SAIFCO GROUP

SAIFCO HYDROPOWER LIMITED

March 02, 2018

The Registrar
National Electric Power Regulatory Authority (NEPRA)
NEPRA Office Building
Ataturk Avenue (E), G-5/1
Islamabad

SUBJECT: Application for grant of a Generation Licence for 102 MW Shigo Kas Hydropower Project

Pakhtunkhwa Energy Development Organization, Government of Khyber Pakhtunkhwa, Peshawar (hereinafter referred to as **"PEDO"**) PEDO invites through Request for Proposals (RFP) Pre-Qualified Bidders to submit Proposals for the right to develop a **102 MW Shigo Kas HPP** at Reference Hydrological Conditions, Run of River based Hydro Power Project to be located at **the Dir Lower District,** on Build, Own, Operate & Transfer (BOOT) basis (the "**Project**"). Accordingly, the sponsors submitted the RFP containing therewith technical as well as financial proposals to the PEDO on 26.04.2016.

2. Now, PEDO through its letter dated 23.02.2018 (copy attached as **Annex-I**) forwarded National Electric Power Regulatory Authority (NEPRA) letter dated 19.02.2018 whereby NEPRA intimated, inter alia, that:

> *"The recommended first ranked bidder, namely M/s Saifco Group, is hereby notified as the successful bidder for the 102 MW Shigo Kas Hydropower Project and is directed to file an application with the Registrar seeking approval generation tariff, under Part III of the CTBR-2014, within 15 days of this notification".*

3. Pursuant to and in accordance with the requirement of Clause 3.4.8(a)(iv) of Request for Proposal, "**SAIFCO HYDROPOWER LIMITED**" has been incorporated as Special Purpose Vehicle (SPV). PEDO has been requested vide our letter dated 01.03.2018 (**Annex-II**) that all the concerned quarters, including NEPRA may kindly be informed regarding the establishment of SPV.

4. As above, application for grant of Generation Licence to Saifco Hydropower Limited for its 102 MW Shigo Kas Hydropower Project is hereby submitted before NEPRA pursuant to Section 15 of NEPRA Act along with the application seeking approval of generation tariff in accordance with NEPRA CTBR-2014. The application for grant of generation licence has been prepared in accordance with the provision of Regulation 3 of NEPRA Licensing (Application and Modification Procedure) Regulation, 1999 (hereinafter referred to as "**the Regulations**").

SAIFCO HYDROPOWER LIMITED SAIFCO GROUP

Islamabad Office: Office Galleria Islamabad,Plot No.12 Markaz I-8 Islamabad, Ph +92 51 4862412
Peshawar Office:-Silk Executive Apartments, Deans complex, Block C, Ground Floor Main

5. Following documents-in-support are submitted as per the requirement of the Regulations:

Regulation	Information/Documents	Status
	Application for grant of Generation Licence	Attached is **F/1.**
3(1)	Authorization from Board Resolution for submission of Generation Licence application	Board Resolution dated 26.02.2018 is attached (**F/2**)
3(2)	Application fee (including Indexation)	Pay Order amounting to Rs. 762,240/- inclusive of CPI is attached (**F/3**)
3(4)	Three copies of Application	The application is being submitted in triplicate
3(5)(a)(i)	Certificate of incorporation	Certified copies of Certificate of Incorporation No. 0116622 dated 22.02.2018 is attached (**F/4**).
3(5)(a)(ii)	Memorandum and articles of association	Certified copies are attached (**F/4**).
3(5)(a)(iii)	Annual Return statements or in lieu thereof	SCHPL has been incorporated on 22.02.2018, hence is not applicable. However, the information as per Regulation 2(5)(a)(iv) will be submitted as soon as prepared.
3(5)(b)	Profile of experience of the applicant its management, staff and its members in power sector.	SCHPL is a newly incorporated company, however, profile of sponsor of the project and senior management of SCHPL is placed at **F/5**.
3(5)(c)	CVs of applicant's Senior Management and Technical professionals	CVs of SCHPL senior management and technical professionals are placed at **F/6**.
3(5)(d)	Adequate evidence of financial and technical resources.	SCHPL is a newly incorporated company as SPV for the development of the project. The audited financial statements of the sponsors are attached at **F/7** and for technical resource please refer to **F/8**.
3(5)(d)(i)	Cash balance & bank certificates	Bank certificate of SCHPL is placed at **F/9**.
3(5)(d)(ii)	Expression of interest to provide credit or financing along with sources and details thereof	Expression of Interest is attached at **F/10**.

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Regulation	Information/Documents	Status
3(5)(d)(iii)	Latest financial statements	Financial statements of the sponsors for FY 2015-16; and FY 2015 are attached as **F/11**. However, the latest statements will be submitted shortly.
3(5)(d)(iv)	Employment records of Engineers & Technical Staff	The company has not started its business activities, so the CVs and other relevant information of engineers and technical staff will be provided to NEPRA as and when they will be hired.
3(5)(d)(v)	Profile of Sub-contractors (if any)	SCHPL has not appointed any sub-contractor as of yet, as soon as the company appointed any contractor, the profile will be provided.
3(5)(d)(vi)	Verified references w.r.t. experience of the Applicant and its sub-Contractors	Verified reference with respect to the sponsors of the project is attached at **F/12**. However, no sub-contractor has been appointed as yet.
3(5)(e)	Encumbrances on assets	There is no charge or encumbrances on the assets of the company. In this regard a certificate is attached at **F/13.**
3(5)(g)(a)	Type of Technology	Francis Vertical
3(5)(h)	Feasibility Report	Attached separately containing 3 volumes.
3(5)(i)	Prospectus	Prospectus is attached at **F/14.**
Schedule 3(A)(c) 1.	Location (location maps, site maps) land	Left Bank of Panjkora River, Village Shigo Kas, in District Lower Dir, Khyber Pakhtunkhwa. Location Maps attached at **F/15**.
2.	Plant: run of river, storage, veir	Run of River
3.	Head: Minimum, maximum	87 meter and 91.5 meter
4.	Technology: Francis, Pelton, etc. Size, number of units.	Francis Vertical 120 MW (34 x 6 MW)
5.	Tunnel (if proposed): length, diameter	Length: 10.22 km Diameter: 7 m Horseshoe
6.	ESSA (Environmental and Social Soundness Assessment)	Statement in this regard is attached at **F/16.**

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Regulation	Information/Documents	Status
7.	Detailed feasibility report	Report has been completed by PEDO. Three copies of the feasibility report containing 3 volumes each are attached.
8.	Resettlement issues	Attached at **F/17**.
9.	Consents	NOC/Consents from PESCO is attached at **F/18**.
10.	Infrastructure development	The development will be started after issuance of LOS from the PEDO
11.	Interconnection with National Grid Co. distance and name of nearest grid, voltage level (single line diagram)	Plant will be connected with 132 kV Taimargara Grid Station. The distance of the grid station is 10 KM. Single line diagram is attached **F/19**.
12.	Project cost, information regarding sources and amounts of equity and debt.	Equity 20% =US$ 61.45 Million Debt 80% = US$ 245.79 Million Total Project Cost= US$ 307.24 Million
13.	Project schedule, expected life	Project Schedule is attached at **F/20.** The life of the project is 30 Years.
14.	Peaking/base load operation	Base load operation
15.	Plant characteristics: generation voltage, power factor, frequency, automatic generation control, ramping rate, control metering and instrumentation	Generation Voltage: 11 kV Power Factor: 0.8 Lagging 0.95 Leading Frequency: 50Hz AGC: No Ramping Rate: NA Static Exciter
16.	System studies load flow, short circuit, stability	Statement in this regard is attached at **F/21**.
17.	Training and development	Attached at **F/22**.

6. Enclosed please find herewith, application for grant of a generation licence in triplicate, prepared in accordance with National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations, 1999. A pay order in the sum of Rupees 762,240/-, being the non-refundable licence application fee calculated in accordance with

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Schedule-II to the National Electric Power Regulatory Authority Licensing (Application and Modification Procedure) Regulations, 1999, is also attached herewith.

7. It is requested to kindly process our subject application and grants us generation licence for expeditiously completion of the project.

(**Dr. Asif Qayyum Qureshi, Ph. D.**)
Chief Operating Officer

Dr. Asif Qayyum Qureshi, Ph.D
Chief Operating Officer (COO)
Saifco Hydropower Limited

SAIFCO HYDROPOWER LIMITED
SAIFCO GROUP

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ANNEX-I

PEDO

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa Peshawar

No. 418-19 /PEDO/DPP/Shigo kas

Dated the Peshawar 23/02/ 2018

To

M/S Saifco Group
Ground Floor Deans Complex Block C, University Road,
Peshawar

Subject: **APPROVAL OF BID EVALUATION REPORT OF 102 MW (NET) SHIGO KAS HYDROPOWER PROJECT**

I am directed to refer to the subject decision noted above and to enclose find herewith the order of the NEPRA Authority in the subject matter for information and necessary action please.

Syed Aziz Ahmad
Assistant Director (Private Power)

Encl: As Above

CC:

1. PS to Chief Executive Officer, PEDO, Peshawar

Syed Aziz Ahmad
Assistant Director (Private Power)

SAIFCO HYDRO POWER LIMITED

National Electric Power Regulatory Authority
Islamic Republic of Pakistan

NEPRA Tower, Attaturk Avenue (East), G-5/1, Islamabad
Ph: +92-51-9206500, Fax: +92-51-2600026
Web: www.nepra.org.pk, E-mail: registrar@nepra.org.pk

Registrar

No. NEPRA/TRF-100/PEDO(SKHP)-2018/2657-58 February 19, 2018

Chief Executive Officer
Pakhtunkhwa Energy Development Organization (PEDO)
Government of Khyber Pakhtunkhwa
First Floor, A-Block, Abdul Wali Khan Multiplex,
Civil Secretariat, Peshawar

Subject: **APPROVAL OF BID EVALUATION REPORTOF 102 MW (NET) SHIGO KAS HYDROPOWER PROJECT**

Reference is made to your letters, No. 3082-83/PEDO/DRE/NEPRA dated 26-12-2017 and No. 2430-32/PEDO/DRE/NEPRA dated 19-10-2017 wherein approval of the Authority is sought on the bid evaluation report for the 102 MW Shigo Kas Hydropower project and notification of successful bidder(s) under the relevant provisions of the Competitive Bidding Tariff (Approval Procedure) Regulations, 2014 (CTBR-2014).

2. The Authority has reviewed the bid evaluation report submitted by PEDO and record placed before it. Despite observed discrepancies and deficiencies in the bid evaluation report, the same has been found to be in material compliance with the RFP. The Authority hereby approves the bid evaluation report for the 102 MW Shigo Kas Hydropower project with a Levelized Tariff for the first ranked bidder @ Rs. 8.2658 per kWh (US cents 7.8947 per kWh). The recommended first ranked bidder, namely M/s Saifco Group, is hereby notified as the successful bidder for the 102 MW Shigo Kas Hydropower project and is directed to file an application with the Registrar seeking approval of generation tariff, under Part III of the CTBR-2014, within 15 days of this notification.

19/2

(Iftikhar Ali Khan)
Director
Registrar Office

CC: Secretary, Energy and Power Department, Government of Khyber Pakhtunkhwa, First Floor, A-Block, Abdul Wali Khan Multiplex, Civil Secretariat, Peshawar

ANNEX - II

SAIFCO GROUP

SAIFCO HYDROPOWER LIMITED

Ref:- Saifco/SPV/PEDO/1-3/18

Islamabad March 1,2018

Chief Executive Officer
Pakhtunkhwa Energy Development Organization
PEDO House, 38/B-2, Phase-V,
Hayatabad, Peshawar

Subject: **Incorporation of Special Purpose Vehicle.**

Dear Sir,

This is with reference to your letter bearing No. 418-19/PEDO/DPP/Shigo Kas dated 23.02.2018 whereby order of the National Electric Power Regulatory Authority (NEPRA) has been forwarded for further necessary action.

2. It is hereby informed that in accordance with the requirement of Clause 3.4.8 (iv) of Request for Proposal, we have incorporated special purpose vehicle in the name of "SAIFCO HYDROPOWER LIMITED". The Certificate of Incorporation bearing No. 0116622 dated 22.02.2018 duly issued by the Securities and Exchange Commission of Pakistan, Islamabad is attached herewith for information.

3. We are in process of filing applications of generation tariff and for grant of generation license before the NEPRA. It is therefore requested that all the concerned quarters, including NEPRA may kindly be informed regarding the establishment of Special Purpose Vehicle.

Attachment: Copy of Certificate of Incorporation

Regards,

Dr. Asif Qayyum Qureshi, Ph. D.
Chief Operating Officer

SAIFCO HYDROPOWER LIMITED
SAIFCO GROUP

SAIFCO GROUP

SAIFCO HYDROPOWER LIMITED

BOARD RESOLUTIONS BY CIRCULATION PASSED BY THE BOARD OF DIRECTORS ON FEBRUARY 26, 2018

The meeting of the Board of Directors of Saifco Hydropower Limited ("**SCHPL**") was held at the registered office of the company i.e. Office Galleria, Plot No. 12, I-8 Markaz, Islamabad on February 26, 2018 have passed the following resolutions:

1. Resolved that Dr. Asif Qayyum Qureshi, (Ph.D.), Chief Operating Officer, is hereby given the mandate to proceed with the submission of the Application for Grant of Generation Licence for 102 MW ShigoKas Hydropower Project before National Electric Power Regulatory Authority (NEPRA).

2. Resolved further that Dr. Asif Qayyum Qureshi, (Ph.D.), Chief Operating Officer, is also hereby given the mandate to proceed with the submission of the application for seeking approval of generation tariff under Part-III of NEPRA Competitive Bidding Tariff (Approval Procedure) Regulations, 2014 before National Electric Power Regulatory Authority (NEPRA).

3. Resolved further that Dr. Asif Qayyum Qureshi, (Ph.D.), Chief Operating Officer is hereby authorized to sign the application for grant of generation Licence and application for tariff approval and any other document/communication thereof for and on behalf of the SCHPL.

This Board Resolution shall remain in full force and effect until an amending resolution shall be passed by the Board.

Malik Saif Ur Rehman
Director

Abid Ur Rehman
Director

Faiz Ur Rehman
Director

Saqib Rehman
Director

Dated: February 26, 2018

SAIFCO HYDROPOWER LIMITED
SAIFCO GROUP

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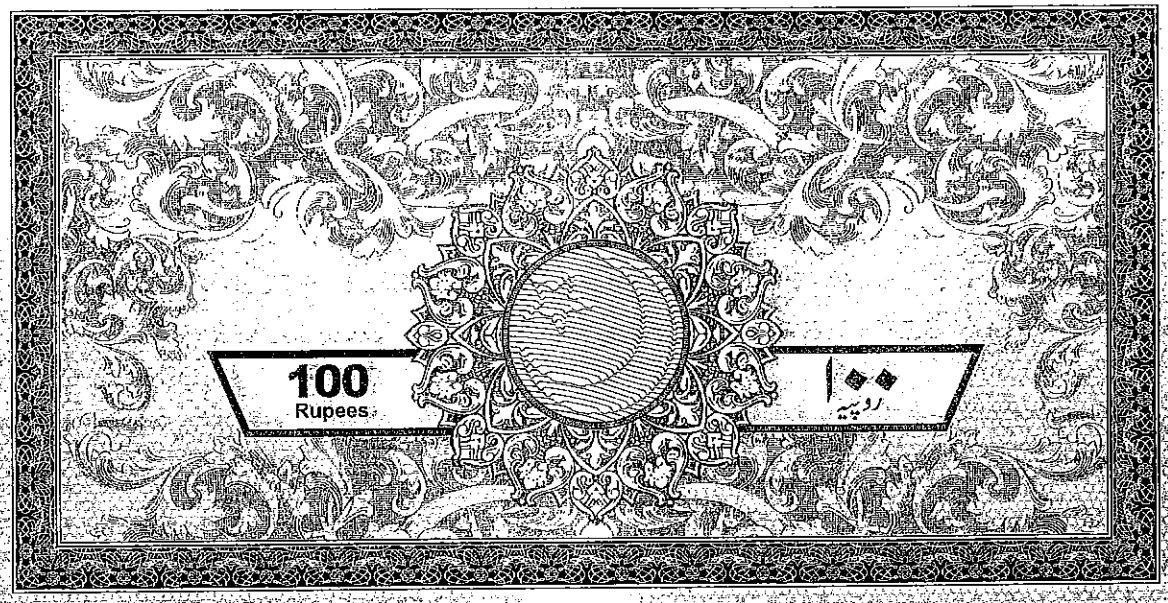


BEFORE NATIONAL ELECTRIC POWER REGULATORY AUTHORITY (NEPRA)

AFFIDAVIT OF

Dr. Asif Qayyum Qureshi S/o Abdul Qayyum Qureshi bearing NIC No. 37405-5114566-5 resident of 47-British Homes, Islamabad

I the above named deponent, in relation to the approval for Generation Tariff for development of approximately **102 MW Shigo-Kas Hydropower Project** before NEPRA do hereby solemnly declare and affirm on oath as under:

1. I am Chief Operating Officer of the SAIFCO HYDRPOWER LIMITED ("Company") and authorized representative of the Company duly authorized by its Board of Directors.

2. That I have filed application for grant of generation licence together with supporting documents before the NEPRA and the contents of the same may kindly be read as an integral part of this affidavit.

3. That the contents of the accompanying application for grant of generation licence and further documentation and/or information to be provided by me in connection with the accompanying generation licence application shall, are true to the best of my knowledge and belief of and according to the information received by the Deponent.

Deponent Verification

Verified on oath this day/month of March 02, **2018** at **Islamabad** that the contents of this affidavit are true and correct to the best of my knowledge and belief and that nothing has been concealed therein.

Deponent Signature:

.....

Name: Dr. Asif Qayyum Qureshi
Designation: Chief Operating Officer
CNIC No. 37405-5114566-5

Place of Signing: Islamabad, Pakistan

ATTESTED
ASAD ABBAS JAFRI
NOTARY PUBLIC
ISLAMABAD

A038885

SECP

SECURITIES AND EXCHANGE COMMISSION OF PAKISTAN

COMPANY REGISTRATION OFFICE

CERTIFICATE OF INCORPORATION

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

Corporate Universal Identification No. **0116622**

I hereby certify that **SAIFCO HYDROPOWER 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 **Islamabad** this **Twenty Second** day of **February**, Two **Thousand** and **Eighteen**.

Incorporation fee Rs. **50500.0/-** only

(Khalida Perveen)
Joint Registrar
Islamabad

No. ADL 302977

Dated 22.2.2018

CERTIFIED TO BE TRUE COPY

(Muhammad Tariq Rasheed)
Assistant Registrar

THE COMPANIES ACT, 2017 (XIX of 2017)

(COMPANY LIMITED BY SHARES)

MEMORANDUM

OF

ASSOCIATION

OF

SAIFCO HYDROPOWER LIMITED

THE COMPANIES ACT, 2017 (XIX of 2017)

(COMPANY LIMITED BY SHARES)

MEMORANDUM OF ASSOCIATION

OF

"SAIFCO HYDROPOWER LIMITED

1. The name of the company is SAIFCO HYDROPOWER LIMITED.

2. The registered office of the Company will be situated in Islamabad Capital Territory.

3. (i) To carry on all or any of the businesses of generating, purchasing, importing, transforming, converting, distributing, transmitting, supplying, exporting, and dealing in electricity and all other forms of energy and products or services associated therewith and of promoting and conservation and efficient use of electricity and to perform all other acts which are necessary or incidental to the business of power generation, transmission, distribution and supply.

(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:

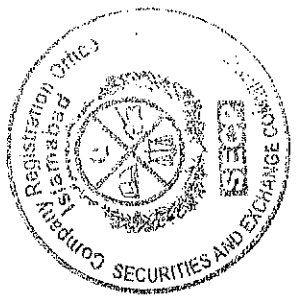
(a) engage in any of the business mentioned in sub-clause (iii) above or any unlawful operation;

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

(c) engage in any of the permissible business unless the requisite approval, permission, consent or licence 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. 10,000,000/- (Rupees Ten Million only) divided into 100,000 (One Hundred thousand) ordinary shares of Rs.100/- (Rupees One Hundredonly) 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:

Name and surname (present & former) in full (in Block Letters)	NIC No. (in case of foreigner, Passport No)	Father's/ Husband's Name in full	Nationality (ies) with any former Nationality	Occupation	Usual residential address in full or the registered/ principal office address for a subscriber other than natural person	Number of shares taken by each subscriber (in figures and words)	Signatures
Malik Saif ur Rehman	17301-5967012-7	Malik Haji Gul Rehman	Pakistani	Businessman/ Developer	House No54 Street No.2 Phase-2 Hayatabad Peshawar	3000 (Three thousand only)	
Abid Ur Rehman	22401-6843182-1	Gul Rehman	Pakistani	Businessman/ Developer	Qoam Zarghan khail P.O dara Adam Khel Dara Bazar FATA Kohat	2000 (Two Thousand Only)	
Faiz Ur Rehman	17301-9322764-3	Malik Saif Ur Rehman	Pakistani	Businessman/ Developer	House No54 Street No.2 Phase-2 Hayatabad Peshawar	1500 (Fifteen Hundred Only)	
Saqib Rehman	17301-5334894-1	Malik Saif Ur Rehman	Pakistani	Businessman/ Developer	House No54 Street No.2 Phase-2 Hayatabad Peshawar	1500 (Fifteen Hundred Only)	
SAIFCO DEVELOPERS (PVT) LTD	0087275	—	Pakistani	Construction	Plot No. 11-A Markaz F-10 Islamabad	2000 (Two thousand Only)	
Through Nominee Malik Saif Ur Rehman	17301-5967012-7	Malik Haji Gul Rehman	Pakistani	Businessman/ Developer	House No54 Street No.2 Phase-2 Hayatabad Peshawar	—	
TOTAL Number of Shares Taken (TEN THOUSAND ONLY)						10000	

Dated the 22th day of February, 2018

CERTIFIED TO BE TRUE COPY

(Muhammad Tariq Rasheed)
Assistant Registrar
Company Registration Office Islamabad

THE COMPANIES ACT, 2017 (XIX of 2017)

(COMPANY LIMITED BY SHARES)



Articles of Association

Of

SAIFCO HYDROPOWER LIMITED

THE COMPANIES ACT, 2017 (XIX of 2017)

(Company Limited by Shares)

ARTICLES OF ASSOCIATION

OF

SAIFCO HYDROPOWER LIMITED

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

PUBLIC COMPANY

2. The Company is a "Public Company" within the meaning of Section 2(1)(52) of the Act and accordingly:

   1. The number of the members of the Company (exclusive of persons in the employment of the Company), shall not be limited, 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
   2. The right to transfer shares of the Company shall not be restricted in the manner and to the extent herein appearing.

3. The Authorized Share Capital of the Company shall be PK Rs. 10,000,000/- divided into 10,000 ordinary shares of Rupees 100 each.

4. The minimum subscription upon which the directors may proceed to make the first allotment has been fixed as Rs.150,000

TRANSFER OF SHARES

5. The directors shall not refuse to transfer any fully paid shares unless the transfer deed is invalid or defective.

DIRECTORS

6. The number of directors shall not be less than three or a higher number as fixed under the provisions of Section 159 of the Act. The following persons shall be the first directors of the Company and shall hold the office up to the date of First Annual General Meeting

Sr. No	Name of the Directors
1.	Malik Saif Ur Rehman
2.	Abid Ur Rehman
3.	Faiz Ur Rehman
4.	Saqib Rehman

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

Name and surname (present & former) in full (in Block Letters)	NIC No. (in case of foreigner, Passport No)	Father's/ Husband's Name in full	Nationality (ies) with any former Nationality	Occupation	Usual residential address in full or the registered/ principal office address for a subscriber other than natural person	Number of shares taken by each subscriber (in figures and words)	Signatures
Malik Saif ur Rehman	17301-5967012-7	Malik Haji Gul Rehman	Pakistani	Businessman/ Developer	House No54 Street No.2 Phase-2 Hayatabad Peshawar	3000 (Three thousand only)	
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Faiz Ur Rehman	17301-9322764-3	Malik Saif Ur Rehman	Pakistani	Businessman/ Developer	House No54 Street No.2 Phase-2 Hayatabad Peshawar	1500 (Fifteen Hundred Only)	
Saqib Rehman	17301-5334894-1	Malik Saif Ur Rehman	Pakistani	Businessman/ Developer	House No54 Street No.2 Phase-2 Hayatabad Peshawar	1500 (Fifteen Hundred Only)	
SAIFCO DEVELOPERS (PVT) LTD Through Nominee Malik Saif Ur Rehman	0087275 17301-5967012-7	—— Malik Haji Gul Rehman	Pakistani Pakistani	Construction Businessman/ Developer	Plot No. 11-A Markaz F-10 Islamabad House No54 Street No.2 Phase-2 Hayatabad Peshawar	2000 (Two thousand Only) ——	
TOTAL Number of Shares Taken (TEN THOUSAND ONLY)						10000	

Dated the 22th day of February, 2018

CERTIFIED TO BE TRUE COPY

Muhammad Tariq Rasheed

Assistant Registrar

Company Registration Office Islamabad

SAIFCO GROUP CORPORATE PROFILE 2017

SAIFCO GROUP

The Name of Trust

CORPORATE PROFILE – 2017

EXCELLING WITH EXCELLENCE

Welcome to SaifCo Group

Operating since 1971, SaifCo Group of Companies is among Pakistan's leading business entities with multifarious projects. The Group has consistently built its reputation on solid foundations and delivering results that speak for themselves.

The Group's top management is a consortium of strong financiers, investors, professionals, project management teams and high-profile consultants with versatile, vast experience & expertise in multiple business disciplines. The delivered and ongoing projects are undertaken in various business arrangements to ensure choosing best resources and management for a particular project with Specific needs and market dynamics; a rewarding approach for the Group and its subsidiaries offering tailor-made solutions to the stakeholders.

Today, SaifCo Group and its allied businesses enjoy a diverse business profile ranging from *Real Estate Developments (Builders & Developers), Coal Mining, Oil & Gas, Travel & Tourism, Education, General Trading, Transportation and Software Development.*

The business diversity of SaifCo Group ranges from operating mines in the mountains of Darra Adam Khel (FR Kohat, Pakistan) to managing the Deserts Safaris in UAE, taking part in some of the largest construction projects in Pakistan to delivering up-scale, smart malls in the top-notch commercial zones of Islamabad, entering in professional educational sector while pioneering in collaborating with Informatics Holdings, Singapore and achieving affiliation with University of Peshawar to attaining best-selling performance awards in KPK Districts from TOTAL PARCO to running public transport services since 1945, all the while focusing in connecting business opportunity with markets and ushering in prosperity and success for people and communities.

The SaifCo Group believes in excelling with excellence keeping focus on profitability with responsibility.

LOOKING BACK:

Our History

SaifCo Group is an assemblage of individuals having rich experience and expertise of construction of residential and commercial multistoried buildings & plazas.

SaifCo Group carries 46 shining years of experience in developing commercial real estate projects

To its credit; the Group has some of the earliest organized commercial establishments in the KPK's capital city, Peshawar, 'Rehman Medicine Market' as well as some most modern and state-of-the art modern shopping malls like 'AnB Center', Islamabad constructed on the most modern lines & features with the latest available amenities and facilities.

Rehman Medicine Market was constructed by the Group's founder Mr. Haji Gul Rehman in 1973. Being a leading businessman dealing in Arms & Ammunition, Mr. Haji Gul Rehman has a special affinity towards purchasing of the commercial land.

In year 2005, Mr. Saif ur Rehman took over the mission of his father and established a construction firm with name & style of "Deans Builders". He ventured with purchasing 33-Kanal premium commercial land at Civic Centre, Hayatabad, Peshawar, through auction from Peshawar Development Authority to build one of the first multi-storey residential apartments in Peshawar in year 2006.
In late 2007, the company started a gigantic project with name and title of "Deans Complex" which was completed and delivered in 2012.

In addition to being one of the lead financers in Deans Builders commercial ventures, Mr. Saif-ur-Rehman has been taking active part in projects' execution and management.
Deans Builders, under the proficient leadership of Mr. Saif ur Rehman & other active partners along with a dedicated team of qualified professionals and the relation established with numerous lenders, developers, & suppliers, is fully capable of successfully financing, building and developing real-estate projects of relatively at large scale.

By the year 2008, SaifCo Group of Companies evolved and turned into a multifarious business entity with Deans Builders achieving a versatile and full-service general contractor and construction manager's status; working on a wide variety of commercial, residential, industrial, educational, healthcare, and municipal projects as well as Group making its en try in numerous business fields including 'Travel & Tourism, Mining, Professional Education, Petroleum and General Trading'.

At present, the SaifCo's Construction Wing along with its chief partner in real-estate ventures, Deans Builders, is considered as the leading Real Estate Developer in Khyber Pakhtunkhwa in construction of gigantic, multistoried state-of-the-art commercial and residential buildings and towers.

