic Ecology	Loss of Aquatic Biodiversity due to Changes in Ecological Conditions Downstream of the Powerhouse as a Result of Release of Water	C, O	Init	Moderate	[illegible]	Small	Moderate	[illegible]	Medium	-
				Res	Moderate	[illegible]	Small	Moderate	[illegible]	Medium	-
3	Terrestrial Ecology	Terrestrial habitat loss caused by construction of Project infrastructure	C	Init	Minor	Short Term	Small	Low	Possible	Low	-
				Res	Minor	Short Term	Small	Low	Possible	Low	-
4	Terrestrial Ecology	Decline in abundance and diversity of terrestrial flora and fauna caused by construction related activities.	C	Init	Minor	Short Term	Small	Low	Possible	Low	-
				Res	Minor	Short Term	Small	Low	Possible	Low	-
5	Terrestrial Ecology	Project operation leading to animal disturbance, displacement and decline.	O	Init	Minor	[illegible]	Small	Medium	Possible	Medium	-
				Res	Minor	[illegible]	Small	Low	Possible	Low	-
6	Ambient Air Quality	Increase in ambient concentration of air pollutants from construction activities and vehicular movement may cause health impacts on the community.	C	Init	Moderate	Short Term	Intermediate	Medium	Possible	Medium	-
				Res	Minor	Short Term	Intermediate	Low	Possible	Low	-
7	Vibration from blasting	Vibration from blasting during the construction phase may disturb local communities.	C	Init	Moderate	Short Term	Small	Low	Possible	Low	-
				Res	Minor	Medium Term	Small	Low	Possible	Low	-
8	Hazards of Fly Rock from Blasting	Blasting may pose a safety hazard due to flying debris	C	Init	Moderate	Short Term	Intermediate	Medium	Possible	Medium	-
				Res	Minor	Short Term	Small	Low	Possible	Low	-
9	Construction Nosie	Increase in ambient noise levels due to the operation of construction equipment, movement of construction traffic and blasting may create a nuisance for nearby communities and visiting tourists.	C	Init	Moderate	Short Term	Intermediate	Medium	Possible	Medium	-
				Res	Minor	Short Term	Small	Low	Possible	Low	-

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ID	Aspect	Impact	Phase	Stage	Magnitude	Timeframe	Spatial Scale	Consequence	Probability	Significance	+/-
10	Water Availability and Quality	Alterations of natural passage of springs due to tunnel construction may disrupt the water availability at mountain springs for local community.	C	Init	[illegible]	[illegible]	Intermediate	[illegible]	Possible	[illegible]	-
				Res	Minor	Medium Term	Intermediate	Low	Possible	Low	-
11	Water Availability and Quality	Damage to community irrigation channels may occur during construction especially during blasting of the headrace tunnel	C	Init	[illegible]	[illegible]	Intermediate	[illegible]	Possible	[illegible]	-
				Res	Minor	Medium Term	Intermediate	Low	Possible	Low	-
12	Water Availability and Quality	Use of local water resources for construction activities may reduce the water availability for local communities.	C	Init	Moderate	Short Term	Intermediate	Medium	Possible	Medium	-
				Res	Minor	Short Term	Small	Low	Unlikely	Low	-
13	Water Availability and Quality	Contamination of surface and groundwater due to discharge from the construction activities and sewage from the construction camps may affect agricultural productivity and human health.	C	Init	Moderate	Short Term	Small	Low	Possible	Low	-
				Res	Minor	Short Term	Small	Low	Unlikely	Low	-
14	Soil, Topography and Land Stability	Contamination of soil as a result of accidental release of solvents, oils, and lubricants can degrade soil fertility and agricultural productivity.	C	Init	Moderate	Medium	Small	Medium	Possible	Medium	-
				Res	Minor	Medium	Small	Low	Unlikely	Low	-
15	Soil, Topography and Land Stability	Land clearing, excavation, tunnel boring and other construction activities may loosen the top soil in the Project area resulting in loss of soil and possible acceleration of soil erosion and land sliding, especially in the wet season.	C	Init	Moderate	Medium Term	Intermediate	Medium	[illegible]	Medium	-
				Res	Minor	Short Term	Small	Low	Possible	Low	-
16	Soil, Topography and Land Stability	Increased erosion and sediment load entering the river from bunds and sediment ponds during the construction phase and as a consequence of the failure of spoil dumping sites.	C, O	Init	Moderate	[illegible]	Intermediate	[illegible]	Possible	[illegible]	-
				Res	Moderate	Medium Term	Intermediate	Medium	Unlikely	Low	-

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ID	Aspect	Impact	Phase	Stage	Magnitude	Timeframe	Spatial Scale	Consequence	Probability	Significance	+/-
17	Aesthetics	Deterioration of aesthetics and visual amenity of nearby receptors due to construction activities, including vehicular movement on roads, may cause a disturbance in aesthetics for nearby communities.	C	Init	Minor	Short Term	Small	Low	Possible	Low	-
				Res	Minor	Short Term	Small	Low	Possible	Low	-
18	Aesthetics	Permanent impact on aesthetics due to proposed developments.	O	Init	Minor	[illegible]	Small	Low	Possible	Low	-
				Res	Minor	[illegible]	Small	Low	Possible	Low	-
19	Traffic and Road	Improved accessibility of locals due to construction of Project access roads.	C, O	Init	Minor	Medium Term	Small	Low	Possible	Low	+
				Res	Minor	Medium Term	Small	Low	Definite	Low	+
20	Traffic and Road	Increase in congestion, due to increased traffic during construction will cause delays.	C	Init	Minor	Short Term	Small	Low	Possible	Low	-
				Res	Minor	Short Term	Small	Low	Possible	Low	-
21	Traffic and Road	Increased risk to community safety due to increased traffic during the construction phase near communities.	C	Init	[illegible]	Short Term	Small	Medium	Possible	Medium	-
				Res	Minor	Short Term	Small	Low	Possible	Low	-
22	Traffic and Road	Degradation of the pavement due to use by heavy construction traffic.	O	Init	Minor	Short Term	Small	Low	Possible	Low	-
				Res	Minor	Short Term	Small	Low	Possible	Low	-
23	Seismic and Flood Hazard	A potential flood and seismic hazard under natural extreme conditions for which the dam is not designed, albeit very unlikely, has potential to cause loss of life and damage to property.	C	Init	[illegible]	Short Term f	Extensive	High	Unlikely	Medium	-
				Res	Moderate	Short Term	Extensive	Medium	Unlikely	Low	-
24	Greenhouse Gas Emission	GHG emissions from dam construction will increase GHG concentration in the atmosphere thereby contributing to climate change.	C, O	Init	Minor	Short Term	Intermediate	Low	Definite	Low	-
				Res	Minor	Short Term	Intermediate	Low	Definite	Low	-
25	Livelihood and Well-being	Direct, indirect and induced employment at the local level, resulting in increased prosperity and wellbeing due to higher and more stable incomes of people.	C, O	Init	Minor	Long Term	Extensive	Medium	Possible	Medium	+
				Res	Moderate	Long Term	Extensive	High	Definite	[illegible]	+

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ID	Aspect	Impact	Phase	Stage	Magnitude	Timeframe	Spatial Scale	Consequence	Probability	Significance	+/-
26	Livelihood and Well-being	Increase in the stock of skilled human capital due to transfer of knowledge and skill under the Project resulting in enhanced productivity of local labor.	C, O	Init	Minor	[illegible]	Intermediate	Medium	Possible	Medium	+
				Res	Moderate	[illegible]	[illegible]	[illegible]	Possible	[illegible]	+
27	Livelihood and Well-being	Decrease in productivity of agricultural fields due to unavailability of water for irrigation	O	Init	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
				Res	Minor	Short	Small	Low	[illegible]	Low	-
28	Livelihood and Well-being	Loss of assets and livelihood as a result of land acquired for the Project.	D, C	Init	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-
				Res	Minor	Medium	Small	Low	Possible	Low	-
29	Livelihood and Well-being	Increase in population due to in-migration of job seekers (in-migrants) leading to pressure on existing social infrastructure and services in the Study Area.	C	Init	Moderate	Medium	Intermediate	Medium	Possible	Medium	-
				Res	Minor	Medium	Intermediate	Low	Possible	Low	-
30	Livelihood and Well-being	Disputes over the distribution of Project employment within and between Study Area inhabitants and the in-migrants resulting in social unrest.	C	Init	Moderate	Medium	Intermediate	Medium	Possible	Medium	-
				Res	Minor	Medium	Intermediate	Medium	Possible	Medium	-
31	Livelihood and Well-being	Potential social unrest in the Study Area due to conflicting socio-cultural norms amongst the inhabitants and in-migrants.	C	Init	Minor	Short term	Small	Low	Possible	Low	-
32	Livelihood and Well-being	Religious conflicts due to different religious beliefs of workers and locals.	C	Init	Moderate	Medium	Intermediate	Medium	Possible	Medium	-
				Res	Minor	Short term	Intermediate	Low	Possible	Low	-

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8. Grievance Redress Mechanism

Timely and effective redress of stakeholder grievances will contribute to bringing sustainability in the operations of a project. In particular, it will help advocate the process of forming and strengthening relationships between project management and the stakeholder community groups and bridge any gaps to create a common understanding, helping the project management to efficiently operate in the area.

To register and resolve community grievances a Grievance Redress Mechanism (GRM) will be established. The purpose of the GRM is to facilitate the resolution of disputes between community members and the Project without going into litigation. The proposed mechanism will be based on two Grievance Redress Committees (GRCs), one at village level and the other at the Project level. The proposed GRM will help achieve the objectives of sustainability by dealing with any environmental or social issues arising from Project activities in a timely manner.

The project proponent, MHL, will be responsible for establishing and implementing the GRM. MHL will facilitate the formation of GRCs at the village level with the help of community representatives, and will also form a GRC at the Project level. MHL will also be responsible for ensuring that information regarding the GRM is effectively disseminated to communities so that people potentially affected by the project are aware of the procedure for the registration and follow-up of complaints.

The GRM will be established and fully functional (including establishment of both GRCs) before any construction machinery or personnel are mobilized to the Project site.

8.1 Grievance Redress Committees

The GRCs will ensure that the process for redressing grievances remains accessible, fair and independent. The village–level Grievance Redress Committees (Village GRCs) will be established to engage village–level community members/leaders to participate in the decision–making processes and to have "voices" of the aggrieved person/communities in the grievance redress procedures. This will also enhance local ownership of the Project. Having members based in the village, the Village GRC will be helpful in resolving grievances quickly and often without requiring lengthy documentation. Local participation will further build local capacity in dispute resolution and decision–making and provide leadership support in the implementation of the Project. When cases are not satisfactorily resolved or affected persons remain aggrieved, the case will then be forwarded to the Project–level Grievance Redress Committee (Project GRC) as the prime floor for resolution of the grievances.

The decision of the Project GRC will be final within the GRM. However, if any disputant remains dissatisfied with GRM outcome, the disputant may seek redress from a court of law.

The composition of the two committees is shown in **Exhibit 8.1.**

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Exhibit 8.1: Members of GRC

Organization	*Village GRC*	*Project GRC*
MHL	Field staff of MHL Chairperson	Representative from MHL Chairperson
Community	One or two elders nominated by the community	One or two elders nominated by the community

8.2 GRC's Scope of Work

The scope of work of the GRC shall include:

1. The village GRCs will ensure that all grievances related to social and environmental issues are registered, formally recorded, reviewed, resolved and the concerned person is informed in a timely manner.
2. The Project GRC will monitor the working of the Village GRCs and will work as a forum for appeal against the decision of the Village GRCs.
3. GRCs will not consider complaints related to procurements or with any matters pending in the court of law.
4. In resolving disputes, the GRCs would take into consideration the following:

- Merit of the complaints/case received for consideration;
- Evidence to take a decision on the complaint;
- Witness statements;
- Plausibility of the case in light of related project activity;
- Applicable laws, environmental guidelines of Pakistan, environmental and social impact assessment and environmental review document of the project, and the IFC's Sustainability Framework;
- Observations made on the field; and
- Available information on previous complaints of similar nature.

8.3 Approval and Orientation of GRC Members

GRC members from local communities will be selected based on their standing in the community and their personal integrity. Local members of the Village GRCs will be selected after consultation with the communities that are being represented. Local members of the Project GRC will be nominated by members of Project affected communities. All GRC members will be approved and notified by the MHL Environment and Social Unit.

All GRC members will attend a training and orientation meeting prior to commencement of their work. The training will be provided by competent technical experts in social/resettlement and environmental management. The training will address the policy aspects, compliance requirements, expectations of the community, and need for rapport

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and communication with the affected communities, and finally the need for independence and transparent views in dealing with grievances.

8.4 Information Dissemination and Implementation

Establishment of the GRM will commence with the dissemination of information by the MHL Environment and Social Unit to concerned villages explaining how the process will work and the need to form Village and Project GRCs. Once the process has been explained the GRCs will be established and the GRM will go into the implementation phase. After notification of all the GRCs information regarding GRCs will be disseminated in all the concerned villages by MHL's Environment and Social Unit. Information dissemination will comprise the following;

- Information dissemination about GRM and GRCs to villages
- Establishment of GRCs
- Production of required documentation such as grievance registration forms and grievance logs
- Training of GRC members
- Second round of information dissemination to villages
- Implementation of GRM

8.5 Grievance Redress Procedure

The following procedure will be adopted to resolve grievances received by the GRCs. The grievance mechanism will be made public through public consultations by MHL's Environment and Social Unit and Consultant.

8.5.1 Filing of Grievances with Village GRC

For grievances related to social and environmental safeguards, the aggrieved person (or their authorized representatives) may file a grievance with the Village GRC in one of the following ways:

1. Submit a written complaint to any member of the Village GRC.
2. Given the local cultural context, any aggrieved women may submit complaints to GRCs directly or through the head of the household.

Complaint Registration Forms will be available with the secretary of the Village GRCs for registration of complaints. Complaints will be registered in the Grievance Log.

8.5.2 Hearing and Resolution of the Cases by Village GRC

The procedure for hearing and resolution of the complaint will be as follows:

1. On receipt of a complaint:

- The Secretary of the Village GRC will log the complaint in the Grievance Log.
- The Secretary will contact other members of the Village GRC to convene a meeting within 10 calendar days of the logging of the complaint.

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- If needed, the complainant or his representative will be asked to meet the Village GRC on the appointed date to discuss the complaint.
- All the relevant information and documents relevant to the complaint will be prepared and compiled prior to the meeting and copies will be provided to all members.

2. The GRC will meet on the selected date during which it may:

- Deliberate on the nature and circumstances of the complaint;
- Investigate the complaint based on evidence provided by the complainant;
- Meet with the complainant and other persons;
- Visit the site; and
- Take a decision.

3. If the Village GRC needs extra time to investigate or deliberate on the complaint, the secretary will inform the complainant of the time when a decision is expected. In any case, all complaints shall be resolved within 30 calendar days of logging.
4. Once the complaint is resolved the secretary will document the decision and prepare full documentation on the process including minutes of meetings, photographs of visits, documents reviewed, and reasons for the decision.
5. The Village GRC will ensure that the complainant is fully informed of the decision and is also informed about his/her right to appeal to the Project GRC and to the court of law.
6. In case follow–up action is required, the chairperson of the Village GRC will ensure that all actions are taken and are documented.

8.5.3 Hearing and Resolution of Cases by Project GRC

The procedure for hearing and resolution of the complaint by the Project GRC will be as follows:

1. On receipt of a complaint form:

- The Secretary of Project GRC will request all the concerned documentation from the secretary of the concerned Village GRC.
- The Secretary will contact other members of the Project GRC to conduct a meeting within 15 calendar days of the logging of the complaint to the Project GRC.
- If needed, the complainant or his representative will be asked to meet the Project GRC on the appointed date and place to discuss the complaint.
- If needed, members of the Village GRC will be asked to meet the Project GRC on the appointed date and place.
- All relevant information and documents relevant to the complaint will be prepared and compiled prior to the meeting and copies will be provided to all members.

2. The Project GRC will meet on the appointed date during which it may:
- Deliberate on the nature and circumstances of the complaint;
- Investigate the complaint;
- Meet with the complainant and other persons;
- Visit the site; and
- Take a decision.
3. If the Project GRC needs extra time to investigate or deliberate on the complaint, the secretary will inform the complainant of the time when a decision is expected. In any case, all complaints shall be resolved within 45 calendar days of logging with the Project GRC.
4. Once the complaint is resolved the secretary will document the decision and prepare full documentation on the process including minutes of meetings, photographs of visits, documents reviewed, and reasons of the decision.
5. The Project GRC will ensure that the complainant is fully informed of the decision and is also informed about his/her right to appeal to the court of law.
6. In case follow–up action is required, the chairperson of the Project GRC will ensure that the actions are taken and are documented.

8.5.4 Collation and Evaluation of Data by MHL

The MHL Environment and Social Unit will ensure that it receives copies of all complaints, meeting notices, decisions, and documentation related to proceedings of the Village GRCs and Project GRC.

MHL will maintain a complete record of the complaints in a database or tabular form consisting of the following fields:

- Project name
- Village, union council, tehsil, and district
- Name of complainant
- Nature of complaint, for example environment (tree cutting, noise, dust, waste, air, water, soil pollution etc.), social (damage to infrastructure, land, privacy, favoritism/nepotism issues, etc.), gender (gender equality, empowerment, privacy etc.) and non–compliance to the Govt. /donor provided guidelines.
- Date of logging of complaint with Village GRC
- Date of first meeting of Village GRC
- Information on members who attended, number of meetings, meeting with complainant, and site visit.
- Date of decision of Village GRC
- Follow–up actions, responsibilities, and completion with dates
- Date of logging of complaint with Project GRC

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- Date of first meeting of Project GRC
- Information on members who attended, number of meetings, meeting with complainant, and site visit.
- Date of decision of Project GRC
- Follow–up actions, responsibilities, and completion with dates

MHL will prepare periodic reports on the GRM, reporting on, for example:

- Number of complaints received and resolved by Village GRCs, Project GRC and the nature of complaints;
- The average time of it took to resolve complaints; and
- The percentage of complaints that were resolved at the Village GRC level.

9. Environmental Management Plan

9.1 Introduction

The Environmental Management Plan (EMP) summarizes the organizational requirements, management and monitoring plans to ensure that the necessary measures are taken by MHL to avoid potentially adverse effects and maximize potential benefits of the Project and to operate in conformance with applicable laws and regulations of KP, as well as the policies of international financial corporation such as IFC.

Due to the nature and applicability of the EMP, it will also be used for contractual purposes through its inclusion as a part of the bid documents for the EPC contractor who has to adhere to it along with other regulatory requirements. The strict implementation of the EMP and project management's strict enforcement of the adequate construction practices and standards will greatly reduce the negative impacts of the Project.

Having an effective and functioning Environmental and Social Management System (ESMS) is a pre-requisite for the implementation of the EMP. A framework for the ESMS is suggested in **Section 9.2**.

The EMP is based on the baseline conditions (see **Section 4**, *Description of the Environment*), the impact assessment (see **Section 7**, *Anticipated Environmental Impacts and Mitigation Measures*), and the results of discussions with the stakeholders (see **Section 6**, *Information Disclosure, Consultation, and Participation*). The EMP is prepared for all the identified environmental impacts during design, construction, and operation of various Project activities. The methodology followed for preparing the EMP includes the following:

- Deriving mitigation/protection measures for identified impacts using impact evaluation methodology.
- Rationalizing and combining series of mitigation, compensation and enhancement measures from each identified impact and risk to prepare overall measures.
- Developing a mechanism for monitoring the proposed mitigation measures.
- Estimating budget requirements for implementation, mitigation and monitoring measures.
- Identifying responsibilities of various agencies involved in the Project for implementation and monitoring of mitigation measures.

9.2 Environmental and Social Management System

This section describes the framework for the Environmental and Social Management System (ESMS) for the Project. It is the responsibility of each project company affiliated with the Project to establish its own ESMS to ensure implementation of the EMP.

The basic elements of the ESMS are outlined in **Exhibit 9.1** with more details on each element, and how it applies, given in the following sections. The elements of the ESMS

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are discussed under the headings of the "plan-do-check-act" business performance improvement cycle. Emergency planning and response and stakeholder engagement are elements of the ESMS that apply to all steps of the "plan-do-check-act" cycle as shown in **Exhibit 9.1**.

9.2.1 Planning Elements

Leadership and Accountability

Policy

The Project is being undertaken in accordance with MHL's policies. MHL will periodically review the scope and effectiveness of these policies. The policies will be documented, maintained, implemented and communicated to MHL employees, contractors, suppliers and the public.

Legal Requirements and Other Obligations

The Project's ESMS takes into account of both legal and other obligations imposed on the Project. The various types of obligations that need to be considered are shown conceptually in **Exhibit 9.2**.

Exhibit 9.1: Elements of the ESMS for Arkari Gol HPP

Steps of the "plan-do-check-act" cycle	*Elements of the ESMS for the Project*		*Elements applying to all steps of the cycle*	
	Elements	*Primary function*		
Plan (**Section 9.2.1**, *Planning Elements*)	Leadership and accountability	Produce and communicate a statement of MHL's commitment to environmental and social management Establish, document, implement, maintain and improve the Project ESMS	Stakeholder engagement An ongoing process, throughout the life of the project. Serves to build and maintain a constructive relationship with communities affected by the Project	Emergency planning, response and recovery Maintain emergency response preparedness through the identification of potential environmental emergencies, development of response plans and allocation of response and recovery resources.
	Legal and other requirements	Identify and provide access to legal requirements and other obligations		
	Aspect identification and impact assessment	Identify aspects ("mechanisms" by which project activities impact on the environment) and assess associated impacts throughout the Project life (the ESIA falls under this element of the ESMS)		
	Objectives, targets and plans	Define objectives, targets, criteria and actions for the management of potential impacts (the EMP falls under this element of the ESMS)		
Do (**Section 9.2.2**, *Implementation Elements*)	Roles and responsibility	Provide sufficient management sponsorship of human and financial resources Establish roles and responsibilities for implementation		
	Contractors, suppliers and vendors	Consider environmental and social impact management and performance in the selection and management of third party services		
	Competence, training and awareness	Make personnel aware of their responsibilities and enable them to be capable and competent in meeting their responsibilities		
	Communication	Maintain internal and external communications to enable effective environmental management		
	Operational controls and maintenance	Implement operational controls and maintain equipment to uphold environmental performance and compliance and to manage impacts and risks		
	Documentation and record keeping	Control and maintain documents and records associated with environmental and social management		
Check (**Section 9.2.3**, *Check Elements*)	Assessing, correcting and improving performance	Monitor environmental and social management and performance and take measures to continually improve performance		
	Non-conformance and incident reporting	Promptly report non-conformances and incidents are promptly reported and take corrective and preventative actions to reduce the likelihood of recurrence		
	EMP and ESMS reporting	Report on compliance with the EMP and ESMS performance to senior management, regulatory authorities and affected communities		
Act (**Section 9.2.4**, *Act Elements*)	Governance/ management review	Require site, regional and senior management to review the suitability, adequacy and effectiveness of the ESMS and identify improvement actions to facilitate continuous improvement		
	Management of change	Modify the ESMS in response to changes in the Project and to changes in the organization, personnel, operations and processes		
	The arrows show where there is integral relationship between stakeholder engagement and other elements of the ESMS.			