PROSPECTUS

A. BRIEF INTRODUCTION OF THE APPLICANT

Saifco Hydropower Limited (the Project Company)

Saifco Hydropower Limited (**SCHPL**) is a Limited Company, incorporated in Pakistan on 22 February 2018 under the Companies Ordinance, 1984. It registered office is located at Office Galleria, Plot No. 12, I-8 Markaz, Islamabad. SCHPL has been incorporated as special purpose vehicle to carry on all or any of the businesses of generating, purchasing, importing, transforming, converting, distributing, transmitting, supplying, exporting and dealing in electricity and all other forms of energy and products or services associated therewith and of promoting and conservation and efficient use of electricity and to perform all other act which are necessary or incidental to the business of power generation, transmission, distribution and supply.

SaifCo Group of Companies (the Sponsor)

Operating since 1971, SaifCo Group of Companies (hereinafter referred to as "the Group") is among Pakistan's leading business entities with multifarious projects. The Group has consistently built its reputation on solid foundations and delivering results that speak for themselves. The head of the group is located at Ground Floor, Deans Complex, Block C, University Road, Peshawar.

The Group's top management is a consortium of strong financiers, investors, professionals, project management teams and high-profile consultants with versatile, vast experience & expertise in multiple business disciplines. The delivered and ongoing projects are undertaken in various business arrangements to ensure choosing best resources and management for a particular project with specific needs and market dynamics; a rewarding approach for the Group and its subsidiaries offering tailor-made solutions to the stakeholders.

Today, the Group and its allied businesses enjoy a diverse business profile ranging from Real Estate Developments (Builders & Developers), Coal Mining, Oil & Gas, Travel & Tourism, Education, General Trading, Transportation and Software Development.

The business diversity of the Group ranges from operating mines in the mountains of Darra Adam Khel (FR Kohat, Pakistan) to managing the Deserts Safar is in UAE, taking part in some of the largest construction projects in Pakistan to delivering up-scale, smart malls in the top-notch commercial zones of Islamabad, entering in professional educational sector while pioneering in collaborating with Informatics Holdings, Singapore and achieving affiliation with University of Peshawar to attaining best selling performance awards in KPK Districts from TOTAL PARCO to running public transport services since 1945,

SAIFCO HYDROPOWER LIMITED
SAIFCO GROUP

while focusing in connecting business opportunity with markets and ushering in prosperity and success for people and communities.

The Group believes in excelling with excellence keeping focus on profitability with responsibility.

China National Machinery Industry Corporation (the Sponsor:

China National Machinery Industry Corporation Ltd(Sinomach), established in January 1997, is an important State-owned backbone enterprise directly managed by the central government. Sinomach is a Fortune Global 500 enterprise. Sinomach's headquarters is located in the Silicon Valley of China, Beijing's Zhongguancun.

Sinomach Group has 160,000 employees, over 40 wholly-owned or majority-owned subsidiaries, 12 listed companies, and more than 200 overseas service agencies. Sinomach Group is an international, diversified, comprehensive equipment industrial group committed to providing quality services globally. The group's primary businesses include four main areas of R&D and manufacturing: mechanical equipment, project contracting, trade and services, as well as finance and investment. Its service scope covers critical national economic fields including machinery, electric power, metallurgy, agriculture and forestry, transportation, construction, automobiles, ship building, light industry, electronics energy, environmental engineering, aeronautics and astronautics. The group has a market presence in over 170 countries and regions around the world.

For years, Sinomach has promoted further optimization of its resources, rebuilt its core competencies, accelerated the pace of "going global," and extensively advanced its strategic transformation with continuous technological and managerial innovations. The group has evolved from a traditional management-style State-owned enterprise to a highly competitive modern corporation. It has become the largest State-owned group with the most diverse and comprehensive lines of business, and strongest R&D capabilities in China's machinery industry.

By adhering to the business philosophy of "working together and pursuing win-win innovation," promoting "harmonious" cultural construction and focusing on two major core business areas of equipment manufacturing and modern manufacturing services, SINOMACH is committed to creating a new, "four-wheel-driven" development pattern involving "manufacturing, engineering, trade and capital." The company is determined to build a world-class enterprise with international competitiveness, thus becoming a front-runner of China's machinery industry and a propellant for mankind's progress.



B. SALIENT FEATURES OF THE FACILITY

Shigo Kas Hydropower Project (**"the Project"**) was one of the several projects identified during the joint study of Pakhtunkhwa Energy Development Organization (PEDO) and its German Consultant, GTZ in 1992. The project was proposed as run-of-river scheme on Panjkora River in the Lower Dir District of Khyber Pakhtunkhwa. The site is located at 10 km downstream of Timergara Town. The electric power generated at Shigo Kas Hydropower Station will disbursed at 220 kV Chakdara Grid Station.

General Information

(1)	Name of Applicant	Saifco Hydropower Limited
(2)	Registered/Business Office	Office Galleria, Plot No. 12, I-8 Markaz, Islamabad
(3)	Plant Location	Left Bank of Panjkora River, Village Shigo Kas, in District Lower Dir, Khyber Pakhtunkhwa
(4)	Type of Generation Facility	Hydropower Plant
(5)	Plant Size Installed Capacity (Gross)	102 MW
(6)	Plant type	Run of River
(7)	Water Source	Panjkora River
(8)	Type of Technology	Francis Vertical
(9)	Number of Units & Size(MW)	3 x 34 MW
(10)	Turbine Make & Model	Turbine Type is HL-LJ-245
(11)	De-rated Capacity at Mean Site Conditions	102.00 MW
(12)	Auxiliary Consumption	1.02 MW
(13)	Net Capacity	100.98 MW
(14)	Expected Commissioning and Commercial Operation Date (COD)	30 March 2024
(15)	Expected Life of the Facility from COD	30 Years

C. THE PROPOSED INVESTMENT

Debt 80% of the Total	=	US$ 245.79 Million
Equity 20% of the Total	=	US$ 61.45 Million
Total Project Cost	=	US$ 307.24 Million

SAIFCO HYDROPOWER LIMITED
SAIFCO GROUP

D. SOCIAL AND ENVIORNMENTAL IMPACT

The present EIA reveals that some moderate to significant negative environmental impacts are likely to occur due to the construction activities with few minor impacts during operations after the proposed construction. Recommendations are made to mitigate expected negative impacts. Implementation of appropriate mitigation measures during the construction, and operation phases will minimize the negative impacts of the Project to acceptable levels.

The Project will have an overall beneficial impact and any negative environmental impacts will be carefully monitored and mitigated. Therefore, the completion of this EIA fully meets both the ADB and EPA standards.

Lands in Shigo Kas Hydropower Project area comprise low cultivated lands, and larger area is waste lands. The project will consume 957 kanals of private land, of which 52 kanals are under cultivation and while the rest include community land and waste land.

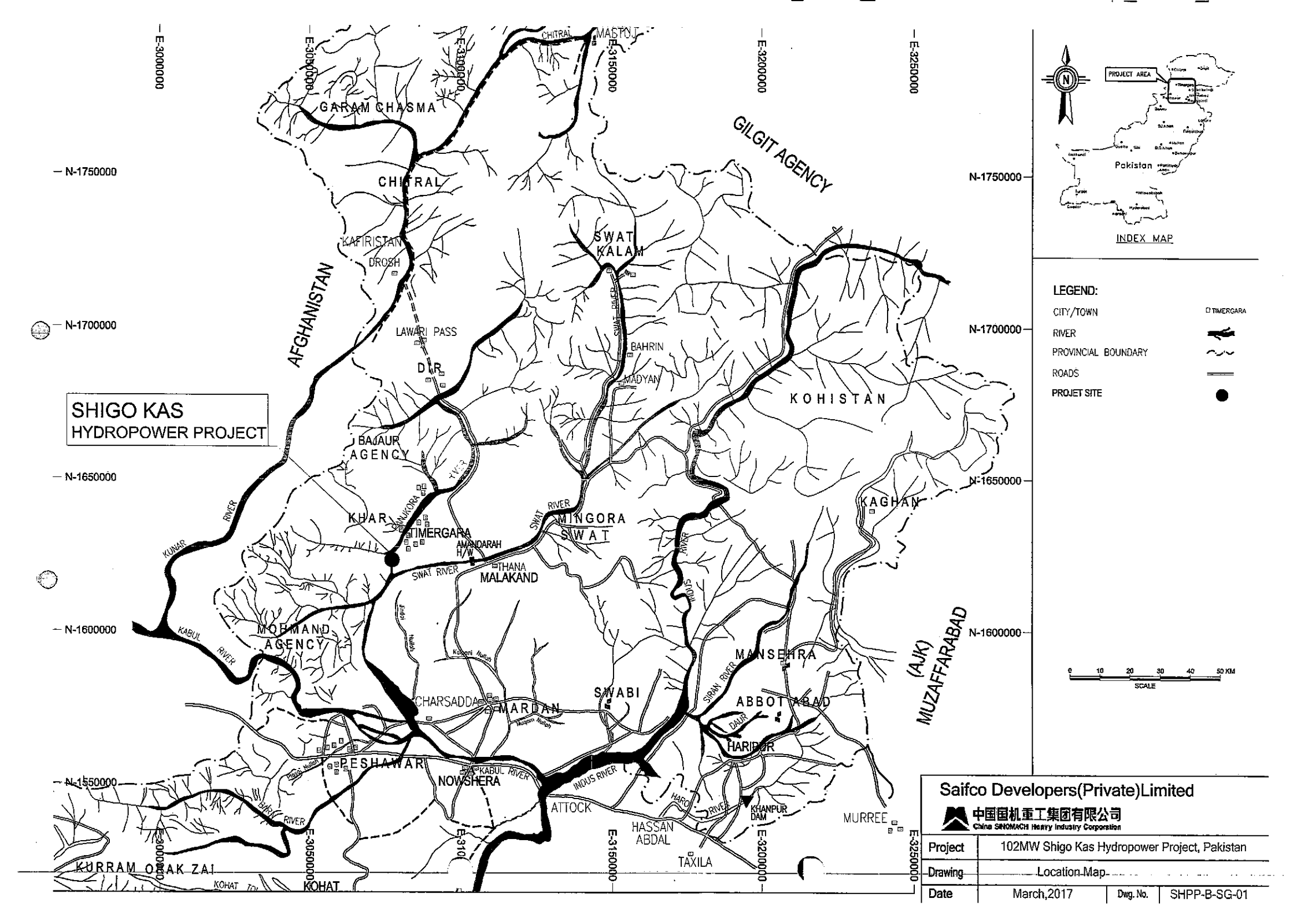
The Project will have an overall beneficial impact and the construction of the project will open job opportunities for the local people. This will help in raising their livelihood.

No resettlement issues are expected to arise.

No indigenous persons or female-headed household, being affected by the project, were identified.

No mosques, graves and sties of archaeological and historical importance will be affected due to implementation of proposed project.

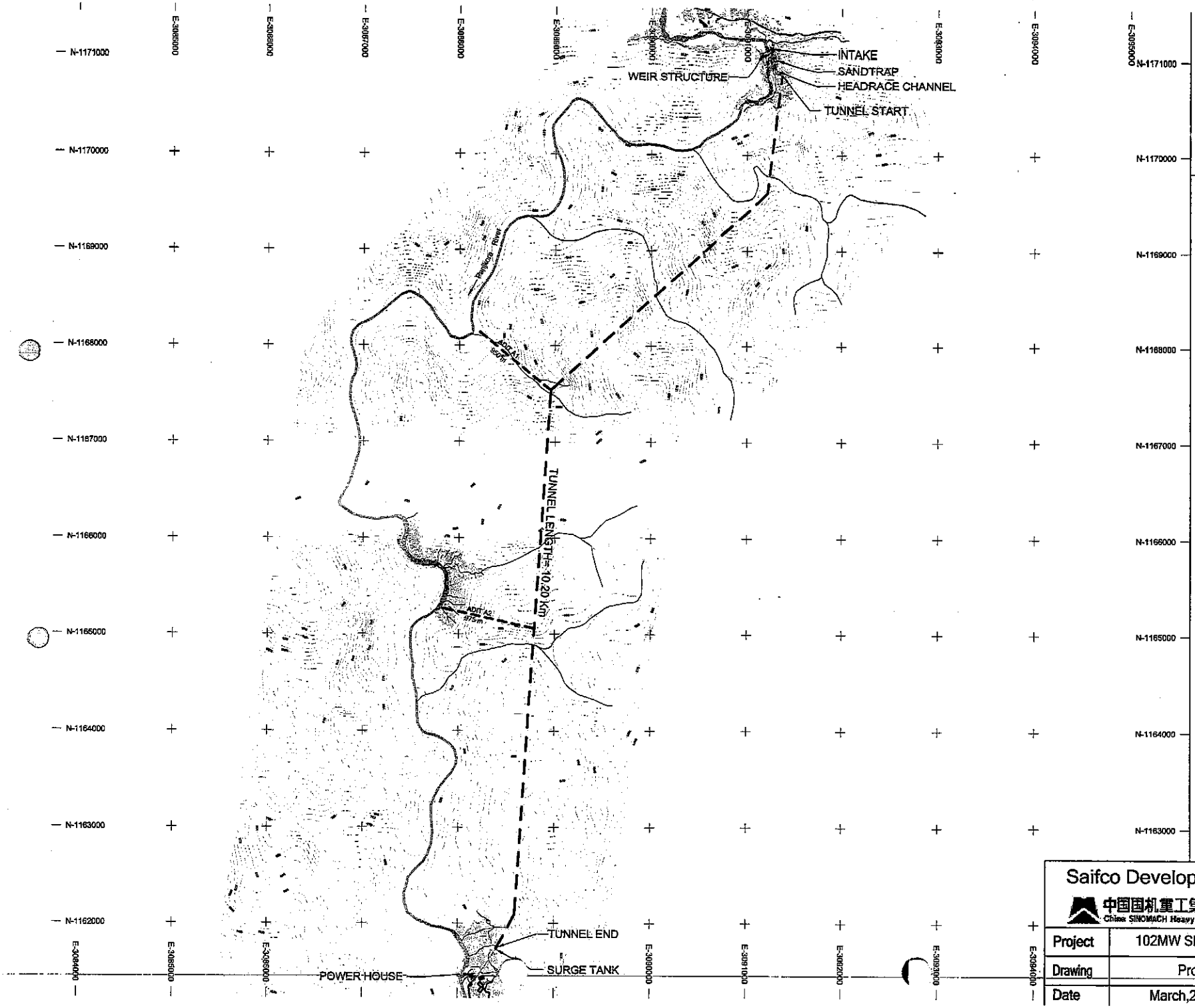
SAIFCO HYDROPOWER LIMITED
SAIFCO GROUP



Saifco Developers(Private)Limited

中国国机重工集团有限公司
China SINOMACH Heavy Industry Corporation

Project	102MW Shigo Kas Hydropower Project, Pakistan		
Drawing	Location Map		
Date	March,2017	Dwg. No.	SHPP-B-SG-01



N

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.

LEGEND:

- RIVER
- NULLAH
- HOUSES/SHOPS
- MOSQUE/SCHOOL
- ROAD
- TRACK

Saifco Developers(Private)Limited

中国国机重工集团有限公司
China SINOMACH Heavy Industry Corporation

Project	102MW Shigo Kas Hydropower Project, Pakistan		
Drawing	Project Layout Plan		
Date	March,2017	Dwg. No.	SHPP-B-SG-02

Environmental and Social Soundness Assessment (ESSA)

The ESSA of the Project was conducted as Part of Feasibility Study Report and incorporated in Chapter 11 & 12 of the Feasibility Report attached with the instant application. The summarized report of the ESSA is as follows:

(a) The present EIA reveals that some moderate to significant negative environmental impacts are likely to occur due to the construction activities with few minor impacts during operations after the proposed construction. Recommendations are made to mitigate expected negative impacts. Implementation of appropriate mitigation measures during the construction, and operation phases will minimize the negative impacts of the Project to acceptable levels.

(b) The Project will have an overall beneficial impact and any negative environmental impacts will be carefully monitored and mitigated. Therefore, the completion of this EIA fully meets both the ADB and EPA standards.

(c) Lands in Shigo Kas Hydropower Project area comprise low cultivated lands, and larger area is waste lands. The project will consume 957 kanals of private land, of which 52 kanals are under cultivation and while the rest include community land and waste land.

(d) The Project will have an overall beneficial impact and the construction of the project will open job opportunities for the local people. This will help in raising their livelihood.

(e) No resettlement issues are expected to arise.

(f) No indigenous persons or female-headed household, being affected by the project, were identified.

(g) No mosques, graves and sties of archaeological and historical importance will be affected due to implementation of proposed project.

Pakhtunkhwa Energy Development Organization (PEDO) vide its letter No. 418-19/PEDO/DPP/Shigo kas dated 23.02.2018 has forwarded National Electric Power Regulatory Authority (NEPRA) letter dated 19.02.2018 whereby we have been informed that (copies attached):

SAIFCO HYDROPOWER LIMITED
SAIFCO GROUP

"....The Authority hereby approves the bid evaluation report for the 102 MW Shigo Kas Hydropower Project, with a Levelized Tariff for the first ranked bidder @ Rs. 8.2658 per kWh (US cents 7.8947 per kWh). The recommended first ranked bidder, namely M/s Saifco Group, is hereby notified as the successful bidder for the 102 MW Shigo Kas Hydropower Project and is directed to file an application with the Registrar seeking approval of generation tariff, under Part-III of the CTBR-2014, within 15 days of this notification."

From perusal of the above, it is clear that we have been declared as success bidder by the NEPRA Authority and have been directed to file an application for approval of Generation Tariff within 15 days of the notification. Pursuant to Regulation 6(iv) of NEPRA Competitive Bidding Tariff (Approval Procedure) Regulations, 2014, the project company is required to file an application of Generation Licence.

We have appointed the consultant to revise/update the Environment and Social Impact Assessment including ESSA for the Project Site and we are expecting its completion shortly and would submit same to Environmental Protection Department, Government of Khyber Pakhtunkhwa, Peshawar for its approval within shortest possible time. We will submit before the NEPRA, approval of the ESSA as soon as it is received from the respective department.

It is further affirm and declare that we will comply with all the standards as may be notified by the relevant agency from time to time.

SAIFCO HYDROPOWER LIMITED
SAIFCO GROUP

RESETTLEMENT ISSUES

Lands in Shigo Kas Hydropower Project area comprise low cultivated lands, and settlements and larger area is waste lands. The project will consume 957 kanals of private land, of which 52 kanals are under cultivation and while the rest include community land and waste land.

The Project will have an overall beneficial impact and the construction of the project will open job opportunities for the local people. This will help in raising their livelihood.

No resettlement issues are expected to arise.

No indigenous persons or female-headed household, being affected by the project, were identified.

No mosques, graves and sties of archaeological and historical importance will be affected due to implementation of proposed project.

SAIFCO HYDROPOWER LIMITED
SAIFCO GROUP

PESHAWAR ELECTRIC SUPPLY COMPANY

PROJECT MANAGEMENT UNIT PESCO PESHAWAR
Phone # 091-9210987, Fax # 091-9213018

No. CE (Dev)/ 3114-181 Dated 29/07/2015

Chief Engineer (T&D)
PEDO Peshawar

Subject: **NOC / CONSENT OF PESCO FOR POWER EVACUATION OF ADVERTISED PRIVATE SECTOR PROJECTS**

Reference your letter No. 575-78/PEDO/DRE dated 22.07.2016.

The subject projects proposed / offered by PEDO to private sector can be connected to the existing / proposed grids of PESCO.

DA/List of projects

Chief Engineer (Dev) PMU
PESCO Peshawar

Copy to:

1. Chief Commercial Officer PESCO Peshawar.

SAIFCO HYDRO POWER LIMITED

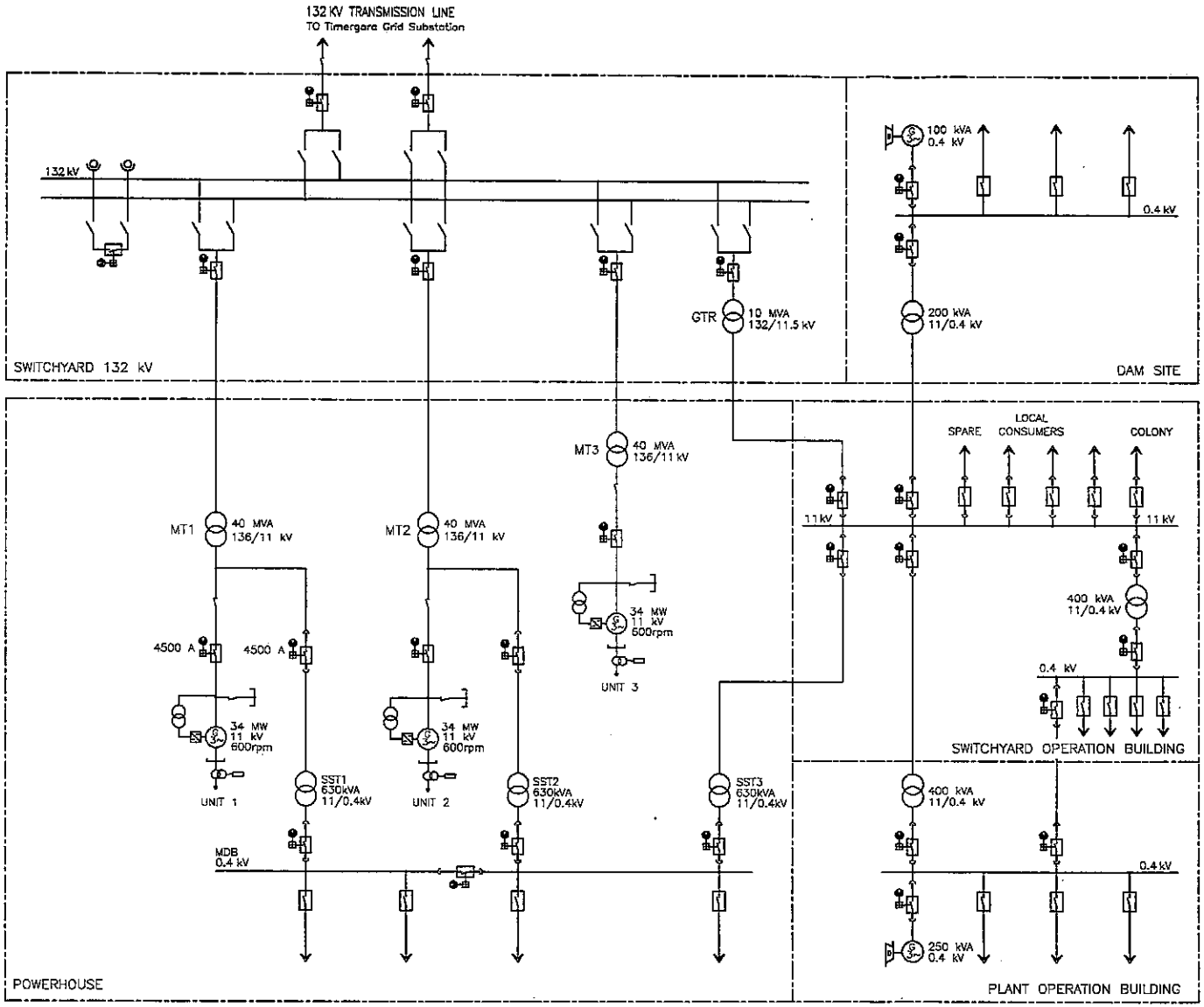
PEDO

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa Peshawar

PEDO Proposed Private Power Projects& their Connectivity / Grid Availability

S.No	Project Name	District	Capacity MW	Approximate Distance from Proposed Grid
1	Naran HPP	Manshera	188	60 kM from Balakot Grid Station ✓ Need G.Mansh
2	Batakundi HPP	Manshera	96	70 kM from Balakot Grid Station ✓
3	Arkari Gol HPP	Chitral	99	66 kM from Darosh Grid Station up gradation of 33 kV Darosh to 132 kV
4	Shigo Kach HPP	Lower Dir	102	20 kM from Chakdara Grid Station 220 kV Chakdara
5	Shaumai HPP	Upper Dir	150	10 kM from Chukitan, Dir up gradation of 66 kV Dir to 132 kV
6	Ghorband HPP	Shangla	21	12 kM from Besham Grid Station New 132 kV Besham
7	Nandihar HPP	Battagram	12	7 kM from Thakot Grid station upgradation of 33 kV Thakot to 132 kV

SAIFCO HYDRO POWER LIMITED
A SAIF GROUP



NOTES

1. ALL BAYS ARE SIMILAR AS REGARDS METERING.Total ... bays.
2. ALL GENERATORS SIMILAR IN DETAILS TO GENERATORS 1 & 2 INCLUDING PROTECTION
3. UNIT AUX. TRANSFORMERS ONLY ON GEN.1&2
4. FOR LEGEND AND ABBREVIATIONS SEE DRAWING NO.DQ-01.

Saifco Developers(Private)Limited

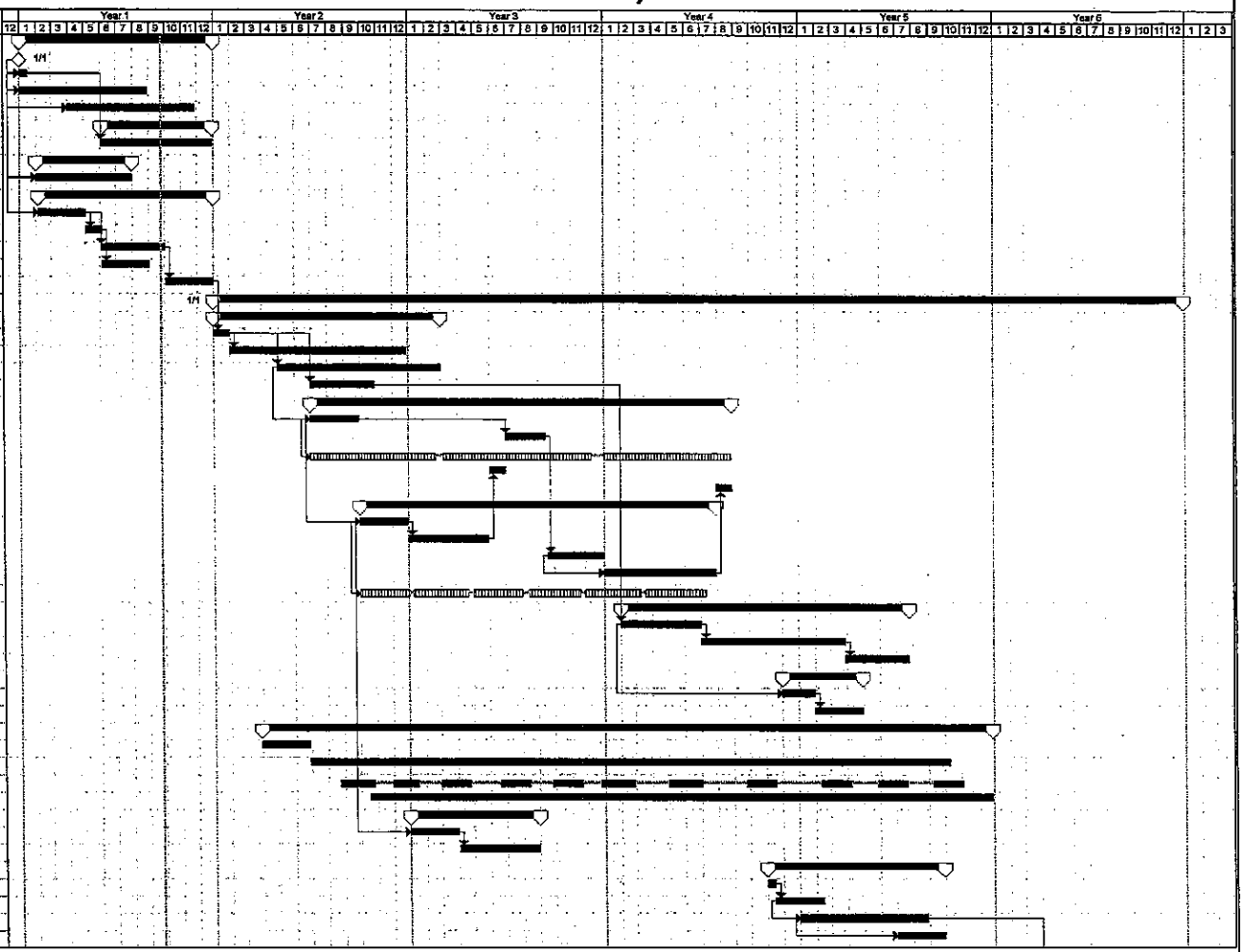
中国国机重工集团有限公司
China SINOMACH Heavy Industry Corporation

Project	SHIGO KAS Hydropower Project, Pakistan		
Drawing	Electrical equipment overall single line diagram		
Date	March,2017	Dwg. No.	SHPP-B-DQ-02

FIGURE 14.1

SHIGO KAS HYDROPOWER PROJECT DISTRICT DIR
(OVER ALL IMPLEMENTATION SCHEDULE)

ID	Task Name	Duration
1	**1 Pre-Construction Stage**	**365 days**
2	1.1 Feasibility Study	0 days
3	1.2 PC - I	15 days
4	1.3 Tariff, Power Sales Terms & NEPRA Approval, Misc.Legal Issues & Approvals	240 days
5	1.4 Power Purchase Agreement & Water Use Agreement	240 days
6	**1.5 Land Acquisition**	**210 days**
7	1.5.1 Program Set-up & Land Acquisition	210 days
8	**1.6 Permits and Approvals**	**180 days**
9	1.6.1 Environmental Clearance & Generation License	180 days
10	**1.7 Consultancy and Tendering**	**330 days**
11	1.7.1 Appointment of Consultant	90 days
12	1.7.2 Additional Investigation and surveys	30 days
13	1.7.3 Tender Design & Tender Documents, Tendering and Receiving Bids	120 days
14	1.7.4 Prequalification of EPC Contractor	90 days
15	1.7.5 Tender Evaluation and Selection of Contractor & Negotiation and Awards	90 days
16	**2 Construction Stage**	**1824 days**
17	**2.1 Preparatory Works**	**425 days**
18	2.1.1 Notice to Proceed + Mobilization	30 days
19	2.1.2 Detail Design of Civil other Works, Offices, Camps, Colony & Other Site Facilities	330 days
20	2.1.3 Access Road in working area I/c Power House & Colony	305 days
21	2.1.4 Concrete Plant and Equipment	120 days
22	**2.2 River Diversion**	**790 days**
23	2.2.1 Construction of Embankment for Stage-I Cofferdam	90 days
24	2.2.2 Construction of Embankment for Stage-II Cofferdam	75 days
25	2.2.3 Care and Handling of Water & Dewatering	750 days
26	2.2.4 Removal of Cofferdam Stage-I	30 days
27	2.2.5 Removal of Cofferdam Stage-II	30 days
28	**2.3 Construction of Weir and Intake**	**668 days**
29	2.3.1 Excavation Stage-I and backfilling	90 days
30	2.3.2 Foundation Treatment, RCC in (Weir, Intake), Installations of (Trash racks, Contr	150 days
31	2.3.3 Excavation Stage-II and backfilling	105 days
32	2.3.4 Foundation Treatment, RCC in (Weir, Intake), Installations of (Trash racks, Contr	210 days
33	2.3.5 Care and Handling of Water & Dewatering	600 days
34	**2.4 Sand Trap**	**540 days**
35	2.4.1 Excavation and backfilling	150 days
36	2.4.2 Reinforced Concrete in Sand Trap Chambers / Forebay	270 days
37	2.4.3 Installations of (Mechanical Embedded Parts, Trash racks, Control Gates, S.Guard	120 days
38	**2.5 Connecting Channel**	**150 days**
39	2.5.1 Surface Excavation	60 days
40	2.5.2 Lean Concrete, RCC in Channel Walls / bed , Instalation of (Guardrail + security f	90 days
41	**2.6 Power Tunnel**	**1372 days**
42	2.6.1 Portal Excavations	90 days
43	2.6.2 Underground Excavations,	1200 days
44	2.6.3 Rock Bolting and Shortcrete,	630 days
45	2.6.4 Reinforced Concrete in Power Tunnel Lining	1169 days
46	**2.7 Surge Shaft**	**243 days**
47	2.7.1 Portal & Underground Excavations	90 days
48	2.7.2 Concreting and Rock Bolting, Reinforced Concrete in Portals & in Surge Shaft & I	150 days
49	**2.8 Penstock / Pressure Shaft**	**332 days**
50	2.8.1 Alignment for Penstock	15 days
51	2.8.2 Excavations	90 days
52	2.8.3 Fabrication & Erection of Steel Liner / Gate / Trashrack	240 days
53	2.8.4 Reinforced Concrete in Anchor Blocks for Penstock	90 days



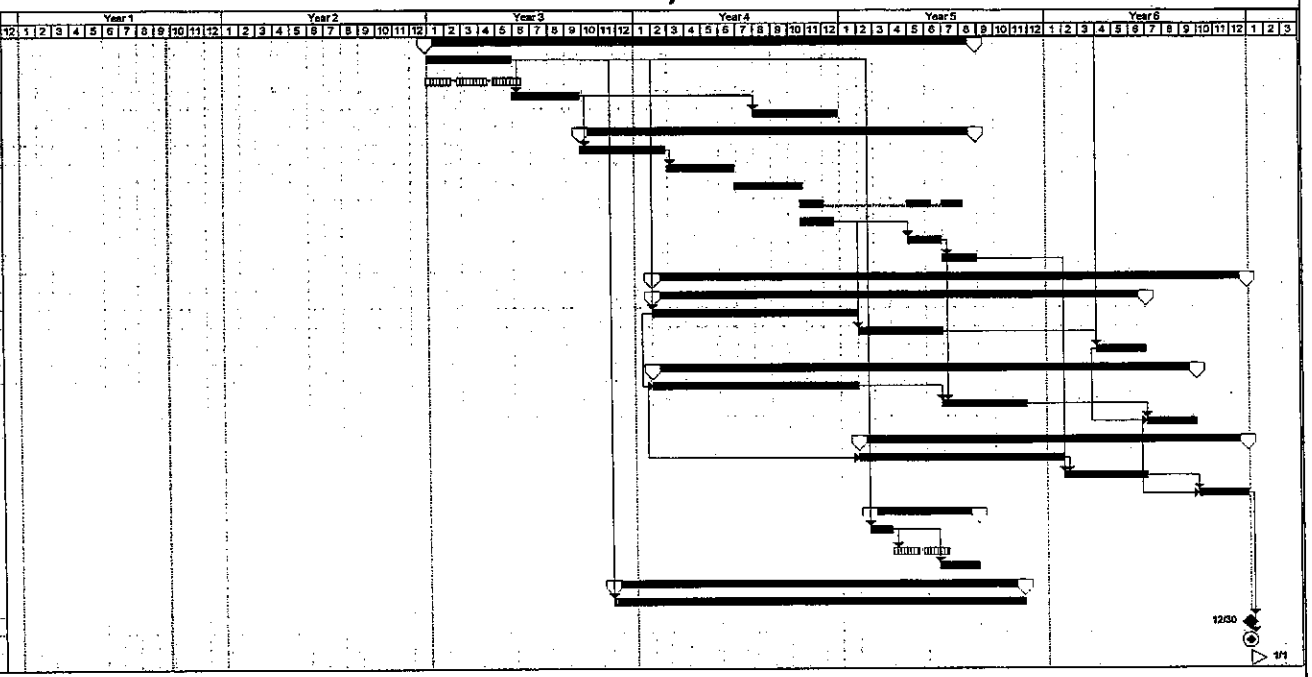
Project: Shigo Kas HPP
Location: District Lower Dir

Task
Mile Stone
Task Summary
Split
Care & Handeling of Water
Comercial Operation
Takeover Certificate

FIGURE 14.1

SHIGO KAS HYDROPOWER PROJECT DISTRICT DIR
(OVER ALL IMPLEMENTATION SCHEDULE)

ID	Task Name	Duration
54	**2.9 Power House**	**975 days**
55	2.9.1 Excavation	150 days
56	2.9.2 Dewatering	150 days
57	2.9.3 Foundation Treatment	120 days
58	2.9.4 Fabrication and Fixing of Doors & Windows & Architectural Works	150 days
59	**2.9.5 Concrete**	**701 days**
60	2.9.5.1 Concrete in Foundations	150 days
61	2.9.5.2 RCC in (Draft tubes , Turbine Floor and Walls)	120 days
62	2.9.5.3 Reinforced Concrete in Superstructure	120 days
63	2.9.5.4 Second Stage Conrete	120 days
64	2.9.5.5 Installation of Embedded Parts of Unit -1	60 days
65	2.9.5.6 Installation of Embedded Parts of Unit -2	60 days
66	2.9.5.7 Installation of Embedded Parts of Unit -3	60 days
67	**2.10 Electrical and Mechanical Works**	**1062 days**
68	**2.10.1 Unit-1**	**879 days**
69	2.10.1.1 Fabrication and Delivery of Embedded Parts, E & M Equipment	365 days
70	2.10.1.2 Erection of (Turbine, Generator and other Equipment)	150 days
71	2.10.1.3 Wet testing and Commissioning	90 days
72	**2.10.2 Unit-2**	**970 days**
73	2.10.2.1 Fabrication and Delivery of Embedded Parts, E & M Equipment	365 days
74	2.10.2.2 Erection of (Turbine, Generator and other Equipment)	150 days
75	2.10.2.3 Wet testing and Commissioning	90 days
76	**2.10.3 Unit-3**	**697 days**
77	2.10.3.1 Fabrication and Delivery of Embedded Parts, E & M Equipment	365 days
78	2.10.3.2 Erection of (Turbine, Generator and other Equipment)	150 days
79	2.10.3.3 Wet testing and Commissioning	90 days
80	**2.11 Tailrace**	**193 days**
81	2.11.1 Excavation	40 days
82	2.11.2 Dewatering	90 days
83	2.11.3 Reinforced Concrete in Tailrace, Installations of Mechanical Embedded Parts and	70 days
84	**2.12 Transmission Interconnection**	**730 days**
85	2.12.1 Construction of Powerhouse Switchyard, Transmission Line	730 days
86	**3 Start of Commercial Operation**	0 days
87	**4 Taking over Certificate**	1 day
88	**5 Deffect Liability Period (As per Client Requirement)**	0 days



Project: Shigo Kas HPP
Location: District Lower Dir

Task
Mile Stone
Task Summary
Split

Care & Handeling of Water
Comercial Operation
Takeover Certificate

SYSTEM STUDIES LOAD FLOW, SHORT CIRCUIT, STABILITY

Pakhtunkhwa Energy Development Organization (PEDO) vide its letter No. 418-19/PEDO/DPP/Shigo kas dated 23.02.2018 has forwarded National Electric Power Regulatory Authority (NEPRA) letter dated 19.02.2018 whereby we have been informed that (copies attached):

> *"....The Authority hereby approves the bid evaluation report for the 102 MW Shigo Kas Hydropower Project, with a Levelized Tariff for the first ranked bidder @ Rs. 8.2658 per kWh (US cents 7.8947 per kWh). The recommended first ranked bidder, namely M/s Saifco Group, is hereby notified as the successful bidder for the 102 MW Shigo Kas Hydropower Project and is directed to file an application with the Registrar seeking approval of generation tariff, under Part-III of the CTBR-2014, within 15 days of this notification."*

From perusal of the above, it is clear that we have been declared as Success Bidder by the NEPRA Authority and have been directed to file an application for approval of Generation Tariff within 15 days of the notification. Pursuant to Regulation 6(iv) of NEPRA Competitive Bidding Tariff (Approval Procedure) Regulations, 2014, the project company is required to file an application of Generation Licence.

The Request for Proposal (RFP) issued by Pakhtunkhwa Energy Development Organization (PEDO) stats that:

> *"2.1.2 The Successful Bidder will be responsible for construction, operation and maintenance of Power Generation Complex and* ***Transmission System up to designated Interconnection point****. The power evacuation arrangement will be made by DISCO/NTDCL from the designated Interconnection point."*

We have appointed consultant to carryout System Studies Load Flow, Short Circuit, Stability and it is hoped that the same will be completed and submitted to NTDC for its approval within shortest possible time. We will submit before the NEPRA, approved studies as soon as it is received from the respective departments.

SAIFCO HYDROPOWER LIMITED
SAIFCO GROUP

TRAINING AND DEVELOPMENT

Job Site Training

When the Employer deems it advisable to send on the Site five (5) employees intended to operate and maintain the Plant, the Contractor shall instruct such employees in the operation and maintenance of the said Plant. This course of instruction shall be carried out by one or more of the Contractor's Plant Erectors and such instructions shall be in English language. These services may commence during erection of the Plant and shall be required periodically up to the completion of Commissioning Tests.

Foreign Training

The Contractor shall provide such facilities for the training of such numbers of staff of the Employer on the Contractor's premises or wherever else work.

(a) All costs and expenses towards such training including boarding, lodging and transportation of trainees shall be borne by the Contractor. Besides daily allowance shall be paid by the Contractor to the trainees at the rate specified in the Schedule of Prices. The rates entered in the Schedule of Prices shall be deemed to have included these costs.

(b) The cost for such training entered in the Schedule of Prices shall constitute full compensation for the costs of round trip economy class air tickets for the trainee from Pakistan to the place of training and back to Pakistan, the cost of all inland transportation in the country of visit, and all other incidentals related to such training. The prices in the Schedule of Prices shall be deemed to include the wages of the Contractor's personnel providing training and use of office facilities, literature, drawings, models etc. to be supplied by the Contractor to the trainees of the Employer's staff.

(c) The Contractor shall also provide medical expenses or medical insurance for trainees. The cost of which shall be deemed to have been included in the rates entered in Schedule of Prices.

(d) Language of training at Contractor"s premises shall be English otherwise the Contractor shall be responsible for providing language course to the trainees as well as services of suitable number of interpreters and such costs shall be deemed to be included in the rate quoted for the training.

(e) The Contractor shall provide such facilities for the training of such numbers of staff of the Employer on the Contractor's premises or wherever else work in connection with the Contract is in hand as specified in the Schedule of Prices or directed by the Employer.

(f) All costs and expenses towards such training including boarding, lodging and transportation of trainees shall be borne by the

SAIFCO HYDROPOWER LIMITED
SAIFCO GROUP

Contractor. Besides daily allowance shall be paid by the Contractor to the trainees at the rate specified in the Schedule of Prices. The rates entered in the Schedule of Prices shall be deemed to have included these costs.

(g) The cost for such training entered in the Schedule of Prices shall constitute full compensation for the costs of round trip economy class air tickets for the trainee from Pakistan to the place of training and back to Pakistan, the cost of all inland transportation in the country of visit, and all other incidentals related to such training. The prices in the Schedule of Prices shall be deemed to include the wages of the Contractor's personnel providing training and use of office facilities, literature, drawings, models etc. to be supplied by the Contractor to the trainees of the Employer's staff.

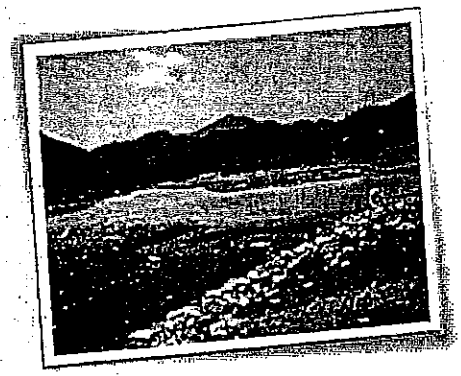
(h) The Contractor shall also provide medical expenses or medical insurance for trainees. The cost of which shall be deemed to have been included in the rates entered in Schedule of Prices.

(i) Language of training at Contractor's premises shall be English otherwise the Contractor shall be responsible for providing language course to the trainees as well as services of suitable number of interpreters and such costs shall be deemed to be included in the rate quoted for the training.



PEDO

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
GOVERNMENT OF KHYBER PAKHTUNKHWA







SHIGO KAS HYDROPOWER PROJECT DISTRICT LOWER DIR

FEASIBILITY REPORT

October 2014

VOL 1 OF 3

ELECTRA CONSULTANTS
In association with
INTEGRATION environment & energy GmbH

Project Office:
71, Street 4, Sector N-3, Phase IV, Hayatabad, Peshawar, KPK
Tel: +92 91-5812934, Fax: +92 91-5837842, Email: dir3projects@yahoo.com

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
DISTRICT LOWER DIR

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LIST OF ABBREVIATIONS

AC	Alternating Current
ADB	Asian Development Bank
AIS	Air Insulted Switchgear
AJK	Azad Jammu & Kashmir
ANSI	American National Standards Institute
ASTM	American Standards of Testing Materials
BC	Benefit Cost Ratio
BM	Bench Mark
BOO	Build–Own–Operate
BOT	Build–Operate–Transfer
BS	British Standards
CAD	Computer-Aided Design
CAM	Computer-Aided Manufacturing
CCTV	Closed-Circuit Television
CDM	Clean Development Mechanism
CER	Certified Emission Reductions
CMTL	Central Materials Testing Laboratory
COSHH	Control of Substances Hazardous to Health
CT	Current Transformer
DC	Direct Current
DEM	Digital Elevation Model
DTM	Digital Terrain Model
DWT	Dead Weight Tonnage
E&M	Electrical & Mechanical
EA	Environmental Assessment
EDM	Electronic Distance Measurement
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EPA	Environmental Protection Agency
FGDs	Focus Group Discussions
FIRR	Financial Internal Rate of Return
GIR	Geotechnical Investigation Report
GIS	Geographical Information System



GPS	Global Positioning System
GRSC	Grievance Redress and Settlement Committee
GSP	Geological Survey of Pakistan
GTZ	Deutsche Gesellschaft fur Techniche Zusammenarbeit
HV/LV	High Voltage/Low Voltage
ICOLD	International Commission on Large Dams
IEC	International Electro-technical Commission
IEE	Initial Environmental Examination
IEEE	Institute of Electrical and Electronics Engineers
ILO	International Labour Organization
IUCN	International Union for Conservation of Nature
JICA	Japan International Cooperation Agency
KP	Khyber Pakhtunkhwa
LAN	Local Area Network
LED	Light Emitting Diode
MASL	Meter Above Sea Level
MPa	Mega Pascal
MSDS	Material Safety Data Sheets
MW	Mega-Watt
NE	North East
NEQS	National Environmental Quality Standards
NFPA	National Fire Protection Association
NPCC	National Power Control Center
NPV	Net Present Value
NSL	Natural Surface Level
NTDC	National Transmission and Dispatch Company
O&M	Operation & Maintenance
OPGW	Optical Ground Wire
PABX	Private Automatic Branch Exchange
PAPs	Project Affected Persons
PEDO	Pakhtunkhwa Energy Development Organization
PMD	Pakistan Meteorological Department
PRA	Participatory Rural Appraisal
PVC	Polyvinyl Chloride
RQD	Rock Quality Designation
SBM	Standard Bench Mark



SCADA	Supervisory Control and Data Acquisition
SOP	Survey of Pakistan
SRR	Seismic Refraction Report
SRTM	Shuttle Radar Topographical Mission
SWHP	Surface Water Hydrology Project
SWOT	Strengths, Weaknesses, Opportunities and Threats
TEUs	Twenty-Foot Equivalent Units
TOR	Terms of Reference
UHF	Ultrahigh Frequency
UPS	Uninterrupted Power Supply
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
VT	Voltage Transformer
WAPDA	Water and Power Development Authority
WHO	World Health Organization



EXECUTIVE SUMMARY

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EXECUTIVE SUMMARY

1. Introduction

Shigo Kas Hydropower Project was one of the several projects identified during the joint study of Pakhtunkhwa Energy Development Organization (PEDO) and its German Consultant, GTZ in 1992. Shigo kas Hydropower Project was proposed as run-of-river scheme on Panjkora River in lower Dir District of Khyber Pakhtunkhwa. The Site is located at 10 Km downstream of Timergara Town.

In the year 2012, PEDO appointed M/s ELECTRA in association with M/s INTGERATION to conduct feasibility study for Shigo Kas Hydropower Project i.e. 26 MW (Project TOR) in lower Dir District of KPK. Location of the project is shown on Figure 8.1 of the main report.

The present Feasibility Report pertains to Shigo Kas Hydropower Project is preceded by draft feasibility report, Mid Term Report and Inception Report submitted earlier. The latest planning studies and surveys reveal that the project can be upgraded to as much as 102 MW capacity instead of 26 MW mentioned in TOR. Salient features of the project are given in Table 1 at the end of the Executive Summary.

2. Topographic Survey and Satellite Images (GIS)

Topographic survey of Shigo Kas HPP area is conducted earlier in 2012/2013. Planning and layout studies are based on Topographic maps developed there from.

Topographic Survey has been carried out in the project area for establishing, inter alia, the existing ground levels. Locations of physical features like rivers, streams, roads and communication systems have been marked using modern equipments. Consultants also established control points at locations easily accessible and identifiable at later stage and acquired field survey data in digital format. The data has been processed using appropriate computer software.

To carry out the project layouts and the feasibility level engineering design of hydropower project sites, following main tasks have been included in the survey scope of work:

- Installation of Permanent survey control points established at appropriate locations with BM level.
- Processing of topographic survey digital data by using survey software.

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- Generation of topographic sheets by using CAD/CAM techniques.
- Production of topographic survey drawings for different structures as per scale and mentioned in TOR.

Most of the survey mapping was carried out at different structures at a scale of 1:500 and contour interval of 1m. Survey maps were prepared on standard format containing location of each control point, its detailed description, final coordinates and elevation above sea level. Traversing was carried out to establish control points whereafter vertical control was established and detailed topographic survey was completed. Topographic map of the project area is shown in chapter 3 of main report.

3. Geology, Geotechnical Engineering and Construction Materials

Geological and geotechnical investigations have been carried out to study regional and local area geological and tectonic set up through geological mapping, scan line discontinuity survey, drilling works and geophysical survey. Test pits were excavated for determining potential sources of construction materials.

The project area lies at the margin of Kohistan island arc and Higher Himalaya near the Main Mantle Thrust, MMT. The southern part of project area is comprised of Higher Himalayan rocks while the northern part comprised of rock of Kohistan sequence.

Higher Himalayan rocks are comprised of granite gneisses and its cover metamorphosed amphibolites .These units further extended westward to Dir, Bajaur and Afghanistan.Two distinct varieties of gneisses can be characterized in the project area i.e. Granite Gneiss and Schistose Gneiss.

Rocks of Kohistan sequences are found in the north of MMT and it is comprised of ultramafics-mafic rocks of ophiolites and Kamila amphibolites and volcanics.

Following are the main units of the soil / rock in the project area

Stratigraphic sequence of the project area consists of Indian mass rocks of lower Sawat Buner group mainly consists of granitic gneiss (Chakdara Granite Gneisses), it is granite with siliceous schist layers on the peripheries. These rocks are medium to coarse grained with association of Schistose Gneisses and Quartz mica Schist phyllitic gneiss, Phyllite and quartzite intercalations have been observed in the project area at higher elevations.

Major rock group of the project area are Granitic gneiss and widely spread along well, intake area, Sand trap, intake of tunnel, along the tunnel and power house areas. Poorly to well

outcropped in and around Tunnel and outlet portal, in most of the reaches along Tunnel, rock of the area is well exposed and widely distributed under thin to thick cover of Secree/Colluviums and terrace deposits, details are described in next relevant sections.

River bed is composed of medium to coarse grained sand, gravel, pebble, cobble even boulders. These materials belong to all three type crustal rock but especially at weir metamorphic with few igneous boulder and gravel material are dominated. Riverbed of Panjkora River itself is narrow to sufficiently wide at places. Hence deltas and meander are happening to exist at different area.

Cultivated land of the project area is flat to medium terraces on slopes composed of Silty Clayey Sand/Clayey Sandy Silt with gravels and occasional boulders at the surface.

Geotechnical investigation study was carried out, aimed at provide the required surface and sub-surface information about the Rock, Overburden materials/Colluviums, terraces / river deposits (Alluviums) and Scree materials, sliding zones and the rock strata at the significant structures in the Project area and to develop the geotechnical design parameters for all the structures and most important part of this stage of study is to define the structures at sound and safe areas regarding geological and geotechnical conditions.

Various investigation and field testing were carried out i.e. Exploratory drilling of borehole (Bore hole logs), Test Pits logs, Field testing (Permeability Tests, Water Pressure Tests), Lab Results of material (Chemical Analysis of rock core samples, Rock core modulus, grain size analysis, ASR analysis), Shigo Kas Seismic Refraction Survey.

The availability of the construction materials for the Project has also been studied and it has been found that suitable materials for concrete aggregates shall be available at and near the vicinity of site. The Panjkora river bed and its higher terraces are the major source of nearly all types of the construction materials. The coarse and fine (sand) aggregates are currently being mined at numerous places from the river bed for local use. Second sources are the manufacturing crush plants in the vicinity of project area. Cohesive soils for the blanket can also be obtained from the upper terraces of Panjkora river, selecting the terraces which are relatively barren.

Cement can be transported from Cherat, Nizamabad and Bestway cement factories situated some 150 to 250 km from the Project area, near Nowshehra and Islamabad or other cement manufacturing industry.

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Water in general seems quite suitable for construction purposes; however with reference to some other close vicinity Panjkora water analysis, results meet the requirement of portable water and can be used for all construction works.

Steel, like cement, is not locally available and shall have to be procured from markets in Peshawar, Rawalpindi and Lahore.

4. Hydrology and Sedimentation

The available Hydro-meteorological data such as daily and hourly rainfall, daily stream flows, temperatures, evaporations and sediment data etc. has been collected and used for determining power potential, maximum floods and flow duration curve.

Flow measurements are being performed on Panjkora River at hydrological station since the installation of the gauge by PEDO at Zulam Bridge. Daily flow data is available from year 2000 to 2004 and 2010 to 2011. The same has been collected from PEDO for further processing to study the behavior of the flows. Keeping in view the missing data series of this stream from August 1961 to Oct 2009, the flows of Panjkora River were extended with the help of runoff relationship of nearby rivers with long term recorded data.

Extension of flows for Panjkora River at Shigo Kas has been made with the help of available long term recorded daily flows of nearby rivers having same characteristics. In this regards nearby rivers Panjkora at Koto, Zulam, Bibior, Sharmai, Swat at Kalam and Chitral River at Chitral were considered and relationships were investigated. Long term flow series 1961-2011 of Panjkora River at Shigo kas have been used for the final selection of flow pattern for water availability. Location of these stations is given in Chapter-4 (Hydrology and Sedimentation) of the main report.

From flow duration curve and the subsequent optimization studies, it has been concluded that the optimum discharge for power generation is the one that is available for about 37% of the time during the year which comes to 150m^3/s.

Flood studies have been carried out using statistical approach, Flood Frequency Analysis, Unit Hydrograph method, Regional Method, Method of Relationship with Peak Floods in Sub-catchments, Slope Area Method, 24 hours maximum rainfall data and estimation of floods using HEC-HMS. It is concluded that 10,000 year return period flood of 5569 m^3/s is appropriate for the design of weir. The above mentioned analysis can be seen in Chapter-4 of Main Report.

Total sediment load at proposed dam site has been computed by adding the bed load to the estimated suspended sediment load as given below:

Sr. No.	Description	Sediment Load (Million Tons)
1	Mean Annual Suspended Sediment Load	4.66
2	Mean Annual Bed Load	0.89
3	Total Annual Load	5.55

Mean monthly variation of the total sediment load is shown in Figure 4.85 of the main report.

The results show a large amount of sediment inflow which requires appropriate arrangements and design for effective and timely flushing of the sediments for proper operation of the power plant.

5. Seismic Hazards

Geotectonic of the Northern Pakistan is related to the collision of the two plates namely Indian Plate with Eurasian plate, and subsequent formation process of the Himalayan ranges. The intercontinental collision has resulted in intense deformation with complex folding involving strike-slip and thrust faulting. This tectonic process is the origin of the seismicity along the Himalayas and in particular where Northern Pakistan is located. The major regional faults related to the intercontinental collision and considered to be active and capable of generating earthquakes, include;

- Hazara Thrust Fault System
- Main Boundary Thrust (MBT)
- Main Frontal Thrust (MFT)
- Kashmir Thrust (KT)
- Main Mantel Thrust (MMT)

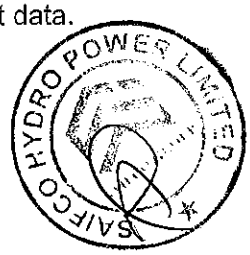
Shigo kas Hydropower project is located in Dir, near the vicinity of Main Mantle Thrust (MMT), in a zone which is seismically active due to the Continuing northward drifting of the Indian plate and its subduction under the Eurasian plate. This tectonic activity has resulted in the production of a crustal accretion wedge; The Himalayan range. Seismic Hazard Evaluation, based on

available data / literature regarding regional geology, tectonics, non-instrumental and instrumental seismicity, has been carried out for Shigo kas Hydro Power Project by including some 618 events in the present study (since 1927).