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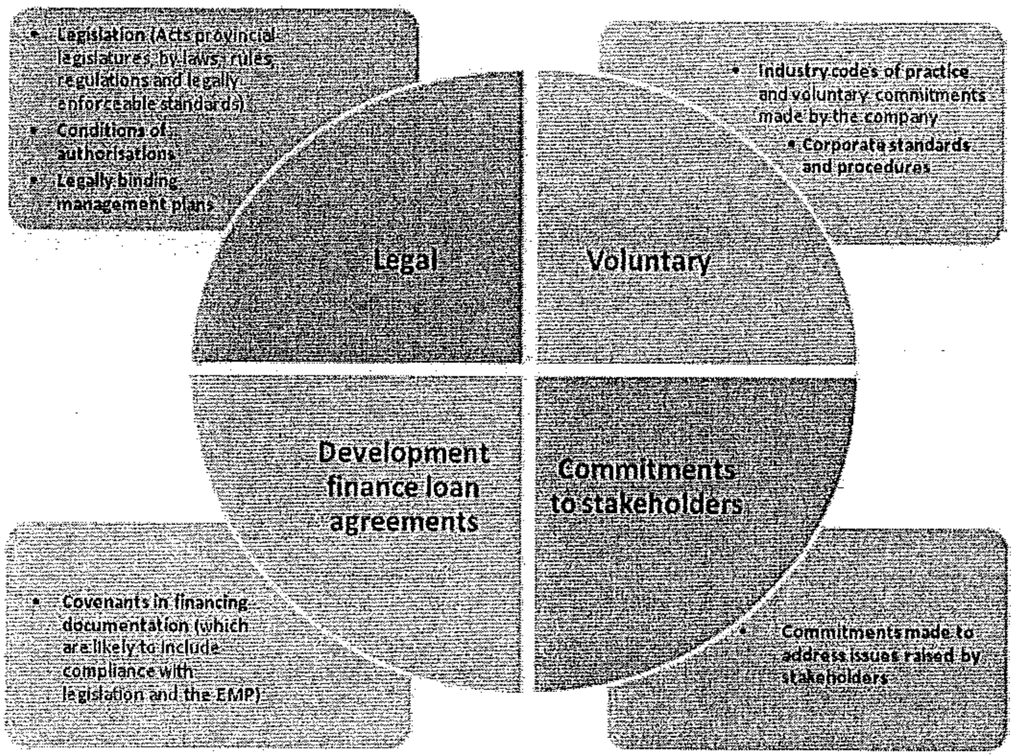
Exhibit 9.2: Types of Obligations Relevant to the ESMS



MHL will identify, document and maintain a register of legal requirements and other obligations applicable to the Project. It will also:

- manage recurring legal and other obligations (such as inspections, sampling, analysis and reporting);
- track developing legislation and regulations that may apply to operations and activities to anticipate and prepare for compliance;
- inform employees and others working on behalf of the company of existing and emerging obligations that apply to their job responsibilities; and
- consider the register in the setting and review of objectives, targets and plans for management of impacts.

Aspect Identification and Impact Assessment throughout the Project Life

A key element of ESMS is identification of aspects and assessment of impacts. The ESIA is a part of this element of the ESMS. The impacts identified in the ESIA in **Section 7** (*Anticipated Environmental Impacts and Mitigation Measures*) are addressed in this EMP

Procedures will be set up, implemented and maintained for identification of significant environmental aspects and undertaking of impact and risk assessments on an ongoing basis through the Project life. These will address:

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- aspects not covered by this ESIA;
- any impact arising that was not predicted by the ESIA or did not develop as predicted by the ESIA; and
- any changes in the Project or new developments arising subsequent to the completion of this ESIA.

Objectives, Targets and Plans for Management throughout the Life of the Project

This element of the ESMS pertains to the setting of objectives and targets for environmental and social management, and plans for the achievement of these objectives and targets at corporate and Project levels. The EMP embodies this element of the ESMS at the Project level.

The primary purpose of the EMP is to guide environmental and social management throughout the life of the Project. The core of the EMP is a statement of environmental and social management objectives and associated management measures. The EMP will be supported by other documentation, such as the original Project design and specific management plans and operating procedures.

The preliminary EMP commitments are derived from the following sources:

- inherent design or management measures described in the ESIA and Project Feasibility Study;[1]
- mitigation and enhancement measures identified in the ESIA, which are required to manage identified impacts; and
- good practice management measures, which may not significantly alter the impact rating but are considered standard industry practice for the management of such impacts.

9.2.2 Implementation (do) Elements

Effective implementation and functioning of the EMP depends on adequate human and financial resources, clearly defined responsibilities for environmental and social management, appropriate training and good communication. An outline of how these features will be managed for the Project is presented below.

Roles and Responsibility

MHL will define, document and communicate the environmental and social management roles and responsibilities of Project personnel, including contractors, Owners Engineers, and others working on behalf of the company, in all phases of Project implementation from detailed design through to closure, before the start of each phase. Personnel with specific roles and responsibilities will have the authority, and be held accountable for, carrying out these.

The basic roles required to implement the EMP, and establish and maintain the ESMS, are shown in **Exhibit 9.3**. These roles need to be reviewed and incorporated into the

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1 Pakhtunkhwa Hydel Development Organization (PHYDO), Government of Khyber Pakhtunkhwa, March 2014, Feasibility Study for the Arkari Gol Hydropower Project, District Chitral, (Lower), Khyber Pakhtunkhwa, Volume 1, Main Report

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organizational structures for the various phases of the Project from detailed design through to closure. A key requirement is for the senior environmental management professional to report directly to the on-site senior manager (the Operations/General Manager).

Exhibit 9.3: Key Roles for Environmental and Social Management

Roles	*Relevant Responsibilities*
Project Director for the Arkari Gol HPP Project Management Unit (PMU)	▶ Endorse the environmental and social management policy and require it to be communicated to the public ▶ Allocate adequate human and financial resources to enable effective functioning and continual improvement of the ESMS ▶ Establish and maintain a governance system
Project site management and PMU's senior management	**Compliance** ▶ Confirm necessary authorizations (licenses/ permits) have been obtained for the Project ▶ Confirm compliance with legal requirements and other obligations pertaining to environmental and social management ▶ Commit contractors and suppliers to meeting relevant environmental and social obligations by means of specific conditions in the contracts of appointment **Roles and responsibility** ▶ Define, document and communicate environmental and social management roles, responsibilities and authorities ▶ Provide sufficient appropriately trained human resources and adequate financial resources to enable effective functioning and continual improvement of the ESMS ▶ Hold personnel responsible for meeting their assigned responsibilities **Communication and reporting** ▶ Confirm there is adequate ongoing stakeholder engagement ▶ Confirm obligations for reporting to regulatory authorities, development financiers and affected communities are met **Management review** ▶ Provide leadership in the pursuit of environmental and social management ▶ Examine and review the ESMS periodically to determine its suitability, adequacy and effectiveness ▶ Support action to enhance the ESMS and make improvements in environmental and social management performance
Environmental management	**ESMS** ▶ Establish the ESMS, with assistance from the senior management, division managers and community relations managers

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Roles	Relevant Responsibilities
	▶ Liaise with division managers regarding environmental management roles, responsibilities and authorities throughout operational divisions ▶ Coordinate monitoring and evaluation activities and confirm corrective actions (an action taken to address a non-conformance) are taken to address incidents and non-conformances (a failure to comply with the Project's ESMS) ▶ Report progress in implementation and functioning of the ESMS to senior management, development financiers, regulatory authorities and stakeholders **EMP** ▶ Keep the EMP up to date and confirm it addresses all relevant environmental and social obligations ▶ Present the EMP in an appropriate format for communication with regulatory authorities and other stakeholders ▶ Present the EMP in an appropriate format for communication with parties responsible for Project execution ▶ Compile EMP compliance reports ▶ "Sign-off" actions in the EMP and non-conformances once they have been completed
Community relations management	▶ Assist the Environmental Management team with ongoing reporting to stakeholders on EMP and supporting management plans, and progress with implementation of management measures ▶ Assist Environmental Manager and division managers with stakeholder communication where awareness and/ or co-operation of stakeholders are required to implement management measures ▶ Manage the community grievance mechanism
Division management (management that oversees certain specified sections in an organization)	▶ Confirm the ESMS and EMP are established, communicated, implemented and maintained in their respective areas ▶ Provide leadership in the pursuit of environmental and social management ▶ Identify ways to improve environmental and social performance through daily monitoring of their activities and evaluating implementation ▶ Review monitoring results, incidents and corrective actions taken ▶ Evaluate adequacy and effectiveness of awareness and skills training programs pertinent to environmental and social management ▶ Maintain internal communication of environmental and social matters between the Environmental Manager, Community Relations Manager and other personnel, and promote environmental and social awareness.

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Roles	Relevant Responsibilities
	▶ Examples of key responsibilities of specific Division Managers include: ▷ Human resources—Organize in association with the Environment Manager and Community Relations Manager environmental and social related training, maintain linkages between the ESMS and human resources management systems, as necessary, and manage worker grievance mechanism. ▷ Finance—Track budget/spend data used in implementing and maintaining ESMS in association with the Environment Manager and Community Relations Manager ▷ Purchasing—With the support of environment and community relations teams, assess contractors' and suppliers' environmental and social compliance and control purchase and disposal of hazardous materials ▷ Maintenance—Implement preventive maintenance program for equipment ▷ Health, safety and security—With the support of community relations teams, confirm safeguarding of personnel and property is carried out without adverse impacts on local communities
All personnel and contractors	▶ Work in accordance with the EMP and supporting documents ▶ Report problems or deviations from the ESMS or EMP to division managers and/or environmental managers, as instructed.

Contractors, Suppliers and Vendors

Environmental and social performance, programs and risk management will be considered in the selection and management of contractors, suppliers and vendors. Contracts will address potential environmental and social liabilities and responsibilities including:

- use of competent, trained staff, including subcontractors;
- consequences for failing to meet obligations;
- monitoring of performance;
- required job-specific, site-specific training;
- compliance with MHL policies and site standards and applicable legal requirements;
- responsibility for chemicals brought on-site and wastes generated on-site, including closure activities where appropriate; and
- identification of a lead responsible person for both MHL and the contractor.

Contractors, including their employees and associated subcontractors, will be made aware of the environmental risks, associated controls, procedures and standards relevant to their

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work on-site. The activities and performance of contractors will be monitored through Owner Engineer's Environmental & Social Development Cell (ESDC) against the terms of the contracts.

Training

Personnel, including contractors' personnel, working for or on behalf of the Project will receive training to maintain awareness of relevant environmental and social aspects, impacts and risks associated with the Project and corresponding controls. The training will also maintain awareness of the environmental benefits of improved personal performance and the potential consequences of departure from specified procedures. Visitors to Project sites will receive relevant environmental and social awareness training as part of site induction training.

Personnel, including contractors' personnel, will be made aware of the particular environmental and social management responsibilities that apply specifically to their jobs. Training needs analyses will be undertaken and personnel will be given adequate training to meet these responsibilities.

The training program comprises the following elements:

- identification of training needs for all employees specific to their varying responsibilities;
- development of a training plan and schedule to address defined needs;
- verification of training programs to confirm consistency with organizational requirements;
- training of employees and documentation of training received;
- evaluation of training effectiveness; and
- review and modification of training programs, as required.

Personnel with direct responsibility for implementation of the EMP and functioning of the ESMS will have additional training to:

- provide them with the knowledge and skills necessary to perform their work;
- maintain their knowledge of relevant environmental and social obligations; and
- enable them to implement specific measures required under the EMP in a competent and efficient manner.

Training requirements and completed training will be documented. Procedures to evaluate the effectiveness of such training will be implemented.

Communication

To effectively implement environmental and social management, the relevant managers will maintain lines of internal communication and provide information regarding the EMP, ESMS and environmental and social management performance, incidents, best practices, lessons learned and concerns to personnel electronically, on notice boards and/or in newsletters. Such communication will be used to inform the personnel of their individual responsibilities with respect to the ESMS and to raise awareness on specific

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matters. External stakeholder engagement is discussed in **Section 6** *(Information Disclosure, Consultation, and Participation).*

A grievance redress mechanism will be established (see **Section 8**, *Grievance Redress Mechanism*) and will provide a means for Project personnel, including contractors' personnel, to anonymously raise environmental and social concerns (this grievance mechanism will be separate from the system dealing with employee grievances that need to be handled by the human resources department).

Operational Controls

Operational controls will be implemented to maintain performance and compliance, and to manage impacts and risks. Operational controls may include:

- administrative controls such as performance standards;
- standard operating procedures and work instructions; and
- engineered controls such as pollution control equipment.

Written operational controls are required where their absence could lead to deviation from environmental obligations or objectives and targets. Written operational controls will be part of the EMP supporting documentation.

The adequacy, suitability, and effectiveness of operational controls will be reviewed regularly.

Documentation on the design basis and operating criteria/limits for equipment having the potential to impact environmental performance will be maintained.

Operating equipment, as well as environmental monitoring and measurement devices, will be maintained consistent with manufacturers' specifications and best management practice to reduce the potential for environmental incidents and adverse environmental impacts.

Documentation and Record Keeping

Elements of the ESMS will be documented and controlled in accordance with a document control system. Records demonstrating compliance with legal requirements and conformance with the ESMS will also be maintained. MHL will establish, implement and maintain procedures for:

- ESMS document control detailing how the creation, review and updating of various types of documents will be managed and who will be responsible; and
- record identification, storage, protection, retrieval, retention and disposal.

Documentation and record keeping controls will include:

- measures to enable relevant documents (including those of external origin deemed necessary for planning and operation of the ESMS) and records to be readily available and identifiable (labelled, dated and properly filed), legible and protected from damage;
- review, revision and approval of documents for adequacy by authorized personnel at least once a year;

- making current versions of relevant documents available at locations where operations essential to the effective functioning of the ESMS are performed;
- suitably identifying obsolete documents retained for legal and knowledge preservation purposes; and
- identification and segregation of confidential and privileged information.

9.2.3 Check Elements

Checks are required to confirm the existence of an effective ESMS and compliance with the EMP. Checks includes monitoring, site inspections and formal audits. Linked to this, measures need to be taken to remedy non-conformances and to continually improve environmental performance. These are also classified as "check" elements of the ESMS.

Assessing, Correcting and Improving Performance

Monitoring Programs

The aim of monitoring programs are to:

- provide measurements of environmental and social impacts of the Project;
- ascertain and demonstrate compliance with conditions of approval and other legislation;
- provide sufficient evidence to address any claims made against the Project in respect of environmental and social matters;
- track performance of the ESMS and progress in the implementation of the EMP;
- track and measure key indicators and other performance measures over time to improve the Project's performance and reduce the likelihood of environmental incidents; and
- inform decision processes for determining management actions.

The monitoring programs cover the physical, biological and social components of the operation and are integrally linked with the assessment criteria stated in the EMP. Where appropriate and possible, the sampling parameters and locations used in the ESIA baseline studies have been retained to provide data continuity.

The monitoring program identifies monitoring parameters, sampling locations, sampling frequency and duration and detection limits (where appropriate). It includes control sites, where relevant. The focus and extent of monitoring is commensurate with the risk of impacts occurring, the sensitivity of the surrounding areas and the affected communities' perceptions of risks to their health and environment. For some types of monitoring, thresholds or targets are available, for example the emission and ambient limits. In other cases, the monitoring results will be compared to the baseline data set gathered as part of this ESIA. Lastly, where neither thresholds nor baseline data are available, the initial data collection may form the baseline for future data collection.

Data will be documented and interpreted. Temporal and spatial trends in the data will be discerned and compliance with relevant thresholds will be evaluated. Monitoring reports will be produced to meet internal and external reporting requirements. If monitoring

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results indicate non-conformance with stipulated thresholds or if a significant deteriorating trend is observed, it will be recorded as a non-conformance and handled by the non-conformance and incident procedure.

Preliminary monitoring programs have been prepared and are presented in the EMP. These provide a framework of monitoring to evaluate performance and assist in predicting and managing impacts. In conjunction with the development of supporting documentation for the EMP, detailed monitoring plans, with appropriate sampling protocols where relevant, may need to be developed. These more detailed supporting documents would include the criteria against which the monitoring results will be compared and the actions required if the criteria or thresholds are exceeded. The supporting documents may also cover:

- sample or data collection methods;
- sample handling, storage and preservation;
- sample or data documentation;
- quality control;
- data reliability (calibration of instruments, test equipment, and software and hardware sampling);
- data storage and backup, and data protection;
- interpretation and reporting of results; and
- verification of monitoring information by qualified and experienced external experts.

The frequencies and locations of monitoring may need to be adjusted depending on final Project design and ongoing review of results obtained by the monitoring programs. Therefore the programs will be reviewed on a regular basis (at least annually) and adjusted, where necessary. Changes to the EMP or obligations register may also result in changes to the monitoring program.

Site Inspections

Site inspections will be undertaken regularly in relevant areas of the Project. The inspections will focus on compliance with the EMP and conformance with the ESMS. The inspections will play an important role in increasing awareness of EMP and ESMS requirements.

Continuous observation and monitoring by site and HSE managers and other responsible parties for compliance with the EMP and conformance with the ESMS will be part of their core responsibilities.

Minor non-conformances will be discussed during the inspection and recorded as a finding in the inspection report. Major non-conformances will be reported as incidents. Inspection results will be disclosed at management meetings.

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Formal Audits

Formal audits will be undertaken at planned intervals in accordance with the requirements of MHL, MHL owners and regulatory authorities. Procedures for audits will be established, implemented and maintained. These will cover the audit criteria, scope, frequency and methods, and will address the responsibilities and requirements for planning and conducting audits, reporting results and retaining associated records.

Negative findings arising from an audit will be dealt with in accordance with the non-conformance and incident procedure. Results from audits and evaluations of compliance with legal requirements will be reported to site and senior management and subject to management reviews.

Non-conformances and Incident Reporting

Non-conformances include the following:

- exceedances of relevant thresholds as identified during routine monitoring;
- non-conformances with the requirements of the EMP or supporting documentation identified during an internal inspection;
- non-conformances identified during an audit or by regulatory authorities, including legal non-conformances;
- events, such as spills, resulting in potential or actual environmental harm;
- events that did or could result in injury to staff, visitors to site or surrounding communities; and
- significant complaints or grievances received from any source.

Corrective and preventive actions will be identified and implemented in response to these non-conformances. These actions will address the root cause of the non-conformance and will reduce or prevent repeated non-conformances.

A process will be established for the identification, investigation and tracking of non-conformances, including:

- prioritizing and classifying non-conformances based on the type and severity of the non-conformance;
- recording of non-conformances and the results of corrective and/or preventive actions, including the actions necessary to mitigate or remedy any associated impacts;
- defining results expected from the corrective and/or preventative actions;
- confirming the corrective and/or preventive actions taken to eliminate the causes of the non-conformance are appropriate to the magnitude of problem and commensurate with the impacts encountered;
- reviewing the effectiveness of the corrective and/or preventive actions taken; and
- implementing and recording required changes in the EMP or monitoring program resulting from corrective and preventive action.

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Serious non-conformances will be classified as incidents. Incidents will be promptly reported to appropriate management. MHL will prepare a guideline on:

- the types of incidents reportable to internal management at the site, Project and corporate levels, as well as to regulatory authorities and other external stakeholders; and
- standards to be observed when reporting incidents.

The investigation of incidents and evaluation of effectiveness of existing controls and response actions will be undertaken at a level commensurate with the severity of the incident.

EMP and ESMS Reporting

Progress on compliance with the EMP and functioning of the ESMS (environmental and social performance) will be reported to:

- Project site and MHL senior management;
- development financiers, if required in terms of the loan agreement;
- regulatory authorities, as required; and
- affected communities and other stakeholders who have an interest in the Project.

9.2.4 Act Elements

Governance/ Management Review

MHL senior management will review the EMP and ESMS on a periodic basis to determine its suitability, adequacy and effectiveness. Each management review will initiate a new plan-do-check-act cycle with enhancement of the ESMS and continuous improvements in environmental and social management performance. The management review will cover:

- progress and closure of actions from previous management reviews;
- monitoring programs findings/ the extent to which objectives and targets have been met;
- findings of audits;
- incidents and the status of corrective and/or preventative actions;
- impact and risks assessments;
- changing circumstances, including changes to operations, Pakistan legislation or guidelines, ownership, socio-political circumstances;
- legal compliance and compliance with other obligations;
- stakeholder concerns, requests or complaints;
- adequacy of policies, EMP, monitoring plans, support documents and overall functioning of the ESMS to meet operational and corporate requirements; and
- recommendations for improvement.

Management of Change

Changes to the Project can be expected throughout the life of the Project. These can range from changes to operations and infrastructure, new developments (such as an expansion), changes to personnel and the Company, changes in legislation and changes to the environment of the Project (such as a new settlement established near Project infrastructure). These changes could result in changes to the significance of environmental and social impacts and risks. This may necessitate updates to existing authorizations/ permits, changes to the EMP, which may have to be approved by regulatory authorities, and general changes to the ESMS framework.

A procedure for the management of change will be established and maintained by MHL. This will:

- observe the corporate owners' requirements for the management of change;
- identify proposed changes that could alter environmental or social impacts and risks and/ or require new authorizations/ permits or changes to existing authorizations/ permits; and
- define the impact and risk assessments appropriate to different types of changes, which need to be undertaken by competent personnel.

Changes will not be made without the required authorizations/ permits in place. The measures identified as necessary to mitigate impacts and risks will be implemented. The various elements of the ESMS will be modified as required in response to the change,

A procedure specifically for changes to the policy/s, EMP, monitoring plans and supporting documentation will be established. This will detail:

- how the changes are to be recorded;
- who has responsibility for overseeing changes and checking they do not conflict with any planning conditions or other obligations;
- the process of review and sign off in response to changes; and
- how changes to the EMP should be communicated internally and externally.

9.3 Stakeholder Engagement

Stakeholder engagement provides stakeholders with opportunities to express their views on project risks, impacts and impact mitigation measures and involves appropriate consideration of the views and responses by project management. **Exhibit 9.4** shows stakeholder engagement applies to each of the steps of ESMS "plan-do-check-act" cycle and is an integral part of several ESMS elements. The relationship between stakeholder engagement and these elements is explained further in **Exhibit 9.4**.

Exhibit 9.4: General Overview of the Relationship between Stakeholder Engagement and the ESMS elements

Steps of the "plan-do-check-act" cycle ESMS Elements that Stakeholder Engagement is Integral to		
	ESMS Elements	*Role of Stakeholder Engagement*
Plan	ESIA	During the ESIA, the focus of stakeholder engagement has been the involvement of stakeholders in project-planning and project-approval decision-making processes. It facilitated identification of stakeholder's concerns so they could be addressed in the Project design and/or EMP. It forms the basis for stakeholder engagement throughout the life of the Project.
	EMP	Stakeholders will be involved in the review and approval of the preliminary EMP. Throughout the life of the Project, there should be ongoing reporting to stakeholders on progress in the implementation of the EMP and supporting management plans that are of interest to them. The EMP and supporting management plans may need to be revised in response to stakeholders' concerns.
	SEP	A stakeholder engagement plan is to be developed. It will detail national regulation and good practices on stakeholder engagement, a summary of previous stakeholder engagement undertaken for this Project, required additional consultations, and the structure for future stakeholder engagement.
Do	Communication	Communication with stakeholders will be required to implement some management actions. The communication will be required to raise awareness and/or co-operation of potentially affected communities and other stakeholders. MHL will determine effective communication methods for making affected communities aware of actions they may need to take to avoid exposure to operation-related hazards and how they can maximize on opportunities resulting from the operation.
Check	Assessing, correcting and improving performance	Participatory monitoring is desirable. This entails involvement of stakeholders, particularly affected communities, in monitoring and verifying information to check that impact mitigation measures are appropriate.
		Grievances will be handled as incidents and managed through the incident procedure to enable the grievance to be received, documented, addressed and results fed back to the complainants. This procedure will protect the confidentiality of the persons raising the complaint, where necessary. The feedback will be easily accessible and understandable to members of the affected community and/or staff.
	Reporting	Stakeholders affected by the Project will be informed of progress in the implementation of the management plans and of the effectiveness of management measures.

MHL has established an initial program of stakeholder engagement for the Project and this will continue throughout the life of the Project. Currently, this program includes disclosure of information and consultation with stakeholders as part of the ESIA process.

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When the Project enters the construction phase, and throughout the remaining life of the Project, stakeholder engagement will include:

- a grievance mechanism, for receiving concerns about the Project's environmental and social performance and for facilitating the resolution of the concerns (the grievance mechanism applies to Project stakeholders, including potentially affected communities and Project personnel.
- reporting on the implementation of the EMP and relevant supporting management plans;
- opportunities for stakeholders to respond to the information received; and
- constructive dialogue on environmental and social issues and performance.

The stakeholder engagement process will be documented, including:

- maintenance of a stakeholder database with stakeholder details;
- records of information disclosed to stakeholders;
- records of stakeholder engagements; and
- records of inputs from stakeholders and responses to these.

9.4 Roles and Responsibilities of Key Staff

To be effective, this EMP must be viewed as a tool reflecting to the contractors and sub-contractors overall commitment to environmental protection. This must start at the most senior levels in the organization. Contractor management must provide strong and visible leadership to promote a culture in which all employees share a commitment to environmental awareness and protection. The following are commitments to be achieved by the highest position in Pakistan from MHL:

- Putting environmental matters high on the agenda of meetings;
- Highlighting the importance of environmental issues in relation to the HSE considerations in business decisions and communication with stakeholders;
- Evaluating environmental aspects, before final decisions are reached;
- Being fully aware of the main environmental hazards associated with the Contractor and Sub Contractor activities and the systems, procedures and field practices in place to manage these hazards;
- Immediately and visibly responding and being involved in investigating incidents or other abnormal events related to environmental and HS issues;
- Seeking internal and external views on environmental issues; and recognizing their achievement.