The Deterministic Seismic Hazard Analysis (DSHA) has revealed that for Shigo kas Hydropower Project, Main Mantle Thrust/Reshun Fault could be the critical fault, capable of generating a magnitude 7.6 Mw Earthquake (equivalent October 8, 2005 Kashmir Earthquake). Maximum Credible Earthquake due to active faults in the region is calculated to be of the order of 0.46g due to an earthquake 7.6 magnitude, having a hypocenter at 30 km from the site.
Operating Basis Earthquake (OBE) acceleration can be assumed to be half of MCE value, but keeping the fact in mind that the seismic gap perpetually floats on the fault and wherever the situation is seismically suitable, a quake is triggered. Once an area experiences a quake, its epicentral volume is crushed and it becomes unable to accept any further geo-technical stress. This means that once an area has experienced an earthquake, it will not experience another earthquake of a similar magnitude for a long time. The time gap is usually about three to five times the return period of the earthquake. The available seismic data has been analyzed to evaluate Peak Ground acceleration (PGA) at the site. The calculated value of Peak Ground acceleration for Shigo kas Hydropower project site is 0.05g. After applying the necessary safety factor and calculating the rupture of MMT and Reshun fault the calculated PGA again comes out to be 0.31g.

Peak Ground Acceleration at Shigo kas Hydropower Project Site from Earthquake records since 1927.	0.05g
Design Spectral Acceleration Value	0.11g to 0.5g (mean 0.31g)
Half of MCE value	0.31g
Operational Basis Earthquake value at Shigo kas Hydropower Project site	**0.31g**

Shigo kas site is around 80 km from major tectonic features called Main Mantle Thrust (MMT) and appears to be a seismically active tectonic zone. Data of 618 earthquake events within 110 kilometers (1 degree) quadrangle distance, around Shigo kas has been collected from International and National agencies. The density of earthquakes is quite scattered, and apparently no structural/tectonic features can be interpreted from that data.



6. Project Layout and Hydraulic Design Considerations

6.1 Project Layout

The head works site from GTZ report has been recommended by the Client and therefore adopted by the Consultants. The headwork is proposed near Shigo kas village. The headwork comprises of concrete weir having two distinct sections in plan view, one overflow section and other Gated section. The intake of water is located on the left bank of Panjkora River. The sand trap is just downstream the intake. Three chambered sand trap has been proposed along the left bank for sediment exclusion. From the end of the sand trap, the water is conveyed to the headrace tunnel by a 65 m connecting rectangular channel. The headrace tunnel is 10.22 Km long having7m diameter horseshoe section with cross-sectional area of 40.63 m^2- finish. Surge shaft (20m Dia) is located at end of the tunnel is exposed to the surface. A horizontal pressure tunnel of 6m diameter leads to a valve chamber. An inclined penstock 5.5 m in diameter will drop from valve chamber to penstock manifold, feeding three generating units accommodated in the powerhouse in open cut on the left bank of Panjkora River. The powerhouse site is located at village Mitta which is downstream of village Utala. A 31 m long tailrace channel conveys water from powerhouse and discharges into the Panjkora River.

6.2 Hydraulic Design Considerations

The hydraulic design studies of Shigo kas Hydropower Project include design of weir, intake, sand trap, power tunnel, surge shaft, penstock, powerhouse and tailrace.

The hydrological studies show that minimum and maximum mean monthly discharges in Panjkora River at Shigo Kas site are 40 m^3/s and 366 m^3/s respectively. Based on economic evaluation and optimization, it was decided that power intake would be designed for rated discharge of 150 cumecs that will produce approximately 102 MW of power.

The overall weir length is 113 m comprising of an overflow section of 25 m and two gated section. The full reservoir elevation is 650 masl. The average river bed level is at El. 639 masl. The total height of the weir is 11 m above the average bed. The weir is designed to pass a flood of 5600 cumecs corresponding to a flood level of 654 masl. The gated section with stilling basin will be provided in the center of existing river course. It will be used to spill excess flows and small floods in summer season while the powerhouse is still in operation. It has a discharge capacity of up to 2000 m^3/s at normal operating level of 650 masl.

The gated section with roller buckets will be provided at the left bank. It will only be used during extreme floods when the tailwater level is sufficiently high for proper operation of roller buckets.

It will also be used occasionally to flush the river bed load which has been deposited in front of the power intake. The plan and sections of weir structure are shown in Figures 8.3 to 8.8 of the main report.

The intake structure off takes from the left bank of Panjkora River, The intake consists of 03 no. culvert inlets each 9.8m x 5m. The height of inlet gradually reduces from 5m to 3m through a parabolic profile of roof curve. The width of inlets reduces from 5m to 3.5m in a length of 5m. Three vertical lift type intake gates, each 5.8m x 3.5m, are provided after the bend section. There is provision of stop logs at the downstream side of intake gates in order to carry our repairs of one gate while the other gate is still open and transferring flows to the connecting channel. The inlet structure is shown in Figure 8.9 & 8.10 of the Main Report.

The inlet of sandtrap is located 15m downstream of the centerline of gates for intake structure The flows from intake directly enter the sand trap . The inlet width of sandtrap is 20.5 m which gradually increases to its maximum width of 49m in a length of 31.1 m. The sand trap is divided into three main chambers each 15m in width. Each chamber has been further divided into three hopper shaped compartments through vertical vanes/walls. There will be two locations for flushing ducts/galleries along the entire 115 m length of sandtrap. This arrangement is required because the optimal depth of sandtrap could not be achieved due to the relatively mild slope of river viz-a-viz the lower elevation of sandtrap flushing ducts as compared to river bed level. It is designed to retain 0.2 mm and bigger sized sediment. Complete arrangement of the sandtrap is shown on Figures 8.11 to 8.13 of the Main Report.

The flows from sandtrap will be carried to the tunnel inlet through a 65m concrete lined rectangular headrace channel (18m bed width and 8m depth) excavated along the left bank of river. A freeboard of 0.5 m will still be available for operation at maximum headwater level with design flow velocity at normal operating level will be 2.1 m/s using a Manning's roughness coefficient of n=0.016.detail of channel is shown in Figure 8.14 of Main Report.

The power tunnel is designed as a Horseshoe conduit of 7 m diameter having 40.63 m^2 area. It is 10.22 km long, and has a slope of 1 in 500. At start of the power tunnel the invert has an elevation of 630 masl and at the end elevation of 610 masl. The velocity in the power tunnel will be 3.5 m/sec. The plan, profile and cross section of the power tunnel are shown on Figures 8.15 and 8.16 of the Main Report.

Surge tank has been provided at the end of concrete lined tunnel. Based on the hydraulic considerations, restricted orifice type surge tank has been selected with finished diameter of 20 m as required by Thoama's criteria. The diameter of orifice at the inlet of surge tank is 3m. The

total height of surge tank will be 42 m including 6 m freeboard. The details are shown in Figure 8.17.

A 197.96m horizontal pressure tunnel having 6m inner diameter, comprises of two sections 107.97 concrete lined ant 90m steel lined, leads to a valve chamber at El. 606. An inclined Penstock 105 m having diameter 5.5m will drop from valve chamber at El. 606 masl up to El. 558 masl from where penstock manifold starts, branches to the three units. The arrangements are shown in Figure 8.18 of main report.

A surface type powerhouse in open cut has been proposed on the left bank of the river. The powerhouse will be equipped with three vertical Francis turbine units. The plan of powerhouse is shown in Figure 8.20 and the section is shown in Figure 8.21 of the main report.

The concrete lined tailrace length is about 31m from the draft tube outlet gates up to the left overbank of Panjkora River. Details of plan and section of tail race are shown in Figure 8.22 of main report

The diversion arrangements on the Panjkora River for constructing the main weir cater for 26 months of construction period.

7. Mechanical Equipment Studies

Mechanical equipment and systems will include turbines, governors, inlet valves, gates, stoplogs, trashracks, cranes and hoists etc. The turbine selection was made considering 78.5m as rated head. As stated earlier, for the installed capacity of power plant 150 m^3/sec flow at 38% exceedence has been selected. From the comparative study of various turbine sizes and combinations, three units of vertical Francis turbines each with 50m^3/sec flow have been selected. Considering turbine efficiency of 92% for the net head of 78.5m and design flow of 50m^3/s, the power will be 35.4 MW for each turbine. These values will result in the turbine specific speed (Ns) of 272.7 rpm. An average runner diameter is considered as 2.46m.

For determining the appropriate unit capacity, both technical as well as economic aspects have been examined in a comparative study taking into account equipment dimensions, transport limitations, power and energy benefits, manufacturing experience, power system regulation, and cost estimates etc. Considering generator efficiency as 97% and turbine efficiency as 93%, the turbine output will be 102MW corresponding to total rated discharge of 150m^3/s and rated head of 78.5m.

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8. Electrical Equipment Studies

The most important components of the main electrical equipment are the 11 kV with all its excitation equipment and other auxiliary equipment as specified. The generators with generating capacity of 40 MVA have thus been selected. The electric power generated at Shigo kas hydropower station will be fed to Timergara Grid Station through single circuit 132KV transmission line.

9. Initial Environmental Examination, Resettlement and Social Assessment

Lands in Shigo kas HPP area comprise very less cultivated lands, and settlements and larger area is waste lands. The project will consume 957 kanals of private land, of which 52 kanals are under cultivation and while the rest include community land and waste land.

The present EIA reveals that some moderate to significant negative environmental impacts are likely to occur due to the construction activities with few minor impacts during operations after the proposed construction. Recommendations are made to mitigate expected negative impacts. Implementation of appropriate mitigation measures during the construction, and operation phases will minimize the negative impacts of the Project to acceptable levels.
The Project will have an overall beneficial impact and any negative environmental impacts will be carefully monitored and mitigated. Therefore, the completion of this EIA fully meets both the ADB and EPA standards.

The construction of the project will open job opportunities for the local people. This will help in raising their livelihood.

The total environmental and resettlement cost is estimated as Rs. 560.17 million including land acquisitions.

The client should make necessary arrangements such that during operation of the project sufficient release of water is ensured from the Weir for downstream uses because some agricultural practices do depend on river water.

10. Construction Planning, Cost Estimate and Economic and Financial Analysis

10.1 Construction Planning

The construction planning for 102 MW Shigo kas Hydropower project is largely dependent on Construction of weir, power tunnel and powerhouse, which are on the critical path, High and low

flow periods in the Panjkora River, Excavation in hard strata of powerhouse & power tunnel and Transmission line.

Main components of the project are Weir & intake, Connecting channel, Sandtrap, Power Tunnel, Surge Tank, Penstock, Powerhouse, Switchyard, Colony and Transmission line.

The work on all these components can be carried out independently and the schedule has been prepared in such a way, that the work is taken up simultaneously on various sites in order to complete the project in the shortest possible time. It is thereby estimated that the construction of the project will be completed in 81 months. The sequence, in which the construction of various components of the project will be taken up, has been shown in Figure-14.1 of the Main Report. The construction activities along with time required to complete them is summarized as follows:

Summary of Construction Schedule

Sr. No.	Description of Activity	Duration
1.	Mobilization	30 Days
2.	Acquisition of Land	7 Months
3.	Temporary and Preliminary works	12 Months
4.	Coffer Dams (two Nos.)	3/2.5 Months
5.	Left part of main Weir, Intake and ancillary works	08 Months
6.	Right part of main Weir and ancillary works	10.5 Months
7.	Connecting channel	5 Months
8.	Sandtrap and ancillary works	18 Months
9.	Power Tunnel and ancillary works	46 Months
10.	Surge Shaft	8 Months
11.	Penstock	11 Months
12.	Powerhouse Civil works	32.5 Months
13.	Tailrace and ancillary works	6.5 Months
14.	Powerhouse E&M manufacturing and installation	35 Months
15.	Switchyard, Transmission Line ancillary works	24.5 Months
16.	Testing and Commissioning	9 Months

10.2 Cost Estimate

1. The estimated cost of the project has been worked out as Rs. 32,623 million out of which local cost is Rs. 27,834 million, while for import of Electrical / Mechanical &

transmission line equipment, a provision of Rs. 4,789 Million has been made. For realistic cost estimate the following factors / criteria has been considered.

i. Market Rate System 2013 Khyber Pakhtunkhwa.
ii. Prevailing market Rates
iii. Unit rates adopted for similar constructed / under construction projects
iv. US$ versus Pak rupee impact.

2. The summary of the project capital cost (Amount in Million Rs.) is given as under:

(Amount in Million Rs.)

Sr. No.	Component	Estimated Cost		
		Local	FEC	Total
A	Preliminary Works	600.20	0.00	600.20
B	Environment & Resettlement Costs(Land Acquisition)	560.17	0.00	560.17
C	Civil Works	18502.45	0.00	18502.45
D	Electrical & Mechanical Works	478.36	4305.20	4783.56
	Transmission Line	105.00	245.00	350.00
	Total Works Cost	**20246.18**	**4550.20**	**24796.38**
E	Physical Contingencies (Unforeseen) @ 3% of C+D	572.58	136.50	709.08
F	Transportation and Erection Charges of E&M Equipments @3% of D	131.48	0.00	131.48
G	Survey, geotech investigation and Detail Design of Civil and E&M Works @ 2% of (C + D)	472.72	0.00	472.72
H	Management Consultancy Cost @ 3% of (A + C + D)	727.08	0.00	727.08
	Total Base Cost	**22150.04**	**4686.70**	**26836.74**
I	Client Expenses, Administration and Legal Costs @1% Base Cost	268.37	0.00	268.37

J	Custom Duty@ 5% of D (on FEC)	227.51	0.00	227.51
K	Escalation @ 6.50% on Local cost & 1.3% on FEC	2330.24	102.06	2432.30
L	Interest during Construction (IDC) @10.65% of Base Cost	2858.12	0.00	2858.12
	Total Project Cost	**27834.28**	**4788.76**	**32623.04**

10.3 Economic and Financial Analysis

The annual energy of the Project is 520 GWh. Based on it the unit generation cost comes out to be Rs. 8.05 & US cent 8.13. A summary of Economic and Financial Analysis indicator is given as under:

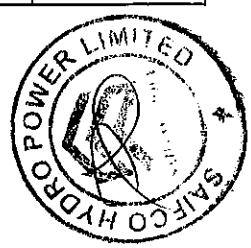
NPV (Million Rs.)	13,289
BCR	1.61
EIRR	21.58%
FIRR (Without CDM)	14.85 %
FIRR (With CDM)	15.60 %

The sensitivity analysis results are summarized as under:-

Scenario	NPV (Rs. Millions)	EIRR	BC Ratio
10 % cost over-run.	11,118	19.21%	1.47
One year delay in benefits	9530	17.69%	1.44
Combination of above	7368	16.03%	1.31

11. Conclusions & Recommendations

11.1 Conclusions



- Base cost of the project is estimated as Rs. 26,837 million, while the capital cost is estimated as Rs. 32,623 million.

- Environmental Impact Assessment Studies have determined the overall impact rating of the project activities as "low to medium".

- The EIRR calculated in comparison with equivalent thermal plants as replacement alternative to the proposed Hydropower Project, comes to 21.58 %.

- Financial analysis indicates a Financial Internal Rate of Return (FIRR) as 14.85 % and the project is adjudged viable.

11.2 Recommendations

- Flow measurements and gauge observations should be continued at PEDO Gauge Station located near proposed weir site in order to have essential data of flows, floods and sediment before project implementation.

- The geological and geotechnical investigations, conducted during the feasibility studies, have provided the data required for feasibility level design of the Shigo Kas Hydropower Project. At detailed design stage, additional investigations are recommended

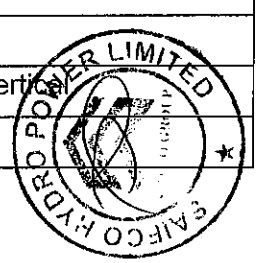
- The access road to weir site, surge area and powerhouse need to be constructed and bridges are to be strengthened.

-Engineering, economic and financial studies have classified Shigo Kas Hydropower Project as viable. **Hence the project is recommended for detailed engineering design or Engineering Procurement Contract and execution.**

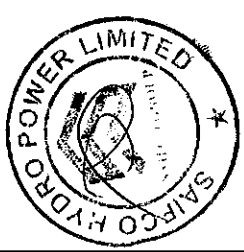


Table 1: SALIENT FEATURES

Hydrology	
Catchment Area	5816 km^2
Design Discharge	150 m^3/s
Working Head	
Normal Head Water Level	650 masl
Tailrace Water Level	558.5 masl
Gross Head	91.5 m
Net Head	78.5 m
Diversion Weir	
Type of Intake	Gated (3 Nos. Each Gate 5.8m x 3.5m)
Height Above River Bed	11 m
Length of the Overflow Crest	25 m
Gated Section with stilling basin	56 m with 4 radial gates (10m x 12m)
Sluicing section (Gated Section with roller bucket)	28 m with 2 radial gates (10m x 12m)
Type of Energy Dissipater	Stilling Basin Type II
Stilling Basin Length	75 m
Sand Trap	
Number of Chambers	3
Total Width of Sand Trap	53.5 m
Length of Sand Trap	115 m
Height of Chamber	09 m
Headrace Tunnel	
Length	10.22 km
Diameter	7 m Horseshoe
Surge Shaft	
Diameter	20 m
Height	42 m
Power House	
Type	Surface
Size (l x w x h)	73m x 35m x 36m
No. of Turbines	3
Type of Turbine	Francis vertical
Tailrace Channel	



Section (w x h)	20m x 9.5m
Length of the Channel	31 m
Power Potential	
Gross Power	102 MW
Annual Energy	520 GWh
Plant Factor	58.2 %
Project Cost & Economic Viability	
Total Project Cost	**32,623** Million Rs.
Benefit / Cost Ratio	1.61
Unit Cost Generated	8.05 Rs. / kWh
Unit Cost Generated	8.13 US cent / kWh



CHAPTER 1

INTRODUCTION

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INTRODUCTION

1.0 General

Pakistan is situated in South Asia and it stretches over 1,600 kilometers from southwest to northeast. It lies between 23° and 37° north latitude and 60° and 76° east longitude. The population of Pakistan was about 182 million in 2013 and the population density was 225.19 inhabitants per square kilometer. At present, the population growth rate is officially about 1.8 % per annum. While per-capita agricultural output has grown for a long time, it has outpaced by the growth of the non-agricultural sectors, and the share of agriculture has dropped to roughly one-fifth of Pakistan's economy. In recent years, the country has seen rapid growth in industries such as apparel, textiles, cement and services such as telecommunication, advertising and finance.

Pakistan is endowed with a hydel potential of more than 40,000 MW, most of which lies in the Khyber Pakhtunkhwa Province. However, an abundant hydel potential is still untapped which needs to be harness. The total installed capacity of the hydropower stations in the country is about 6700 MW, out of which 3850 MW is in Khyber Pakhtunkhwa Province, 1699 MW in Punjab, 1039 MW in Azad Jammu & Kashmir (AJK) and 117 MW in the Gilgit Baltistan.

Energy is critical for the developing countries not only for social development and human welfare but also as a catalyst for overall development in the New Millennium. Energy in the form of electricity provides the basic infrastructural input to the national economic growth. The per capital electric consumption is considered as an index of a nation's progress and development.

Pakistan has been facing a chronic shortage of energy. With the passage of time, the gap between demand and deliverable capacity from the national power stations is widening. Water and Power Development Authority (WAPDA) has been endeavoring hard to narrow the gap, through installation of thermal power stations with steam and gas turbines as well as combined cycle units. The power generation through these stations is not only expensive but also is not convenient to rely upon, due to ever increasing cost of oil and depleting resources. Water is the primary source of energy in Pakistan. The shortage of energy can minimize by exploring small and medium hydel projects in Khyber Pakhtunkhwa Province.



1.1 Background of the Study and Project Description

The German Technical Cooperation (GTZ) originally studied many hydropower projects over the whole country as a part of water resources development in the early 1990's and a local

consulting company (Jafri and Associates) reviewed in 2005 after many years. However, the studies stopped at preliminary stage or at 'desk-level study' and on-site survey was not actually conducted in detail. The statistical data of the GTZ report and its review report are very limited accordingly. In addition, nearly 20 years have passed since the original study was done and it is believed that the project area has become quite a different situation due to the land cultivationand so on.

Pakhtunkhwa Energy Development Organization (PEDO) and Deutsche Gesellschaft fur Techniche Zusammenarbeit (GTZ), a German Government Agency for Technical Co-operation, carried out extensive studies in Dir Kohistan of Pakistan for the identification of potential sites for the generation of hydropower. During this identification high head hydropower potential in Khyber Pakhtunkhwa Province have been identified, needs to be explored further.

Government of Khyber Pakhtunkhwa has included in their development program the feasibility studies of hydropower sites located in Dir Kohistan of Khyber Pakhtunkhwa Province. In this regard PEDO has entered into an agreement with M/s ELECTRA in association with M/s INTGERATION to provide consultancy services for conducting feasibility study of 26 MW Shigo Kas Hydropower Project.

1.2 Project Location and Accessibility

Roads and communication are necessary for the development of infrastructures and these play a vital role in the socio-economic development of any area. Shigo Kas HPP area is accessible from Peshawar via Dir road. The project area is located 10 km downstream from Temergara Town, where Panjkora River becomes narrow again and passes a bottleneck. This bottleneck is located 13 km upstream the Junction of Panjkora River with Swat River. The Project is located on the left bank of Panjkora River and is accessible through metalled road from Chakdara to Timergara. Panjkora River is the main artery of the area which joins the Swat River some 40 km downstream of Temergara. Chakdara - Timergara road provides the access to the left bank of the Project area. The site location map is shown in **Figure 1.1**.

1.3 CLIMATE

The summer season is hot and winter is extremely cold. A steep rise of temperature occurs from May to June, and then very hot during July to the end of August but during September weather turn in normal especially at nights. A rapid fall of temperature occurs from October onwards. The coldest months are December and January. The minimum temperature is -2.5 C° in the month of January while the maximum temperature is 32.4 C° in the month of June. Most of the rainfall

occurs in the months of July, August, December, January and February. Towards the end of cold weather there are occasional thunderstorms and hail storms.

The annual rainfall over the area can be taken as similar to the surrounding areas. **Table 1.1** given below shows the rainfall pattern relevant to the area.

Table 1.1: Rainfall Pattern Relevant to the Area

Long Term Areal Monthly Precipitation, Kalkot Barik				
Month	Station			
	Dir	Kalam	Drosh	Areal Barikot
	(mm)			
Jan	115.7	76.7	64.1	84.0
Feb	165.2	121.6	72.0	117.3
Mar	238.9	194.0	123.9	182.9
Apr	169.4	153.5	112.7	144.0
May	89.4	82.9	66.9	79.2
Jun	53.9	30.1	20.4	33.8
Jul	144.8	36.0	22.6	63.9
Aug	145.3	36.5	23.3	64.5
Sep	82.0	35.7	24.8	45.8
Oct	66.7	47.5	32.6	48.0
Nov	51.8	53.0	27.3	43.6
Dec	78.5	50.8	42.0	56.1
Annual	1401.7	918.4	632.5	963.3

1.4 Previous Studies

Shigo Kas Hydropower Project was initially conceived by GTZ / PEDO during 1992-98. Earlier studies by PEDO & GTZ were of preliminary nature. These were based on regional hydrology of the area and 1:50,000 scale maps of Survey of Pakistan. The parameters selected there from provided valuable guidelines for identification and general planning of hydel schemes, however, verification and evaluation of these parameters had to be done through collection and analysis of hydrological data and by conducting topographic surveys of the project area. All other essential studies and investigations related to planning and design of each project such as Geology, Seismicity, Environment, Hydraulic and Structural design, Cost Estimates, Economic & Financial Analysis etc. had to be conducted to evaluate the project feasibility. All these tasks were included in the scope of services to be provided by the Consultants under the Consultancy Contract.

1.5 Proposed Scheme of Shigo Kas HPP

The project area is located on left side of Panjkora River. The coordinates of start of the intake and powerhouse are shown in **Table 1.2.** There will be a sand trap, tunnel, Surge shaft, spillway, penstock, Powerhouse and tailrace canal.

Table 1.2: Coordinates of Start of the Intake and Powerhouse

Site	Latitude	Longitude
Weir Intake site	34°-45'-33.3"	71°-48'-18.2"
Powerhouse	34°-45'-12.2"	71°-47'-58.6"

1.6 Final Report

The Final Report pertains to Shigo Kas HPP is preceded by Inception Report, Quarterly Progress Reports and midterm report are submitted earlier. The present report complies with this requirement.

Different studies are done which are listed below:

i.) Different alternatives have been studied and a detail presentation was given to the client. Further studies on approved alternatives are carried out. Project, Consultants carried out additional topographic survey of two alternatives of the power house sites of Shigo Kas HPP, which were not easily accessible. As a result, the power capacity (102 MW) of the project is enhanced significantly to more than three times the capacity (26 MW) mentioned in ToR.

ii.) Topographic survey of the project area has been conducted and topographic maps generated supported by sufficient numbers of cross sections and long sections. Layout studies have been done. The high resolution satellite image was purchased and processed to use for the support of Environmental, Hydrological, Geological and Infrastructure studies and for the layout and alignment of tunnel. The 10 meter contour developed from DEM was superimposed on the satellite image and used to generate the layouts at scale 1:1000.

iii.) Geological Traverse for Shigo Kas site has been completed. A regional geological view has been formulated of the whole valley with the help of data available from various sources and field observations. A Regional geological map of the area on the scale of 1:50,000 have been completed.



iv.) The services of private drilling Contractor has been hired for geotechnical and geophysical investigation works. M/s Pacific Engineering and Geotechnical Services (PEGS) Lahore has been assigned the task of carrying out geotechnical and geophysical investigations. The Contractor up till now has completed nine boreholes at the weir intake, sand trap and tunnel inlet portal site.

v.) Hydrological studies have been conducted.

vi.) This report summarizes the consultation process undertaken as a part of the EIA (Environmental Impact Assessment) for the project Shigo kas with installed capacity 102 MW in Lower Dir District. Scoping is critical, early steps in the preparation of EIA which identifies the issues that are likely to be of most importance during EIA process and eliminates that are of little concern. Initial consultations were undertaken by the expert with the technical experts in design sections working on this project, key government departments which are directly and or indirectly have interests or may likely to affect in this project and most importantly initiating public consultation which is also a part of this report.

vii.) Social studies remained focused on Shigo Kas HPP. The enumerators remained busy in awareness campaign, information dissemination on the proposed project and identification of different stakeholders. Some informal discussions were also held with residents of the area who are likely to be benefitted or affected by the project.

viii.) It has now been revealed that the project can be realized for as much as 102 MW installed capacity instead of 38 MW estimated in the earlier studies of PEDO/GTZ.

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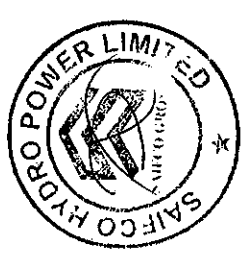
CHAPTER

1

INTRODUCTION

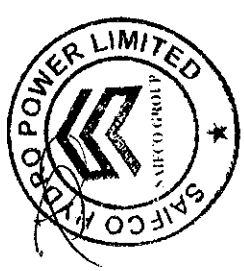


DRAWINGS

CHAPTER

2

PROJECT LAYOUT ALTERNATIVES



CHAPTER 2

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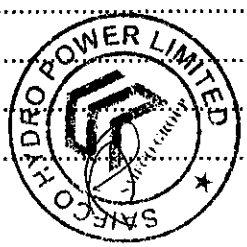

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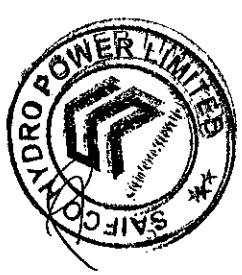

PROJECT LAYOUT ALTERNATIVES

2.0 Introduction

Shigo Kas HPP area is accessible from Peshawar via Dir road. The project area is located 10 km downstream from Timergara Town, where Panjkora River becomes narrow again and passes a bottleneck. This bottleneck is located 13 km upstream the Junction of Panjkora River with Swat River. The Project is located on the left bank of Panjkora River and is accessible through mettaled road from Chakdara to Timergara. This section comprises of alternative layouts that were considered during the selection of the final project layout.

The design discharge of 135 cumecs (as per regional power development study by PEDO and GTZ) has been used for the design of various components of project and installed capacity for comparison and screening of various alternatives. For the seventh alternative a discharge of 150 cumecs is used. The project involves a concrete weir, sand trap, connecting channel headrace tunnel, surge shaft, penstock, powerhouse, tailrace channel, switchyard and residential colony area.

For comparison of different alternatives, the tentative cost estimates of various components of project layouts have been work out based on available Norwegian standard charts and curves for costing.

For the selection of more viable site of the project, seven different alternatives were considered and analyzed to go for the most suitable layout of the project for further studies.

2.1 Background

The preliminary screening of layout alternatives for the projects was carried out immediately after the inception phase. The screening process mainly consisted of site visits, data collection, hydrological studies, topographic studies, basic design of hydraulic structures, and preliminary selection of turbines, power and energy computations, comparative costing and economic analyses. Seven numbers of alternative layouts were prepared for the Project. The alternative layouts included the original layout concepts envisaged by GTZ in their ranking studies for the region. The salient features of GTZ's layouts are given in **Table- 2. 1** below:

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Table- 2.1: Original GTZ'S Layouts for Dir HPPS

Sr. No.	Project	Capacity(MW)	Annual Energy (GWh)	Design Discharge (m^3/s)	Dam Height (m)	Tunnel Length (Km)
1	Shigo Kas HPP	38.0	193.0	135.0	40.0	0.0

The salient features provided in the Consultants' TOR are given in **Table- 2.2** below.