The organizational setup of MHL for implementation of the EMP is provided in **Exhibit 9.5**. Key roles and responsibilities are described below.

9.4.1 MHL

With overall responsibility for the Project, MHL will:

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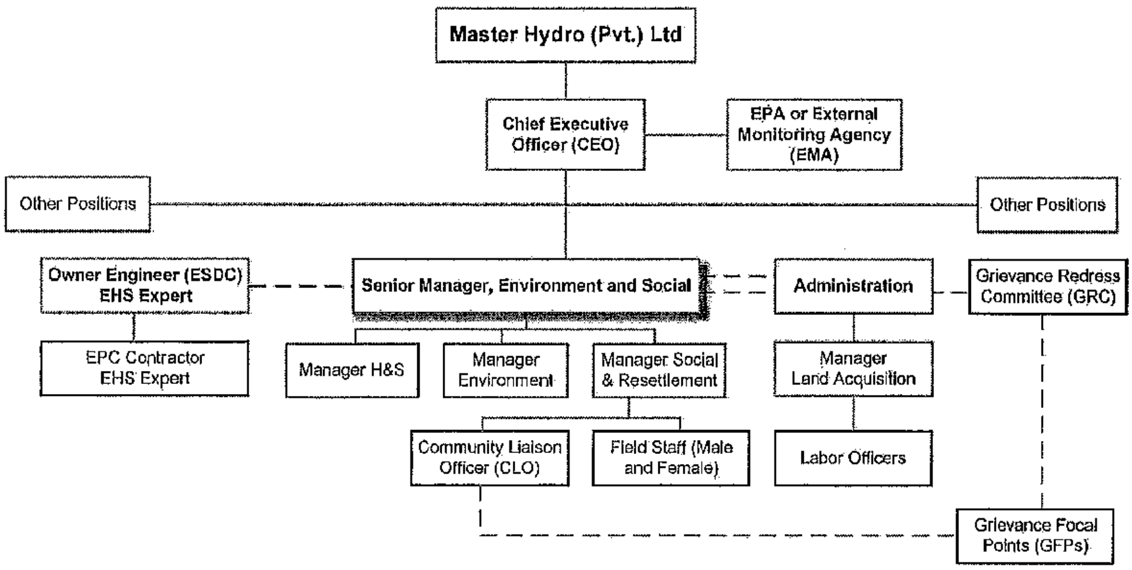
- Prepare the ESMS and implement the ESMS and EMP
- Minimize any impact the Project may have on the environment through preparation of this ESIA (as being carried out in the design stage)
- Appoint responsible contractors who will comply with this ESIA.
- Approve environmental safe materials for use on site in accordance with the ESIA
- Ensure all relevant parties receive a copy of the approved ESIA and that it is incorporated into all contractual documentation
- Obtain the relevant environmental permits, consents and authorizations prior to commencing site works
- Comply with all requirements of EPAs and obtain NOCs related to the Project.

Exhibit 9.5: Organizational Setup of MHL for EMP Implementation



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9.4.2 Owner's Engineer

Hiring an owner's engineer (OE) in the power industry is a practice which is considered a standard since the last two decades.[2] The OE is a person or, more appropriately, a team of experts that serves as an independent advocate for the owner. The OE plays a supporting but a very critical role as he is the technically trained eyes and ears of the project proponents in the field. It is expected that an OE will also be hired for the Arkari Gol HPP construction and commissioning phases. The specific roles and responsibilities of the OE will be defined in their contract. Typically, there are several important environmental roles that the OE can undertake on behalf of MHL.

In general, following types of tasks can be assigned to the OE:

- Prepare technical specifications for design of environmental element
- Approval of technical design developed by the EPC Contractor of environmental elements of the Project
- Review and Approval of SSEMP
- Environmental Monitoring
- Review of the environmental monitoring reports and data produced by EPC.

Some role for the OE is suggested in this document. However, prior to commencement of construction a formal agreement will be reached between MHL and the OE on the latter's environmental role and responsibility.

9.4.3 Construction Contractor

The EPC or Construction Contractor will prepare a 'Construction Management Plan' (CMP) demonstrating the manner in which they will comply with the requirements of mitigation measures proposed in the EMP. After completion of the Construction Contractor's contract, MHL will be in charge of the operation and maintenance of the Project and will be responsible for compliance with the monitoring plan during operations. The Construction Contractor's general responsibilities will be to:

- Ensure the implementation of the ESIA/EMP throughout construction works by all contractor personnel and subcontractors
- Ensure that adequate resources are available to implement the requirements of this EMP
- Undertake quarterly environmental audits and report to MHL on regular basis
- To coordinate with MHL for all correspondence to EPAs
- Prepare a comprehensive legislation list and ensure compliance to these legislations.

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2 http://www.powermag.com/who-needs-an-owners-engineer/

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9.4.4 Sub-Contractors

Any Sub Contractor hired directly or indirectly by the Construction Contractor to carry out Project related tasks will be designated as a subcontractor. It will be the responsibility of those sub-contractors, whose activities have at least one interface with identified key environmental aspects, to comply with the ESIA at all times. They must also designate sufficient competent resources to ensure all Sub-Contractor personnel receive the required training. Sub-Contractors directly in charge of activities shall be registered and approved. Registration documentation will be provided to MHL prior to commencement of any activities. Sub-Contractors will be expected to demonstrate a proactive behavior towards environmental concerns. It will be their responsibility to provide information requested by MHL with regard to their scope of activities and to demonstrate compliance with the applicable environmental requirements.

9.4.5 MHL Personnel

Chief Executive Officer

The Chief Executive Officer (CEO) will manage and superintend all office and site activities for the implementation of the Project. In relation to the ESIA and implementation of EMMS and EMP, the CEO's responsibilities will include:

- Overall responsibility for ensuring implementation of the EMP in compliance of all legal matters regarding the Project
- Development and establishment of adequate Environmental, Safety and Quality Management teams, who will ensure the development, communication and implementation of this ESIA across the entire Project, including all activities being undertaken by subcontractors and suppliers working on the site, and all personnel visiting the site
- Ensure that the Subcontractor has hired an environmental team (see **Exhibit 9.5**) to address environmental requirements in accordance with the ESIA.
- Develop and establish an organization structure adequate to oversee the whole of the works, including overseeing the appointment of an appropriate qualified HSE Manager and Environmental Manager
- Ensure that adequate resources are available to implement the requirements of this ESIA
- Ensure the ESIA is reviewed regularly to correspond with on-going construction activities
- Coordinate with government agencies and bodies regularly to discuss the Project's construction environmental issues and requirements
- Attend regular meetings with Manager EHS and CSR in order to discuss the site's environmental issues and requirements.

Chief Technical Officer

- Taking primary responsibility for all activities on site, including those undertaken by direct or indirectly employed personnel or agencies.
- Ensuring the issue of suitable procedures for the definition of working methods and site regulations that take into consideration the requirements within the ESIA.
- Ensuring that construction and erection works are performed in respect of the ESIA requirements.
- Attending regular meetings in order to discuss the site's environmental issues and requirements.

Manager HSE & CSR

The Manager HSE & CSR manages and supervises the Project activities relating to health, safety and environment. The HSE Manager will be responsible for:

- The overall responsibility for the development and implementation of the Project HSE policy/philosophy
- Coordinating weekly HSE meetings, during which any environmental issues will be discussed and minuted
- Reviewing and ensuring the implementation of Contingency and Emergency Response Procedure
- Providing specialized HSE input into engineering, construction and contracts, ensuring requirements are properly integrated into Project planning, design criteria, construction plans and specifications and contracts
- Supporting/leading incident investigations as per Project procedure and report to all concerned. Follow up and review the corrective and preventive action taken, and close-out the incidences
- Conducting HSE inspections of Project construction activities and monitoring compliance with requirements including contractual commitments, permits and projects HSE plan and other applicable HSE requirements and ensure that the Project HSE inspection plan is implemented
- Ensuring that all internal as well as external incidents and complaints are appropriately resolved with all applicable forms and records duly filled and maintained
- Coordinating and organizing regular meetings with the CEO, Construction Manager and Environmental Manager in order to discuss the site's HSE issues and requirements
- Coordinating the environmental activities with the higher management time to time
- Coordinating with the EPAs, other regulatory authorities and stakeholders on environmental issues related to construction of the Project

- Monitoring construction activities and performance to ensure compliance with the ESIA and effectiveness of control measures adopted
- Ensuring that no works are carried out outside the construction corridor as defined in the ESIA, especially within the protected areas (e.g. forests)
- Ensuring the issue and updating of the Project's environmental plans
- Coordinating Project document review activities from an environmental standpoint, assuring that the execution of these activities is compatible with development of the Project and reporting any discrepancies between the environmental requirements and other Project objectives to the Head Hydro Power and CEO
- Supplying essential information for the preparation of the environmental control plan for construction.
- Updating EPAs regularly on construction information
- Coordinate the development of environmental monitoring data relevant to construction activities
- Performing environmental checks and monthly internal audits of onsite activities, in coordination with the HSE Manager
- Supporting the higher management in relations with the governmental agencies and with the EPAs on environmental matters
- Implementing the environmental requirements of the project management system including inspection and reporting
- Monitoring construction activities and performance to ensure compliance with the Construction Management Plan and effectiveness of control measures adopted
- Developing and implementing of the environmental training program.
- Conducting staff environmental training, inductions and Tool Box Talks (TBT)
- Advise the Project Manager, or in his absence the relevant Construction Manager, to stop work which could, or is, causing unacceptable environmental impacts
- Communicate with internal and external parties as required
- Coordinating daily and weekly site inspections and approving the associated environmental inspection report
- Reviewing daily and weekly checklists to ensure that appropriate recording of site activities and observations
- Preparing of the monthly environmental reports, quarterly performance reports and incident reports
- Reporting of any environmental incidents to the higher management
- Ensuring that major environmental incidents are reported to KP-EPA within a maximum of 3 days
- Participating in environmental management reviews

- Reviewing environmental monitoring data
- Raise non-conformance and issue CAPs reports in coordination with the EHS Manager (MHL)
- Ascertaining that effective measures and relevant actions are undertaken to avoid or minimize adverse environmental impacts
- Attending regular meetings with the CEO and staff that reports to the Manger EHS and CSR (see **Exhibit 9.5**) in order to discuss the site's environmental issues and requirements
- Ensuring that all internal as well as external environmental incidents, emergencies and complaints are appropriately resolved with all applicable forms and records duly filled and maintained
- Regular reviewing of environmental plans and procedures to assess compliance and recommend revisions, where required
- Review reports provided by the Construction Contractor and submit periodic reports to EPAs

9.5 Mitigation and Management Plan

The first part of this section summarizes, as the mitigation and management plan, the mitigation measures for the Project as prescribed in the ESIA and divides the responsibilities for implementation of these measures. The second part describes additional management plans that must be developed to facilitate implementation.

9.5.1 Overall Mitigation Measures

The list of impacts is provided in **Exhibit 9.6.** Each impact is given a unique reference number so that, if required, the discussion in the **Section 7** (*Anticipated Environmental Impacts and Mitigation Measures*) can be referred back.

For the purpose of implementation, the measures are grouped as follows:

- Design Phase Mitigation Considerations (**Exhibit 9.7**) identifies the measures that need to be undertaken during detailed design of the project and during construction planning.
- Construction Phase Mitigation Plan (**Exhibit 9.8**) summarizes the mitigation measure that are required to be implemented during construction, the timing of implementation, responsibilities for implementation and monitoring indicators.
- Operation Phase Mitigation Plan (**Exhibit 9.9**) summarizes the mitigation measure that are required to be implemented during operation, the timing of implementation, responsibilities for implementation and monitoring indicators.

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Exhibit 9.6: Impacts Assessed during the ESIA

Impact Reference	*Impact*
1	Loss of aquatic biodiversity due to creation of a low flow section downstream of the dam
2	Loss of aquatic biodiversity due to changes in ecological conditions downstream of the powerhouse as a result of release of water
3	Terrestrial habitat loss caused by construction of Project infrastructure
4	Decline in abundance and diversity of terrestrial flora and fauna caused by construction related activities.
5	Project operation leading to animal disturbance, displacement and decline.
6	Increase in ambient concentration of air pollutants from construction activities and vehicular movement may cause health impacts on the community.
7	Vibration from blasting during the construction phase may disturb local communities.
8	Blasting may pose a safety hazard due to flying debris.
9	Increase in ambient noise levels due to the operation of construction equipment, movement of construction traffic and blasting may create a nuisance for nearby communities and visiting tourists.
10	Alterations of natural passage of springs due to tunnel construction may disrupt the water availability at mountain springs for local community.
11	Damage to community irrigation channels may occur during construction especially during blasting of the headrace tunnel
12	Use of local water resources for construction activities may reduce the water availability for local communities.
13	Contamination of surface and groundwater due to discharge from the construction activities and sewage from the construction camps may affect agricultural productivity and human health.
14	Contamination of soil as a result of accidental release of solvents, oils, and lubricants can degrade soil fertility and agricultural productivity.
15	Land clearing, excavation, tunnel boring and other construction activities may loosen the top soil in the Project area resulting in loss of soil and possible acceleration of soil erosion and land sliding, especially in the wet season.
16	Increased erosion and sediment load entering the river from bunds and sediment ponds during the construction phase and as a consequence of the failure of spoil dumping sites.
17	Deterioration of aesthetics and visual amenity of nearby receptors due to construction activities, including vehicular movement on roads, may cause a disturbance in aesthetics for nearby communities.
18	Permanent impact on aesthetics due to proposed developments.
19	Improved accessibility of locals due to construction of Project access roads.
20	Increase in congestion, due to increased traffic during construction will cause delays.
21	Increased risk to community safety due to increased traffic during the construction phase near communities.
22	Degradation of the pavement due to use by heavy construction traffic.
23	A potential flood and seismic hazard under natural extreme conditions for which the dam is not designed, albeit very unlikely, has potential to cause loss of life and damage to property.

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Impact Reference	*Impact*
24	GHG emissions from dam construction will increase GHG concentration in the atmosphere thereby contributing to climate change
25	Direct, indirect and induced employment at the local level, resulting in increased prosperity and wellbeing due to higher and more stable incomes of people.
26	Increase in the stock of skilled human capital due to transfer of knowledge and skill under the Project resulting in enhanced productivity of local labor.
27	Decrease in productivity of agricultural fields due to unavailability of water for irrigation
28	Loss of assets and livelihood as a result of land acquired for the Project.
29	Increase in population due to in-migration of job seekers (in-migrants) leading to pressure on existing social infrastructure and services in the Study Area.
30	Disputes over the distribution of Project employment within and between Study Area inhabitants and the in-migrants resulting in social unrest.
31	Potential social unrest including gender issues in the Study Area due to conflicting socio-cultural norms amongst the inhabitants and in-migrants.
32	Religious conflicts due to different religious beliefs of workers and locals.

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Exhibit 9.7: Design Phase Mitigation Considerations

IR	*Impact*	*Mitigation Measure*	*When*	*Responsibility*
3	Terrestrial habitat loss caused by construction related activities	▸ Minimize disturbance to, or movement of, soil and vegetation ▸ Minimize project footprint. ▸ Retain as much natural vegetation as possible. ▸ Locate construction facilities based on a knowledge of the soil, slope and vegetation cover of the area to avoid disturbance to the natural environment.	During detailed design	EPC Contractor
4	Decline in abundance and diversity of terrestrial flora and fauna caused by construction related activities.	▸ Locate vehicle yards away from open soils and top soil stockyard ▸ Maximize use of locally-sourced aggregate and borrow material ▸ Minimize contact of non-local aggregate and borrow material with native soil. ▸ Minimize disturbance to, or movement of, soil and vegetation.	During detailed design	EPC Contractor
9	Increase in ambient noise levels due to operation of construction equipment, movement of construction traffic and blasting may create nuisance for nearby communities and visiting tourists.	▸ Use visual alarms in preference to audible alarms. ▸ Locate noisy equipment behind parking lots, parks or behind sound barriers or sound absorbers, for example, gravel stockpiles or constructed barriers. ▸ Maximize use of vibratory piling instead of impact piling. ▸ Erect earth mounds around the site boundary to provide acoustic as well as visual screening.	During detailed design	EPC Contractor
10	Alterations of natural passage of springs due to tunnel construction may disrupt the water availability at mountain springs for local community.	▸ Record location of the springs especially those in areas proximal to where the underground headrace tunnel will be closer to the ground level (see **Section 7.7** *Hydrology and Water Quality* for spring considered at risk).	During detailed design	Supervision Consultant
11	Use of local water resources for construction activities may reduce the	▸ Prepare a **Water Sourcing and Abstraction Plan** specifying the source, owner, total yield, current usage, allowable quantity and the duration for which water can be obtained.	During detailed design	EPC Contractor

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IR	Impact	Mitigation Measure	When	Responsibility
	water availability for local communities.	▶ To the extent possible avoid, and where unavoidable, minimize the use of water from local sources (springs) for the Project. Where local abstraction is unavoidable: ▷ Undertake an assessment of the local source identifying its total yield and current usage. If the abstraction from a single source extends three months, the assessment shall be repeated ▷ Fix the allowable quantity to not more than 50% of the available yield (total yield minus current usage) ▷ Enter into a formal agreement with the owner for the water source (or government if it is a public source).		
15	Increased erosion and sediment load entering river from bunds and sediment ponds during the construction phase and as a consequence of failure of spoil dumping sites.	▶ Dumping sites should not be in the path of 20-year return period flood. ▶ The EPC contractor should report the exact quantities of material to be dumped to the regulator ▶ the spoil dumping locations should be reported to the regulator ▶ The planning should accommodate dumping sites as close as possible to the construction area to avoid transport of spoil in large vehicles on public roads ▶ in case the spoil material is requested by private land owners for dumping on their land, the EPC Contractor should be able to negotiate with them to dump spoil	During detailed design	EPC Contractor
17	Permanent impact on aesthetics due to proposed developments.	▶ Develop and implement a Site Rehabilitation and Landscaping Plan. ▶ Use colors that better integrate with the landscape. ▶ Disguise elements with vegetation where possible. ▶ Retain as much natural vegetation as possible.	During detailed design	EPC Contractor
18	Improved accessibility of locals due to construction of Project access roads.	▶ Consult communities during final design and location of site access roads.	During detailed design	EPC Contractor

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IR	*Impact*	*Mitigation Measure*	*When*	*Responsibility*
19	Increase in congestion, due to increased traffic during construction will cause delays.	▶ Make roundabouts for the congestion points. ▶ Retain as much natural vegetation as possible to reduce the impact of smoke due to vehicles.	During detailed design	EPC Contractor
27	Decrease in productivity of agricultural fields due to unavailability of water for irrigation.	▶ Providing alternative source of water for irrigation, water flour mills and micro hydro power plant.	During detailed design	EPC Contractor
28	Loss of income from agricultural activity due to acquisition of agricultural land and assets for the Project.	▶ Implement Resettlement Action Plan (RAP)	Before construction	MHL
29	Increase in population due to in-migration of job seekers (in-migrants) leading to pressure on existing social infrastructure and services.	▶ Development of a Grievance Redressal Mechanism ▶ Encourage local communities to use the grievance procedure for concerns related to deterioration of local services. ▶ Support local government in the implementation of infrastructure projects. ▶ Support NGOs specializing in development of local infrastructure.	During construction	EPC Contractor
30	Disputes over distribution of Project employment within and between Study Area inhabitants and the in-migrants resulting in social unrest.	▶ Maintaining regular communication with local communities and other stakeholders to minimize tensions arising from Project activities; ▶ Maintaining a grievance procedure, and encourage and facilitate stakeholders to use the mechanism to express concerns; and ▶ Providing sufficient resources to the community relations officers to enable them to monitor negative perceptions and associated tensions, and to address them in a timely fashion.	During construction	EPC Contractor
31	Potential social unrest in the Study Area due to conflicting socio-cultural norms amongst the	▶ Development of a Grievance Redressal Mechanism ▶ Encourage local communities to use the grievance procedure for concerns related to deterioration of local services.		EPC Contractor

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IR	Impact	Mitigation Measure	When	Responsibility
	inhabitants and in-migrants	▶ A clause will be added in the contract that workers will use main routes and will not use routes within settlements unnecessarily. ▶ A clause will be added in the contract that workers are to respect local norms and religious beliefs.		
32	Religious conflicts due to different religious beliefs of workers and locals.	▶ Development of a Grievance Redressal Mechanism ▶ Encourage local communities to use the grievance procedure for concerns related to deterioration of local services. ▶ A clause will be added in the contract that workers are to respect local norms and religious beliefs.		EPC Contractor
34	A potential flood and seismic hazard under natural extreme conditions for which the dam is not designed, albeit very unlikely, has potential to cause loss of life and damage to property.	The recommended mitigation and management measures include: ▶ Prepare an emergency preparedness and response plan for the Project that includes consideration of flooding, earthquake, evacuation procedure, co-ordination with local administration and communities. ▶ Maintain network of climate gauges in the Arkari catchment to monitor potential floods through WAPDA or in conjunction with other hydropower developers. ▶ Automated telemetric flow gauges can be installed upstream of the reservoir. This will allow the Arkari Hydropower operators to be well aware of any potential flooding conditions using upstream flow data, in addition to climatic conditions recommended above. ▶ Design Basis Earthquake included in the structural design for Powerhouse and weir. ▶ Design the river diversion facilities according to 10-years return period flood as per international practice. ▶ The design of the Project to be based on 1000 years return period flood.	During detailed design	MHL

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Exhibit 9.8: Construction Phase Mitigation Plan

IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
	Construction Impacts	▸ **The Site Specific Environmental Management Plan** (SSEMP) for each site will outline areas to be cleared, vegetated areas to be protected or fenced, slopes to be stabilized and solid waste disposal locations. ▸ Submit all SSEMP to Owner's Engineer for approval.	At start of construction	Site Managers of EPC	SSEMPs prepared before initiation of construction
1	Loss of aquatic biodiversity due to creation of a low flow section downstream of the dam	1. Maintain environmental flow as recommended in Project design 2. Regulate activities of the staff so that they do not engage in illegal exploitation of wildlife such as illegal fishing 3. Construction activities should be carried out whilst ensuring that there is no run-off of silt into the river and that the river is not contaminated to ensure that water quality is not affected 4. Limited subsistence fishing using rods and cast nets will be allowed through a permitting system.	During and after construction	EPC Contractor	Fish abundance and diversity
2	Loss of aquatic biodiversity due to changes in ecological conditions downstream of the powerhouse as a result of release of water	1. Design peaking operation to reduce impacts on aquatic ecology as recommended in the Eflow Assessment (see **Appendix M**) 2. Regulate activities of the staff so that they do not engage in illegal exploitation of wildlife such as illegal fishing 3. Construction activities should be carried out whilst ensuring that there is no run-off of silt into the river and that the river is not contaminated to ensure that water quality is not affected 4. The Project will help the Wildlife and Fisheries Departments by providing one field office, three motor cycles, 5 guards and 1 inspector to protect river biodiversity and terrestrial wildlife, subject to an agreement in which the responsibilities of the Project and the Departments are clearly defined and performance of the protections activities is independently monitored. Improvement in aquatic and terrestrial biodiversity through protection will partly offset the residual impacts of the Project on aquatic ecology 5. Limited subsistence fishing using rods and cast nets will be allowed through a permitting system.	During and after construction	EPC Contractor	Fish abundance and diversity

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
3	Terrestrial habitat loss caused by construction related activities	▶ Provide awareness training to staff and contractors on: prevention of injury of animals; identification of likely species (Snow Leopard, Himalayan Lynx, Grey Wolf, Asiatic Jackal, Red Fox, Flare-horned Markhor and Himalayan Ibex) found on site; identifications of animal hazards (such as venomous snakes); and what to do if dangerous animals are encountered. ▶ Solid waste should only be disposed of at designated sites and a Waste Management Plan developed and implemented. ▶ Prepare an Environmental Training Plan that contains awareness training to staff and contractors on: prevention of injury of animals; identification of likely species (Snow Leopard, Himalayan Lynx, Grey Wolf, Asiatci Jackal, Red Fox, Flare-horned Markhor and Himalayan Ibex) found on site; identifications of animal hazards (such as venomous snakes); and what to do if dangerous animals are encountered. Also see guidelines for the Environmental Training Plan in IR 5. ▶ Regulation of poaching of wildlife species (Snow Leopard, Himalayan Lynx, Flare-horned Markhor, Himalayan Ibex and other water fowls). ▶ Close coordination with the wildlife and fisheries departments ▶ Facilitating government department staff when they arrive at the site for example providing them accommodation and vehicles. ▶ Encourage personnel to report sightings of wildlife of conservation importance or incidents of poaching to MHL. MHL to report incidents of poaching and illegal fishing to concern government departments.	During construction	EPC Contractor	SSEMPs prepared before initiation of construction Visual confirmation of replantation Waste Management Plan Environmental Training Plan

IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		► Minimize disturbance to, or movement of, soil and vegetation. ► Prevent soil damage and erosion. ► Prevent Alien Invasive Species (AIS) establishment on exposed stored soil (do not store bare soil near known sources of AIS). The habitat most at risk is the Riparian Habitat. The species that are highest risk include Marijuana, Strumarium and Castor Oil Plant. These invasive plant species are quite common in the lower parts of the Aquatic Study Area. ► Train and raise awareness regarding AIS among Project staff and contractors. ► Retain as much natural vegetation as possible. ► Solid waste should only be disposed of at designated sites. ► Minimize the project footprint, clearly delineate and restrict access beyond work sites and other areas to be disturbed. ► Within the quarry and borrow areas, activities will be restricted to areas at a distance from perennial water channels so as to avoid disturbances to them including the risk of siltation.			
4	Decline in abundance and diversity of terrestrial flora and fauna caused by construction related activities.	► Large flood lights should not be installed outside 50 m of the Project fence. ► Lights should be directed towards Project facilities and not towards the natural habitats. ► Regulations for Project staff and contractors to avoid illegal poaching to be incorporated in contract documents. ► Provide awareness training to staff and contractors on: prevention of injury of animals; identification of likely	Before and during construction	EPC Contractor	Environmental Training Plan Training Schedule Evidence of trainings and attendance lists Provision of required regulations in contract documents. Evidence of tree planting to required levels and yearly survival records.