Table- 2.2: Salient Features of Dir HPPs as per TOR/PEDO

Sr. No.	Project	Capacity (MW)	Design Discharge (m^3/s)
1	Shigo Kas HPP	26.0	90

The Consultants identified additional layout alternatives for the project considering the environmental impacts of relatively high dams proposed by GTZ. The options of low to medium high weirs were also compared. For this purpose the elevation data was acquired from 5.0 m interval contour maps prepared from SRTM's 30 m resolution data which is freely available for the entire planet. The long term flow series of Panjkora River at the proposed dam/weir sites was updated to year 2010 before using it for the determination of annual energy outputs for different alternatives of the project.

Effort was made to remain within the vicinity of potential sites identified by GTZ and forwarded by PEDO in the Consultants' TOR. New sites for weir and powerhouse structures were also identified after extensive site visits and included in the screening exercise. Costing of civil works and plant equipment was done to compare the NPV and unit installation costs for proposed layout alternatives. The results of layout screening exercise were presented to the Client for approval in two different presentations during November 20, 2012 and December 14, 2012. The salient features of approved layout alternative for the project are given in **Table- 2.3** below.

The design discharges were kept the same as proposed by GTZ however, optimization of design discharge has been carried out at this stage for the selected layout alternative of the project which results in a design discharge of 150 cumecs for the selected layout.

Table- 2.3: Project Layouts for Dir HPPs Approved by the Client

Sr. No.	Project	Capacity (MW)	Annual Energy (GWh)	Design Discharge (m^3/s)	Weir Height (m)	Tunnel Length (Km)
3	Shigo Kas HPP	46.8	239.4	135.0	5.0	6.3

The layout alternative recommended by the Consultants for Shigo Kas HPP included an 11 m high weir and 10.22 Km long tunnel giving about 102 MW. The recommended weir site is located near GTZ dam site. The alternative layouts studied for Shigo Kas HPP are shown in **Figure 2.1** below.

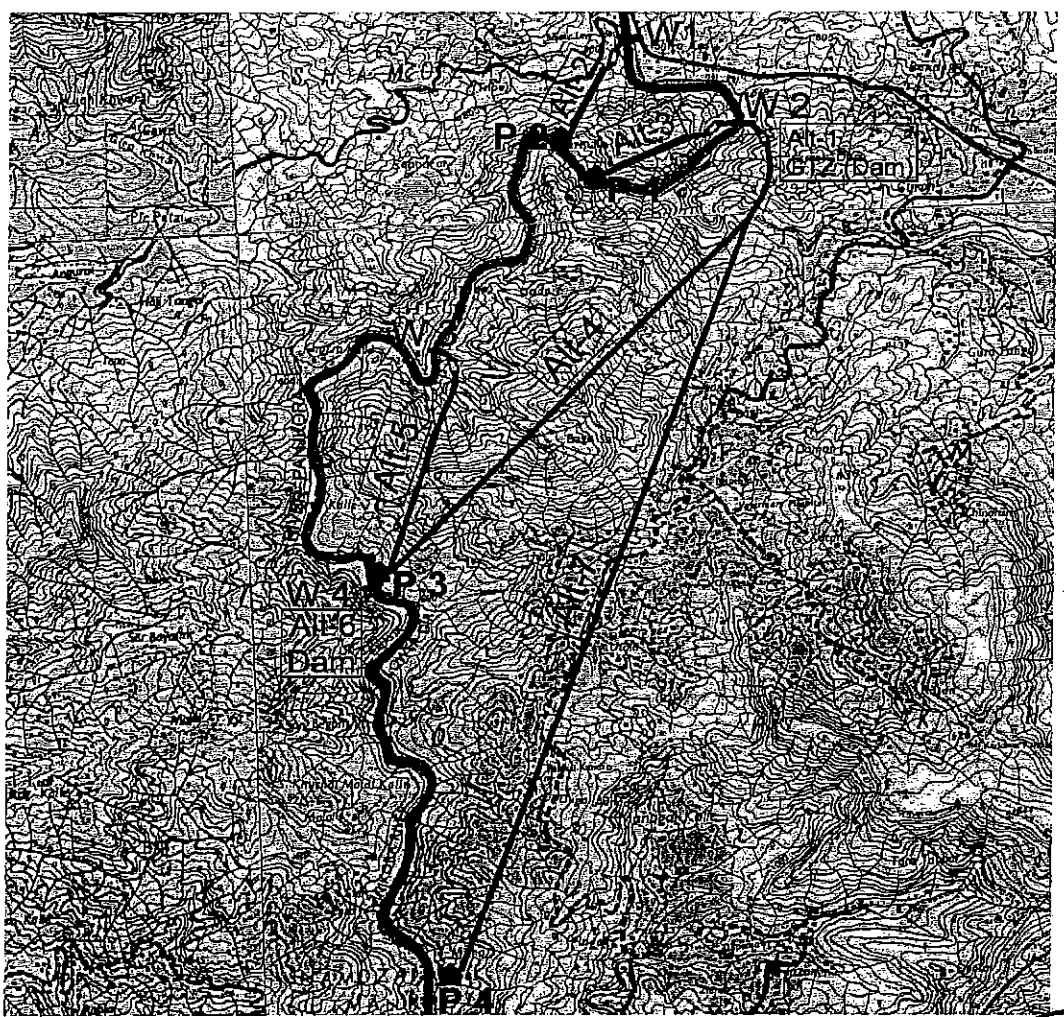

Figure 2.1: Layout Alternatives for Shigo Kas HPP

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The summary of layout alternatives for Shigo Kas HPP is given in Table 1 to 5 in Annexure-2A. The selected powerhouse site P4 is located on the left bank of Panjkora River about 10 Km downstream of the GTZ dam site. Access road is already available up to the new powerhouse site. Shigo Kas HPP area is accessible from Peshawar via Dir road. The project area is located 10 km downstream from Timergara Town, where Panjkora River becomes narrow again and passes a bottleneck. This bottleneck is located 13 km upstream the Junction of Panjkora River with Swat River. The Project is located on the left bank of Panjkora River and is accessible through metalled road from Chakdara to Timergara. Panjkora River is the main artery of the area which joins the Swat River some 40 km downstream of Timergara. Chakdara-Timergara road provides the access to the left bank of the Project area.

2.2 Project Layout Alternative 1

2.2.1 Accessibility

The proposed dam is located near Shigo Kas village and powerhouse is located at toe of dam. The site is located on right bank of Panjkora River. Access to project site is easy from Chakdara Road. An access road of 4.5 km should be constructed to reach project power house site.

2.2.2 Dam/Intake

A high dam of 40.0m height will be constructed, having crest length of 180.0 m, crest level 708.0 masl. 10 gated, spillway will be provided to control the overflow of water.

2.2.3 Connecting Channel, Gross head and Sand trap

The length of the connecting channel is about 60 m while gross head is 35 m. the headrace and tailrace water levels are 705 masl and 670 masl respectively. The sand trap will be required for this alternative.

2.2.4 Headrace Tunnel and Pressure Shaft

No pressure tunnel is needed because powerhouse is located at toe of dam. The length of the penstock is 140.0 m with an internal diameter of 5.5 m.

2.2.5 Powerhouse

The proposed powerhouse will be located on right bank of Panjkora River. The protection from high flood will be required. The powerhouse has an installed capacity of 39.3 MW and design discharge of 135 cumecs. The proposed type of turbine is "Francis Turbine" which has been selected on the basis of medium head i.e. 35 m.

2.2.6 Transmission Line

The nearest national grid is available at Timergara about 5.5 km from powerhouse.

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2.2.7 Environmental and Social Issues

This alternative will have severe environmental and social issues. Road of 8.3 km will be submerged. The powerhouse of this alternative is located outside built up area, therefore, it will have minimum environmental and social issues. This alternative has high mitigation and compensation costs.

2.2.8 Tentative Project Cost Estimate

The tentative cost estimate of different alternatives is worked out for comparison and screening based on available Norwegian standards charts and curves whish are presented in Table 4 of **Anexxure-1**. The power capacity of alternative 1 is estimated as Rs. 285.19 Millions per MW whereas the energy cost is Rs. 9.63 per kWh.

2.2.9 Basic Data

The basic data of Alternative No.1 is given in **Table- 2.4** below;

Table- 2.4: Basic data of Alternative No.1

Gross Head	35 m
Design Discharge	135 cumecs
Installed Capacity	39.3 MW
Weir Type	High Dam with gated spillway
Sand Trap Structure	Yes
Gravel Spill Structure	No
Headrace Tunnel Length	No
Connecting Channel Length	60 m
Surge Shaft	No
Penstock Length	140 m
Access Road	4.5 km
Environmental/Social Issues	Severe
Energy Cost (Rs/kWh)	9.63

Detail calculations are attached at Annexure-2A.

2.3 Project Layout Alternative 2

2.3.1 Accessibility

The proposed weir is located near Shigo Kas village and powerhouse is located about 2 km downstream. The site is located on right bank of Panjkora River. Access to dam site is easy from main Timergara road whereas powerhouse site is difficult to access without constructing about 5.0 km of mettaled road.

2.3.2 Weir/Intake

The weir will be overflow with under-sluices. Stilling basin is also provided. The weir height is 5.0 m, crest length is 180 m and crest level is 673 masl. 8 gates are provided to control the flow of water.

2.3.3 Connecting Channel, Gross Head and Sand Trap

The length of the connecting channel is about 60 m while gross head is 20 m. the headrace and tailrace water levels are 672 masl and 652 masl respectively. The sand trap will be required for this alternative.

2.3.4 Headrace Tunnel and Pressure Shaft

The length of headrace tunnel is 1.30 km with internal diameter of 7 m. The penstock is made of mild steel with a length of 170 m.

2.3.5 Powerhouse

The proposed powerhouse will be located on right bank of Panjkora River. The protection from high flood will be required. The powerhouse has an installed capacity of 20.6 MW and design discharge of 135 cumecs based on PEDO & GTZ report. The proposed type of turbine is "Kaplan Turbine" which has been selected on the basis of low head i.e. 20 m.

Water, from the powerhouse, discharges in to River Panjkora through tailrace channel. The length of tailrace channel is 110 m.

2.3.6 Transmission Line

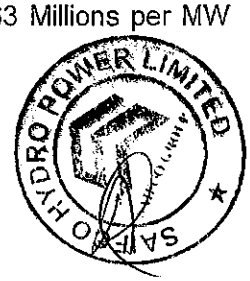
The nearest national grid is available at Timergara about 6 km from powerhouse.

2.3.7 Environmental and Social Issues

This alternative will have minimum environmental and social issues. No road submergence occurs. The powerhouse of this alternative is located outside built up area, therefore, it will have minimum environmental and social issues. This alternative has low mitigation and compensation costs.

2.3.8 Tentative Project Cost Estimate

The tentative cost estimate of different alternatives is worked out for comparison and screening based on available Norwegian standards charts and curves whish are presented in Table 4 of **Anexxure-1**. The power capacity of alternative 2 is estimated as Rs. 253.63 Millions per MW whereas the energy cost is Rs. 8.58 per kWh.



2.3.9 Basic Data

The basic data of Alternative No.2 is given in **Table- 2.5** below;

Table- 2.5: Basic data of Alternative No.2

Gross Head	20 m
Design Discharge	135 cumecs
Installed Capacity	20.6 MW
Weir Type	Ogee and Gated
Sand Trap Structure	Yes
Gravel Spill Structure	Yes
Headrace Tunnel Length	1.30 km
Connecting Channel Length	60 m
Surge Shaft	30 m high & 20 m diameter
Penstock Length	170 m
Access Road	5.0 km
Environmental/Social Issues	Minimum
Energy Cost (Rs/kWh)	8.58

Detail calculations are attached at Annexure-2A.

2.4 Project Layout Alternative 3

2.4.1 Accessibility

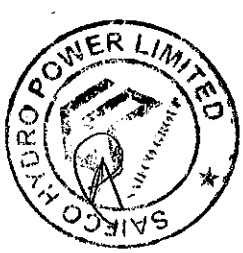
The proposed weir is located near Shigo Kas village and powerhouse is located about 2 km downstream. The site is located on right bank of Panjkora River. A metalled road of 4.5 km will be constructed to access project power house site.

2.4.2 Weir Intake

The weir will be overflow with under-sluices. Stilling basin is also provided. The weir height is 5.0 m, crest length is 110 m and crest level is 673 masl. 10 gates are provided to control the flow of water.

2.4.3 Connecting Channel, Gross Head and Sand Trap

The length of the connecting channel is about 60 m while gross head is 18 m. the headrace and tailrace water levels are 672 masl and 654 masl respectively. The sand trap and gravel spill structure will be required for this alternative.



2.4.4 Headrace Tunnel and Pressure Shaft

The length of headrace tunnel is 1.40 km with internal diameter of 7 m. the penstock is made of mild steel with a length of 160 m.

2.4.5 Powerhouse

The proposed powerhouse will be located on right bank of Panjkora River. The protection from high flood will be required. The powerhouse has an installed capacity of 18.1 MW and design discharge of 135 cumecs based on PEDO & GTZ report. The proposed type of turbine is "Kaplan Turbine" which has been selected on the basis of low head i.e. 18 m.

Water, from the powerhouse, discharges in to River Panjkora through tailrace channel. The length of tailrace channel is 110m.

2.4.6 Transmission Line

The nearest national grid is available at Timergara about 5.5 km from powerhouse.

2.4.7 Environmental and Social Issues

This alternative will have minimum environmental and social issues. About 500 m road will be submerged. The powerhouse of this alternative is located outside built up area, therefore, it will have minimum environmental and social issues. This alternative has low mitigation and compensation costs.

2.4.8 Tentative Project Cost Estimate

The tentative cost estimate of different alternatives is worked out for comparison and screening based on available Norwegian standards charts and curves whish are presented in Table 4 of **Anexxure-1**. The power capacity of alternative 3 is estimated as Rs. 314.64 Millions per MW whereas the energy cost is Rs. 10.64 per kWh.

2.4.9 Basic Data

The basic data of Alternative No.3 is given in **Table- 2.6** below;

Table- 2.6: Basic data of Alternative No.3

Gross Head	18 m
Design Discharge	135 cumecs
Installed Capacity	15.8 MW
Weir Type	Ogee and Gated
Sand Trap Structure	Yes
Gravel Spill Structure	Yes
Headrace Tunnel Length	1.40 km

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Connecting Channel Length	60 m
Surge Shaft	26 m high & 20 m diameter
Penstock Length	160 m
Access Road	4.5 km
Environmental/Social Issues	Minimum
Energy Cost (Rs/kWh)	10.64

Detail calculations are attached at Annexure-2A.

2.5 Project Layout Alternative 4

2.5.1 Accessibility

The proposed weir is located near Shigo Kas village and powerhouse is located about 7 km downstream. The site is located on left bank of Panjkora River. A mettaled road of 12.5 km will be constructed to access project site.

2.5.2 Weir/Intake

The weir will be overflow with under-sluices. Stilling basin is also provided. The weir height is 5.0 m, crest length is 110 m and crest level is 673 masl. 10 gates are provided to control the flow of water.

2.5.3 Connecting Channel, Gross Head and Sand Trap

The length of the connecting channel is about 60 m while gross head is 48 m. the headrace and tailrace water levels are 670 masl and 622 masl respectively. The sand trap and gravel spill structure will be required for this alternative.

2.5.4 Headrace Tunnel and Pressure Shaft

The length of headrace tunnel is 6.30 km with internal diameter of 7 m. the penstock is made of mild steel with a length of 170 m.

2.5.5 Powerhouse

The proposed powerhouse will be located on left bank of Panjkora River. The protection from high flood will be required. The powerhouse has an installed capacity of 46.8 MW and design discharge of 135 cumecs based on PEDO & GTZ report. The proposed type of turbine is "Francis Turbine" which has been selected on the basis of medium head i.e. 48 m.

Water, from the powerhouse, discharges in to River Panjkora through tailrace channel. The length of tailrace channel is 110 m.

2.5.6 Transmission Line

The nearest national grid is available at Timergara about 10 km from powerhouse.

2.5.7 Environmental and Social Issues

This alternative will have severe environmental and social issues. About 500 m road will be submerged. The powerhouse of this alternative is located outside built up area, therefore, it will have minimum environmental and social issues. This alternative has low mitigation and compensation costs.

2.5.8 Tentative Project Cost Estimate

The tentative cost estimate of different alternatives is worked out for comparison and screening based on available Norwegian standards charts and curves whish are presented in Table 4 of **Anexxure-1**. The power capacity of alternative 4 is estimated as Rs. 215.93 Millions per MW whereas the energy cost is Rs. 7.31 per kWh.

2.5.9 Basic Data

The basic data of Alternative No.4 is given in **Table- 2.7** below;

Table- 2.7: Basic data of Alternative No.4

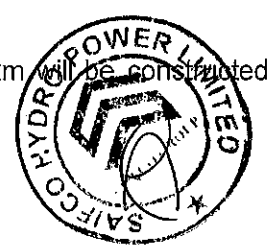
Gross Head	48 m
Design Discharge	135 cumecs
Installed Capacity	46.8 MW
Weir Type	Ogee and Gated
Sand Trap Structure	Yes
Gravel Spill Structure	Yes
Headrace Tunnel Length	6.30 km
Connecting Channel Length	60 m
Surge Shaft	55 m high & 20 m diameter
Penstock Length	170 m
Access Road	12.5 km
Environmental/Social Issues	Minimum
Energy Cost (Rs/kWh)	7.31

Detail calculations are attached at Annexure-2A.

2.6 Project Layout Alternative 5

2.6.1 Accessibility

Access to the weir site and powerhouse is difficult. A road of 12.5 km will be constructed for accessibility purposes.



2.6.2 Weir/Intake

The weir will be overflow with under-sluices. Stilling basin is also provided. The weir height is 24.0 m, crest length is 170 m and crest level is 672 masl. 13 gates are provided to control the flow of water.

2.6.3 Connecting Channel, Gross Head and Sand Trap

The length of the connecting channel is about 60 m while gross head is 48 m. the headrace and tailrace water levels are 670 masl and 622 masl respectively. The sand trap and gravel spill structure will be required for this alternative.

2.6.4 Headrace Tunnel and Pressure Shaft

The length of headrace tunnel is 2.30 km with internal diameter of 7 m. the penstock is made of mild steel with a length of 170 m.

2.6.5 Powerhouse

The proposed powerhouse will be located on left bank of Panjkora River. The protection from high flood will be required. The powerhouse has an installed capacity of 51.7 MW and design discharge of 135 cumecs based on PEDO & GTZ report. The proposed type of turbine is "Francis Turbine" which has been selected on the basis of medium head i.e. 48 m.

Water, from the powerhouse, discharges in to River Panjkora through tailrace channel. The length of tailrace channel is 110 m.

2.6.6 Transmission Line

The nearest national grid is available at Timergara about 10 km from powerhouse.

2.6.7 Environmental and Social Issues

This alternative will have minimum environmental and social issues. The powerhouse of this alternative is located outside built up area, therefore, it will have minimum environmental and social issues. This alternative has low mitigation and compensation costs.

2.6.8 Tentative Project Cost Estimate

The tentative cost estimate of different alternatives is worked out for comparison and screening based on available Norwegian standards charts and curves whish are presented in Table 4 of **Anexxure-1**. The power capacity of alternative 5 is estimated as Rs. 190.66 Millions per MW whereas the energy cost is Rs. 6.46 per kWh.

2.6.9 Basic Data

The basic data of Alternative No.5 is given in **Table- 2.8** below;

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Table- 2.8: Basic data of Alternative No.5

Gross Head	48 m
Design Discharge	135 cumecs
Installed Capacity	51.7 MW
Weir Type	Ogee and Gated
Sand Trap Structure	Yes
Gravel Spill Structure	Yes
Headrace Tunnel Length	2.3 km
Connecting Channel Length	110 m
Surge Shaft	38 m high & 20 m diameter
Penstock Length	170 m
Access Road	12.5 km
Environmental/Social Issues	Minimum
Energy Cost (Rs/kWh)	6.46

Detail calculations are attached at Annexure-2A.

2.7 Project Layout Alternative 6

2.7.1 Accessibility

Access to the weir site and powerhouse is difficult. A road of 12.5 km will be constructed for accessibility purposes.

2.7.2 Weir/Intake

The weir crest length is 230 m and height 48 m. the type of weir will be ogee with spillway and bottom outlets.

2.7.3 Connecting Channel, Gross Head and Sand Trap

The length of the connecting channel is about 60 m while gross head is 48 m. the headrace and tailrace water levels are 670 masl and 622 masl respectively. The sand trap and gravel spill structure will be required for this alternative.

2.7.4 Powerhouse

The proposed powerhouse will be located on toe of dam. The protection from high flood will be required. The powerhouse has an installed capacity of 54.4 MW and design discharge of 135 cumecs based on PEDO & GTZ report. The proposed type of turbine is "Francis Turbine" which has been selected on the basis of medium head i.e. 48 m.

Water, from the powerhouse, discharges in to River Panjkora through tailrace channel. The length of tailrace channel is 110 m.

2.7.5 Transmission Line

The nearest national grid is available at Timergara about 10 km from powerhouse.

2.7.6 Environmental and Social Issues

This alternative will have minimum environmental and social issues. This alternative will have low compensation and mitigation cost. The powerhouse of this alternative is located outside built up area.

2.7.7 Tentative Project Cost Estimate

The tentative cost estimate of different alternatives is worked out for comparison and screening based on available Norwegian standards charts and curves whish are presented in Table 4 of **Anexxure-1.** The power capacity of alternative 6 is estimated as Rs. 229.95 Millions per MW whereas the energy cost is Rs. 7.77 per kWh.

2.7.8 Basic Data

The basic data of Alternative No.6 is given in **Table- 2.9** below;

Table- 2.9: Basic data of Alternative No.6

Gross Head	48 m
Design Discharge	135 cumecs
Installed Capacity	54.4 MW
Weir Type	Ogee and Gated
Sand Trap Structure	Yes
Gravel Spill Structure	Yes
Headrace Tunnel Length	0 km
Connecting Channel Length	60 m
Surge Shaft	No surge shaft
Pressure Shaft/Tunnel	140 m with internal dia of 5.5 m
Access Road	12.5 km
Environmental/Social Issues	Minimum
Energy Cost (Rs/kWh)	7.77

Detail calculations are attached at Annexure-2A.

2.8 Project Layout Alternative 7

2.8.1 Accessibility

Access to the weir site and powerhouse is difficult. A road of 500 m will be constructed for accessibility purposes to Weir and improvement of 2 km road is required for accessibility purposes to powerhouse.

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2.8.2 Weir/Intake

The weir will be overflow with under-sluices. Stilling basin is also provided. The weir height is 11 m, overflow crest length is 25 m and crest level is 650 masl. Two type gated section are provided.

I. Gated section with stilling basin provided with 4 radial gates (Each 10 m wide).

II. Gated section with roller buckets provided with 2 radial gates (Each 10 m wide).

2.8.3 Connecting Channel, Gross Head and Sand Trap

The length of the connecting channel is about 65 m while gross head is 91.5 m. the headrace and tailrace water levels are 650 masl and 558.5 masl respectively. The sand trap structure will be required for this alternative.

2.8.4 Headrace Tunnel and Pressure Shaft

The length of headrace tunnel is 10.22 km with internal diameter of 7 m ,a pressure shaft with a length of 198 m and a penstock manifold arrangement.

2.8.5 Powerhouse

The proposed powerhouse will be located on left bank of Panjkora River. The protection from high flood will be required. The powerhouse has an installed capacity of 102 MW and design discharge of 150 cumecs based on feasibility study. The proposed type of turbine is "Francis vertical Turbine"

Water, from the powerhouse, discharges in to River Panjkora through tailrace channel. The length of tailrace channel is 31 m.

2.8.6 Transmission Line

The nearest national grid is available at Timergara about 13 km from powerhouse.

2.8.7 Environmental and Social Issues

This alternative will have minimum environmental and social issues. The powerhouse of this alternative is located outside built up area, therefore, it will have minimum environmental and social issues. This alternative has low mitigation and compensation costs.

2.8.8 Tentative Project Cost Estimate

The tentative cost estimate of different alternatives is worked out for comparison and screening based on available Norwegian standards charts and curves whish are presented in Table 4 of Anexxure-1. The power capacity of alternative 7 is estimated as Rs. 156.21 Millions per MW whereas the energy cost is Rs. 6.28 per kWh.

2.8.9 Basic Data

The basic data of Alternative No.7 is given in **Table- 2.10** below;

Table- 2.10: Basic data of Alternative No. 7

Gross Head	91.5 m
Design Discharge	150 cumecs
Installed Capacity	102 MW
Weir Type	Ogee and Gated
Sand Trap Structure	Yes
Gravel Spill Structure	Yes
Headrace Tunnel Length	10.22 km
Connecting Channel Length	65 m
Surge Shaft	42 m high & 20 m diameter
Pressure shaft Length	220 m
Access Road	25.5 km
Environmental/Social Issues	Minimum
Energy Cost (Rs/kWh)	6.28

Detail calculations are attached at Annexure-2A

Table- 2.11: Comparison of Alternatives Layouts

S#	Feature	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
1	Gross Head (m)	35	20	18	48	48	48	91.5
2	Design Discharge (m^3/sec)	135	135	135	135	135	135	150
3	Installed Capacity (MW)	39.3	20.6	18.1	46.8	51.7	54.4	102.0
4	Weir Type	High Dam with spillway, bottom outlets	Overflow Weir with under-sluices and stilling basin	Overflow Weir with under-sluices and stilling basin	Overflow Weir with under-sluices and stilling basin	Weir with spillway, bottom outlets & stilling basin	Dam with spillway, bottom outlets	Overflow Weir with under-sluices and stilling basin
5	Turbine	Francis	Kaplan	Kaplan	Francis	Francis	Francis	Francis Vertical
6	Sand Trap	Yes	Yes	Yes	Yes	Yes	Yes	Yes

S#	Feature	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
7	Gravel Spill Structure	No	No	No	No	No	No	No
8	Headrace Tunnel Length (km)	0	1.30	1.40	6.3	2.3	0	10.22
9	Surge Shaft	No	Yes	Yes	Yes	Yes	No	Yes
10	Penstock Length (m)	140	170	160	170	170	140	97
11	Inspection Road (km)	No	No	No	No	No	No	No
12	Access Road	4.5	5.0	4.5	12.5	12.5	12.5	25.5
13	Environmental / Social issues	Severe	Minimum	Minimum	Minimum	Minimum	Minimum	Minimum
14	Energy Cost (Rs / kWh)	9.63	8.58	10.64	7.31	6.46	7.77	6.28

Table- 2.12: Financial Comparison

Alt. No.	Capacity	Energy	Cost			NPV		Tariff
			Civil	Equipment	Total	Economic	Financial	
	(MW)	(GWh/year)	(Million Rs.)			(Million Rs.)		(Rs./KWh)
1	39.3	182.09	9119.87	2098.46	11218.34	4776.96	626.57	6.93
2	20.6	95.43	3924.98	1303.95	5228.93	3554.32	1092.01	8.58
3	18.1	73.13	3867.97	1102.64	4970.61	1920.62	-330.93	10.64
4	46.8	216.42	7599.71	2469.00	10095.71	8851.88	4637.09	7.31
5	51.7	239.40	7145.35	2714.69	9860.04	11050.96	9705.80	6.46
6	54.4	251.71	9685.18	2818.65	12503.82	9381.57	4484.79	7.77
7	102.0	520.0	11109.55	4823.89	15933.43	12833.60	9052.18	6.28

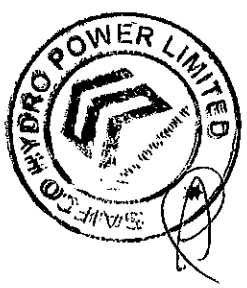
2.9 Project Layout

Alternative 7 has higher power generation capacity and lesser per kWh unit cost i.e. 6.28 than any other alternative which makes it more economical alternative. The layout alternative recommended by the Consultants for Shigo Kas HPP included 11m high weir and 10.22 Km long tunnel giving about 102.0 MW.

2.10 Conclusions & Recommendations

Taking all these factors into consideration; ***Alternative 7*** *was* recommended for further study.