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		species (Snow Leopard, Himalayan Lynx, Grey Wolf, Asiatic Jackal, Red Fox, Flare-horned Markhor and Himalayan Ibex) found on site; identifications of animal hazards (such as venomous snakes); and what to do if dangerous animals are encountered. ▶ Incorporate regulations for Project staff and contractors to avoid illegal poaching in contract documents. ▶ Provide adequate knowledge to the workers on relevant government regulations and punishments for illegal poaching. ▶ Encourage personnel to report sightings of wildlife of conservation importance or incidents of poaching to MHL ▶ Project staff and contractors to report kills of large mammals particularly designated species (Snow Leopard, Grey Wolf and Flare-horned Markhor) of conservation concern. ▶ Train and raise awareness regarding AIS among Project staff and contractors. ▶ The Contractor shall prepare an **Environmental Training Plan** for all construction workers: the Plan shall address the following items: ▶ All Contractor's employees shall be required to comply with environmental protection procedures and they shall be able to provide evidence that they attended the training sessions detailed in the Plan; ▶ The Plan shall educate all construction workers on the following issues but not limited to them: fire arm possession, traffic regulations, illegal logging and collection of non-timber forestry products, non-disturbance of resettlement communities, hunting and fishing restrictions, waste management, erosion control,			

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		health and safety issues, all prohibited activities, the Code of Conduct requirements and disciplinary procedures, and general information on the environment in which they will be working and living; ▶ Establishment of penalties for those who violate the rules; ▶ Proposed methods for conducting the training program, which shall include formal training sessions, posters, data in newsletters, signs in construction and camp areas and 'tool box' meetings. ▶ Equipment emitting excessive noise in comparison with other similar equipment will not be allowed to operate. ▶ Equipment under use will be regularly maintained, tuned, and provided with mufflers to minimize noise levels. ▶ Equipment in poor state of maintenance, particularly without effective noise control will be checked to determine if it can be improved, and replaced with less noisy equipment as soon as practicable. ▶ Blowing of horn will be prohibited on all sensitive areas except under emergency conditions. ▶ Enforce speed limits in ecologically sensitive areas if identified ▶ Compensatory trees will be planted. The EPC Contractor will plant a minimum of ten trees for each tree removed in acquired land. ▶ MHL will monitor and maintain the vegetation until it is established.			
6	Increase in ambient concentration of air pollutants from construction activities	▶ Develop and implement an **Air Pollution Control Plan.** ▶ Prepare a Site Specific Environmental Management Plan (SSEMP) for each construction site that must	Before and during construction	EPC Contractor	SSEMP documents prepared before initiation of construction

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
	and vehicular movement may cause health impacts on the community.	outline areas to be cleared, vegetated areas to be protected or fenced, solid waste disposal locations, and sprinkling locations. All appropriate measures indicated in Generic **Construction Site Environmental Management Plan** (CSEMP) (**Appendix** N) should be incorporated in the SSEMP. **Fugitive and exhaust emissions from transport vehicles** ▶ Cover all trucks hauling soil, sand, and other loose materials or require all trucks to maintain at least two feet of freeboard (i.e., the minimum required space between the top of the load and the top of the trailer). ▶ Install and maintain appropriate emission control equipment on vehicles and machinery. ▶ Regularly maintain vehicles and equipment to keep emissions in check. ▶ Smoke from internal combustion engines should not be visible for more than ten seconds. ▶ Use new and low emission equipment and vehicles to the extent possible. ▶ Purchase best quality fuel and lubes and where possible use lead free oil and lubes. ▶ Sprinkle water on all unsealed roads used by Project vehicles that are within 200 m of any settlement. ▶ Cover loads and long-term piles of friable material to reduce fugitive dust emission. ▶ Reduce traffic speeds on all unpaved surfaces to 15 miles per hour or less to avoid dust emissions from vehicular movement. ▶ Paved roads shall be swept frequently if soil material has been carried onto adjacent paved, public thoroughfares from the Project site.			Air Pollution and Control Plan Continuous observation for non-compliance Vehicle and equipment maintenance logs

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		▸ Install wheel washers where vehicle exit onto paved road from unpaved and prior to each trip. **Fugitive dust emissions from blasting** ▸ Indicate the limits of a clearing land with highly visible markers. ▸ Leave a layer of about 5 m of undisturbed softs above the top of the overburden blasts. This will act as a blanket to contain air blast, dust and fly rock. ▸ Sprinkle water on the area where blasting is done to settle down the particulate matter emissions. **Fugitive dust emissions from quarry areas** ▸ Indicate the limits of a clearing land with highly visible markers. ▸ Avoid earth stripping or moving in periods of dry and windy weather. ▸ Carry out dust generating activities where maximum protection can be obtained through topography or in areas where prevailing winds will blow dust away from sensitive areas/uses. ▸ Water spraying of conveyors/conveyor transfer points, stockpiles and roads. ▸ Covering of fine dry loads or spraying of loads prior to exiting the site, and if necessary regular cleaning of public roads in the vicinity of the entrance. **Fugitive dust emissions from concrete batching plants** ▸ Suspend earthwork operation when wind speed exceeds 20 km per hour. ▸ The whole process of weighing and mixing would be performed in a fully enclosed environment. ▸ The mixers should be equipped with dust collectors.			

IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		▶ Site the concrete batching plant out of prevailing high winds to minimize dust emissions. ▶ Consider the prevailing wind direction when siting the batching plant. ▶ Ensure that bunkers and conveyors are sited in the leeward direction to minimize the effects of the wind. ▶ Consider the natural wind barriers such as trees and landforms to help control the emission of dust from the batching plant. ▶ Batching plants should be sited on land that is not flood prone. **Fugitive dust emissions from aggregate production and handling system** ▶ Suspend operation when wind speed exceeds 20 km/hr. ▶ Consider prevailing wind direction to ensure that aggregate handling systems located in the leeward direction to minimize the effects of the wind. ▶ Sprinkle water on all exposed surfaces, particularly those close and up-wind of settlements. **Wind-blown dust from exposed surfaces such as bare land, stockpiles and waste dumping sites** ▶ Cover all exposed surfaces, particularly those close and up-wind of settlements. ▶ Suspend all grading operations on a Project when winds exceed 20 km per hour. ▶ Minimize disturbance to, or movement of, soil and vegetation. ▶ Sprinkle water on all exposed surfaces, particularly those close and up-wind of settlements. ▶ Retain as much natural vegetation as possible.			

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		▶ Cover on-site dirt piles or other stockpiled areas. ▶ Install wind breaks and employ water and/or soil stabilizers to reduce wind-blown dust emissions. ▶ Adequately wet, cover with plastic, or provide with wind shield all stockpiles to reduce dust emission.			
7	Vibration from blasting during the construction phase may disturb local communities including annoyance, sleep disturbance and potentially damage the structure.	▶ Develop a **Blasting and Explosives Management** Plan and Vibration Monitoring Plan. ▶ Conduct a pre-construction survey of structures at risk of vibration impacts households. ▶ In the initial stages, the blasting induced vibration shall be measured as a function of maximum instantaneous charge and distance from the blasting site. This data shall be then used to refine the Blasting Induced Vibration Risk Zones on the basis of the adopted criteria. ▶ Using, the refined Blasting Induced Vibration Risk Zones maps and the tunnel boring schedule, the Supervision Consultant in consultation with the MHL and the Construction Contractor, shall identify the houses that will be affected and the impact duration and schedule. ▶ For the houses that will fall in the Structural Damage Risk Zone, a temporary relocation plan will be developed. An amendment to the Resettlement Action Plan (RAP) will be commissioned for this purpose. Before start of blasting, all residents of houses in the Structural Damage Risk Zone will be relocated as per the RAP. Temporary relocation means relocation while blasting is being conducted while too close to the houses, and depends on the blasting schedule. It is likely that no houses are near enough to be classified as	During Construction	EPC Contractor	Blasting and Explosives Control Plan document Blasting timetable available in nearby villages Results of preconstruction survey Availability of GRM

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		within the Structural Damage Risk Zone due to the low population density in the area. ▸ A survey will be undertaken in both zones, to determine the pre-blasting conditions of the buildings. The survey will be commissioned by the Supervision Consultant and will identify and record any existing damage to the structures. The survey will cover the following aspects: ▹ Overall condition of the structures, both exterior and interior. ▹ Documentation of defects observed in the structure using digital imagery along with notes, measurements and sketches. ▹ Documentation of pre-existing cracks using digital imagery along with notes, measurements and sketches. ▸ Following completion of the blasting, the survey will be repeated in the Structural Damage Risk Zone to determine the condition of the buildings and verify that they are safe for re-occupation. If the buildings are safe, the residents will be allowed to return to their houses following any necessary damage repairs. If the buildings are damaged beyond repair, compensation will be paid to the owners as per the LARP. If there are any claims or reports of damage in the Cosmetic Damage Risk Zone, the affected house will be surveyed against the pre-Project survey and repairs will be undertaken as appropriate. ▸ Following are key mitigation measures for the management of blasting: ▹ Blasting will be scheduled during the day only. ▹ Local communities will be informed of blasting timetable in advance and will be provided adequate notice of when blasts are required outside of the planned schedule. ▹ A Blasting Management Plan will be developed by the Construction Contractor. The Plan will be reviewed and			

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		approved by the Supervision Contractor before the initiation of the blasting work. ▷ Throughout the blasting activity, vibration sensors will be installed at strategic location to monitor the impact of blasting and to ensure that the vibration levels are within the adopted criteria. The monitoring plan will be part of the Blasting Management Plan. ▷ Unscheduled blasting will be strictly prohibited in any case. ➤ Meaningful contact with the community shall be maintained and their grievance shall be attended to in a timely manner. In this regard: ▷ A meaningful community engagement plan will be developed. The plan will cover identify the affected community; the key contact persons; frequency of engagement; the information to be shared; the responsibilities to manage the plan; and the notice period to be giving to the community for various blasting related generating activities. ▷ The Grievance Redress Mechanism will be used to record, investigate, and respond to any complaints. Investigation of the complaints will be undertaken by the Supervision Consultant. ➤ Develop a Vibration Monitoring Plan that will include monitoring of vibration levels and frequency around the blasting sites. The objectives of the monitoring will be to: ▷ Ensure that vibration levels in the communities are within the adopted criteria levels; ▷ Maintain record of vibration to settle any potential conflicts; and ▷ Monitor changes in the vibration levels due to possible changes in the rock formation and take appropriate corrective actions.			
8	Blasting may pose a health and safety	➤ A minimum buffer of 500 m should be provided between the settlements and point of blasting or if not possible then these settlements should be temporarily evacuated	During Construction	EPC Contractor	Blasting and Explosives Control Plan document

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
	hazard due to flying debris.	during blasting. Temporary relocation means relocation while blasting is being conducted while too close to the houses, and depends on the blasting schedule. ▶ Leave a layer of about 5 m of undisturbed softs above the top of the overburden blasts. This will act as a blanket to contain air blast, dust and fly rock. ▶ Ensure that the holes are correctly collared with respect to the back-break/inclination of the face and also that digging alongside the initiation face well controlled. ▶ Inadequate forward displacement of the front row burden arising out of the under charging of these holes will result in fly rock from vertical catering of the rear holes. ▶ Where fly rock possess a serious problem, the stemming length should not be less than the hole burden. Also an effective stemming material like crushed angular rock should be used to prevent premature venting of explosion gases through the stemming column. ▶ The forward fly rock could be fairly controlled to the commonly used 'inline open loop' pattern. The maximum inter-row delay interval consistent with the absence of cut off helped in minimizing the fly rock formation. As a thumb rule an inter-row delay of 4-8ms/m of burden could be used for this purpose. ▶ Adequate care should be taken while connecting the delay devices in the holes/rows and the initiation sequence properly checked before firing to avoid initiation of blast holes out of sequence. ▶ Blasts designed on a face length to width ratio in the range of 3 to 4 produces minimum fly rock.			Blasting timetable available in nearby villages Results of preconstruction survey Availability of GRM

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
9	Increase in ambient noise levels due to operation of construction equipment, movement of construction traffic and blasting may create nuisance for nearby communities and visiting tourists	► Develop a Noise and Vibration Control Plan **Noise generated from construction sites from construction activities** ► Select the quietest available plant and equipment that can economically undertake the work required. ► Undertake maintenance of the equipment as simple maintenance can reduce noise levels by as much as 50%. Parts may become loose, creating more noise because of improper operation or scraping against other parts. Grinding noises may also occur as the result of inadequate lubrication. ► Maintain equipment under use regularly. ► Install mufflers on the equipment to minimize noise levels. ► Use visual alarms in preference to audible alarms. ► Enclose noisy equipment. ► Provide noise attenuation screens, where appropriate. ► Build an enclosure around the noise source so that noise is contained. The enclosure should be free from gaps and made of dense material and be lined with noise-absorbing material like glass or polyester batts. ► Locate noisy equipment behind parking lots or parks. ► Close liaison with the community and regular monitoring of the noise levels in the community are key to successfully implementation of the above mitigation measures. Specifically, inform communities of all major construction activities three days in advance.	During Construction	EPC Contractor	Noise and Vibration Control Plan document Maintenance record of equipment Records of community meetings regarding noise. Noise level monitoring in nearby communities

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		Construction noise from traffic ▶ Install residential class mufflers and silencers to the mobile plants such as excavators, front-end loaders and other diesel-engine equipment as applicable. ▶ Construct paved Project access roads and locate where the gradient is low. ▶ Implement special noise reduction measures, such as erecting purpose-built acoustic barriers, restricting opening hours and maintaining transport vehicle. **Construction noise from on-site plant operations and equipment** ▶ Select plant equipment appropriately that required minimal mitigation. ▶ Install mufflers and silencers on the equipment and provide acoustical enclosures. ▶ Modify the equipment or the work area to make it quieter by substituting existing equipment with quieter equipment; retro-fitting existing equipment with damping materials, mufflers, or enclosures; erecting barriers; and maintenance. ▶ Shift to a quieter construction process for example pile driving is very loud as compared to boring which is a much quieter way to do the same work. ▶ Combine noisy operations to occur in the same time period. The total noise level produced will not be significantly greater than the level produced if the operations were performed separately. ▶ Maintain and monitor plant and equipment regularly. ▶ Move static plant and equipment as far as possible from sensitive boundaries, as work allows. A distance of four			

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		times further away lowers the noise by 12 dBA. A reduction of 10 dBA will sound half as loud. ▶ Provide baffles and specialized mufflers, and acoustic enclosures to the plant and equipment. ▶ Design and built acoustic barriers if needed. Vegetated buffer zones can also be planted to mitigate noise from operations using suitably selected native plantings local to the area. ▶ Reduce workers' exposure to high noise levels by keeping moving workers away from the noise source; restricting access to areas; rotating workers performing noisy tasks; and shutting down noisy equipment when not needed. ▶ Use earplugs to reduce workers' exposure to high noise levels. **Noise generated from the blasting in quarry areas** ▶ Use vibratory piling instead of impact piling. ▶ House conveyor belts and crushing/screening equipment to provide acoustic screening. ▶ Ensure that the noise-reduction equipment fitted to machinery is used and maintained properly. ▶ Erect earth mounds around the site boundary can provide acoustic as well as visual screening. **Noise emissions from concrete batching** ▶ Locate noisy equipment behind sound barriers or sound absorbers – for example, gravel stockpiles or constructed barriers. ▶ Install silencing devices to all pressure operated equipment.			

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
10	Alterations of natural passage of springs due to tunnel construction may disrupt the water availability at mountain springs for local community.	➤ Record location of the springs especially those in areas proximal to where the underground headrace tunnel will be closer to the ground level. ➤ Monitor flow for identified springs and maintain records and ensure the availability of water to the communities and the access of the communities to the water resources being used by them is not adversely affected. Provide water to communities where needed to offset any disturbance. ➤ Support the community in development of alternate water supply schemes through local NGOs	During construction	EPC Contractor	Flow records of identified springs
	Damage to community irrigation channels may occur during construction especially during blasting of the headrace tunnel	➤ Document the current status of the irrigation channels. Record location of the springs close to the Project construction site. ➤ Engage local communities through GRM for periodic monitoring of the status of the channels. ➤ If the channel is damaged, then provide support for fast and complete repair.	During construction	EPC Contractor	Monitoring records of the Irrigation Channels Presence of GRM
11	Use of local water resources for construction activities may reduce the water availability for the local communities.	➤ Develop a Water Sourcing and Abstraction Plan ➤ Source water for construction from authorized abstraction sources agreed between the local communities, local government and EPC contractor. ➤ Water conservation techniques will be developed and implemented by the EPC contractor. ➤ Access of community to water sources shall be kept clear so that the community's ability to meet its water requirements are not compromised. ➤ Exercise care while moving heavy machinery to avoid damage or blockage of natural waterways and channels.	Before and during construction	EPC Contractor	Agreements documents for water use. Water Sourcing and Abstraction Plan Water use record documents

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IR	*Impact*	*Mitigation Measure*	*When*	*Responsibility*	*Monitoring Indicators*
		➤ Maintain records of water usage in all Project activities. ➤ Incorporate the above measures in the Construction SSEMP			
12	Contamination of surface and groundwater due to discharge from the construction activities and sewage from the construction camps may affect agricultural productivity and human health.	➤ Develop and implement a Water Quality Management Plan. ➤ Develop and Implement a Hazardous Material Management Plan. ➤ Prepare and implement a **Waste Management Plan.** ➤ Prepare and implement a **Spill Prevention and Response Plan** and inducted to the staff for any incident of a spill. ➤ Septic treatment facility will be developed at each camp and construction site to manage waste generated on-site. ➤ Provide and use spill prevention trays at refueling locations. ➤ Collect runoff from maintenance workshops using impervious channels and pass through oil water separators (OWS) before final disposal. Properly dispose of the sludge and oil collected at the OWS. ➤ Build separate impervious pits (with concrete walls and proper shed) at the construction sites for temporary handling and storage of contaminated soil and water if encountered during construction such as sludge from OWS. ➤ Keep all fuel storage tanks and lubricating oil drums in secondary containment impervious pits with impervious shed walls. ➤ Avoid on-site maintenance of construction vehicles and equipment, as far as possible.	During Construction	EPC Contractor	Water Quality Management Plan documents Spill Prevention and Response Plan document Visual implementation of mitigation measures such as use of spill prevention trays and proper storage of fuel storage. Record of spills and remedial actions taken

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IR	*Impact*	*Mitigation Measure*	*When*	*Responsibility*	*Monitoring Indicators*
		► Regularly inspect construction vehicles and equipment to detect leakages. ► Store fuels and lubricants in covered and dyked areas, underlain with impervious lining. ► Spill control kits (shovels, plastic bags, and absorbent materials) will be available near fuel and oil storage areas, vehicle parking, and vehicle maintenance areas as well as at construction sites. ► Remove contaminated soil from the site and dispose of in a manner to ensure the protection of water sources. ► Construct the bottom of any soak pit or septic tank at least 100 m away from springs and water bores. ► Maintain records of spills and volume of removed contaminated soil. ► Maintain a record of remedial measures taken. ► Use silt traps to prevent contamination of river and streams. ► Mechanical works and shops, secondary containment (>110% of volume) for storage and use of paints and other hazardous materials should be done over impermeable surfaces. ► Incorporate the above measures in the Construction Site Environmental Management Plan			
ee	Contamination of soil as a result of accidental release of solvents, oils and lubricants can degrade soil fertility and agricultural productivity.	► Prepare a **Spill Prevention and Response Plan** and induct to the staff for any incident of spill. ► Appropriately mark fuel tanks by content and store in dyked areas with an extra 10% of the storage capacity of the fuel tank. The area will be lined with an impervious base.	During Construction	EPC Contractor	Spill Prevention and Response Plan document Visual verification of conformance

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		▸ Install grease traps on the site, wherever needed, to prevent flow of oily water. ▸ Spill cleaning kit (shovels, plastic bags and absorbent materials) will be available near fuel and oil storage areas. ▸ Carry cleanup kits in all fuel trucks. ▸ Fueling should only take place over impermeable surfaces, other hazardous materials should be stored and used over impermeable surfaces. ▸ The bottom of any soak pit or septic tank shall be at least 10 m above the groundwater table. The distance can be reduced, based on the soil properties, if it is established that distance will not result in contamination of groundwater.			
14	Land clearing, excavation, tunnel boring and other construction activities may loosen the top soil in the Project area resulting in loss of soil and possible acceleration of soil erosion and land sliding, especially in the wet season.	▸ Develop a Surface Runoff, Site Restoration and Erosion Control Plan. ▸ Limit vegetation loss to demarcated construction area. ▸ Cover areas such as muck disposal area, batching plant, labor camp and quarry sites after the closure shall with grass and shrubs. ▸ Adopt slope stabilization measures such as adequate vertical and horizontal drains, drainage along roadsides, cross drainage and retaining walls. ▸ Monitor slope movements around excavation work areas. ▸ Salvage, store, and reuse all topsoil at all construction sites. ▸ The height of the stockpile will be minimized to the extent possible by increasing the size of the land for the stockpile.	During Construction	EPC Contractor	Erosion Control Plan document

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		▶ Topsoil will be carefully stripped to ensure that it is not mixed with subsoil. The stockpiles will be revegetated to minimize loss of soil quality, minimizing weed infestation, maintaining soil organic matter levels, maintaining soil structure and microbial activity. ▶ Topsoil stockpiles will be clearly signposted for easy identification and to avoid any inadvertent losses. ▶ The establishment of declared plants on the stockpiles will also be monitored and control programs implemented as required. The topsoil will be treated with temporary soil stabilization and erosion control measures. ▶ During removal of topsoil stockpile for restoration of project affected areas, it is preferred that the soil is removed in layers (less than 0.5 m thick) under a gradual process. The top layer will be mixed with the remainder of the stockpile to ensure that living organisms are distributed throughout the topsoil material at the time of final placement. The use of micro-organism inoculates may be necessary to re-establish micro-organisms in topsoil material. ▶ Select local species for plantation to restore the biodiversity of the area in consultation with Forest Department after completion of respective activities.			
15	Increased erosion and sediment load entering river from bunds and sediment ponds during the construction phase and as a consequence of failure of spoil dumping sites.	**Mitigation measures:** 1. Design sedimentation ponds and dumping sites to a have a flood prevention design for a 20-year flood since the dumps will be left in place permanently. 2. Periodically remove sediments from bunds and sedimentation ponds before monsoon and after each large flood. 3. Maintain and monitor the sedimentation ponds to avoid sediment introduction in the river.	During construction	EPC Contractor	Spoil Disposal Plan Document

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		4. Undertake vegetation restoration works at all dumping sites including surface leveling, covering and forest/grass planting or agricultural land rehabilitation 5. Monitor slope movements excavation work areas. 6. Restore to the maximum extent possible the hydrological regime and reinstate natural drainage of the land (including provisions to maintain the water balance of the site and protect from flooding where appropriate) 7. Reinstate topsoil (in case it was stripped before construction activities) 8. Revegetate sites with suitable native plant species 9. Drain spoil piles to prevent the concentration of flow and to prevent rill and gully erosion 10. Separate organic material (e.g., roots, stumps) from the dirt fill and store separately. Place this material in long-term, upland storage sites, as it cannot be used for fill. 11. Store "clean" material in a short-term disposal site (stockpile) if it will likely be re-used for fill. 12. Recycle asphalt material in embankments and shoulder backing, where possible. Place these materials where they will not enter the stream system. Asphalt that is 5 years old is considered "inert" (that is, all oils washed off). 13. Do not add excess unusable material to permanently closed sites. 14. Spread material not to be re-used in compacted layers, generally conforming to the local topography. 15. Design the final disposal site reclamation topography to minimize the discharge of concentrated surface water and sediment off the site and into nearby watercourses. Cover the compacted surfaces with a 6-inch layer of organic or fine-grained soil, if feasible. 16. After placement of the soil layer, track walk the slopes perpendicular to the contour to stabilize the soil until vegetation is established. Track walking creates indentations that trap seed and decrease erosion of the reclaimed surfaces.			