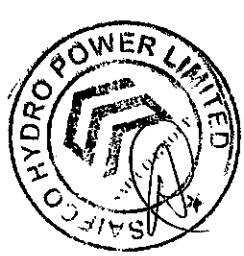
The powerhouse P4 has been identified and visited. The site is located about 4.0 Km downstream of the P-3 powerhouse conceived location. This site is located near village Utala which is about 20 km SW of main Timergara-Dir road and is accessible via mettaled road. From village Utala, a kacha track is available to the site leading to village Mitta. This site offers an additional head of about 30.0 m as compared to the alternative W2-P3 which was earlier approved by the Client for further studies and investigations. The tunnel length would be about 10.22 km (6.3 Km earlier approved by the Client) and there would be possibility of generating additional 45 to 50 MW.



ANNEX

2A

LAYOUT SCREENING



CHAPTER

3

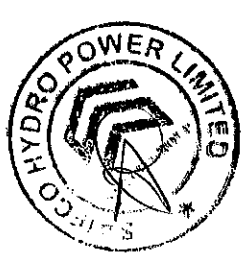
TOPOGRAPHIC SURVEY



ANNEX

3B

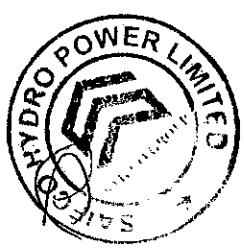
SATELLITE IMAGINARY



ANNEX

3A

SURVEY DRAWINGS



CHAPTER 3

TOPOGRAPHIC SURVEY

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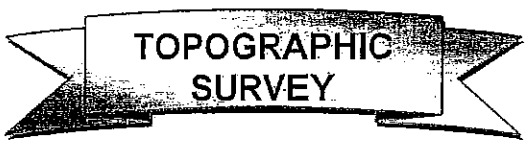


3.0 Introduction

Shigo Kas Hydropower Project area is located 10 km downstream from Timergara Town at Panjkora River. The catchment area is estimated about 5816 km^2. This chapter will describe the detailed topographic survey works carried out at the feasibility stage of the proposed Shigo Kas Hydropower Project.

Topographic survey is the foremost activity to start the feasibility study of any Hydropower Project. The project area was visited and survey requirements were assessed keeping in view the location of various components of the proposed schemes. The survey was carried out concentrating various options of project layout at appropriate scale, so that it would help in planning an optimum layout. This planning was essential because studies and investigations depend on the availability of accurate topographic maps of the area depicting all essential existing features.

3.1 Project Site

The project site which has been included for Feasibility Studies is Shigo Kas (District Lower Dir). The project area is accessible from Peshawar via Dir road. The project area is located 10 km downstream from Timergara Town, where Panjkora River becomes narrow again and passes a bottleneck. Topographic survey of Shigo Kas HPP located in district lower Dir has been carried out.

3.2 Instruments Used

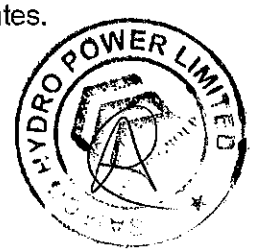
The following instruments have been used for topographic survey data at site:

3.2.1 Total Station SOKKIA 630R

The instrument works on a unique pulse laser technology which allows measuring upto 100 m in reflector-less mode with complete safety and confidence.

3.2.2 E-Trex Ground Positioning System (GPS)

E-Trex GPS is used for finding out approximate co-ordinates of various features in the project area. The instrument has an accuracy rating of ± 3 meter in locating coordinates.



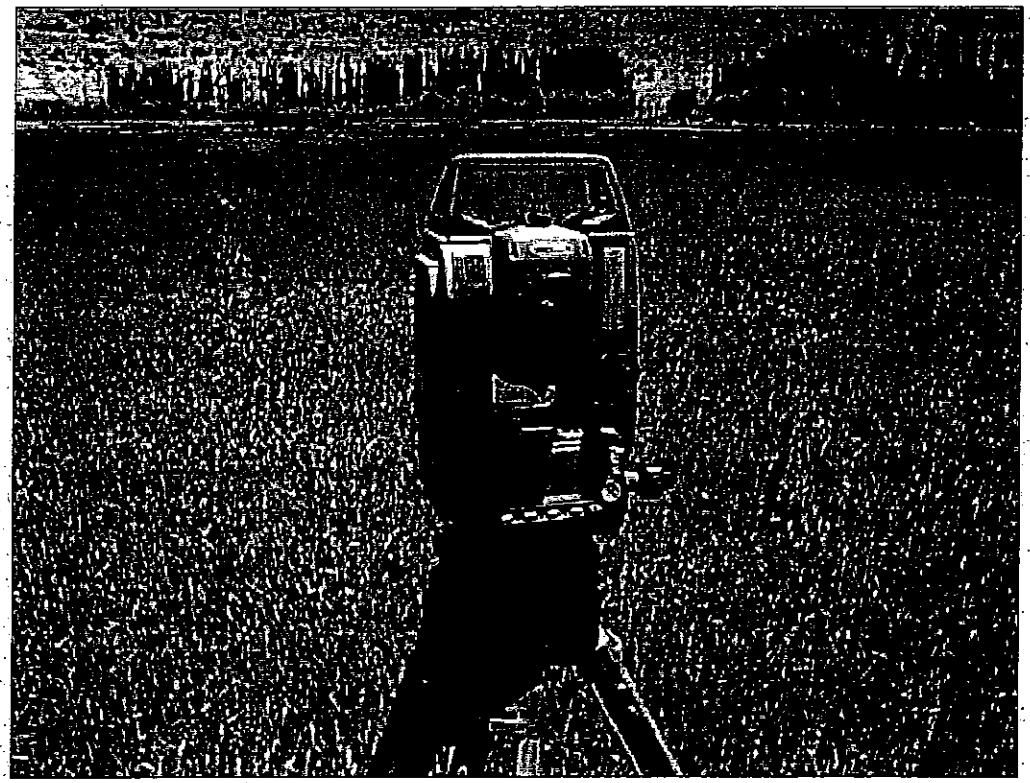


Figure - 3.1: Instrument used by the Electra Survey Team

3.2.3 SOKKIA B40 Engineers Automatic Level

The automatic levels provide quick setup, easy sighting, and superior durability against vibration and shock, ensuring the increased productivity over an extra-long period of time.

3.3 Bench Marks

Two points on Zulam Bridge were established with reference to SOP points near the weir site at Shigo kas area, shown in **Figure 3.2.** For the development of project layout we need to establish more SBM. These bench marks provide the horizontal as well as vertical control to the project.

These points were used for establishing the control points in the project area. These values are given here under the coordinates have been prepared with reference to nearest SBM. The coordinates of the survey Bench Marks are given in **Table - 3.1.**

Table - 3.1: Coordinates of Survey Benchmarks

S.NO	Easting (m)	Northing (m)	Elevation (m)
S-1	3090141.640	1171855.820	661.000
S-2	3090042.076	1171864.307	661.022

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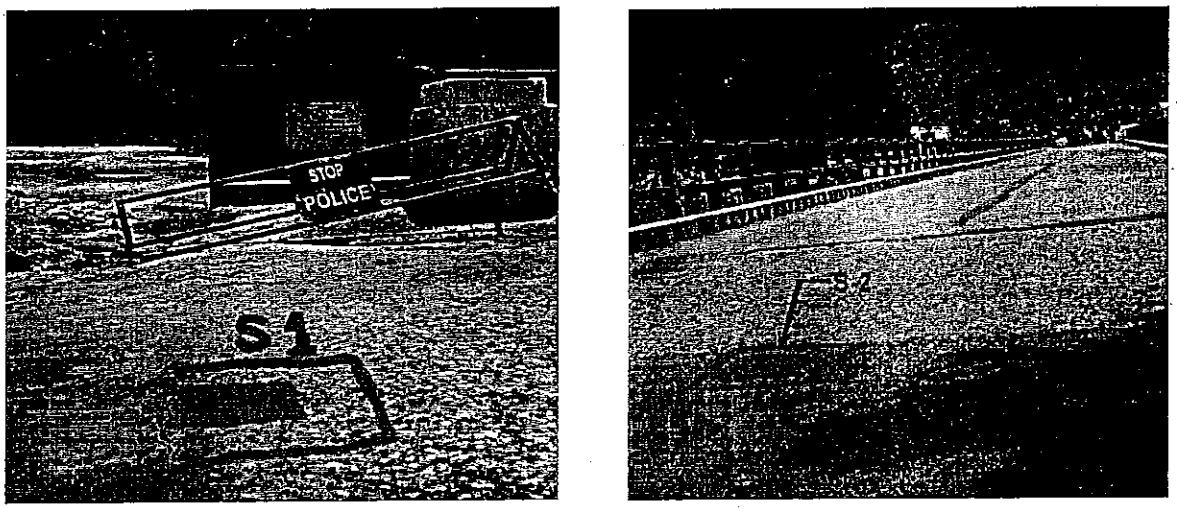

Figure 3.2: Survey Point S-1 & S-2 on Zulam Bridge

Table 3.2 & 3.3 shows the benchmark and Survey control points of Intake to Power House Option-I (Alternative 4) & Option-II (Alternative 7). Also shown in **Figure SKS-001-01.**

Table - 3.2: Shigo Kas HPP Area Bench Marks

Point	Easting (m)	Northing (m)	Elevation (m)	Site
S-1	3090141.640	1171855.820	661.000	Intake
S-2	3090042.076	1171864.307	661.022	Intake
S-7	3091271.056	1171139.314	649.415	Intake
S-43	3087755.276	1165764.306	600.152	Power House (Option-I)
S-44	3087639.893	1165767.268	594.236	Power House (Option-I)
S-31	3088224.063	1162003.237	667.883	Power House (Option-II)
S-32	3088313.494	1161417.809	640.079	Power House (Option-II)

Table - 3.3: LIST OF SURVEY TRAVERSE POINTS

S#	Point	Easting (m)	Northing (m)	Elevation (m)	Site
From Intake to Power House Option-I					
1	S2	3090042.08	1171864.31	660.94	From Intake to Power House Option-I
2	S3	3090242.22	1171619.20	663.86	From Intake to Power House Option-I
3	S4	3090363.76	1171537.50	668.62	From Intake to Power House Option-I
4	S5	3090583.67	1171493.59	670.77	From Intake to Power House Option-I
5	S6	3090802.16	1171396.38	666.10	From Intake to Power House Option-I
6	S7	3091271.20	1171139.24	649.42	From Intake to Power House Option-I
7	S8	3090739.90	1171262.06	645.16	From Intake to Power House Option-I
8	S9	3090223.48	1171239.96	651.23	From Intake to Power House Option-I
9	S2	3090042.10	1171864.49	660.81	From Intake to Power House Option-I
10	S1	3090141.68	1171855.95	660.83	From Intake to Power House Option-I
11	S7	3091271.06	1171139.31	649.42	From Intake to Power House Option-I
12	S10	3091457.58	1171245.97	670.46	From Intake to Power House Option-I
13	S11	3091638.18	1171285.66	688.93	From Intake to Power House Option-I
14	S12	3092384.85	1171169.98	710.99	From Intake to Power House Option-I
15	S13	3092621.56	1171146.53	717.32	From Intake to Power House Option-I
16	S14	3092906.92	1171001.08	718.05	From Intake to Power House Option-I
17	S15	3093106.91	1170796.05	728.77	From Intake to Power House Option-I
18	S16	3093477.96	1170515.91	752.33	From Intake to Power House Option-I
19	S17	3093869.91	1170278.37	771.93	From Intake to Power House Option-I
20	S18	3093799.74	1170090.12	776.51	From Intake to Power House Option-I
21	S19	3093683.04	1170034.09	777.00	From Intake to Power House Option-I
22	S20	3092990.87	1169755.97	834.99	From Intake to Power House Option-I
23	S21	3092189.85	1169386.37	766.19	From Intake to Power House Option-I

S#	Point	Easting (m)	Northing (m)	Elevation (m)	Site
24	S22	3091948.86	1169050.89	779.38	From Intake to Power House Option-I
25	S23	3091670.52	1168420.42	869.09	From Intake to Power House Option-I
26	S24	3090963.92	1167719.78	1046.99	From Intake to Power House Option-I
27	S25	3090356.32	1166561.60	1114.34	From Intake to Power House Option-I
28	S26	3090215.57	1166221.38	1068.17	From Intake to Power House Option-I
29	S27	3089707.60	1165619.93	950.29	From Intake to Power House Option-I
30	S42	3089065.74	1165646.02	963.83	From Intake to Power House Option-I
From Intake to Power House Option-II					
31	S2	3090042.08	1171864.31	660.94	From Intake to Power House Option-II
32	S3	3090242.22	1171619.20	663.86	From Intake to Power House Option-II
33	S4	3090363.76	1171537.50	668.62	From Intake to Power House Option-II
34	S5	3090583.67	1171493.59	670.77	From Intake to Power House Option-II
35	S6	3090802.16	1171396.38	666.10	From Intake to Power House Option-II
36	S7	3091271.20	1171139.24	649.42	From Intake to Power House Option-II
37	S8	3090739.90	1171262.06	645.16	From Intake to Power House Option-II
38	S9	3090223.48	1171239.96	651.23	From Intake to Power House Option-II
39	S2	3090042.10	1171864.49	660.81	From Intake to Power House Option-II
40	S1	3090141.68	1171855.95	660.83	From Intake to Power House Option-II
41	S7	3091271.06	1171139.31	649.42	From Intake to Power House Option-II
42	S10	3091457.58	1171245.97	670.46	From Intake to Power House Option-II
43	S11	3091638.18	1171285.66	688.93	From Intake to Power House Option-II
44	S12	3092384.85	1171169.98	710.99	From Intake to Power House Option-II
45	S13	3092621.56	1171146.53	717.32	From Intake to Power House Option-II
46	S14	3092906.92	1171001.08	718.05	From Intake to Power House Option-II
47	S15	3093106.91	1170796.05	728.77	From Intake to Power House Option-II
48	S16	3093477.96	1170515.91	752.33	From Intake to Power House Option-II

S#	Point	Easting (m)	Northing (m)	Elevation (m)	Site
49	S17	3093869.91	1170278.37	771.93	From Intake to Power House Option-II
50	S18	3093799.74	1170090.12	776.51	From Intake to Power House Option-II
51	S19	3093683.04	1170034.09	777.00	From Intake to Power House Option-II
52	S20	3092990.87	1169755.97	834.99	From Intake to Power House Option-II
53	S21	3092189.85	1169386.37	766.19	From Intake to Power House Option-II
54	S22	3091948.86	1169050.89	779.38	From Intake to Power House Option-II
55	S23	3091670.52	1168420.42	869.09	From Intake to Power House Option-II
56	S24	3090963.92	1167719.78	1046.99	From Intake to Power House Option-II
57	S25	3090356.32	1166561.60	1114.34	From Intake to Power House Option-II
58	S26	3090215.57	1166221.38	1068.17	From Intake to Power House Option-II
59	S27	3089707.60	1165619.93	950.29	From Intake to Power House Option-II
60	S28	3089025.41	1164202.96	936.27	From Intake to Power House Option-II
61	S29	3089238.82	1163176.22	994.91	From Intake to Power House Option-II
62	S14	3089238.76	1163176.53	994.91	From Intake to Power House Option-II
63	S30	3088462.10	1162825.43	898.21	From Intake to Power House Option-II
64	S31	3087990.96	1162041.09	673.58	From Intake to Power House Option-II
65	S32	3088078.15	1161450.43	645.54	From Intake to Power House Option-II

3.4 Traversing

Traversing was carried out in a closed loop form to establish control in the area of interest starting from the first survey control point. The traverse distances were measured in two directions (forward & back) and mean adopted. Apart from establishing Permanent Bench Marks, a traverse consisted of Sixty Six (66) points were also established in the project area. The list of Traverse Points is presented in **Table 3.3.** Triangulation method was used for traversing. At least three traverse stations at the same or higher level were intervisible and there was no hinged connection at traverse stations. Every triangle of the traverse had at least one side common with another triangle of the traverse. There were three levels of traverse. A

traverse station fixed by two known stations was checked by the third known station. The accuracy of this check was of the first order.

3.5 Methodology

A credible topographic survey is one of the basic requirements for quality planning/design of a project. To carry out the project layouts and the feasibility level engineering design of hydropower project sites, following main tasks have been included in the survey scope of work:

- Installation of Permanent survey control points established at appropriate locations with BM level.
- Processing of topographic survey digital data by using survey software.
- Generation of topographic sheets by using CAD/CAM techniques.
- Production of topographic survey drawings for different structures as per scale and mentioned in TOR.

The project sites are scattered and situated in upper and lower Dir districts of Khyber Pakhtunkhwa province. The survey parties have been stationed at rented accommodation in close vicinity of the sites. They were equipped with laptop computers to download and process the survey data then and there.

A crew of surveyors and assistant surveyors were mobilized. They were equipped with Electronic Total Stations and Auto Levels. The survey helpers were hired from amongst the locals, who were not only acted as guides apart from survey work but were also helpful in maintaining cordial relations with local population.

The Consultants establish a triangulation network in the every project area site. Bench marks has been set in accordance with usual practice. The Global Positioning System (GPS) is commonly used in Pakistan and has been utilized as and when required particularly for the establishment of survey Bench Marks.

The triangulation network has been used to survey cross sections and longitudinal profiles along the Panjkora River. These profiles will be needed for the establishment of the main project structures with a precision of up to 5.0 meters.

3.6 Survey Maps

Survey maps in respect of each permanent survey point (Survey Marker) are prepared on standard format. It contains general sketch for location of each control point, its detailed description, final coordinates and elevation value, refer to **Figure SKS-002-01**. The following features were surveyed and included in the maps in different layers:

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- Spot levels
- Break lines at significant slope changes such as top and toe of embankments.
- River/Khwar embankment
- Rock outcrop, the rock faces and single rock boulders> 5m
- Land use classification
- Survey control points
- Buildings
- Bridges
- Roads, tracks and retaining walls
- Any other physical features of significant importance.

3.7 SRTM Data Processing

Contours were first generated from the erected SRTM elevation points. Points were downloaded from the internet free data banks, and then interpolated with the help of Krigging method to generate the DTM, which was later used to generate 5 meter interval contours. Prints of these contours were also generated for study purposes in the inception phase.

In the second step, survey points of certain selected areas were acquired from topographic survey using total station. These points were later mixed in the SRTM data to verify the accuracy of SRTM points and also to generate more precise contours of the study area.

3.8 Units of Measurement

The linear measurement units used in survey and mapping work are metric and the angular measurement in degrees, minutes and seconds of arc. Indian Zoned Grid system is used for surveying. Our site is located in Indian Zone I and reference datum is WGS84.

3.9 Structural Survey

Topographic survey of Shigo Kas HPP located in district lower Dir has been carried out for alignment/layout of structures as per TOR. The Consultants carryout the surveys with the most modern and sophisticated total stations and computer software "Eagle Point" has been be used for plotting the surveys. GPS has been used to establish the control points at suitable locations. These controls points have been used for observing cross sections.

The following topographic surveys in the area of the main structures has been carried out and mapped as per the detail given below.

- **Intake Area:**

  Diversion weir with area of all appurtenant structures with contour interval of 1 m in a scale of 1:500 supported by sufficient number of Cross section and Long Sections as per site requirements.

- **Connecting Channel:**

  Connecting channel with 1 m contour interval at a scale of 1:500 supported by sufficient number of Cross section and Long Sections as per site conditions.

- **Head Race Tunnel:**

  Survey of inlet and outlet portal of proposed tunnel alignment with contour interval of 1m in a scale of 1:500 supported by sufficient number of Cross sections and Long Section as per site conditions.

- **Surge Tank Structure:**

  In location of surge chamber an alignment with contour interval of 1m in a scale of 1:500 supported by sufficient number of Cross sections and Long Section as per site conditions.

- **Penstock:**

  Area with contour interval of 1m in a scale of 1:1000 supported by sufficient number of Cross sections and Long Section as per site requirements.

- **Power House:**

  Area including tailrace canal with contour interval of 1m in a scale of 1:500 supported by sufficient number of Cross sections and Long Sections as per site requirements.

  The topographical survey maps of all sites are presented in the survey report.

3.10 Reference Datum

Survey of Pakistan (SOP) control points have been adopted as reference datum for establishment of horizontal / vertical controls for the project. The nearest SOP permanent stations, present at workable locations, have been connected to those stations. The Consultants have established a triangulation network in the whole project area. Bench marks have been set in accordance with usual practice. The Global Positioning System (GPS) has been adopted, where required.

3.11 Horizontal Control

The horizontal control has been done through a combination of conventional triangulation and EDM traversing method. All survey work was conducted by having digital display infrared beam Total Station. Triangulation network consists of well balanced quadrilaterals or center point polygons and well balanced triangles. The EDM traversing is in the closed loop form and all traversing lines measured two ways and mean was used provided two measurements agree to 1:10,000. Horizontal angle measurement with maximum spread of 20 seconds has been used in computations. Vertical angles are not taken because the Total Station with provision for field slope distance to horizontal was employed.

3.12 Vertical Control

The mean sea level (masl) of SoP, cross checked by Total Station, has been taken as reference for the project sites. Standard bench marks were established in the project area through DGPS and verified by leveling and checked using precise leveling instruments. All necessary precautions and standard procedures which are applicable to this class of survey have been adopted.

3.13 Satellite Images

Base map of Shigo Kas Hydropower Project was prepared using the cutting edge technologies of remote sensing and GIS. Latest available high resolution satellite image was procured to digitize the land features, whereas SRTM elevation data was utilized to generate contours. Large scale and highly accurate survey points collected during field topographic survey were also embedded into it to improve the map quality. Latest cartographic environment was then used to prepare the GIS maps. Details of process adopted are given in the following paragraph.

The high resolution satellite image was purchased and processed to use for the support of Environmental, Hydrological, Geological and Infrastructure studies and for the layout and alignment of tunnel. The representation of continuous elevation values over a topographic surface by a regular array of z-values, referenced to a common datum, typically used to represent terrain relief is called a Digital Elevation Model (DEM). SRTM (Shuttle Radar Topographical Mission) data was used as the DEM. The SRTM data was processed and generate the contour interval of 5 meter which was superimposed on the satellite imagery. The 10 meter contour developed from DEM was superimposed on the satellite image and used to generate the layouts at scale 1:1000. For satellite images refer Annexure-3B; **Figure SKS-01 to SKS-03.**

3.14 Satellite Image Acquisition

As per requirement 53 km^2 area was selected to place order for satellite images. The salient features of the image are in **Table - 3.4.**

Table - 3.4: Satellite Imaginary Salient Features

Parameter	Description
Satellite	World View II Geo Eye
Product Type	Imagery
Resolution	50 cm Panchromatic (0.6 m High Resolution)
UTM Zone	43N
Zone Units	Meters
Datum	WGS84

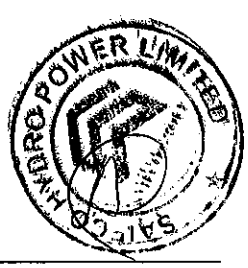
3.15 Elevation Data Processing

The Consultants acquired latest Digital Elevation Model (DEM) including contours for each project site along with purchase of satellite imagery of the area. This DEM data is available at a ground resolution of 5m and is converted to Auto Cad drawing format. This data is used to generate more precise contours of the study area particularly along the tunnel alignment. These contours are also mixed with the contours prepared from detailed topographic survey of weir intake and power house area.

3.16 Map Preparation and Printing

A complete geo-database was then obtained containing 5m interval index contours with other existing features viz, roads, bridges, built up areas, agriculture lands etc. All these products were then overlaid on each other inside a data frame which was already controlled under the SOP's coordinate system. Cartographic rules and mapping standards were then used to prepare maps.

Finally, the spatial data from GIS environment was transformed to CAD format, so that it can be utilized for planning and development purposes. The contour map thus developed is shown in Annexure-3A: Survey Drawings.



LIST OF SURVEY CONTROL POINTS

S.No	Description	Name of BM's	Easting m	Northing m	Elevation m	Site	Remarks
LIST OF SURVEY PERMANENT BENCH MARKS							
1	WEIR SITE	S-1	3090141.840	1171855.820	661.000	Intake	Right side of Zulum Bridge (Center)
		S-2	3090042.076	1171864.307	661.022	Intake	Left side of Zulum Bridge (Center)
		S-7 (Pillar)	3091271.056	1171139.314	649.415	Intake	Left side of Panjkora River, near Weir located on Track
2	POWER HOUSE OPTION-I	S-43	3087755.276	1165764.306	600.152	Power House (Option-I)	Left side of Panjkora River on the Top of Stone
		S-44	3087639.893	1165767.268	594.236	Power House (Option-I)	Left side of Panjkora River on the Top of Stone
3	POWER HOUSE OPTION-II	S-31	3088224.063	1162003.237	667.683	Power House (Option-II)	Left side of Panjkora River, between House and School
		S-32	3088313.494	1161417.809	640.079	Power House (Option-II)	Left side of Panjkora River, near Track and Houses
SURVEY TRAVERSE POINTS From Intake to Power House Option-I							
i	Traverse Points (P.H Option-I)	S2	3090042.08	1171864.31	660.94	–	From Intake to Power House Option-I
		S3	3090242.22	1171619.20	663.86	–	From Intake to Power House Option-I
		S4	3090363.76	1171537.50	668.62	–	From Intake to Power House Option-I
		S5	3090583.67	1171493.59	670.77	–	From Intake to Power House Option-I
		S6	3090802.16	1171396.38	666.10	–	From Intake to Power House Option-I
		S7	3091271.20	1171139.24	649.42	–	From Intake to Power House Option-I
		S8	3090739.90	1171262.06	645.16	–	From Intake to Power House Option-I
		S9	3090223.48	1171239.96	651.23	–	From Intake to Power House Option-I
		S2	3090042.10	1171864.49	660.81	–	From Intake to Power House Option-I
		S1	3090141.68	1171855.95	660.83	–	From Intake to Power House Option-I
		S7	3091271.06	1171139.31	649.42	–	From Intake to Power House Option-I
		S10	3091457.58	1171245.97	670.46	–	From Intake to Power House Option-I
		S11	3091638.18	1171285.66	688.93	–	From Intake to Power House Option-I
		S12	3092384.85	1171169.98	710.99	–	From Intake to Power House Option-I
		S13	3092621.56	1171146.53	717.32	–	From Intake to Power House Option-I
		S14	3092906.92	1171001.08	718.05	–	From Intake to Power House Option-I
		S15	3093106.91	1170796.05	728.77	–	From Intake to Power House Option-I
		S16	3093477.96	1170515.91	752.33	–	From Intake to Power House Option-I
		S17	3093869.91	1170278.37	771.93	–	From Intake to Power House Option-I
		S18	3093799.74	1170090.12	776.51	–	From Intake to Power House Option-I
		S19	3093683.04	1170034.09	777.00	–	From Intake to Power House Option-I
		S20	3092990.87	1169755.97	834.99	–	From Intake to Power House Option-I
		S21	3092189.85	1169386.37	766.19	–	From Intake to Power House Option-I
		S22	3091948.86	1169050.89	779.38	–	From Intake to Power House Option-I
		S23	3091670.52	1168420.42	869.09	–	From Intake to Power House Option-I
		S24	3090963.92	1167719.78	1046.99	–	From Intake to Power House Option-I
		S25	3090356.32	1166561.60	1114.34	–	From Intake to Power House Option-I
		S26	3090215.57	1166221.38	1068.17	–	From Intake to Power House Option-I
		S27	3089707.60	1165619.93	950.29	–	From Intake to Power House Option-I
		S42	3089065.74	1165646.02	963.83	–	From Intake to Power House Option-I

S.No	Description	Name of BM's	Easting m	Northing m	Elevation m	Site	Remarks
SURVEY TRAVERSE POINTS From Intake to Power House Option-II							
ii	Traverse Points (P.H Option-II)	S2	3090042.08	1171864.31	660.94	–	From Intake to Powor House Option-II
		S3	3090242.22	1171619.20	663.86	–	From Intake to Power House Option-II
		S4	3090363.76	1171537.50	668.62	–	From Intake to Power House Option-II
		S5	3090583.67	1171493.59	670.77	–	From Intake to Power House Option-II
		S6	3090802.16	1171396.38	666.10	–	From Intake to Power House Option-II
		S7	3091271.20	1171139.24	649.42	–	From Intake to Power House Option-II
		S8	3090739.90	1171262.06	645.16	–	From Intake to Power House Option-II
		S9	3090223.48	1171239.96	651.23	–	From Intake to Power House Option-II
		S2	3090042.10	1171864.49	660.81	–	From Intake to Power House Option-II
		S1	3090141.68	1171855.95	660.83	–	From Intake to Power House Option-II
		S7	3091271.06	1171139.31	649.42	–	From Intake to Power House Option-II
		S10	3091457.58	1171245.97	670.46	–	From Intake to Power House Option-II
		S11	3091638.18	1171285.66	688.93	–	From Intake to Power House Option-II
		S12	3092384.85	1171169.98	710.99	–	From Intake to Power House Option-II
		S13	3092621.56	1171146.53	717.32	–	From Intake to Power House Option-II
		S14	3092906.92	1171001.08	718.05	–	From Intake to Power House Option-II
		S15	3093106.91	1170796.05	728.77	–	From Intake to Power House Option-II
		S16	3093477.96	1170515.91	752.33	–	From Intake to Power House Option-II
		S17	3093869.91	1170278.37	771.93	–	From Intake to Power House Option-II
		S18	3093799.74	1170090.12	776.51	–	From Intake to Power House Option-II
		S19	3093683.04	1170034.09	777.00	–	From Intake to Power House Option-II
		S20	3092990.87	1169755.97	834.99	–	From Intake to Power House Option-II
		S21	3092189.85	1169386.37	766.19	–	From Intake to Power House Option-II
		S22	3091948.86	1169050.89	779.38	–	From Intake to Power House Option-II
		S23	3091670.52	1168420.42	869.09	–	From Intake to Power House Option-II
		S24	3090963.92	1167719.78	1046.99	–	From Intake to Power House Option-II
		S25	3090356.32	1166561.60	1114.34	–	From Intake to Power House Option-II
		S26	3090215.57	1166221.38	1068.17	–	From Intake to Power House Option-II
		S27	3089707.60	1165619.93	950.29	–	From Intake to Power House Option-II
		S28	3089025.41	1164202.95	936.27	–	From Intake to Power House Option-II
		S29	3089238.82	1163176.22	994.91	–	From Intake to Power House Option-II
		S14	3089238.76	1163176.53	994.91	–	From Intake to Power House Option-II
		S30	3088462.10	1162825.43	898.21	–	From Intake to Power House Option-II
		S31	3087990.95	1162041.09	673.58	–	From Intake to Power House Option-II
		S32	3088078.15	1161450.43	645.54	–	From Intake to Power House Option-II

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NOTES

1. ALL ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

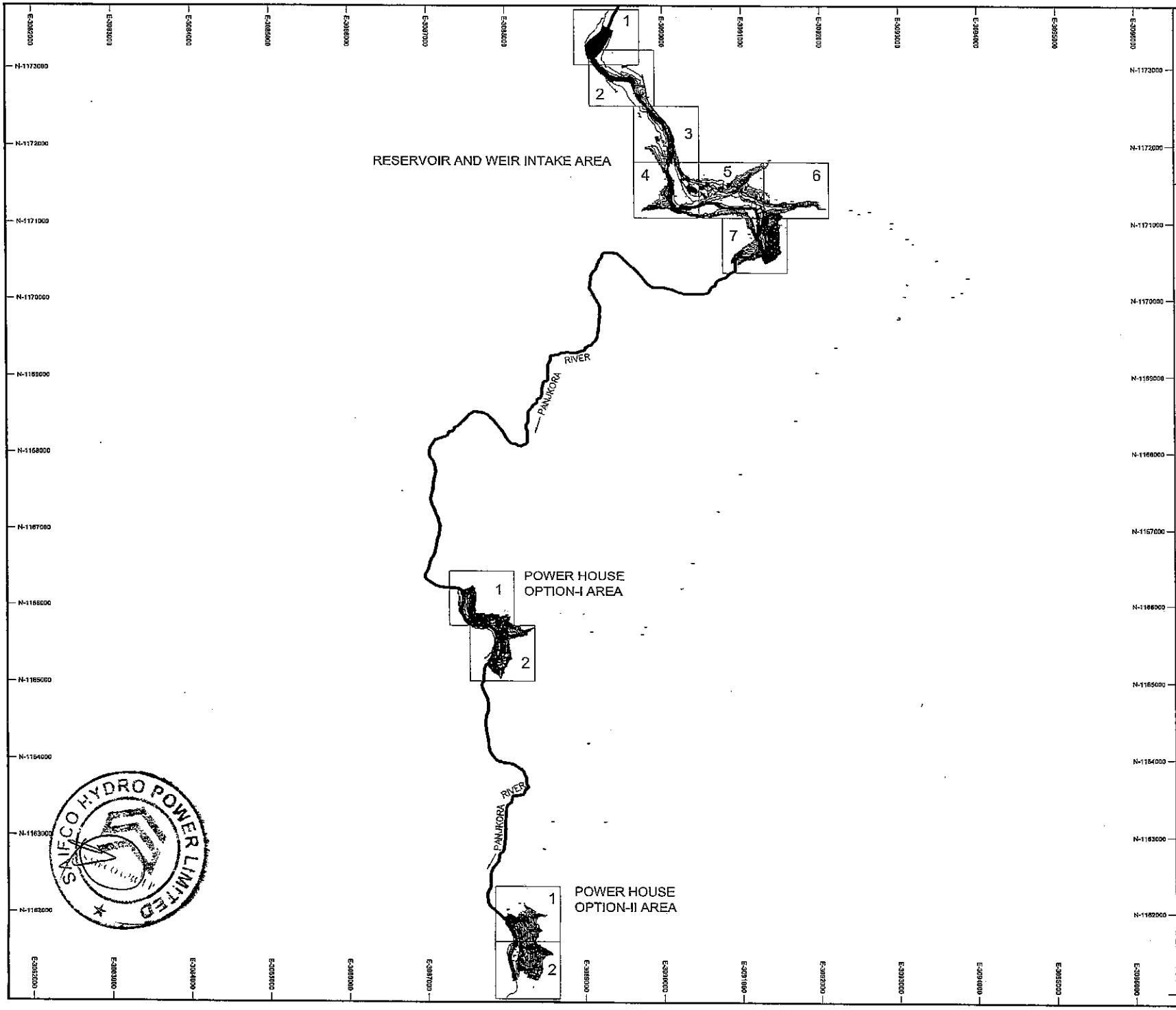
SHIGO KAS HPP

TOPOGRAPHIC SURVEY
LIST OF SURVEY CONTROL POINTS

SHEET 1 of 1

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	April, 2013
SURVEYED:	SHIRAZ	FIGURE NO.	SKS-001-01
CHECKED:	HADI		
APPROVED:	M.H.F	SCALE.	N.T.S



SAIFCO HYDRO POWER LIMITED

N

NOTES

1. ALL ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
2. GRIDS ARE IN 1000m INTERVAL.

LEGEND

RIVER
NULLAH
HOUSES/SHOPS
MOSQUE/SCHOOL
ROAD
TRACK
CONTOURS
BENCH MARK
TRAVERSE POINTS
CP CONTROL POINTS
RETAINING WALL
ELECTRIC POLE
TREES
AGRICULTURE LAND
GRAVE YARD
CULVERT
WATER TANK/TUBE WELL

Meters 0 500 1000 1500 2000

SCALE

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

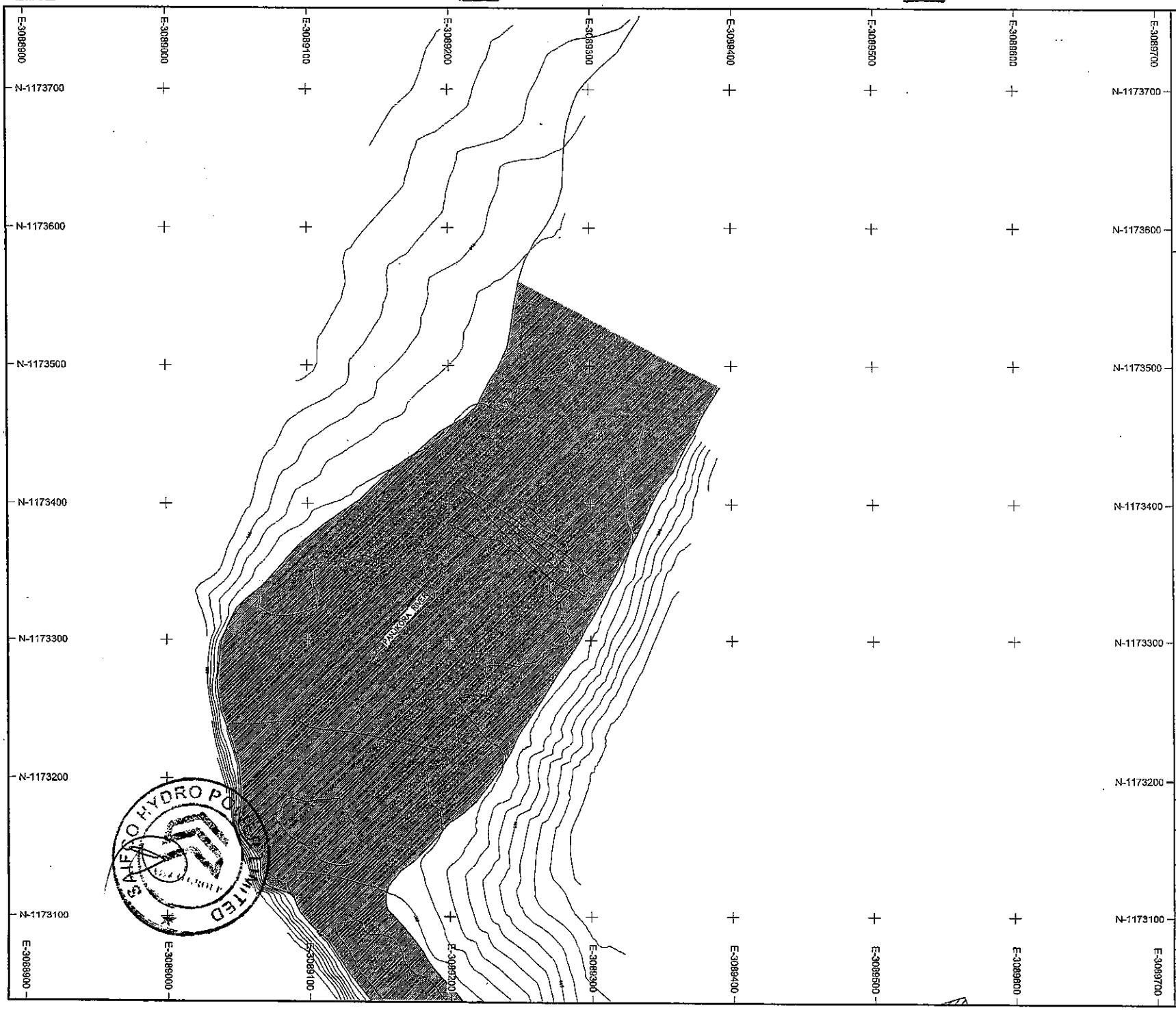
SHIGO KAS HPP

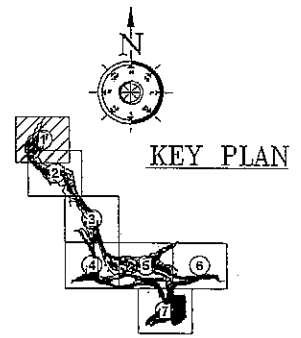
TOPOGRAPHIC SURVEY
(INDEX MAP)

(SHEET 1 / 1)

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	April, 2013
SURVEYED:	SHIRAZ	FIGURE NO.	SKS-002-01
CHECKED:	HADI		
APPROVED:	M.H.F	SCALE.	1 : 45,000





NOTES

1. ALL ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
2. ALL CONTOUR ARE IN 1m INTERVAL.
3. GRIDS ARE IN 100m INTERVAL.

LEGEND

RIVER
NULLAH
HOUSES/SHOPS
MOSQUE/SCHOOL
ROAD
TRACK
CONTOURS
BENCH MARK
TRAVERSE POINTS
CP CONTROL POINTS
RETAINING WALL
ELECTRIC POLE
TREES
AGRICULTURE LAND
GRAVE YARD
CULVERT
WATER TANK/TUBE WELL

Meters 0 25 50 75 100
SCALE

PEDO
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Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

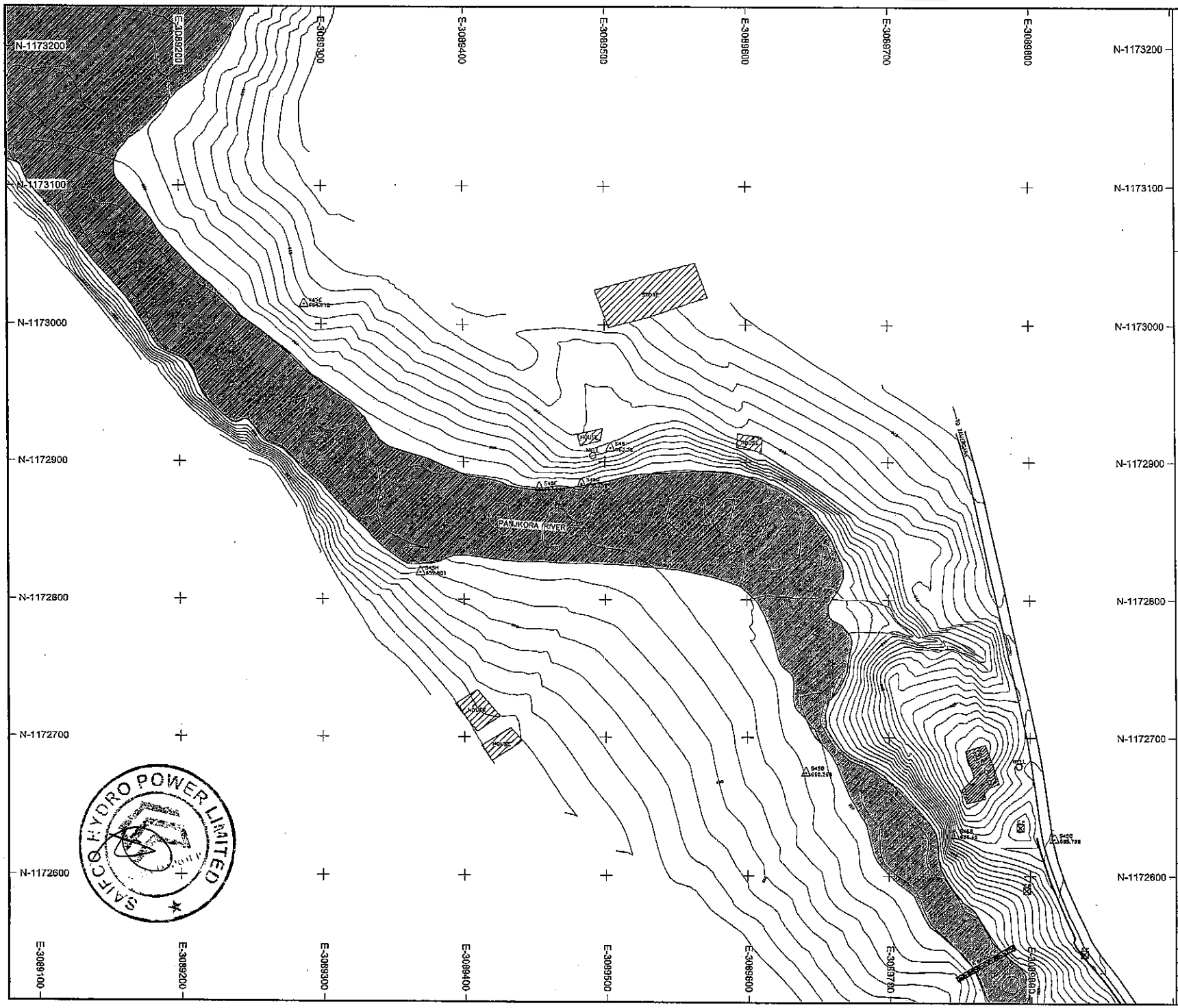
SHIGO KAS HPP

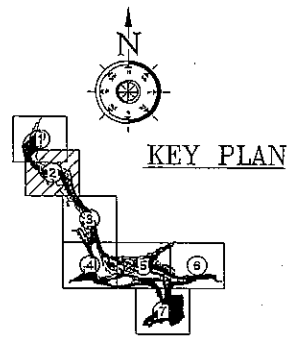
TOPOGRAPHIC SURVEY PLAN
RESERVOIR AND WEIR INTAKE SITE

(SHEET 1/7)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	April, 2013
SURVEYED:	SHIRAZ	FIGURE NO.	SKS-003-01
CHECKED:	HADI	SCALE	1 : 2500
APPROVED:	M.H.F		





NOTES

1. ALL ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
2. ALL CONTOUR ARE IN 1m INTERVAL.
3. GRIDS ARE IN 100m INTERVAL.

LEGEND

RIVER
NULLAH
HOUSES/SHOPS
MOSQUE/SCHOOL
ROAD
TRACK
CONTOURS
BENCH MARK
TRAVERSE POINTS
CP CONTROL POINTS
RETAINING WALL
ELECTRIC POLE
TREES
AGRICULTURE LAND
GRAVE YARD
CULVERT
WATER TANK/TUBE WELL

Meters 0 25 50 75 100
SCALE

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

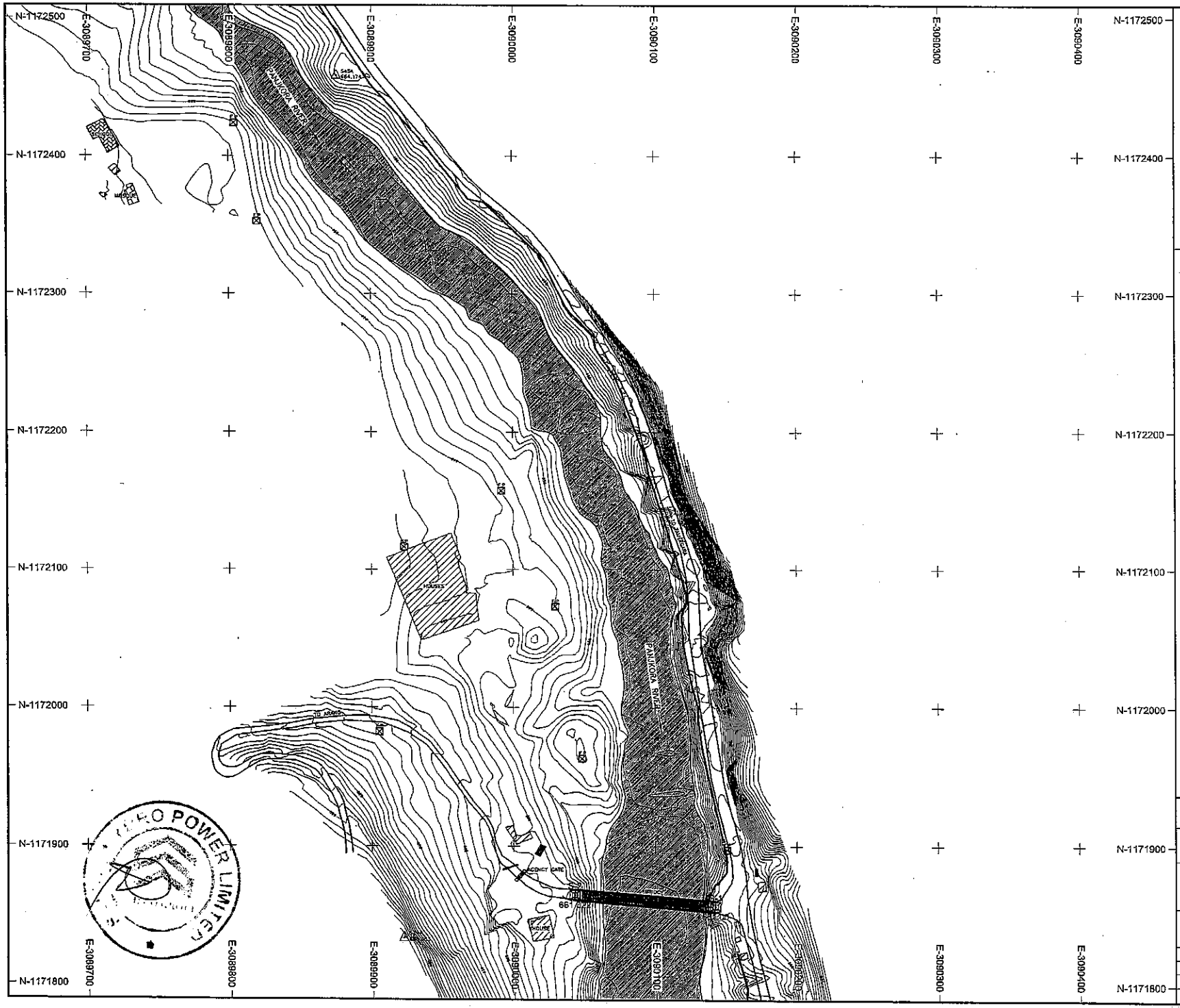
FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

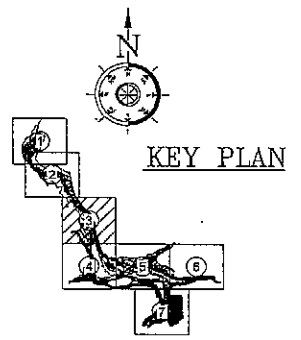
SHIGO KAS HPP

TOPOGRAPHIC SURVEY PLAN
RESERVOIR AND WEIR INTAKE SITE
(SHEET 2 of 7)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	April, 2013
SURVEYED:	SHIRAZ	FIGURE NO.	SKS-003-02
CHECKED:	HADI		
APPROVED:	M.H.F	SCALE.	1 : 2500





NOTES

1. ALL ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
2. ALL CONTOUR ARE IN 1m INTERVAL.
3. GRIDS ARE IN 100m INTERVAL.

LEGEND

RIVER.....
NULLAH.....
HOUSES/SHOPS.....
MOSQUE/SCHOOL.....
ROAD.....
TRACK.....
CONTOURS.....
BENCH MARK.....
TRAVERSE POINTS.....
CP CONTROL POINTS.....
RETAINING WALL.....
ELECTRIC POLE.....
TREES.....
AGRICULTURE LAND.....
GRAVE YARD.....
CULVERT.....
WATER TANK/TUBE WELL.....

Meters 0 25 50 75 100

SCALE

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Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

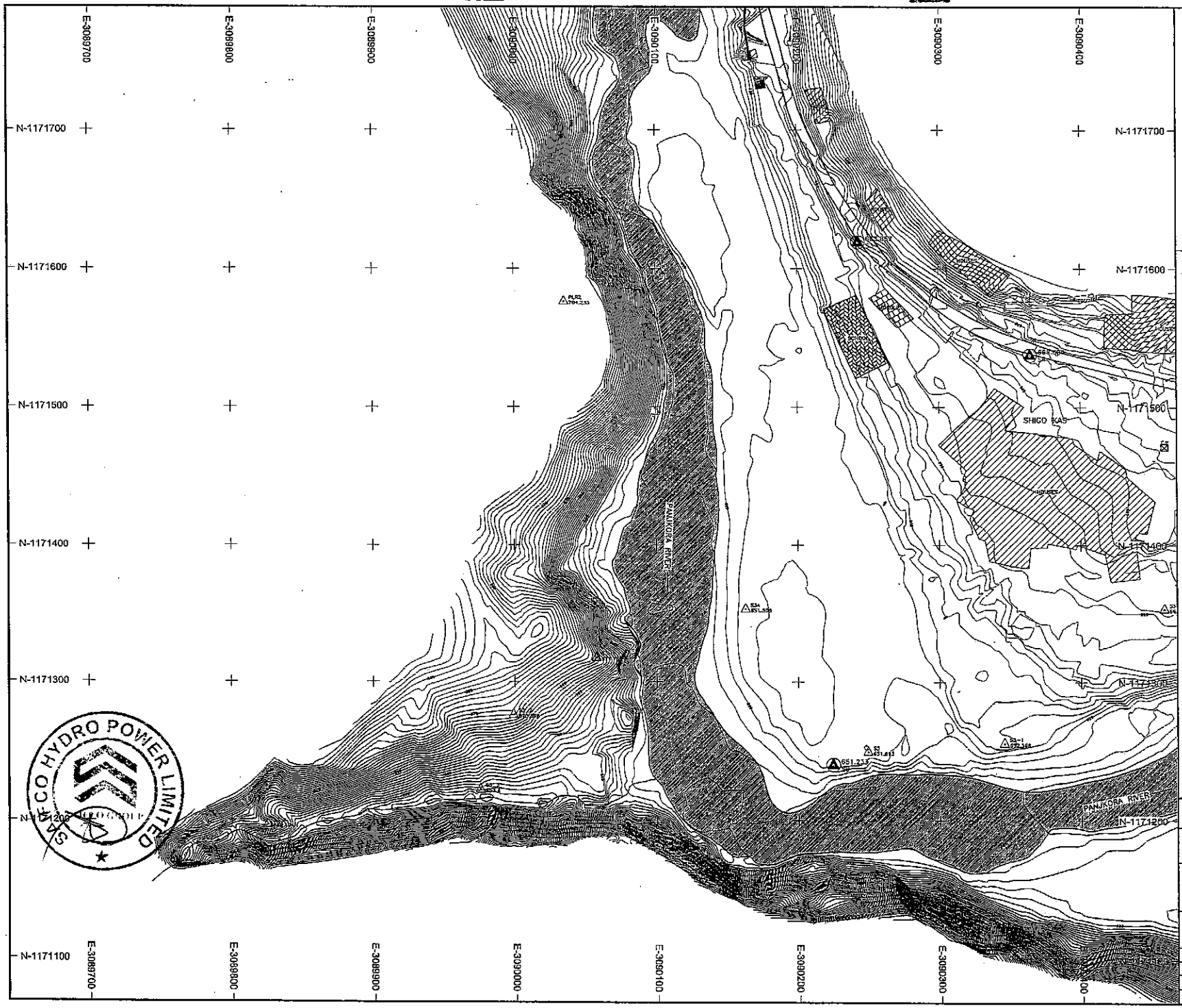
SHIGO KAS HPP

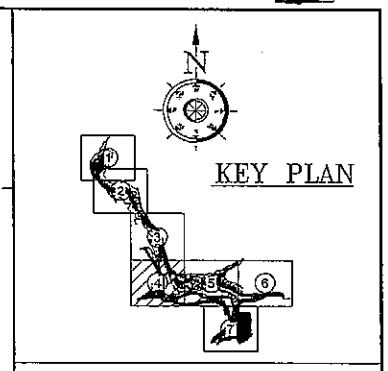
TOPOGRAPHIC SURVEY PLAN
RESERVOIR AND WEIR INTAKE SITE

(SHEET 3 / 7)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	April, 2013
SURVEYED:	SHIRAZ	FIGURE NO.	SKS-003-03
CHECKED:	HADI	SCALE.	1 : 2500
APPROVED:	M.H.F		





NOTES

1. ALL ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
2. ALL CONTOUR ARE IN 1m INTERVAL.
3. GRIDS ARE IN 100m INTERVAL.