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		17. Revegetate the disposal site with a mix of native plant species. Cover the seeded and planted areas with straw compost, mulched with straw at a rate of 1 to 1 ½ tons per netting or similar erosion control fabric on slopes greater than 1:2 if site is erosive. 18. Locate stockpiles away from drainage lines, at least 10 meters away from natural waterways and where they will be least susceptible to wind erosion. 19. Ensure that stockpiles and batters are designed with slopes no greater than 1:2 (vertical\ horizontal). 20. Regularly rehabilitate areas not in use for Project activities during construction to minimize erosion. This includes regrading and immediate revegetation (using fast-growing species and different functional groups of plants for keeping soil in place) of slopes to minimize erosion. 21. Install erosion and sediment control measures, if possible before construction commences. Identify drainage lines and install control measures to handle predicted storm water and sediment loads generated in the mini-catchment. 22. Establish an adequate inspection, maintenance and cleaning program for sediment runoff control structures. Ensure that contingency plans are in place for unusual storm events. 23. Continually assess the effectiveness of sediment control measures and make necessary improvements. 24. Keep temporary disposal sites out of wetlands, adjacent riparian corridors, and ordinary high water areas as well as high risk zones, such as 100-year floodplain and unstable slopes. 25. Anticipate sufficient storage area with no risk for sediment delivery for piles that may slump. Stress cracks indicate that the pile is at risk of slumping. ► Incorporate the above measures in the Spoil Disposal Plan			
16	Deterioration of aesthetics and visual amenity of nearby	► Minimize disturbance to, or movement of, soil and vegetation.	During detailed design	EPC Contractor	Covers used to disguise equipment.

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
	receptors due to construction activities, including vehicular movement on roads, may cause disturbance in aesthetics for nearby communities.	▶ Back fill to original levels. ▶ Reshaping to match in with surrounding topography. ▶ Reinstate vegetation around construction sites.			Visual compliance
17	Permanent impact on aesthetics due to proposed developments.	▶ Develop and implement a Site Rehabilitation and Landscaping Plan. ▶ Use colors that better integrate with the landscape. ▶ Disguise elements with vegetation where possible. ▶ Retain as much natural vegetation as possible.	During detailed design	EPC Contractor	Site Rehabilitation and Landscaping Plan
19	Increase in congestion, due to increased traffic during construction will cause delays.	▶ Make roundabouts for the congestion points. ▶ Retain as much natural vegetation as possible to reduce the impact of smoke due to vehicles. ▶ The vehicles going on the spoil routes and passing through the communities must be completely covered to avoid dust emissions. ▶ Strictly implement speed limits and defensive driving policies.	During construction	EPC Contractor	Traffic Management Plan
21	Increased risk to community safety due to increased traffic volume during the construction phase near communities.	▶ Develop and implement a Traffic Management Plan. ▶ Identify suitable times to transport equipment. ▶ Road safety awareness education will also be included during community visits or information sessions, so that communities can be familiarized with common road signs and the types of vehicles and equipment that will be moving through the area. ▶ Keep speeds slow (30 km/hr) where there is traffic exchange between roads. ▶ Make roundabouts for the congestion points.	During construction	EPC Contractor	Traffic Management Plan

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		▶ Designate traffic wardens at roads on the transport route to manage traffic during school hours. ▶ Construction traffic will not travel during school starting and ending hours on designated road segments in front of schools on the transport route. ▶ Strictly implement speed limits and defensive driving policies. ▶ Maintain vehicles especially brakes.			
22	Degradation of the pavement due to use by heavy construction traffic	Promptly and properly repair and maintain roads that are subject to damage by Project activities.	During construction	EPC Contractor	Number of observations of pavement damage in areas with heavy Project-related traffic.
	GHG emissions from dam construction will increase GHG concentration in the atmosphere thereby contributing to climate change.	1. Implement a Reservoir Clearing Plan	During construction	EPC Contractor	
25	Direct, indirect and induced employment at the local levels, resulting in increased prosperity and wellbeing due to higher and stable incomes of people.	**Enhancement measures:** ▶ Ensure preferential recruitment of local candidates provided they have the required skills and qualifications. ▶ Include an assessment of the contractor's demonstrated commitment to domestic and local procurement and local hiring in the tender evaluation process. ▶ Coordinate recruitment efforts related to non-skilled labor, including for non-skilled labor positions required by contractors. **Good practice measures:** ▶ Determine what is considered to be 'fair and transparent' in recruitment and in distribution of jobs	During construction	EPC Contractor	Contractual documents Number and ratio of local employees to non-local employees

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		between different community groups, in consultation with local communities and their leaders.			
26	Increase in the stock of skilled human capital due to transfer of knowledge and skill under the Project resulting in enhanced productivity of the local labor.	▶ Support a 'Vocational Training Program' to assist local people to qualify for semi-skilled positions focusing on issues such as procurement, involvement of vulnerable groups in Project opportunities and continual professional development of staff. ▶ Assist local people having practical skills but lacking qualifications to obtain their certificates and thus increase their employment opportunities. ▶ Support initiatives promoting a culture of learning in local communities. ▶ Plan and implement training program for vulnerable groups to encourage their participation in economic opportunities created by the Project. ▶ Assist employees and local communities to improve basic personal financial life skills through training and awareness campaigns, respectively. ▶ Consider further training programs to prepare retrenched workers to seek employment in sectors not related to dam construction.	During construction	EPC Contractor	Vocational Training Program document including annual schedule. Budget allocation for trainings. Documentary evidence including photographs and attendance lists of trainings.
27	Decrease in productivity of agricultural fields due to unavailability of water for irrigation	▶ Rehabilitation of Watercourses damaged or affected by the project.	During construction	MHL/ EPC Contractor	See RAP
28	Loss of assets and livelihood as a result of land acquired for the Project.	▶ Implement RAP	Before construction	MHL/Land Acquisition Collector	See RAP
29	Increase in population due to in-migration of job seekers (in-	▶ Develop an Influx Management Plan ▶ Development of a Grievance Redressal Mechanism	During construction	EPC Contractor	Grievance register and records Influx Management Plan

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
	migrants) leading to pressure on existing social infrastructure and services.	▸ Encourage local communities to use the grievance procedure for concerns related to deterioration of local services. ▸ Support local government in the implementation of infrastructure projects. ▸ Support NGOs specializing in development of infrastructure to assist local government.			
30	Disputes over distribution of Project employment within and between Study Area inhabitants and the in-migrants resulting in social unrest.	▸ Implement Stakeholder Engagement Plan including: ▹ maintaining regular communication with local communities and other stakeholders to minimize tensions arising from Project activities; ▹ maintaining a grievance procedure, and encourage and facilitate stakeholders to use the mechanism to express concerns; and ▹ providing sufficient resources to the community relations officers to enable them to monitor negative perceptions and associated tensions, and to address them in a timely fashion.	During construction	MHL/ EPC Contractor	Stakeholder Engagement Plan Minutes of community and stakeholder consultations Provision in budget for activities.
31	Potential social unrest in the Study Area due to conflicting socio-cultural norms amongst the inhabitants and in-migrants	▸ Development of a Grievance Redressal Mechanism ▸ Encourage local communities to use the grievance procedure for concerns related to deterioration of local services. ▸ A clause will be added in the contract that workers will use main routes and will not use routes within settlements unnecessarily. ▸ A clause will be added in the contract that workers are to respect local norms and religious beliefs.	During construction	MHL/ EPC Contractor	Grievance register and records Influx Management Plan
32	Religious conflicts due to different religious beliefs of workers and locals.	▸ Development of a Grievance Redressal Mechanism ▸ Encourage local communities to use the grievance procedure for concerns related to deterioration of local services.	During construction	MHL/ EPC Contractor	Grievance register and records Influx Management Plan

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		► A clause will be added in the contract that workers are to respect local norms and religious beliefs.			
24	GHG emissions from dam construction.	► Implement a Reservoir Clearing Plan ► Offsets for emissions from vehicles include: ► Make sure vehicles are maintained ► Regular inspection of vehicle exhaust emissions to meet required NEQS standard for exhaust emissions	During Construction	EPC Contractor	Reservoir Clearing Plan document Vehicle inspection log and results

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Exhibit 9.9: Operation Phase Mitigation Plan

IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
1	Loss of aquatic biodiversity due to creation of a low flow section downstream of the dam	▶ Maintain environmental flow as recommended in Project design ▶ Regulate activities of the staff so that they do not engage in illegal exploitation of wildlife such as illegal fishing and poaching ▶ Construction activities should be carried out whilst ensuring that there is no run-off of silt into the river and that the river is not contaminated to ensure that water quality is not affected ▶ The Project will help the Wildlife and Fisheries Departments by providing one field office, three motor cycles, 5 guards and 1 inspector to protect river biodiversity and terrestrial wildlife, subject to an agreement in which the responsibilities of the Project and the Departments are clearly defined and performance of the protections activities is independently monitored. Improvement in aquatic and terrestrial biodiversity through protection will partly offset the residual impacts of the Project on aquatic ecology. ▶ Limited subsistence fishing using rods and cast nets could be allowed through a permitting system.	Operation	MHL	Fish abundance and diversity
2	Loss of aquatic biodiversity due to changes in ecological conditions downstream of the powerhouse as a result of release of water	▶ Design peaking operation to reduce impacts on aquatic ecology as recommended in the Eflow Assessment (see **Appendix M**) ▶ Regulate activities of the staff so that they do not engage in illegal exploitation of wildlife such as illegal fishing ▶ Construction activities should be carried out whilst ensuring that there is no run-off of silt into the river and that the river is not contaminated to ensure that water quality is not affected ▶ The Project will help the Wildlife and Fisheries Departments by providing one field office, three motor cycles, 5 guards and 1 inspector to protect river biodiversity and terrestrial wildlife, subject to an agreement in which the responsibilities of the Project and the Departments are clearly defined and performance of the protections activities is independently monitored. Improvement in aquatic and	Operation	MHL	Fish abundance and diversity

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
		terrestrial biodiversity through protection will partly offset the residual impacts of the Project on aquatic ecology ▶ Limited subsistence fishing using rods and cast nets could be allowed through a permitting system.			
5	Project operation leading to animal disturbance, displacement and decline.	▶ Large flood lights should not be installed outside 50 m of the Project fence. ▶ Direct lights towards Project facilities and not towards the natural habitats. ▶ Dispose solid waste only at designated sites. ▶ Regulation of poaching of wildlife species (Snow Leopard, Flare-horned Markhor, Himalayan Ibex and other water fowls). ▶ Close coordination with the wildlife and fisheries departments. ▶ Facilitating government department staff when they arrive at the site for example providing them accommodation and vehicles. ▶ Incorporate regulations for Project staff and contractors to avoid illegal poaching in contract documents. ▶ Encourage personnel to report sightings of wildlife of conservation importance or incidents of poaching to MHL. MHL to report incidents of poaching and illegal fishing to concern government departments. ▶ Provide adequate knowledge to the workers on relevant government regulations and punishments for illegal poaching. ▶ Provide awareness training to staff and contractors on: prevention of injury of animals; identification of likely species (Snow Leopard, Grey Wolf, Asiatic Jackal, Red Fox, Flare-horned Markhor, Himalayan Ibex and other migratory water fowls) found on site; identifications of animal hazards (such as venomous snakes); and what to do if dangerous animals are encountered.	Operation	MHL	Terrestrial Flora and fauna relative abundance and diversity.
18	Improved accessibility of locals due to construction of Project access roads.	▶ Allow communities use of new site access roads.	Operation	MHL	

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IR	Impact	Mitigation Measure	When	Responsibility	Monitoring Indicators
	A potential flood and seismic hazard under natural extreme conditions for which the dam is not designed, albeit very unlikely, has potential to cause loss of life and damage to property.	▶ Prepare an emergency preparedness and response plan for the Project that includes consideration of flooding, earthquake, evacuation procedure, co-ordination with local administration and communities. ▶ Maintain network of climate gauges in the Arkari catchment to monitor potential floods through WAPDA or in conjunction with other hydropower developers. ▶ Automated telemetric flow gauges can be installed upstream of the reservoir. This will allow the Arkari Hydropower operators to be well aware of any potential flooding conditions using upstream flow data, in addition to climatic conditions recommended above. ▶ Where climatic data and flow data indicate eminent floods, appropriate measures for management of reservoir level can be undertaken by the dam operators. This includes full opening of gates (including low level outlets) with aim of reducing water levels to below Normal Operating Level at Arkari reservoir	Operation	MHL	
25	Direct, indirect and induced employment at the local levels, resulting in increased prosperity and wellbeing due to higher and stable incomes of people.	**Enhancement measures:** ▶ Ensure preferential recruitment of local candidates provided they have the required skills and qualifications. **Good practice measures:** ▶ Determine what is considered to be 'fair and transparent' in recruitment and in distribution of jobs between different community groups, in consultation with local communities and their leaders.	Operation	MHL	Target documents
34	Project, as currently designed, may not sustain increase in extreme flood events, such as the Probable Maximum Flood, which is expected to increase in future.	▶ Develop a flood warning and flood hazard system as part of the Emergency preparedness and response plan to warn and evaluate downstream landholders and users, based on the flood warning gauge network operated by WAPDA will potentially reduce "magnitude of impact". ▶ Develop strategy to manage flood peaks and flows with other HPP developers.	Operation	MHL	Annual Evaluation.

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9.5.2 Specific Environment Management Plans

Specific management plans that are to be developed to facilitate the implementation of the mitigation measures are mentioned as follows:

- Air Pollution Control Plan
- Blasting and Explosives Control Plan
- Construction Site Environmental Management Plan
- Emergency Preparedness and Response Plan
- Environmental Training Plan
- Hazardous Material Management Plan
- Noise and Vibration Control Plan
- Occupational Health and Safety
- Reservoir Clearing Plan
- Site Rehabilitation and Landscaping Plan
- Spill Prevention and Response Plan
- Spoil Disposal Plan
- Surface Run Off and Erosion Control Plan
- Traffic Management Plan
- Vocational Training Plan
- Waste Management Plan
- Water Sourcing and Abstraction Plan
- Worker Accommodation Management Plan

Additional plans may be developed on discretion to further facilitate other areas of mitigation.

It should be noted that these plans (and other required mitigation measures not included within these plans) will be operationalized via Site Specific Environmental Management Plans (SSEMP) that are discussed in detail in **Section 9.6.3**. All construction sites must have a SSEMP prepared by the EPC Contractor and approved by MHL before any major construction activity is started on the site.

Some of the required plans that have been developed as part of the ESIA are described in the following sections.

9.6 Implementation Plan

Effective implementation and functioning of the EMP depends on adequate human and financial resources, clearly defined responsibilities for environmental management, appropriate training and good communication. An outline of how these features will be managed for the Project is presented below.

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9.6.1 Contractual Requirements

MHL will ensure that:

1. EMP is included in the bidding package for the EPC Contractor;
2. During the bid evaluation the environmental performance of the bidders are taken into consideration;
3. Environmental costs are included in the financial bid of the bidders;
4. The environmental requirements are included in the contract of the selected EPC Contractor. Any conditions of the environmental clearance from the EPAs and any subsequent licenses and approvals from EPAs are also included in the environmental requirements for the contractors.
5. The contract of the of the selected EPC Contractor provides for withholding payment for completion of specific works until E&S requirements for those works have been implemented satisfactorily, and penalties for unsatisfactory performance

9.6.2 Design

The approving authority for the detailed design will:

- Ensure that all environmental aspects are communicated to the EPC;
- The detailed design includes the environmental design;

9.6.3 Site Specific Environmental Management Plans

EPC's Contractor's managers during the construction phase will operationalize their responsibilities described in **Section 9.5** (*Mitigation and Management Plan*) by developing Site Specific Environmental Management Plans (SSEMP). These will mulled to the actual site where construction activities will occur. Ideally, the preparation of the SSEMP must occur before the contractor is given access to the project site. However, it can be prepared after the access is given but certainly *before* the initiation of site clearance and any major site construction or erection work. At a minimum the following sites should have an SSEMP prepared:

- Dam Site
- Spoil Disposal Sites
- Quarry Areas
- Workshops
- Batching Plants
- Labor Camp

Some of these sites, such as the headrace tunnel may require multiple SSEMPs to cover the entire spatial extent of the development.

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All contract documents must include the requirement that SSEMPs be prepared by the contractor and reviewed by MHL and OE prior to commencement of construction activities.

Preparing an SSEMP

This section explains the following steps that should be followed while developing an SSEMP:

- Definition of boundaries
- Identification of environmental values and sensitive receptors of the site and its surrounds
- Definition of construction activities
- Assignment of environmental management measures
- Preparation of site plans
- Preparation of environment work plans

Definition of Boundaries

For megaprojects with multiple construction sites, such as a hydropower scheme, there will be a number of SSEMPs for each site. A hydropower scheme would need to have SSEMPs covering works at the dam site, the powerhouse, the switchyard, the downstream channel, headrace and tailrace tunnels, the intake structures, quarries that supply aggregate, the waste disposal areas, contractor's camps, equipment yards, workers' accommodations, etc. Generally, areas falling under the jurisdiction of a construction manager should have a separate SEMP.

Identification of Sensitive Receptors

Once the boundaries of a site to be covered by a SSEMP have been defined, the sensitive receptors surrounding the site and the environmental values of the area need to be confirmed.

Areas that can be considered sensitive receptors include

- Forested area
- Water bodies
- Communities (including schools, hospitals, homes)
- Agricultural areas

The physical, ecological and socioeconomic baselines in the **Section 4**, *Description of the Environment* provide the necessary details. The information is best presented as an overlay on the detailed engineering drawings or maps for the project.

Construction and Associated Mitigation Activities

A schedule of works for the Project will have been prepared during the detailed design phase. It is important to understand what the various phases of work are for each site, as different phases will include different activities and thus different environmental

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management requirements. In this simplified example, the construction of a bridge across a river could have the following schedule of works:

- Site surveying, vegetation clearance
- Site establishment
- Soil stripping and earth movement
- Bridge construction
- Grading approaches
- Surfacing
- Painting and finishing structures
- Landscaping and signage

The planning of the environmental management requirements for the bridge must ensure that the necessary environmental management activities take place at the right time. For example, the site survey should markup areas of vegetation to be removed, trees that must be saved, and the locations of any species of importance. Soil stripping will need to be accompanied by the introduction of erosion-control measures to prevent sediment from entering the river. The concrete pouring and filling of the bridge abutments will require a large number of vehicle movements, so it may be necessary to develop a traffic management plan to ensure that the vehicles don't disrupt traffic on existing roads. If there are sensitive receptors nearby, there may be a requirement to limit working hours that will require a change in the work schedule. These measures are easy to plan for, but very hard to introduce once the project has started. This, again, emphasizes the need for effective planning of the environmental management measures.

Section 9.5 (*Mitigation and Management Plan*) provides a list of required mitigation measures that must be incorporated into the relevant SSEMPs. In addition all appropriate measures indicated in Generic Construction Site Environmental Management Plan (CSEMP) (**Appendix N**) should be incorporated in the SSEMP. A Security Management Plan is included as **Appendix O**.

Site Plan

A site plan must cover the extent of the construction activity and should contain:

- Location and nature of planned work;
- Locations of sensitive receptors; and
- Locations of required mitigation activities.

Other important features may include:

- Indication of North, and scale;
- Existing and planned supporting infrastructure (e.g., access roads, water supplies, electricity supplies, etc.);
- Contours; and
- Drainage systems.

Work Plan

The completed SSEMP provides details of all the environmental management requirements for all stages of the construction process. For individual work teams responsible for only a small part of the overall construction work, it can be hard to understand what is required for their particular work components. For example, the work team responsible for stripping soil for the construction areas are not going to be interested in the requirements for pouring concrete for footings and foundations. However, it is essential that the soil stripping team know exactly what to clear, what to leave, and where to put stockpiles of soil for later use.

When different work activities are required at different times or at different locations, environmental work plans can be prepared. These are similar to the work method statements often produced for major construction projects.

9.6.4 Site Inspection

Site inspections will be undertaken regularly in relevant areas of the Project. The inspections will focus on compliance with the EMP. The inspections will play an important role in increasing awareness of EMP.

Minor non-conformances will be discussed during the inspection and recorded as a finding in the inspection report. Major non-conformances will be reported as incidents. Inspection results will be disclosed at management meetings.

9.6.5 Non Conformance and Incidents

Non-conformances include the following:

- exceedances of relevant thresholds as identified during routine monitoring;
- non-conformances with the requirements of the EMP or supporting documentation identified during an internal inspection;
- non-conformances identified during an audit or by regulatory authorities;
- events, such as spills, resulting in potential or actual environmental harm;
- events that did or could result in injury to staff, visitors to site or surrounding communities; and
- significant complaints or grievances received from any source.

Corrective and preventive actions will be identified and implemented in response to these non-conformances. These actions will address the root cause of the non-conformance and will reduce or prevent repeated non-conformances.

A process will be established for the identification, investigation and tracking of non-conformances, including:

- prioritizing and classifying non-conformances based on the type and severity of the non-conformance;

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- recording of non-conformances and the results of corrective and/or preventive actions, including the actions necessary to mitigate or remedy any associated impacts;
- defining results expected from the corrective and/or preventative actions;
- confirming the corrective and/or preventive actions taken to eliminate the causes of the non-conformance are appropriate to the magnitude of problem and commensurate with the impacts encountered;
- reviewing the effectiveness of the corrective and/or preventive actions taken; and
- implementing and recording required changes in the EMP or monitoring program resulting from corrective and preventive action.

Serious non-conformances will be classified as incidents. Incidents will be promptly reported to appropriate management. A guideline will be prepared on:

- the types of incidents reportable to internal management at the site, Project and corporate levels, as well as to regulatory authorities and other external stakeholders; and
- standards to be observed when reporting incidents.

During construction, environmental monitoring will ensure the protection of air and noise pollution, community relations, and safety provisions. During operation, emissions, air, noise, and waste water quality monitoring and greenbelt development around the plant will be important parameter of the monitoring program.

The monitoring requirement can only be fulfilled by maintaining the proper documentation records of the findings. Daily checklists, weekly reports and monthly audit will be taken in accordance with construction management plan. Based on the ESIA approval a scheduled audit will be conducted by MHL and reports will be shared with the regulatory authority and funding agency if required.

9.6.6 Audits

Formal audits will be undertaken at planned intervals in accordance with the requirements of client and regulatory authorities. Procedures for audits will be established, implemented and maintained. These will cover the audit criteria, scope, frequency and methods, and will address the responsibilities and requirements for planning and conducting audits, reporting results and retaining associated records.

Any negative findings arising from an audit will be treated an incident and dealt with in accordance with the non-conformance and incident procedure. Results from audits and evaluations of compliance with legal requirements will be reported to site and senior management and subject to management reviews. Usually environmental regulatory authorities require a quarterly audit report for large scale projects.

The following audits will be carried out for:

- Labor
- Health and Safety

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- Environment

9.7 Monitoring Plan

Monitoring of environmental components and mitigation measures during implementation and operation stages is a key component of the EMP to safeguard the protection of environment. The objectives of the monitoring are to:

- manage environmental issues arising from construction works through closely monitoring evidence for implementation of the mitigation measures and environmental compliance; and
- monitor changes in the environment during various stages of the Project life cycle with respect to baseline conditions.

A monitoring mechanism is developed for identified impact and includes:

- location of the monitoring (near the Project activity, sensitive receptors or within the Project influence area);
- means of monitoring, i.e. parameters of monitoring and methods of monitoring (visual inspection, consultations, interviews, surveys, field measurements, or sampling and analysis); and
- frequency of monitoring (daily, weekly, monthly, seasonally, annually or during implementation of a particular activity).

Monitoring program will include regular monitoring of construction and commissioning activities for their compliance with the environmental requirements as per relevant standards, specifications and EMP. The purpose of such monitoring is to assess the performance of the undertaken mitigation measures and to immediately formulate additional mitigation measures and/or modify the existing ones aimed at meeting the environmental compliance as appropriate during construction.

The monitoring program will be coupled with a series of supporting procedures, yet to be developed, covering:

- sample or data collection;
- sample handling, sample storage and preservation;
- sample or data documentation;
- quality control;
- data reliability (calibration of instruments, test equipment, and software and hardware sampling);
- data storage and backup, and data protection;
- interpretation and reporting of results; and
- verification of monitoring information by qualified and experienced external experts.

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9.7.1 Specific Monitoring Plan

Environmental monitoring and reporting plan for the construction and operation phases are provided in **Exhibit 9.10.** Moreover each supporting plan (as described in **Section 9.5**) includes monitoring and documentation requirements; the same is also true of the SSEMP (as described in **Section 9.6.3**). Therefore the monitoring plan will also contain requirements of these additional plans once they have been developed.

9.7.2 Documentation and Reporting

Monitoring elements of the EMP will be documented and controlled in accordance with a document control system by the Senior Manager, Environmental and Social and communicated to MHL Records demonstrating compliance with legal requirements and conformance with the EMP will also be maintained. MHL through its Senior Manager, Environmental and Social will supervise, establish, implement and maintain procedures.

Documentation and record keeping controls will include:

- measures to enable relevant documents and records to be readily available and identifiable (labeled, dated and properly filed), legible and protected from damage;
- review, revision and approval of documents for adequacy by authorized personnel at least once a year;
- establishment of the electronic document control version as the 'authorized version';
- making current versions of relevant documents available at locations where operations essential to the effective functioning;
- suitably identifying obsolete documents retained for legal and knowledge preservation purposes; and
- identification and segregation of confidential and privileged information.

Monitoring data will be documented and analyzed to determine temporal and spatial trends and confirm compliance with relevant thresholds. Monitoring reports will be produced to meet internal and external reporting requirements. If monitoring results indicate non-conformance with stipulated thresholds or if a significant deteriorating trend is observed, it will be recorded as a non-conformance and handled by the non-conformance and incident procedure. The following reports will be produced:

- Based on reports provided by the Construction Contractor as listed in **Exhibit 9.10**, quarterly and annual reports will be reviewed by OE/ MHL for monitoring of the physical and social environment and shared with the EPAs.

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Exhibit 9.10: Environmental Monitoring Program for Construction and Operation

Aspect	*Type of monitoring*	*Frequency of Monitoring*	*Location/s*	*Reporting Frequency*	*Monitoring and implementation Responsibility*	*Report Preparation Responsibility*	*Report Receiving Authority*
Construction Phase							
Soil Quality	Visual inspection for any oil and lubricant spills and leakages in the construction area and presence of oil in the drains at the construction site	Daily	Construction area and drains at the construction site	Quarterly	EPC Contractor, OE, MHL	EPC Contractor	MHL, OE and EPA
Soil Erosion	Visual inspection of soil erosion and land sliding, especially in the wet season	Once a month in dry season. Once a week in wet season.	Construction sites, rehabilitated areas and water release points	Quarterly	EPC Contractor, OE, MHL	EPC Contractor	MHL,OE and EPA
Waste Disposal	Inspection of waste disposal areas and channels	Weekly	Waste disposal sites,	Quarterly	EPC Contractor, OE, MHL	EPC Contractor	MHL, OE and EPA
Water Resource Depletion	Record of water used and source of water supply for construction, sprinkling and camp	Daily	Construction sites, truck filling points and water tanks at camp.	Quarterly	EPC Contractor, OE, MHL	EPC Contractor	MHL and EPA
Community Water Supplies	Monitor flow for springs identified as at risk from tailrace construction.	Monthly	Identified springs in communities.	Quarterly	EPC Contractor, OE, MHL	EPC Contractor	MHL and EPA
Fugitive Dust Emissions	Air quality sampling at social receptors in case any complaints regarding excessive particulate matter in ambient air are received.	As required, in case complaints are received	Social receptors	Report as required, in case complaints are received	EPC Contractor, OE, MHL	EPC Contractor	MHL and EPA
Vehicular and Machinery Exhaust Emissions	Visual checks of exhaust emissions from vehicles and batching plant machinery to ensure excess pollutants are not being released	Monthly	Construction sites and batching plant location	Quarterly	EPC Contractor, OE, MHL	EPC Contractor	MHL and EPA

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Aspect	Type of monitoring	Frequency of Monitoring	Location/s	Reporting Frequency	Monitoring and implementation Responsibility	Report Preparation Responsibility	Report Receiving Authority
Noise Nuisance	Monitoring of the noise levels in the nearest communities against the baseline noise conditions	Once a month and when a complaint is received	Nearest settlements or area for which complaint is received	Quarterly	EPC Contractor, OE, MHL	EPC Contractor	MHL and EPAs
Traffic	Random speed checks and inspections and investigations in case of complaints by community	Once a month and in case complaints are received	Different location and different time	Quarterly	EPC Contractor, OE, MHL	EPC Contractor	MHL and EPAs
Vibration	Monitoring of vibration levels using vibration sensors	Once a month informed by the blasting schedule	Structures near blasting sites	Quarterly during blasting	EPC Contractor, OE, MHL	EPC Contractor	MHL and EPAs
Distribution of Project Employment	When complaint is received or an issue observed	When a complaint is received	Construction site, camp and nearby villages	Quarterly	EPC Contractor, OE, MHL	EPC Contractor	MHL and EPAs
Social Unrest due to Conflicting Social Norms	When complaint is received or an issue observed	When a complaint is received	Construction site, camp and nearby villages	Quarterly	EPC Contractor, OE, MHL	EPC Contractor	MHL and EPAs
Operation Phase							
Waste Disposal	Inspection of waste disposal areas and channels	Weekly	Dam and Powerhouse sites	Quarterly report	O&M Contractor	O&M	MHL and EPAs
Environmental Flow	Continuous record of downstream release into river by dam	Continuous	Dam site	Quarterly report	O&M Contractor	O&M	MHL and EPAs

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9.8 Emergency Preparedness and Response

The Project will implement and maintain an Emergency Preparedness and Response Plan (EPRP).

9.8.1 Purpose and Applicability

This framework is intended to guide the means by which MHL and its contractors will ensure that they are prepared for emergency situations and can respond effectively should they arise. For each stage of a project's project life cycle, MHL and/or contractor will develop and implement an ERPR that meets the requirements of this framework. MHL will identify the party responsible for preparing the EPRP. It is expected that most emergencies during construction would take place on the site, so the Plan prepared for the construction period would primarily (but not exclusively) address on-site emergencies. During operation, on the other hand, dam failure or other emergencies could cause significant downstream impacts, so the Plan for the operations period would address a combination of on-site and off-site emergencies and actions.

9.8.2 Approach and Activities

EPRPs for new projects will initially be developed based on the Environmental and Social Impact Assessment or other assessment document that identifies on-site and off-site risks during the project life cycle that could result from an accident or other emergency situation, and on a detailed assessment of site activities. The ESIA and/or other documents would typically identify specific risk-reduction measures as well, which would become part of the EPRP. EPRPs for existing projects will initially be based on due diligence assessments that evaluate risks of ongoing construction and/or operations, and again will include a detailed assessment of site activities. EPRPs will also be informed by and based upon the best judgment of qualified professionals and the experience gained from ongoing activities. EPRPs will become part of the Project's Environmental Management Plan.

The EPRP will identify various emergency situations that could realistically occur, which could include:

- Fire or explosion
- Road or site traffic accident
- Spills of hazardous materials such as fuels, chemicals, oil, paint, etc.
- Landslides, mudslides, or rock falls
- Equipment failure
- Earthquakes (primarily during operation)
- Cofferdam failure
- Partial or complete dam failure
- Floods
- Turbine or blade failure.

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- Site lockdown due to breach of security, external attack, or other event.

The EPRP will call for close coordination with local authorities regarding preparing and responding to emergencies that could affect local people or communities. Particularly if there could be serious off-site impacts, EPRPs will describe the coordination process, including MHL support for community emergency preparedness and response training.

EPRPs will include details for the following elements, which could be different for various types of accidents:

- Organizational and individual responsibilities for both emergency preparedness and for emergency response, which could be very different. This would include roles and responsibilities of responders and decision-makers.
- Measures that need to be taken to prepare for potential emergencies, including equipment, supplies, warning signals, dedicated communication lines, etc.
- Details on how relevant authorities, the public, and third-party emergency response agencies will be informed of potential risks due to emergency situations resulting from project activities, and on agreements that have been reached for cooperative responses to emergencies.
- Contact details of all dedicated and non-dedicated emergency response personnel on the site and personnel who are available off-site.
- Contact details of relevant authorities and third parties who will need to notified for various types of emergencies (nearby residents, landowners, fire brigades, local law enforcement, military, etc.).
- Detailed information on internal and external equipment, personnel, facilities, funding, expert knowledge, and materials that will be required to respond to specific types of emergencies. The EPRP will also need to identify the specialized expertise that may be needed to respond to specific emergencies.
- Procedures for using, inspecting, testing, and maintaining emergency response equipment, which may include equipment under the control of third parties (for example, the local fire brigade or emergency medical teams).
- Clear procedures and protocols for notifications and communications to and within the contractor (if any), local and other authorities, potentially affected people, and other parties.
- Emergency response procedures to be followed, and by whom, for various emergency situations.
- Locations of holding/areas for workers and off-site collection points for others, and conditions under which they would be used.
- Pro forma incident report forms.

The EPRP should call for a root-cause analysis following any emergency or near-emergency situation in order to identify improvements in future preparedness or response. The EPRP, or a separate planning process, should also include measures to ensure business continuity and contingency, including:

- Identifying and making contingency arrangements to exploit replacement supplies or facilities – which could include buildings, electricity, water supplies, equipment and vehicles, fuel, etc. -- to allow business continuity.
- Maintaining backups of critical information, including relevant EPRPs that form the EMP, in a secure but accessible location to ensure continuity or restoration of site activities, including implementation of mitigation measures.

9.8.3 Monitoring, Recordkeeping, and Reporting

The EPRP will describe records that must be kept to document various activities required to maintain emergency preparedness, and the person(s) responsible for maintaining the records. The EPRP will also describe how notice and details of any imminent or actual emergency will be communicated within the contractor (if any), local authorities, potentially affected people, and other parties.

The EPRP will require periodic inspection/monitoring of the Project site(s) and records, with a focus on areas where accidents or other occurrences could lead to emergency situations. The EPRP will need to specify:

- The locations, activities, and records that must be inspected.
- The frequency of inspection.
- The required qualifications of persons who will conduct the monitoring.
- Records that must be kept and the person responsible for keeping the records.
- Special hazards of inspection, including appropriate cross-references to the Occupational Health and Safety Plan for required and recommended risk reduction measures.
- Reports that will be prepared, to whom the reports are to be submitted for review, and the length of time records will be kept. This could include summary reports or detailed technical reports, and could be submitted to company or MHL management, government agencies, or lenders.

The EPRP will describe how remedial actions will be identified and implemented in the event that monitoring reveals shortcomings in emergency preparedness or in recordkeeping, and how follow-up monitoring will be implemented until the requirements of the EPRP are fully met.

9.8.4 Implementation

The EPRP will identify and describe the responsibilities of all parties, including MHL, contractors, and competent authorities. The EPRP must also identify the roles and responsibilities of individual positions within MHL and contractor. This will include the chain of command for directing response activities in case of various types of emergencies. This should be shown in an organogram that includes as much detail as possible, down to the individual person/position.

9.8.5 Training

The EPRP will identify training requirements for staff and managers of MHL and/or contractors, including who will be responsible for conducting the training and who must be trained in what skills. Training will also extend to third parties who may be called upon to respond to emergencies. Training will focus on the assigned responsibilities of the trainees in preparing for emergencies and for responding to emergencies if they occur, and will cover technical and administrative skills needed to perform assigned responsibilities. The EPRP will need to provide for emergency preparedness and response training should be closely coordinated with occupational health and safety training. The EPRP should call for at least the following topics to be part of emergency preparedness and response training.

- Providing information necessary for trainees to understand the possible effects of various types of emergencies and an opportunity to contribute effectively, as appropriate, to decisions concerning preparedness and response.
- Providing specific information on appropriate behavior and safety measures to be adopted in case of various types of emergencies.
- The specific responsibilities of the person being trained in case of various types of emergencies.
- Scheduled and unscheduled drills and practice in responding to various types of emergencies, including site evacuation, and procedures to monitor drills closely to verify that staff and managers are aware of their responsibilities and are able to complete them.

9.8.6 Relationship to other Plans

The emergency preparedness and response plan is related to the following plans:

- Spill Prevention and Response Plan
- Waste Management Plan
- Blasting and Explosives Control Plan
- Stakeholder Engagement Plan
- Dam Safety Review Procedure
- Site Security Plan
- Occupational Health and Safety Plan.

9.8.7 Revision

The EPRP will be reviewed, by MHL or the contractor as appropriate, at least annually, and whenever there is a significant change in project or site conditions, or when it is determined that any measure intended to prevent or reduce the probability of emergency situations is or may be insufficient to achieve its purpose. The EPRP will also be reviewed following the root-cause analysis that is completed after any emergency or near-emergency. It will be revised when necessary to update or improve emergency preparedness and response, and when it is determined necessary to ensure compliance with applicable standards and good international industry practice.

9.9 Social Investment Program

As a Corporate Social Responsibility (CSR), the project implementation is expected to raise hopes of the project area population for their general welfare. It is therefore, necessary that the project sponsor may provide facilities in the form of education, health, improvement of existing access roads and development of parks to the people of the project area.

Considering the betterment of the local community and based on the consultations carried out with the local community and local administration (see **Section 6.4.1**, *Community Consultation*), the need for basic amenities i.e. health, education, roads, safe drinking water is proposed. MHL will finalize social investment program at the start of commercial operations.

The specific investment projects will be selected on the basis of a) community needs and aspirations, and b) the sustainability of the specific proposal.

9.10 Cost Estimate

Cost estimate for EMP implementation is presented in **Exhibit 9.11**.

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Exhibit 9.11: Summary of Cost Estimates for EMP (USD) to be borne by MHL

No	Item	Note	Pre-Construction	Construction Phase			Operation Phase (Annual)
				Capital	Recurring (Annual)	Total (for 4 years)	
1	Biodiversity Protection Management Measures						
1.1	Guards (5)				10,500	42,000	10,500
1.2	Inspector (1)				3,200	12,800	3,200
1.3	Motorcycles (3)			2,800			
1.4	Field Office for Guards (1)			21,500			
1.5	Annual ecology field surveys to monitor aquatic and terrestrial ecological resources						
1.5.1	Aquatic ecology				13,000	52,000	13,000
1.5.2	Terrestrial ecology				7,000	28,000	7,000
1.6	Training for field staff on importance of biodiversity and environment protection				5,000		
2	EFlow Monitoring				15,000	15,000	
3	Land Acquisition and Resettlement Cost	In accordance with RAP/Government assessment.	5,715,686				
4	Social Investment Plan under CSR	To be finalized at the start of commercial operations					
5	Implementation of Stakeholders Engagement Plan						
5.1	Salary of CRO	Estimated at PKR 160,000 per month			16,500	65,900	16,500

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No	Item	Note	Pre-Construction	Construction Phase			Operation Phase (Annual)
				Capital	Recurring (Annual)	Total (for 4 years)	
5.2	Salary of CLO (Male)	Estimated at PKR 65,000 per month			6,696	26,800	6,700
5.3	Salary of CLO (Female)	Estimated at PKR 65,000 per month			6,700	26,800	6,700
5.4	Vehicle for SEP Office (Two)			64,400	–	64,400	–
5.5	Fuel and Maintenance of Vehicle	Estimated at PKR 70,000 per month			7,200	28,850	7,200
5.6	Skill development trainings for affected communities (Trainer's cost, venue, refreshment, training material, and daily stipend)	Estimated at PKR 550,000.			56,650	226,629	56,657
6	Internal Environmental Management	Included in owners budget					
7	External monitoring	To be provided by EPC Contractor					
8	Instrumental monitoring and sampling						
8.1	Monitoring of vehicles for emissions and noise[3]	Monitoring of about 6[4]vehicles at 43.20 USD each		2,60		1,450	
8.2	Monitoring of ambient noise levels	Purchase of noise meter		2,200		2,200	
8.3	Monitoring of ambient dust levels	Purchase of dust meter		6,200		6,200	
9	Mitigation Measures						
9.1	Springs and water resources			25,800		25,800	
	Total		5,715,686	122,900	147,446	624,829	127,457

[3] The number of vehicles has been estimated based on the size and quantity of the material and equipment to be transported for Project activity and may be revised based on actual.

[4] Estimation of vehicle as peak is ~30 truck trips per day if one truck does 5 trips a day that would be 6 vehicles

10. Conclusion and Recommendations

The proposed Project, the 99 MW Arkari Gol HPP in KP was evaluated in this report by HBP and its associated team of experts. The proposed design and construction activities were assessed against the laws of KP, the GoP policies, and OPIC Guidelines. Mitigation and management measures were recommended and made part of the Project design to minimize adverse environmental impacts of the Project.

The aspects of the environment assessed were classified into physical, ecological and socioeconomic. In the physical environment the Project is expected to have significant impacts on water availability, water quality as well as soil, topography and land stability. Socioeconomically the most significant impacts are those associated with disturbances to the local communities especially during construction of the Project and related facilities. Ecologically the most significant impacts are on aquatic biodiversity as the flow of the river will be regulated. Although the Project's impacts are significant, the most important aspect is the impact of peaking on fish fauna downstream of the powerhouse. This will impact aquatic ecology including three fish species the Snow Trout which is Vulnerable on the IUCN Red List as well as the Himalayan Catfish and Chitral Loach.

The Project was assessed using IFC's PS6 on biodiversity. Based on this the Project is not located in a Critical Habitat, however, it is located in a Natural Habitat as the river is unregulated and unpolluted.

Impacts on fish fauna are unavoidable, however, the Project is not impacting Endangered, Critically Endangered or endemic species. It is impacting one long distance migratory species, the Snow Trout. To mitigate these impacts the ESIA suggests that the proponent support the government departments responsible for protecting fish habitat in order to make their efforts more effective within the Chitral valley. In addition a modified form of peaking is recommended which will reduce the impact on the fish fauna.

The cumulative impacts of the Project are also significant, however, they are dependent on future developments in the basin. The Arkari Gol HPP is one of the first in the Chitral Basin. The cumulative impacts of this and other planned projects in the basin will have the greatest impacts on long distance migratory species, for example, the Snow Trout as they will block the species' migratory routes. This will result in population declines due to creation of barriers and genetic isolation causing decline in genetic diversity. Impacts on terrestrial ecology will also be a concern as development of transmission lines and improved transport routes will open up the area for tourism and increased human-induced pressures. In view of this the ESIA recommends basin-wide measures to mitigate cumulative impacts. These include standardization of assessment methods using IFC Guidelines, active regulation by the KP EPA using World Bank Guidelines, increased support to the government departments involved in protection of biodiversity and habitat, greater coordination between developers for achieving synergistic benefits and a balance between environmental and energy requirements in the basin and to support research in the basin for advances in understanding of river ecology.

Socially, the greatest disturbance that will be caused by the Project will be land acquisition for Project infrastructure. Therefore, one of the most important aspects is resettlement. About 50 household are likely to lose their land and residences. A resettlement action plan has been prepared separately to undertake resettlement in a fair and open manner and to minimize social or economic impacts. The basic principles used for resettlement are derived from Pakistani laws and IFC PS5 so that the livelihoods and standards of living for all affected households are improved or at least restored.

All the affected households losing any asset will be compensated according to the replacement cost. Every Project Affected Person (PAP) losing their livelihood resources or places of income generation as a result of Project interventions will be supported with income and livelihood restoration assistance. Moreover eligible PAPs will also receive resettlement allowances like relocation allowance, vulnerable allowance, severe impact allowance etc. The Resettlement Action Plan also provides a grievance redress mechanism and a monitoring and evaluation system.

Measures to minimize impacts are recommended in the ESIA and are included in the EMP. If these measures are implemented, the significance of impacts will be reduced to within acceptable limits.

4.11 Resettlement Issues

A detailed survey of the project area has been conducted to assess the environmental issues. According to our survey, the area is sparsely populated and a total of 48 households will require resettlement due to the project.

Land acquisition will be conducted in accordance with the frameworks specified in the Land Acquisition Act 1894, and affected persons will be adequately compensated.

SECTION - 5

Technical Specification Schedule

5 Technical Specifications

Pursuant to Schedule III of the Licensing Regulations, the technical specifications of the proposed generation facilities are attached.

5.1 Annexure I: Schedule I & II to the Generation License

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TECHNICAL SCHEDULES

to the Generation License

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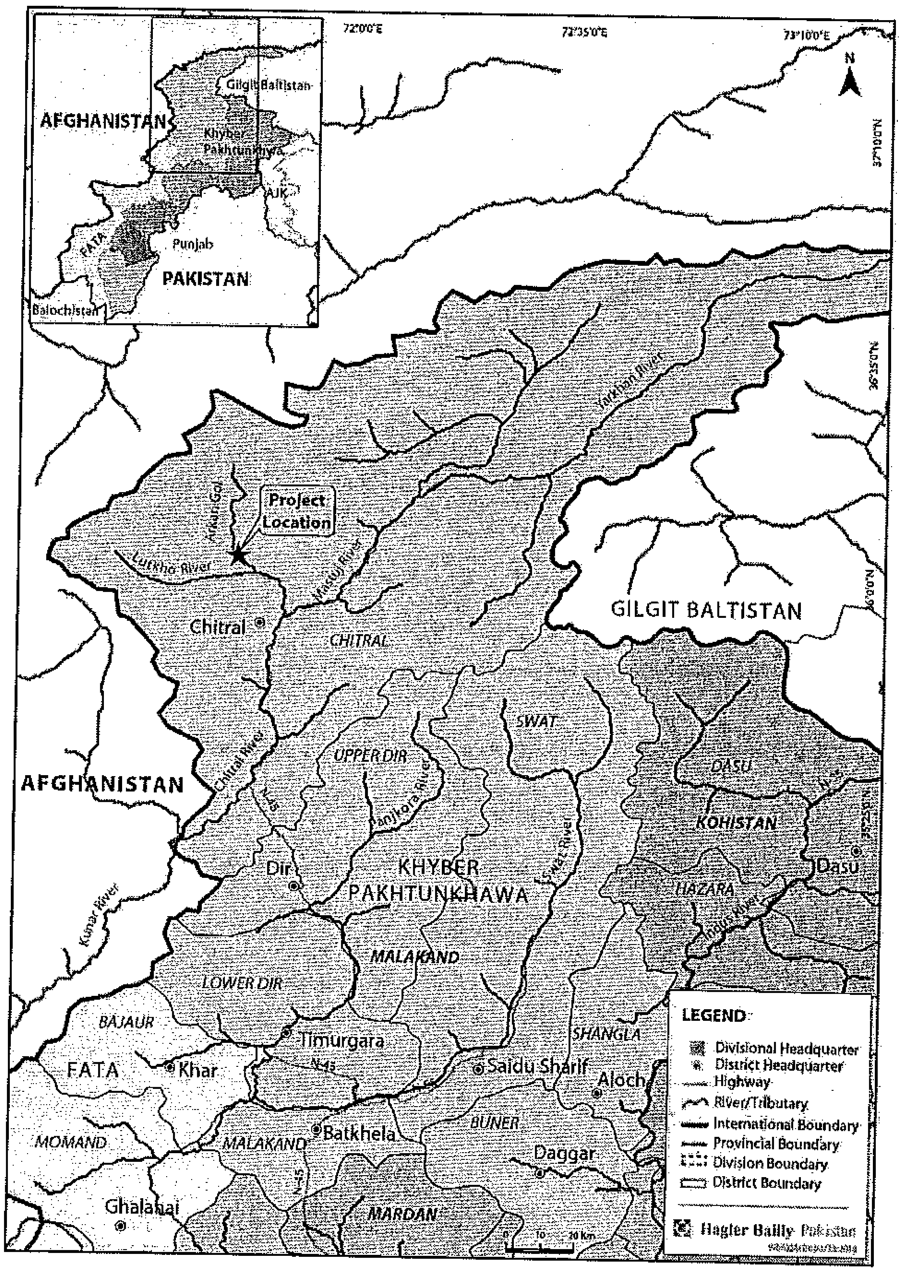
SCHEDULE I

The Location, Size (i.e. Capacity in MW), Type of Technology,
Interconnection Arrangements, Technical Limits,
Technical/Functional Specifications and other details specific to
the Generation Facilities of
the Licensee are described in this Schedule.

Site Location of the Generation Facility/Hydro Power Project of Master Hydro (Private) Limited

The Project site is located 40.5 km upstream of the Chitral main town, about 370 km by road from Peshawar, near the Ucchatur village, Chitral District, KP. The geographical coordinates of the proposed dam site are 36° 4'3.49"N, 71°41'33.99"Eand of the proposed powerhouse site are36° 1'15.32"N, 71°44'13.07"E. The Project site is about 495 km by road from Islamabad.



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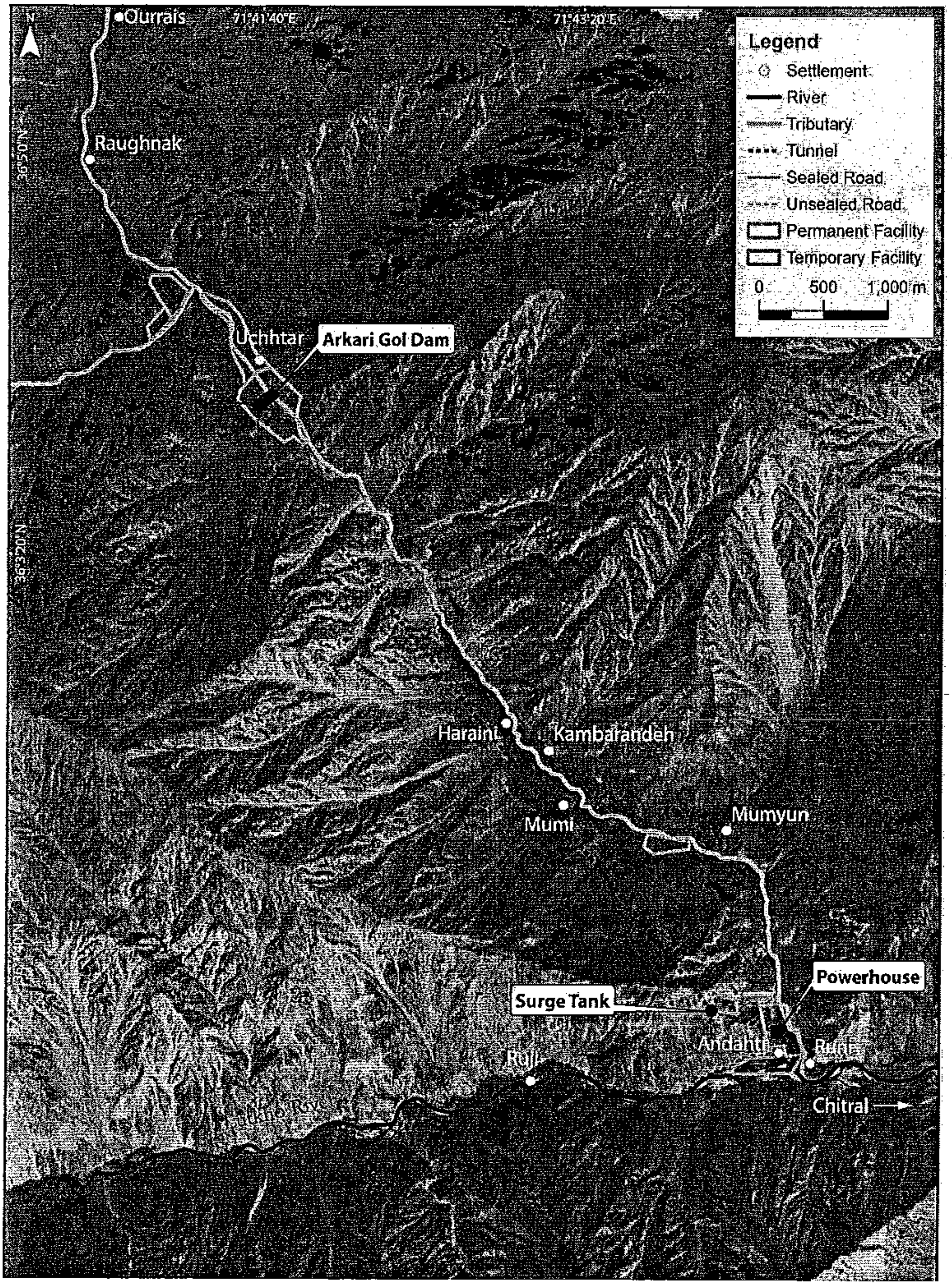
Layout of Generation Facilities/Hydro Power Project of Master Hydro (Private) Limited



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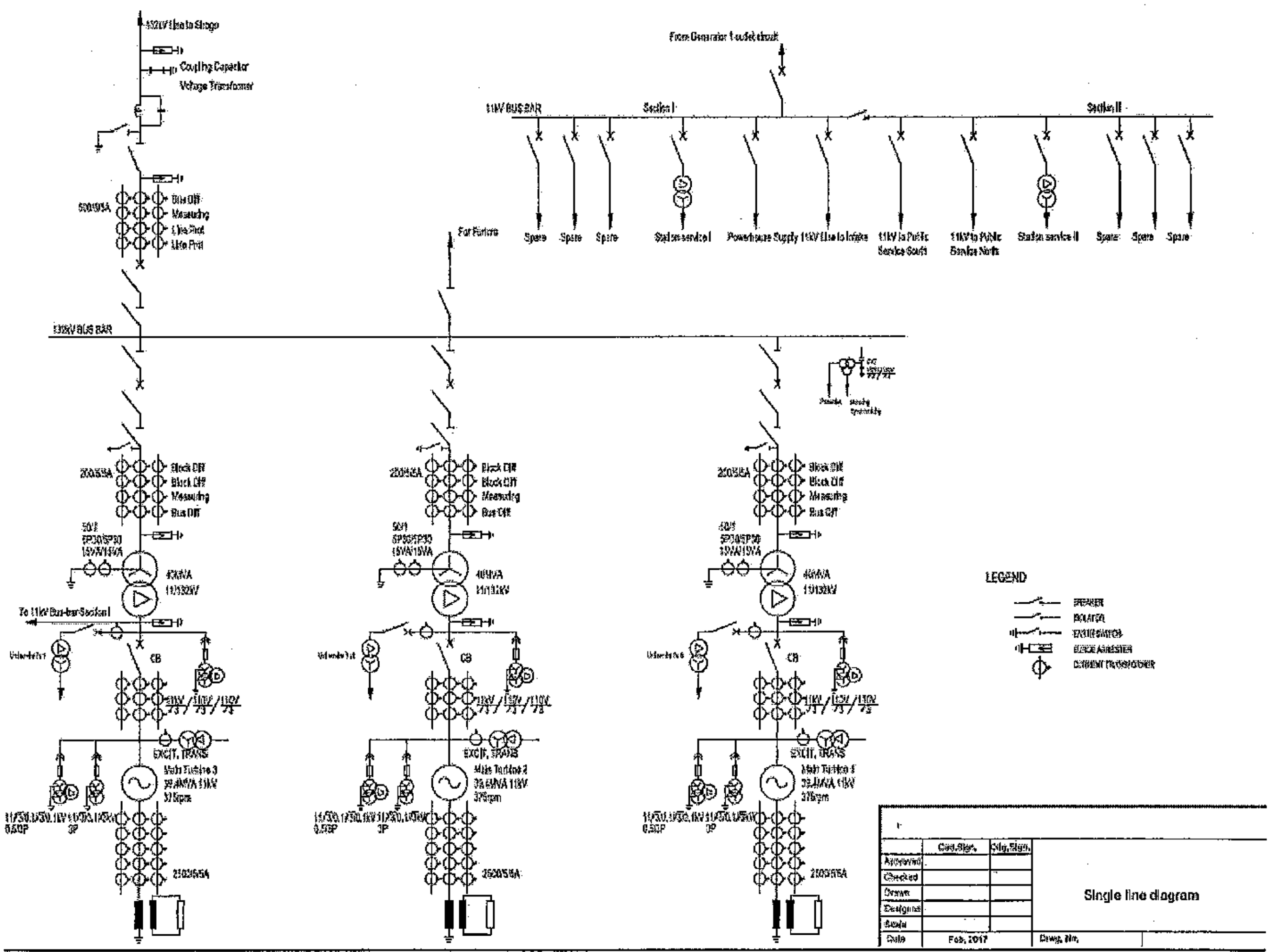
Electrical System Single Line Diagram of Generation Facility/Hydro Power Project of Master Hydro (Private) Limited



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Interconnection Arrangement for Dispersal of Power from the Generation Facility/Hydro Power Project of Master Hydro (Private) Limited

The Project has been awarded under a competitive bidding mechanism held under the mechanism defined in the KPK Hydropower Policy 2016 and the Competitive Bidding Tariff (Approval Procedures) Regulations, 2014. Under this mechanism, a detailed Grid Interconnection Study will be carried out after issuance of Letter of Award to the Project.

Based on information provided by Pakhtunkhwa Energy Development Organisation as part of the Request for Proposal package, the Project is proposed to be connected to the national grid at 132 kV through the grid station of the nearby Golen Gol hydropower project.

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Details of the Generation Facility/Hydel Power Plant

A. General Information

i.	Name of Applicant	Master Hydro (Private) Limited
ii.	Registered/Business Office	Furniture Market, District Upper Dir, Khyber Pakhtunkhwa, Dir, Provincially Administrated Tribal Areas (P.A.T.A) 18000
iii.	Plant Location	Arkari Gol River near Uchhatur village in Chitral District of Khyber Pakhtunkhwa
iv.	Type of Generation	Hydro Power Project

B. Plant Configuration

i.	Plant Type	Run of River
ii.	Water Source	Arkari River
iii.	Type of Technology	Vertical Axis Pelton Turbine
iv.	Number of Units & Size	3 x 34.021 MW
v.	Plant Size/Installed Capacity(Gross)	Mechanical Rating: 102.06 MW Electrical Rating: 99.00 MW
vi.	Turbine Make & Model	GE Renewable Energy
vii.	Expected Commissioning And Commercial Operation Date (COD) of the Generation Facility	July, 2023 (Tentative)
viii.	Expected Useful Life of the Generation Facility from COD	30 Years

C. Main Design Features

i.	Design Discharge	36 m^3/s
ii.	Gross Head	335.3 Meter
iii.	Rated Net Head	318 Meter
iv.	Dam Height	26 Meter above foundation
v.	Dam Type	Concrete gravity dam
vi.	Design Flood	562 m^3/s

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D. Spill Way

i.	Spillway type	Over flow with radial gates
ii.	No. of Gates	2.00
iii.	Gate size	8x12 m
iv.	Spillway discharging capacity	1,294 m^3/s (PMF)

E. Head Race Power Tunnels

i.	No of Tunnels	1
ii.	Tunnel Diameter	5.6m×5.8m (without lining) / 3.8m×4.0m (with lining)
iii.	Tunnel Length	6265 Meter
iv.	Length of Pressure Shaft	296 Meter
v.	Diameter	3.10 Meter

F. Tail Race Channel

i.	No of Tunnels	1
ii.	Tunnel Diameter	3.50 Meter x 11.43 Meter (H x W)
iii.	Tunnel Length	100 Meter

G. Power House

i.	Powerhouse type	Surface External
ii.	Switchyard	Open outdoor

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H. Plant Characteristics

i.	Generation Voltage	11 kV
ii.	Mean Annual Energy	372 GWh (Net)
iii.	Plant Factor	43.6%
iv.	Generator	SAV 340/122/16
v.	Generator Capacity	33.49 MW
vi.	Automatic Generation Control	Yes

SCHEDULE II

The Installed/ISO Capacity (MW), De-Rated Capacity At Mean Site Conditions (MW), Auxiliary Consumption (MW) and the Net Capacity At Mean Site Conditions (MW) of the Generation Facilities of Licensee is given in this Schedule.

SCHEDULE II

i.	Total Installed Capacity of the Generation facility/Hydel Power Plant (Gross ISO)	102.06 MW
ii.	Total De-Rated Capacity of the Generation Facility/Hydel Power Plant at Mean Site Conditions	102.06 MW
iii.	Total De-Rated Capacity (Electrical) of the Generation Facility/Hydel Power Plant at Mean Site Conditions	99.00 MW
iv.	Auxiliary Consumption of the Generation Facility/Hydel Power Plant	1.485 MW
v.	Net Capacity of the Generation facility/Hydel Power Plant at Mean Site Conditions	97.515 MW

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5.2 Annexure II: Other Details of the Plant[2]

[2] Details required pursuant to Schedule III of the Licensing Regulations

INFORMATION REQUIRED UNDER

SCHEDULE III

OF THE LICENSING REGULATIONS

A. Environmental and Social Impact Assessment

The proposed facility is a hydropower generation plant and does not release emissions or harmful pollutants into the atmosphere. On the whole, hydropower projects benefits the environment as it reduces the requirement for fossil fuel based thermal power generation.

Master Hydro conducted a detailed environmental and social impact assessment after being notified by PEDO as the first ranked bidder for the Project. Hagler Bailly Pakistan was engaged for the detailed environmental assessment of the Project site. The complete ESIA is attached in this section.

Please refer to section 4.10 of this document for further details.

B. DETAILED FEASIBILITY STUDY REPORT

Detailed Feasibility Study Report attached as section 4.7 of this document.

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C. RESETTLEMENT ISSUES

A detailed survey of the project area has been conducted to assess the environmental issues. According to our survey, the area is sparsely populated and a total of 48 households will require resettlement due to the project.

Land acquisition will be conducted in accordance with the frameworks specified in the Land Acquisition Act 1894, and affected persons will be adequately compensated.

Please refer to section 4.11 of this document for further details.

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D. CONSENTS

CONSENT/PERMISSION	ENTITY	BRIEF
Notification of First-Ranked bidder	PEDO	Notification of First-Ranked Bidder issued to be issued to the lowest bidder, post opening of commercial proposals
Tariff Determination	NEPRA	NEPRA to review and approve reference generation tariff based on tariff proposed by the First-Ranked Bidder and issue tariff determination in line with procedures for competitive bidding
Letter of Award	PEDO	LOA to be issued after determination of tariff by NEPRA and notification in the official gazette
Generation License	NEPRA	Required under NEPRA Act for any power generation unit for issuance of license.
Letter of Support	PEDO/PPIB	Upon successful fulfillment of conditions in LOA, Project will be issued LOS.
Initiation of Land Acquisition	KPK Revenue Board	Support of KPK Revenue Board required for land acquisition process.
State Bank of Pakistan approvals.	SBP	Approvals are required to open foreign currency accounts and approval for making offshore payments to suppliers.
Power Acquisition Request	CPPA (G) L	Required confirmation from CPPA (G) L that they will be willing to purchase power from the Project.
Confirmation regarding concessionary rates for custom duties on import of plant and machinery.	Tax authorities	Fiscal incentive granted to the Project under the Policy.
Consent for use of grid data	PESCO	PESCO's consent is required for use of grid data for conducting Grid Interconnection Study for the Project.
Power Evacuation Certificate	NTDC/PESCO[1]	NOC issued for evacuation of power from the site. Issued upon approval of Grid Interconnection Study for the Project.
Approval of ESIA	EPA KPK	NOC issue once environmental examination has been approved.

[1] We understand that the Project may be connected at voltage levels lower than those falling under the ambit of NTDC, in which case Power Evacuation Certificate will be required from PESCO.

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E. INFRASTRUCTURE DEVELOPMENT

Road Infrastructure:

The site is accessible from Islamabad and Peshawar via Chitral by air and by road through Lowari Pass/ Lowari tunnel. Both the dam and powerhouse sites are accessible from Chitral Town by a poorly maintained metaled Chitral/Garam Chashma Road and three wooden bridges.

All access roads within site will be built, improvement and extended from the road along Arkari valley road to all the work faces for portals and dam areas, part of temporary roads will also be served as permanent road in future. And three bridges shall be built on Arkari River and Lutkho River for executing work of project.

Electricity Infrastructure:

The electricity supply from the power grid is not available, the diesel generator will work as electricity supply.

Water Infrastructure:

Due to nearby river, subsoil water is easily accessible. High elevation water tank will be arranged separately at dam area, surge tank and powerhouse etc., and the water will be pumped from the river to the water tank, then being distributed to each workface, batching plant and aggregate processing plant.

Communication:

Area receives no signal strength of all major cellular companies. Walkie-talkie will be used for communication within project site.

F. PROJECT COST AND FUNDING PLAN

Please refer to Section 2.3 of this document.

G. PROJECT SCHEDULE

Attached as Annexure III to this document.

H. PEAKING/BASE LOAD OPERATION

Being a plant with daily regulation, the station shall focus on carrying system base load in the flood season, generate electricity at full capacity as far as possible. The station shall focus on carrying system peaking load in the dry season.

I. SYSTEM STUDIES LOAD FLOW, SHORT CIRCUIT, STABILITY

Grid Interconnection Study for the Project was not conducted as part of the Feasibility Study carried out by PEDO. As the Project is under development as a solicited site, complete Grid Interconnection Study, including the load flow, short circuit and stability studies, will be carried out by the sponsors post award of the Project.

J. TRAINING AND DEVELOPMENT

For the training and development, the main focus will be on trainings for accident emergency rescue system and working out accident treatment preplans (including salvage preplans and technological preparation preplans) in view of potentially affected areas, studying out operable responding measures, and designedly organizing actual training exercises so as to grasp the preplans and finding out the errors and detecting the emergency preplans in process of training exercises, hereby working out analysis reports on training exercises, setting forth corrective measures, and finishing the improvement of emergency preplans.

Local Development

- To illustrate approach to sustainability, the Project Company has defined the following themes to contribute to the local development and value creation. The general strategy is as follows:
- To employ local labour and enable knowledge transfer and job creation in local communities.
- To use local suppliers whenever feasible
- To plan for and contribute to local development initiatives
- Ensure to impact positively on local communities by addressing their needs and improving their live standards
- To train and educate people in how best to operate in a new, often foreign, culture to make every project friction free and a collaborative enterprise.
- To increase access to renewable electricity generation capacity in the local community.

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5.3 Annexure III: Project Schedule

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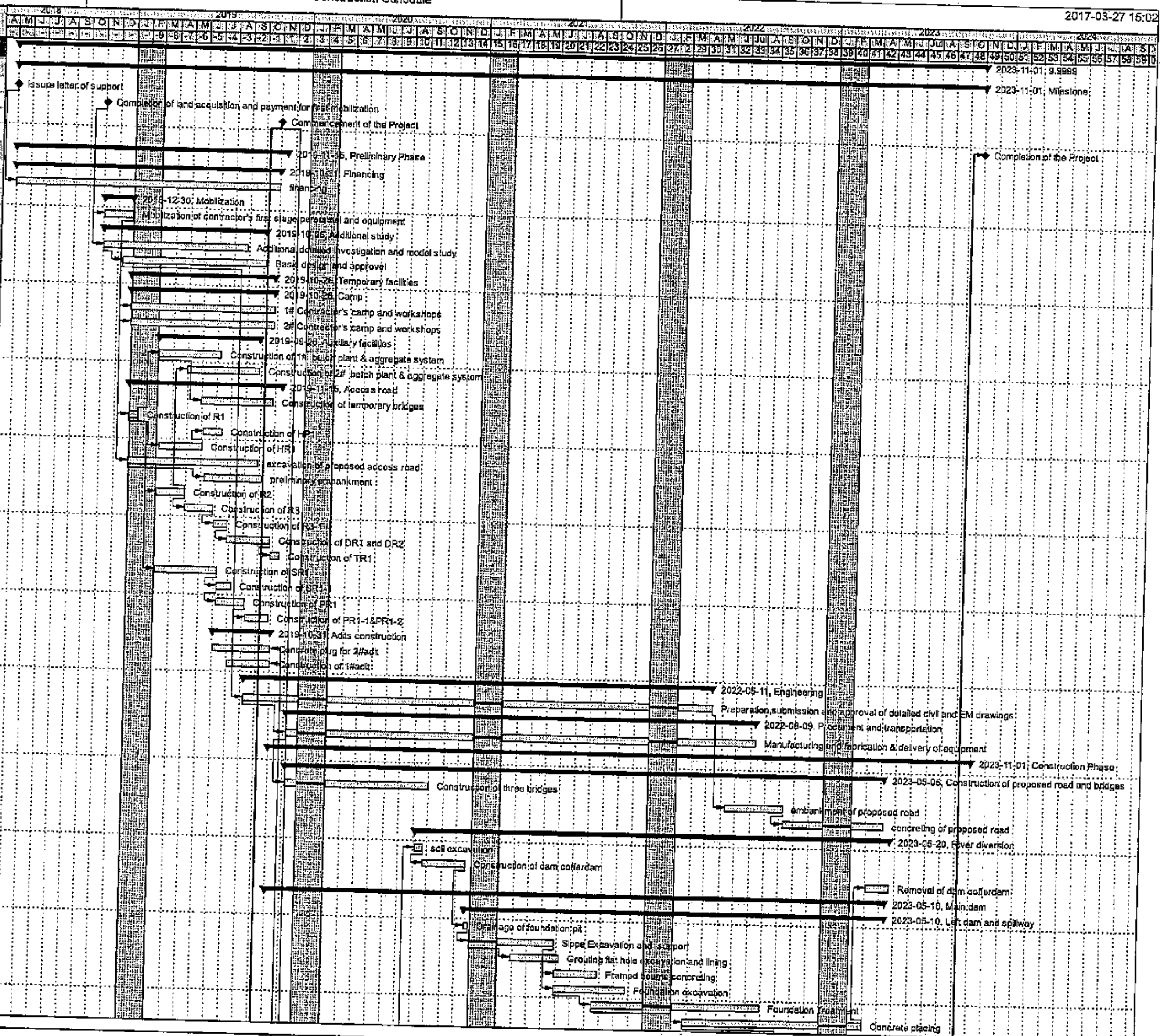
Activity ID	Activity Name	Original Duration	Start	Finish
9.9999		1773	2018-05-01	2023-11-01
Milestone		1773	2018-05-(	2023-11-01
M020	Issure letter of support	0		2018-05-01*
M070	Completion of land acquisition and payment for first m	0		2018-11-01*
M1000	Commancement of the Project	0	2019-11-(	
M1010	Completion of the Project	0		2023-11-01
Preliminary Phase		563	2018-05-(	2019-11-15
Financing		548	2018-05-(	2019-10-31
A1630	financing	548	2018-05-(	2019-10-31
Mobilization		60	2018-11-(	2018-12-30
MZ1000	Mobilization of contractor's first stage personnel and e	60	2018-11-(	2018-12-30
Additional study		340	2018-11-(	2019-10-06
D1000	Additional detailed investigation and model study	300	2018-11-(	2019-08-27
D1010	Basic design and approvel	300	2018-12-'	2019-10-06
Temporary facilities		300	2018-12-:	2019-10-26
Camp		300	2018-12-:	2019-10-26
C1000	1# Contractor's camp and workshops	300	2018-12-:	2019-10-26
C1010	2# Contractor's camp and workshops	300	2018-12-:	2019-10-26
Auxiliary facilities		210	2019-03-(	2019-09-26
AF1000	Construction of 1# batch plant & aggregate system	130	2019-03-(	2019-07-08
AF1010	Construction of 2# batch plant & aggregate system	150	2019-04-:	2019-09-26
Access road		320	2018-12-:	2019-11-15
AR1020	Construction of temporary bridges	150	2019-05-:	2019-10-26
AR1030	Construction of R1	20	2018-12-:	2019-01-19
AR1032	Construction of HP1	40	2019-06-(	2019-07-13
AR1033	Construction of HR1	90	2019-03-(	2019-06-03
AR1040	excavation of proposed access road	270	2018-12-:	2019-09-26
AR1045	preliminary embankment	120	2019-06-(	2019-10-06
AR1050	Construction of R2	60	2019-03-(	2019-04-29
AR1051	Construction of R3	60	2019-04-:	2019-06-28
AR1052	Construction of R3-1	30	2019-06-:	2019-07-28
AR1060	Construction of DR1 and DR2	90	2019-07-:	2019-10-26
AR1080	Construction of TR1	20	2019-10-:	2019-11-15
AR1110	Construction of SR1	130	2019-03-(	2019-07-08
AR1111	Construction of SR1-1	30	2019-07-(	2019-08-07
AR1130	Construction of PR1	60	2019-07-(	2019-09-06
AR1160	Construction of PR1-1&PR1-2	50	2019-09-(	2019-10-26
Adits construction		120	2019-07-(	2019-10-31
HT1029	Concrete plug for 2#adit	120	2019-07-(	2019-10-31
PS050	Construction of 1#adit	90	2019-08-(	2019-10-31
Engineering		800	2019-09-(	2022-05-11
D1020	Preparation,submission and approval of detailed civil a	800	2019-09-(	2022-05-11
Procument and transportation		800	2019-12-(	2022-08-09
A1080	Manufacturing and fabrication & delivery of equipment	800	2019-12-(	2022-08-09
Construction Phase		1225	2019-11-(	2023-11-01
Construction of proposed road and bridges		1010	2019-12-(	2023-05-05
AR1038	Construction of three bridges	240	2019-12-(	2020-09-30
AR1041	embankment of proposed road	120	2022-06-'	2022-10-08
AR1150	concreting of proposed road	150	2022-10-(	2023-05-05
River diversion		810	2020-09-(	2023-05-20
RD1020	soil excavation	15	2020-09-(	2020-09-20
RD1030	Construction of dam cofferdam	90	2020-09-:	2020-12-19
RD1120	Removal of dam cofferdam	50	2023-04-(	2023-05-20
Main dam		1050	2019-11-(	2023-05-10
Left dam and spillway		595	2020-12-:	2023-05-10
DE1000	Drainage of foundation pit	10	2020-12-:	2020-12-29
DE1010	Slope Excavation and support	120	2020-12-:	2021-06-26
DE1011	Grouting flat hole excavation and lining	100	2021-03-:	2021-07-06
DE1020	Framed beams concreting	90	2021-06-:	2021-09-24
DE1030	Foundation excavation	150	2021-06-:	2021-11-23
DE1031	Foundation Treatment	290	2021-09-'	2022-08-29
DE1032	Concrete placing	315	2022-03-:	2023-03-31



Actual Work
Critical Remaining Work
Summary
Remaining Work
Milestone

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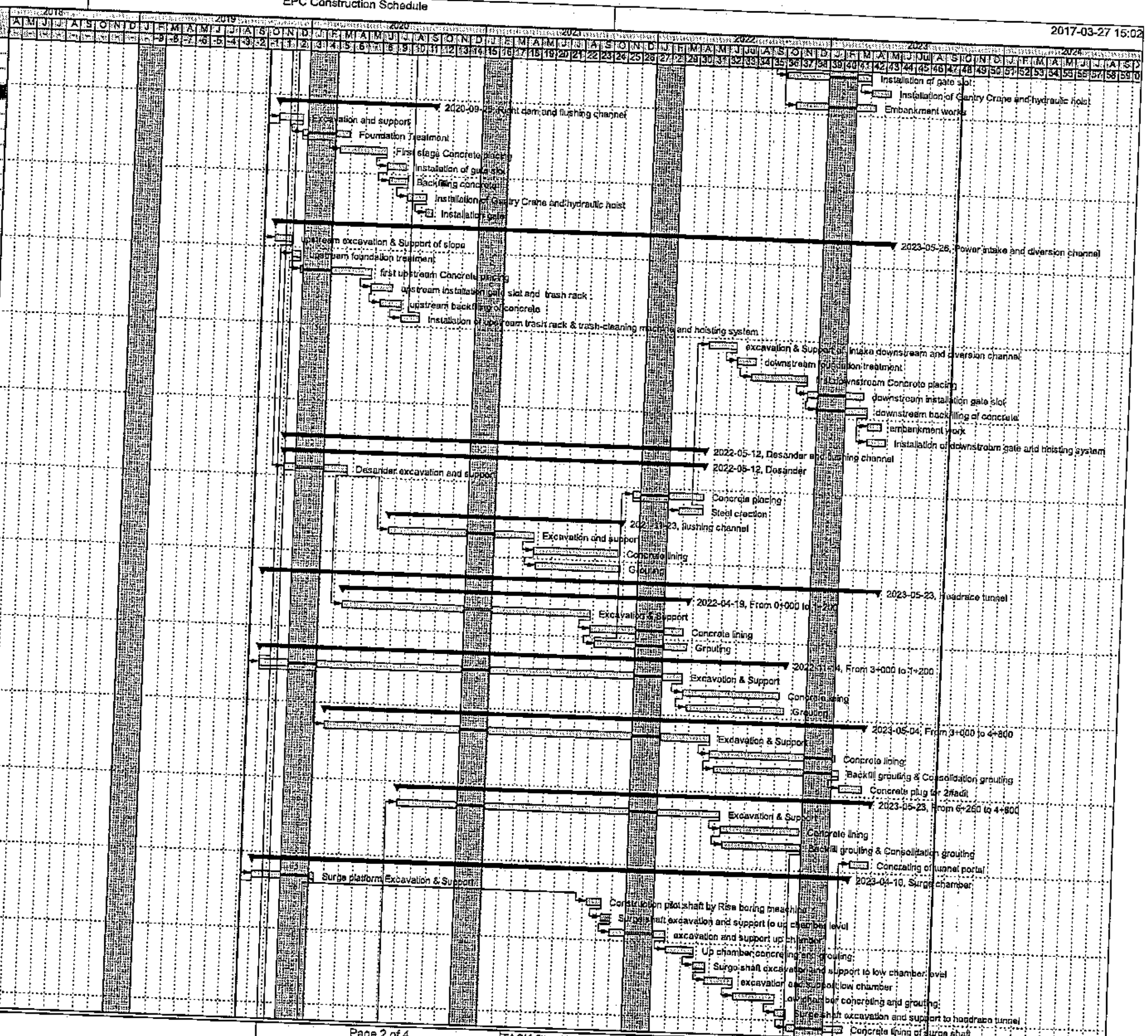
Activity ID	Activity Name	Original Duration	Start	Finish
DE1033	Installation of gate slot	120	2022-10-(	2023-03-31
DE1034	Installation of Gantry Crane and hydraulic hoist	40	2023-04-(	2023-05-10
DE1040	Embankment works	110	2022-10-:	2023-04-10
Right dam and flushing channel		270	2019-11-(	2020-09-25
SP030	Excavation and support	50	2019-11-(	2019-12-20
SP031	Foundation Treatment	40	2019-12-:	2020-03-29
SP032	First stage Concrete placing	100	2020-03-·	2020-06-17
SP1000	Installation of gate slot	40	2020-06-·	2020-07-27
SP1040	Backfilling concrete	40	2020-06-:	2020-08-01
SP1050	Installation of Gantry Crane and hydraulic hoist	40	2020-08-(	2020-09-10
SP1060	Installation gate	15	2020-09-·	2020-09-25
Power intake and diversion channel		1065	2019-11-(	2023-05-26
PI1000	upstream excavation & Support of slope	35	2019-11-(	2019-12-05
PI1010	upstream foundation treatment	20	2019-12-(	2019-12-25
PI1020	first upstream Concrete placing	90	2019-12-:	2020-05-23
PI1040	upstream installation gate slot and trash rack	45	2020-05-:	2020-07-07
PI1050	upstream backfilling of concrete	45	2020-06-·	2020-07-27
PI1051	Installation of upstream trash rack & trash-cleaning m	40	2020-07-:	2020-09-05
PI1052	excavation & Support of intake downstream and dive	60	2022-05-·	2022-07-11
PI1060	downstream foundation treatment	40	2022-07-·	2022-08-20
PI1061	first downstream Concrete placing	120	2022-08-·	2022-12-08
PI1062	downstream installation gate slot	60	2022-12-(	2023-04-06
PI1063	downstream backfilling of concrete	50	2022-12-:	2023-04-16
PI1070	embankment work	30	2023-04-·	2023-05-16
PI1090	Installation of downstream gate and hoisting system	40	2023-04-·	2023-05-26
Desander and flushing channel		711	2019-12-(	2022-05-12
Desander		711	2019-12-(	2022-05-12
A1500	Desander excavation and support	75	2019-12-(	2020-04-18
A1510	Concrete placing	90	2021-12-·	2022-05-12
A1530	Steel erection	50	2022-03-:	2022-05-12
flushing channel		435	2020-07-·	2021-11-23
A1540	Excavation and support	250	2020-07-·	2021-05-22
A1550	Concrete lining	180	2021-05-:	2021-11-18
A1560	Grouting	180	2021-05-:	2021-11-23
Headrace tunnel		1063	2019-11-(	2023-05-23
From 0+000 to 1+200		613	2020-04-·	2022-04-19
HT1000	Excavation & Support	466	2020-04-·	2021-09-25
HT1010	Concrete lining	137	2021-09-:	2022-04-09
HT1020	Grouting	137	2021-10-(	2022-04-19
From 3+000 to 1+200		932	2019-11-(	2022-11-14
HT1030	Excavation & Support	716	2019-11-(	2022-04-12
HT1040	Concrete lining	206	2022-04-·	2022-11-04
HT1050	Grouting	206	2022-04-:	2022-11-14
From 3+000 to 4+800		964	2020-03-:	2023-05-04
HT1060	Excavation & Support	698	2020-03-:	2022-06-13
HT1070	Concrete lining	206	2022-06-·	2023-03-05
HT1080	Backfill grouting & Consolidation grouting	206	2022-06-:	2023-03-15
HT1140	Concrete plug for 2#adit	50	2023-03-·	2023-05-04
From 6+260 to 4+800		923	2020-08-:	2023-05-23
HT1090	Excavation & Support	566	2020-08-:	2022-07-11
HT1100	Concrete lining	167	2022-07-·	2022-12-25
HT1110	Backfill grouting & Consolidation grouting	167	2022-07-·	2022-12-30
HT1120	Concreting of tunnel portal	40	2023-04-·	2023-05-23
Surge chamber		1020	2019-11-(	2023-04-10
SC0050	Surge platform Excavation & Support	70	2019-11-(	2020-03-09
SC1000	Construction pilot shaft by Rise boring meachine	30	2021-10-·	2021-11-08
SC1001	Surge shaft excavation and support to up chamber le	20	2021-11-(	2021-11-28
SC1002	excavation and support up chamber	60	2021-11-:	2022-03-27
SC1003	Up chamber concreting and grouting	60	2022-03-:	2022-05-26
SC1004	Surge shaft excavation and support to low chamber le	25	2022-05-:	2022-06-20
SC1010	excavation and support low chamber	60	2022-06-:	2022-08-19
SC1030	Low chamber concreting and grouting	90	2022-08-:	2022-11-17
SC1070	Surge shaft excavation and support to headrace tunnel	25	2022-11-·	2022-12-12
SC1080	Concrete lining of surge shaft	60	2022-12-·	2023-04-10



Actual Work   Critical Remaining Work   Summary
Remaining Work ◆   ◆ Milestone

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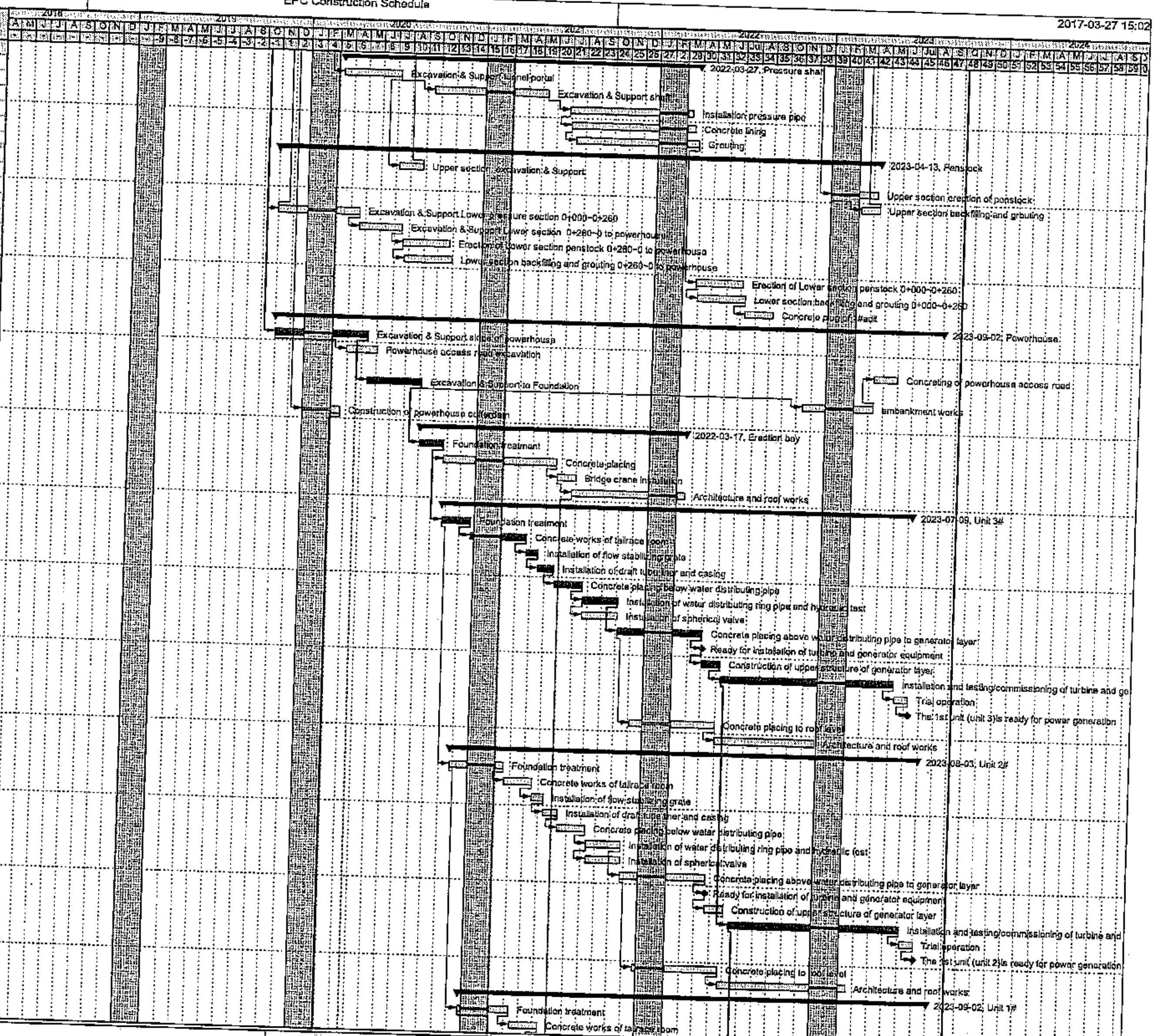
Activity ID	Activity Name	Original Duration	Start	Finish
Pressure shaft		630	2020-03-	2022-03-27
PT1006	Excavation & Support tunnel portal	120	2020-03-	2020-07-07
PT1007	Excavation & Support shaft	180	2020-09-	2021-05-12
PT1008	Installation pressure pipe	200	2021-06-	2022-03-12
PT1010	Concrete lining	200	2021-07-	2022-03-17
PT1020	Grouting	200	2021-07-	2022-03-27
Penstock		1023	2019-11-	2023-04-13
PS010	Upper section excavation & Support	50	2020-07-	2020-08-26
PS012	Upper section erection of penstock	40	2022-12-	2023-04-08
PS013	Upper section backfilling and grouting	40	2023-03-	2023-04-13
PS1000	Excavation & Support Lower pressure section 0+000-	110	2019-11-	2020-04-18
PS1001	Excavation & Support Lower section 0+260~0 to pow	90	2020-04-	2020-07-17
PS1002	Erection of Lower section penstock 0+260~0 to power	100	2020-07-	2020-10-25
PS1003	Lower section backfilling and grouting 0+260~0 to pow	100	2020-07-	2020-10-30
PS1020	Erection of Lower section penstock 0+000~0+260	100	2022-03-	2022-07-05
PS1030	Lower section backfilling and grouting 0+000~0+260	100	2022-04-	2022-07-10
PS1100	Concrete plug of 1#adit	60	2022-07-	2022-09-08
Powerhouse		1165	2019-11-	2023-09-02
A1030	Excavation & Support slope of powerhouse	135	2019-11-	2020-05-13
A1160	Powerhouse access road excavation	65	2020-03-	2020-06-02
A1330	Concreting of powerhouse access road	50	2023-04-	2023-05-30
A1331	Excavation & Support to Foundation	115	2020-05-	2020-09-05
A1410	embankment works	90	2022-11-	2023-04-10
RD1040	Construction of powerhouse cofferdam	20	2019-12-	2020-03-19
Erection bay		440	2020-09-	2022-03-17
A1010	Foundation treatment	50	2020-09-	2020-10-25
A1130	Concrete placing	180	2020-10-	2021-06-21
A1140	Bridge crane installation	40	2021-06-	2021-07-31
A1150	Architecture and roof works	180	2021-07-	2022-03-17
Unit 3#		810	2020-10-	2023-07-09
A1031	Foundation treatment	60	2020-10-	2020-12-24
A1032	Concrete works of tailrace room	60	2020-12-	2021-04-22
A1033	Installation of flow stabilizing grate	25	2021-04-	2021-05-17
A1035	Installation of draft tube liner and casing	35	2021-05-	2021-06-21
A1036	Concrete placing below water distributing pipe	60	2021-06-	2021-08-20
A1037	Installation of water distributing ring pipe and hydraulic	75	2021-08-	2021-11-03
A1038	Installation of spherical valve	75	2021-08-	2021-11-03
A1039	Concrete placing above water distributing pipe to gen	120	2021-11-	2022-05-01
A1040	Ready for installation of turbine and generator equipm	0		2022-05-01
A1045	Construction of upper structure of generator layer	40	2022-05-	2022-06-10
A1046	Installation and testing/commissioning of turbine and g	305	2022-06-	2023-06-09
A1056	Trial operation	30	2023-06-	2023-07-09
A1066	The 1st unit (unit 3)is ready for power generation	0		2023-07-09
A1134	Concrete placing to roof level	120	2021-12-	2022-05-31
A1211	Architecture and roof works	210	2022-06-	2022-12-27
Unit 2#		805	2020-11-	2023-08-03
A1640	Foundation treatment	55	2020-11-	2021-03-18
A1650	Concrete works of tailrace room	60	2021-03-	2021-05-17
A1660	Installation of flow stabilizing grate	25	2021-05-	2021-06-11
A1670	Installation of draft tube liner and casing	30	2021-06-	2021-07-11
A1680	Concrete placing below water distributing pipe	60	2021-07-	2021-09-09
A1690	Installation of water distributing ring pipe and hydraulic	75	2021-09-	2021-11-23
A1700	Installation of spherical valve	75	2021-09-	2021-11-23
A1710	Concrete placing above water distributing pipe to gen	120	2021-11-	2022-05-21
A1720	Ready for installation of turbine and generator equipm	0		2022-05-21
A1730	Construction of upper structure of generator layer	40	2022-05-	2022-06-30
A1740	Installation and testing/commissioning of turbine and g	300	2022-07-	2023-07-04
A1750	Trial operation	30	2023-07-	2023-08-03
A1760	The 1st unit (unit 2)is ready for power generation.	0		2023-08-03
A1770	Concrete placing to roof level	120	2021-12-	2022-06-20
A1780	Architecture and roof works	210	2022-06-	2023-03-16
Unit 1#		805	2020-12-	2023-09-02
A1790	Foundation treatment	50	2020-12-	2021-04-12
A1800	Concrete works of tailrace room	60	2021-04-	2021-06-11



Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone

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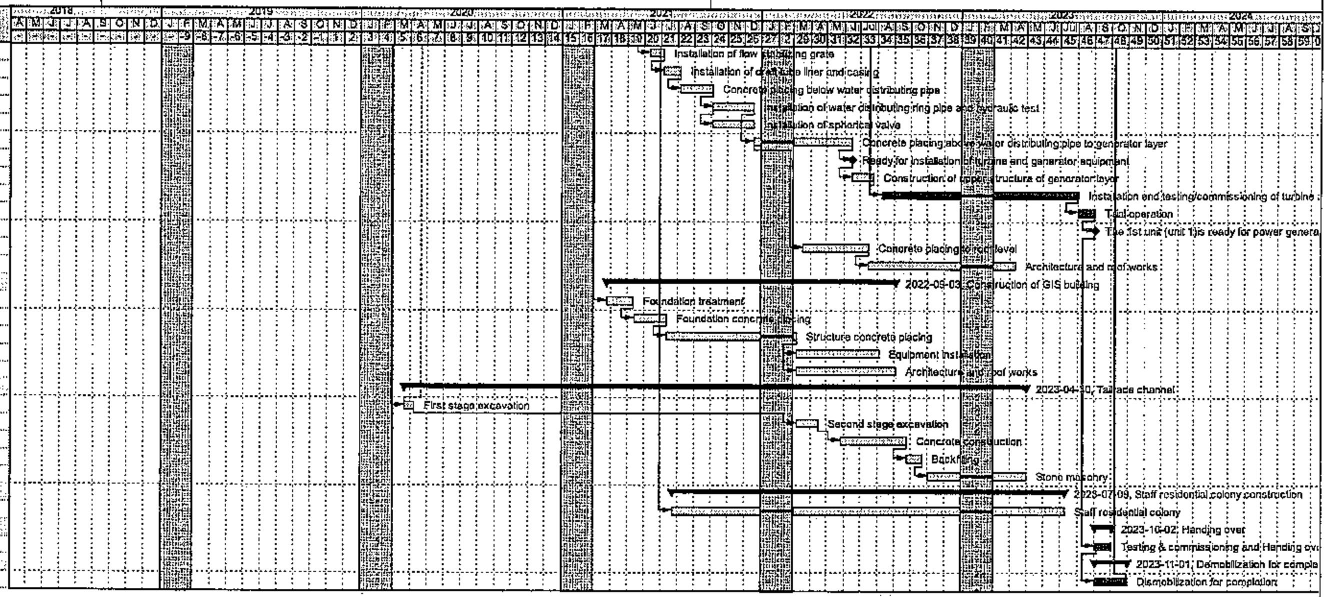
EPC Construction Schedule

2017-03-27 15:02

Activity ID	Activity Name	Original Duration	Start	Finish
A1810	Installation of flow stabilizing grate	25	2021-06-	2021-07-06
A1820	Installation of draft tube liner and casing	30	2021-07-(	2021-08-05
A1830	Concrete placing below water distributing pipe	60	2021-08-(	2021-10-04
A1840	Installation of water distributing ring pipe and hydraulic	75	2021-10-(	2021-12-18
A1850	Installation of spherical valve	75	2021-10-(	2021-12-18
A1860	Concrete placing above water distributing pipe to gen(	120	2021-12-	2022-06-15
A1870	Ready for installation of turbine and generator equipm(	0		2022-06-15
A1880	Construction of upper structure of generator layer	40	2022-06-	2022-07-25
A1890	Installation and testing/commissioning of turbine and g	300	2022-08-	2023-08-03
A1900	Trial operation	30	2023-08-(	2023-09-02
A1910	The 1st unit (unit 1)is ready for power generation.	0		2023-09-02
A1920	Concrete placing to roof level	120	2022-03-	2022-07-15
A1930	Architecture and roof works	210	2022-07-	2023-04-10
Construction of GIS building		470	2021-03-	2022-09-03
A1580	Foundation treatment	50	2021-03-	2021-05-12
A1590	Foundation concrete placing	60	2021-05-	2021-07-11
A1610	Structure concrete placing	180	2021-07-	2022-03-07
A1620	Equipment installation	150	2022-03-(	2022-08-04
A1940	Architecture and roof works	180	2022-03-(	2022-09-03
Tailrace channel		960	2020-03-	2023-04-30
TT1000	First stage excavation	20	2020-03-	2020-04-08
TT1001	Second stage excavation	40	2022-03-(	2022-04-16
TT1010	Concrete construction	120	2022-05-	2022-09-23
TT1020	Backfilling	30	2022-09-	2022-10-23
TT1030	Stone masonry	120	2022-11-(	2023-04-30
Staff residential colony construction		600	2021-07-	2023-07-09
A1570	Staff residential colony	600	2021-07-	2023-07-09
Handing over		30	2023-09-(	2023-10-02
A1000	Testing & commissioning and Handing over	30	2023-09-(	2023-10-02
Demobilization for completion		60	2023-09-(	2023-11-01
A1440	Dismobilization for completion	60	2023-09-(	2023-11-01



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Actual Work / Critical Remaining Work / Summary / Remaining Work / Milestone	Page 4 of 4	TASK filter: All Activities

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