LEGEND

- RIVER
- NULLAH
- HOUSES/SHOPS
- MOSQUE/SCHOOL
- ROAD
- TRACK
- CONTOURS
- BENCH MARK
- TRAVERSE POINTS
- CP CONTROL POINTS
- RETANING WALL
- ELECTRIC POLE
- TREES
- AGRICULTURE LAND
- GRAVE YARD
- CULVERT
- WATER TANK/TUBE WELL

Meters 0 25 50 75 100

SCALE

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FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

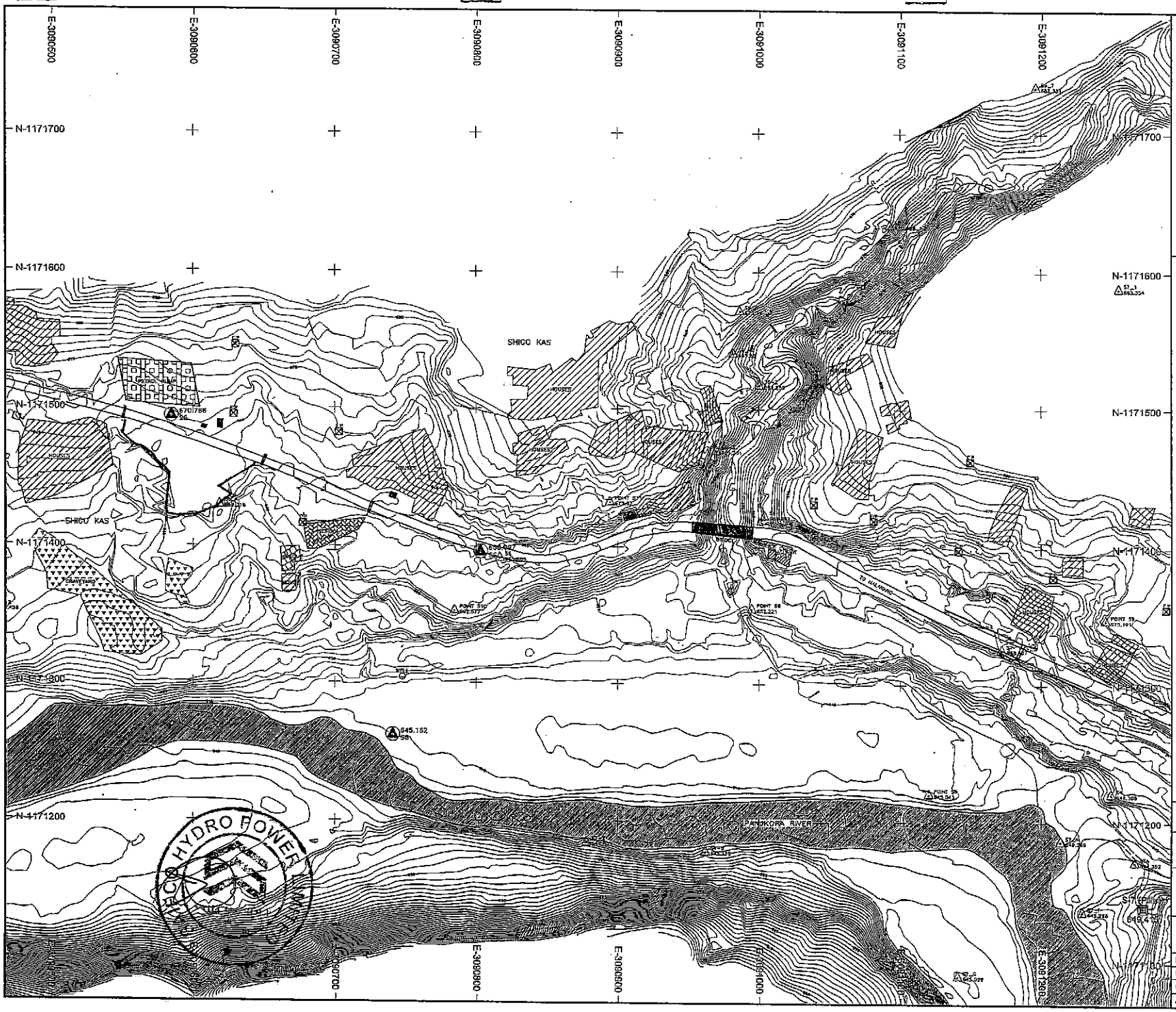
TOPOGRAPHIC SURVEY PLAN
RESERVOIR AND WEIR INTAKE SITE

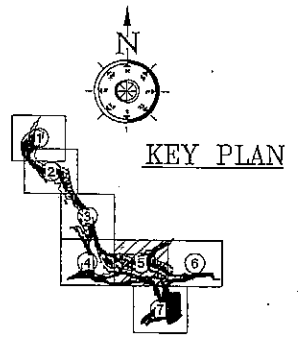
(SHEET 4/7)

CONSULTANTS:

ELECTRA CONSULTANTS — IN ASSOCIATION WITH — INTEGRATION

DRAWN:	ALI	DATE:	April, 2013
SURVEYED:	SHIRAZ	FIGURE NO.	SKS-003-04
CHECKED:	HADI		
APPROVED:	M.H.F	SCALE	1 : 2500





NOTES

1. ALL ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
2. ALL CONTOUR ARE IN 1m INTERVAL.
3. GRIDS ARE IN 100m INTERVAL.

LEGEND

- RIVER
- NULLAH
- HOUSES/SHOPS
- MOSQUE/SCHOOL
- ROAD
- TRACK
- CONTOURS
- BENCH MARK
- TRAVERSE POINTS
- CP CONTROL POINTS
- RETANING WALL
- ELECTRIC POLE
- TREES
- AGRICULTURE LAND
- GRAVE YARD
- CULVERT
- WATER TANK/TUBE WELL

Meters 0 25 50 75 100

SCALE

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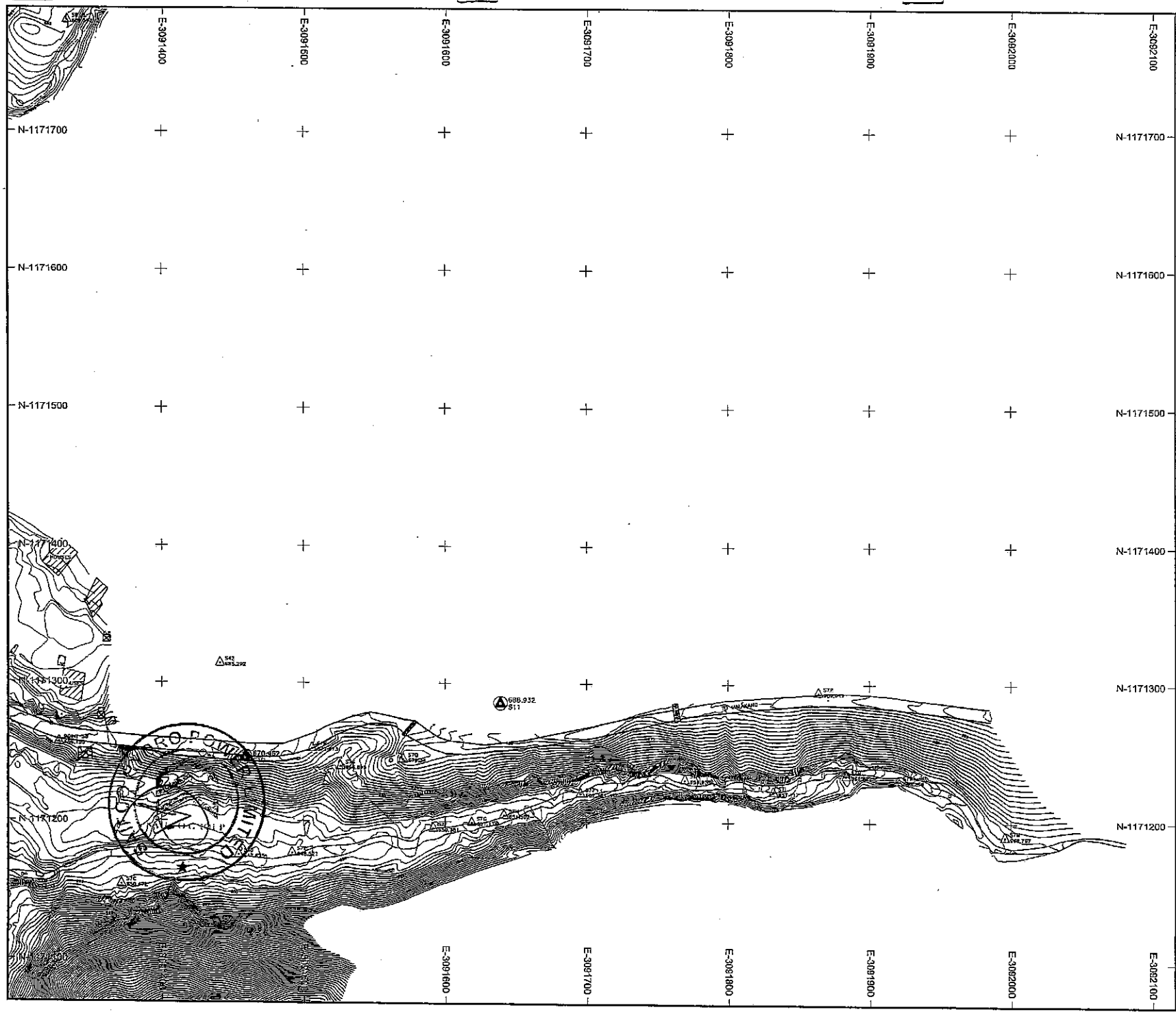
FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

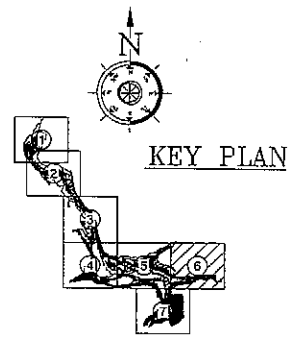
SHIGO KAS HPP

TOPOGRAPHIC SURVEY PLAN
RESERVOIR AND WEIR INTAKE SITE

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	April, 2013
SURVEYED:	SHIRAZ	FIGURE NO.	SKS-003-05
CHECKED:	HADI		
APPROVED:	M.H.F	SCALE.	1 : 2500





NOTES

1. ALL ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
2. ALL CONTOUR ARE IN 1m INTERVAL.
3. GRIDS ARE IN 100m INTERVAL.

LEGEND

RIVER
NULLAH
HOUSES/SHOPS
MOSQUE/SCHOOL
ROAD
TRACK
CONTOURS
BENCH MARK
TRAVERSE POINTS
CP CONTROL POINTS
RETAINING WALL
ELECTRIC POLE
TREES
AGRICULTURE LAND
GRAVE YARD
CULVERT
WATER TANK/TUBE WELL

Meters 0 25 50 75 100

SCALE

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FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

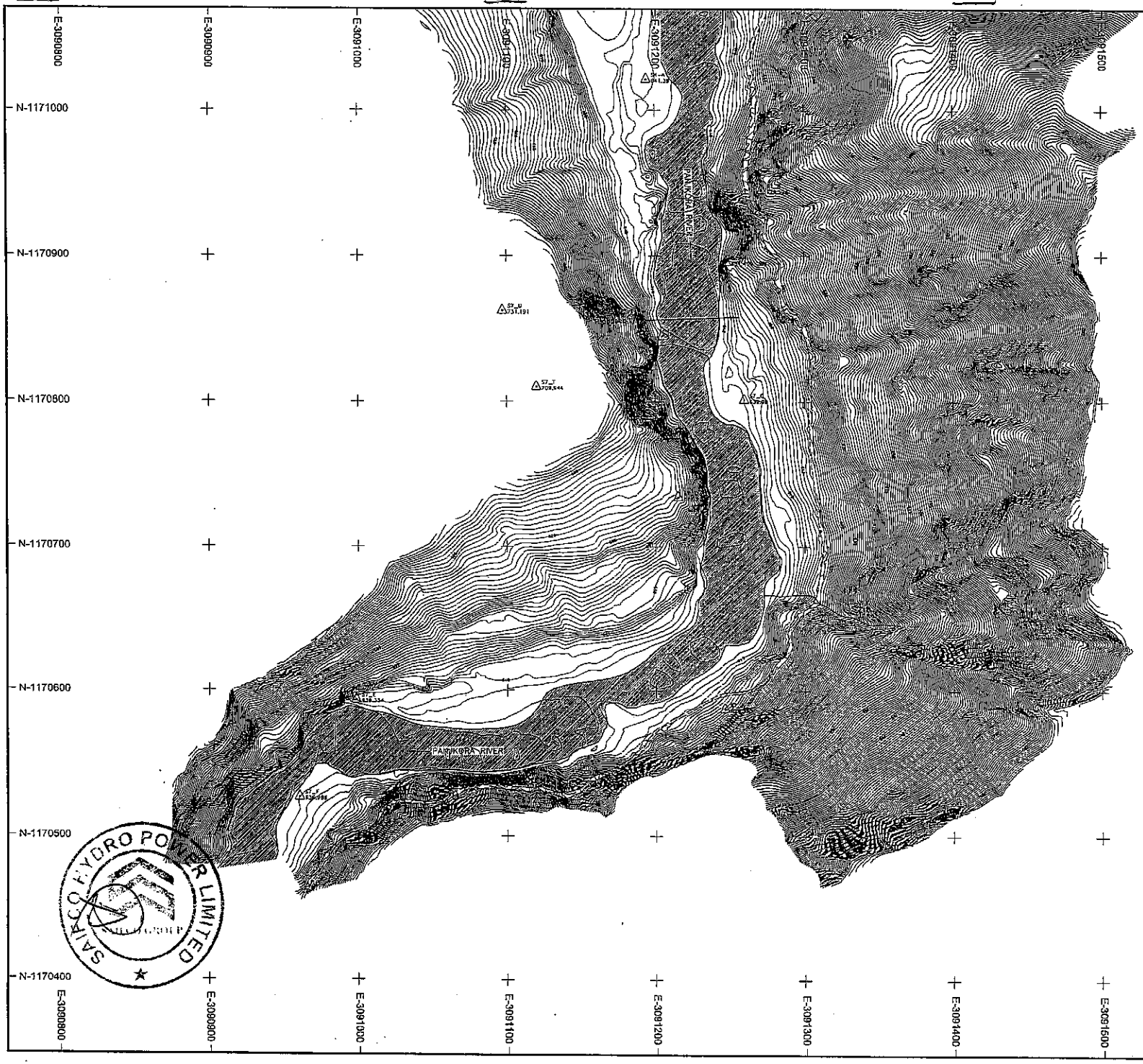
SHIGO KAS HPP

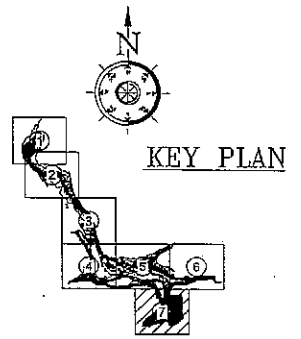
TOPOGRAPHIC SURVEY PLAN
RESERVOIR AND WEIR INTAKE SITE

(SHEET 1 OF 1)

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	April, 2013
SURVEYED:	SHIRAZ	FIGURE NO.	SKS-003-05
CHECKED:	HADI		
APPROVED:	M.H.F	SCALE.	1 : 2500





NOTES

1. ALL ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
2. ALL CONTOUR ARE IN 1m INTERVAL.
3. GRIDS ARE IN 100m INTERVAL.

LEGEND

RIVER
NULLAH
HOUSES/SHOPS
MOSQUE/SCHOOL
ROAD
TRACK
CONTOURS
BENCH MARK
TRAVERSE POINTS
CP CONTROL POINTS
RETAINING WALL
ELECTRIC POLE
TREES
AGRICULTURE LAND
GRAVE YARD
CULVERT
WATER TANK/TUBE WELL

Meters 0 25 50 75 100
SCALE

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FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

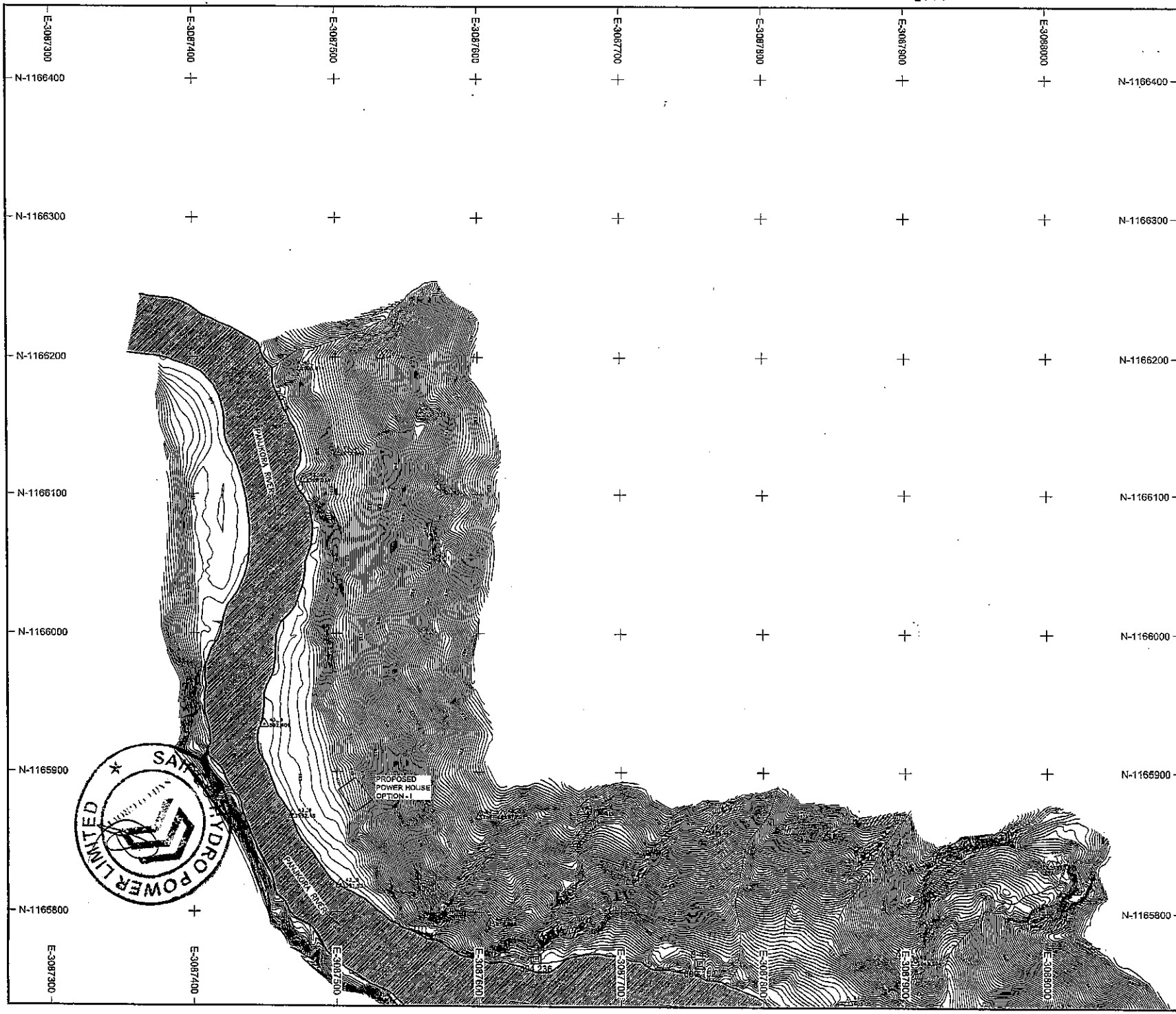
SHIGO KAS HPP

TOPOGRAPHIC SURVEY PLAN
RESERVOIR AND WEIR INTAKE SITE

(SHEET 7)

CONSULTANTS:
ELECTRA CONSULTANTS in ASSOCIATION with INTEGRATION

DRAWN:	ALI	DATE:	April, 2013
SURVEYED:	SHIRAZ	FIGURE NO.	SKS-003-07
CHECKED:	HADI		
APPROVED:	M.H.F	SCALE.	1 : 2500



N

KEY PLAN



NOTES

1. ALL ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
2. ALL CONTOUR ARE IN 1m INTERVAL.
3. GRIDS ARE IN 100m INTERVAL.

LEGEND

RIVER.....
NULLAH.....
HOUSES/SHOPS.....
MOSQUE/SCHOOL.....
ROAD.....
TRACK.....
CONTOURS.....
BENCH MARK.....
TRAVERSE POINTS.....
CP CONTROL POINTS.....
RETANING WALL.....
ELECTRIC POLE.....
TREES.....
AGRICULTURE LAND.....
GRAVE YARD.....
CULVERT.....
WATER TANK/TUBE WELL.....

Meters 0 25 50 75 100

SCALE

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PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

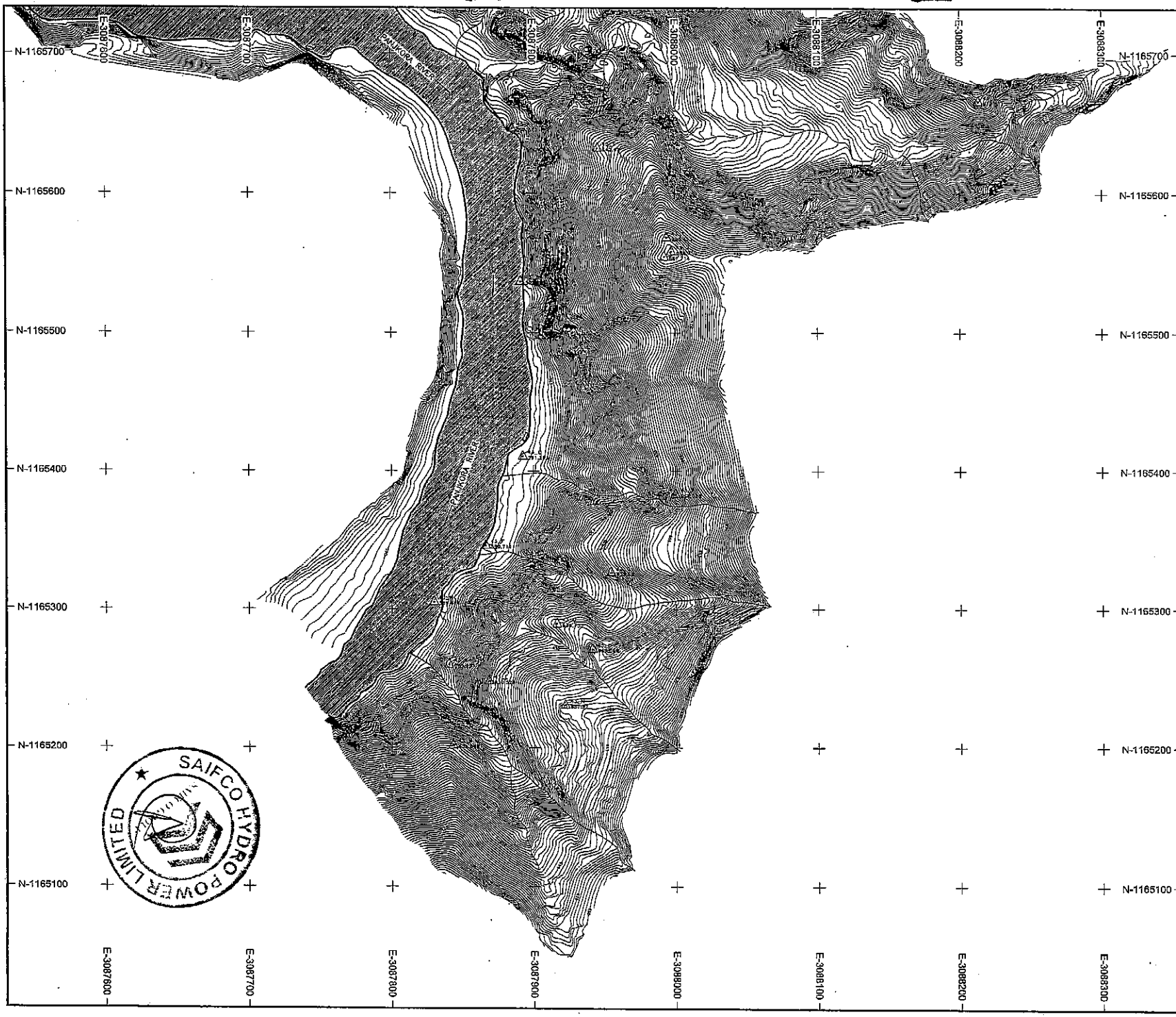
SHIGO KAS HPP

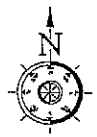
TOPOGRAPHIC SURVEY PLAN
POWER HOUSE AREA (OPTION-I)

(SHEET 1/2)

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	April, 2013
SURVEYED:	SHIRAZ	FIGURE NO.	SKS-004-01
CHECKED:	HADI		
APPROVED:	M.H.F	SCALE.	1 : 2500





KEY PLAN



NOTES

1. ALL ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
2. ALL CONTOUR ARE IN 1m INTERVAL.
3. GRIDS ARE IN 100m INTERVAL.

LEGEND

RIVER
NULLAH
HOUSES/SHOPS
MOSQUE/SCHOOL
ROAD
TRACK
CONTOURS
BENCH MARK
TRAVERSE POINTS
CP CONTROL POINTS
RETAINING WALL
ELECTRIC POLE
TREES
AGRICULTURE LAND
GRAVE YARD
CULVERT
WATER TANK/TUBE WELL

Meters 0 25 50 75 100

SCALE

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FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

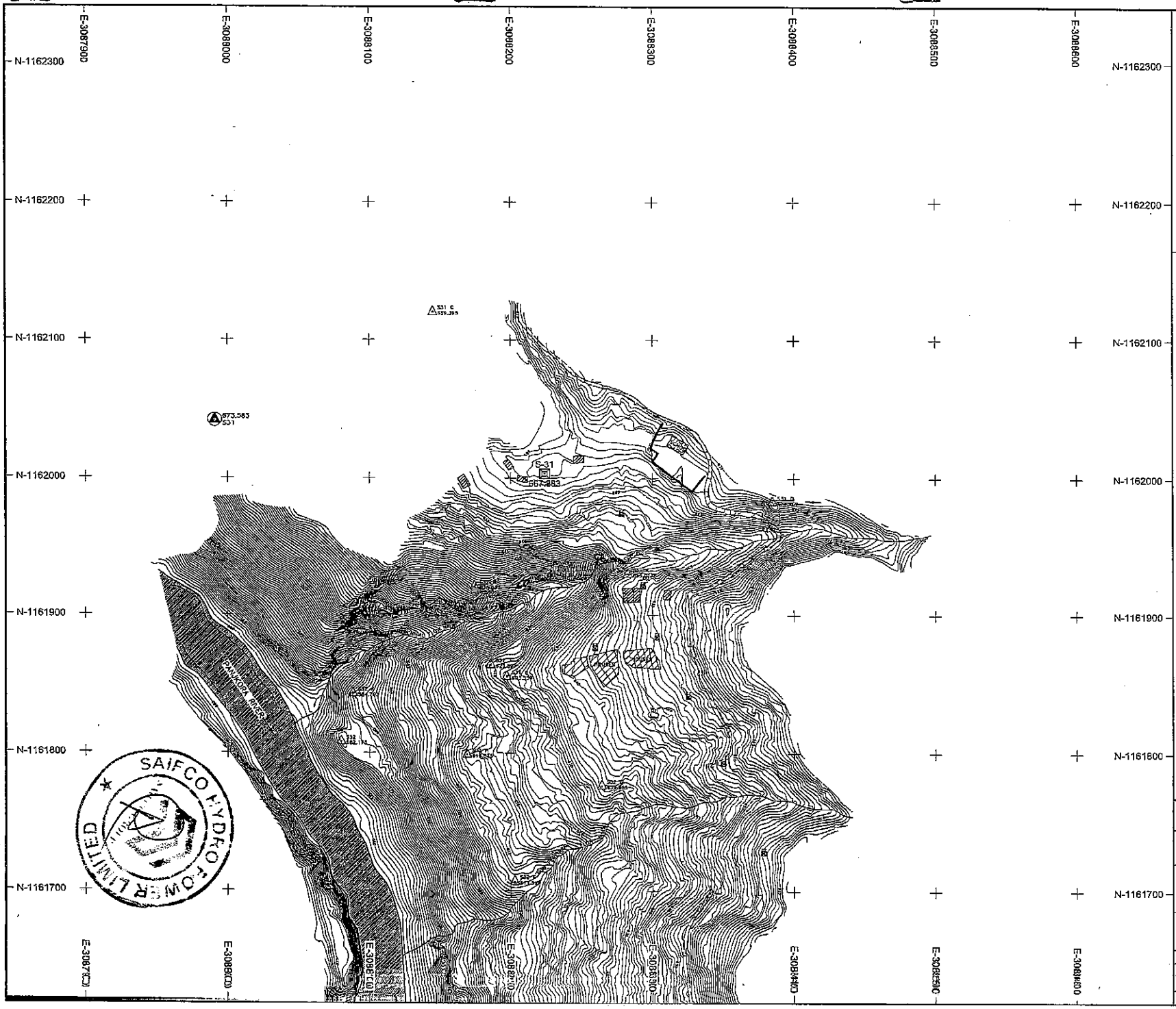
SHIGO KAS HPP

TOPOGRAPHIC SURVEY PLAN
POWER HOUSE AREA (OPTION-I)

(SHEET 2 OF 2)

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	April, 2013
SURVEYED:	SHIRAZ	FIGURE NO.	SKS-004-02
CHECKED:	HADI		
APPROVED:	M.H.F	SCALE.	1 : 2500



KEY PLAN



NOTES

1. ALL ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
2. ALL CONTOUR ARE IN 1m INTERVAL.
3. GRIDS ARE IN 100m INTERVAL.

LEGEND

- RIVER
- NULLAH
- HOUSES/SHOPS
- MOSQUE/SCHOOL
- ROAD
- TRACK
- CONTOURS
- BENCH MARK
- TRAVERSE POINTS
- CP CONTROL POINTS
- RETANING WALL
- ELECTRIC POLE
- TREES
- AGRICULTURE LAND
- GRAVE YARD
- CULVERT
- WATER TANK/TUBE WELL

Meters 0 25 50 75 100

SCALE

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FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

TOPOGRAPHIC SURVEY PLAN
POWER HOUSE AREA (OPTION-II)

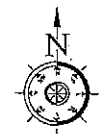
(SHEET 1/2)

CONSULTANTS:

ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	April, 2013
SURVEYED:	SHIRAZ	FIGURE NO.	[illegible]
CHECKED:	HADI		
APPROVED:	M.H.P	SCALE.	1 : 5000





KEY PLAN



NOTES

1. ALL ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.
2. ALL CONTOUR ARE IN 1m INTERVAL.
3. GRIDS ARE IN 100m INTERVAL.

LEGEND

RIVER
NULLAH
HOUSES/SHOPS
MOSQUE/SCHOOL
ROAD
TRACK
CONTOURS
BENCH MARK
TRAVERSE POINTS
CP CONTROL POINTS
RETAINING WALL
ELECTRIC POLE
TREES
AGRICULTURE LAND
GRAVE YARD
CULVERT
WATER TANK/TUBE WELL

Meters 0 25 50 75 100

SCALE

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Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

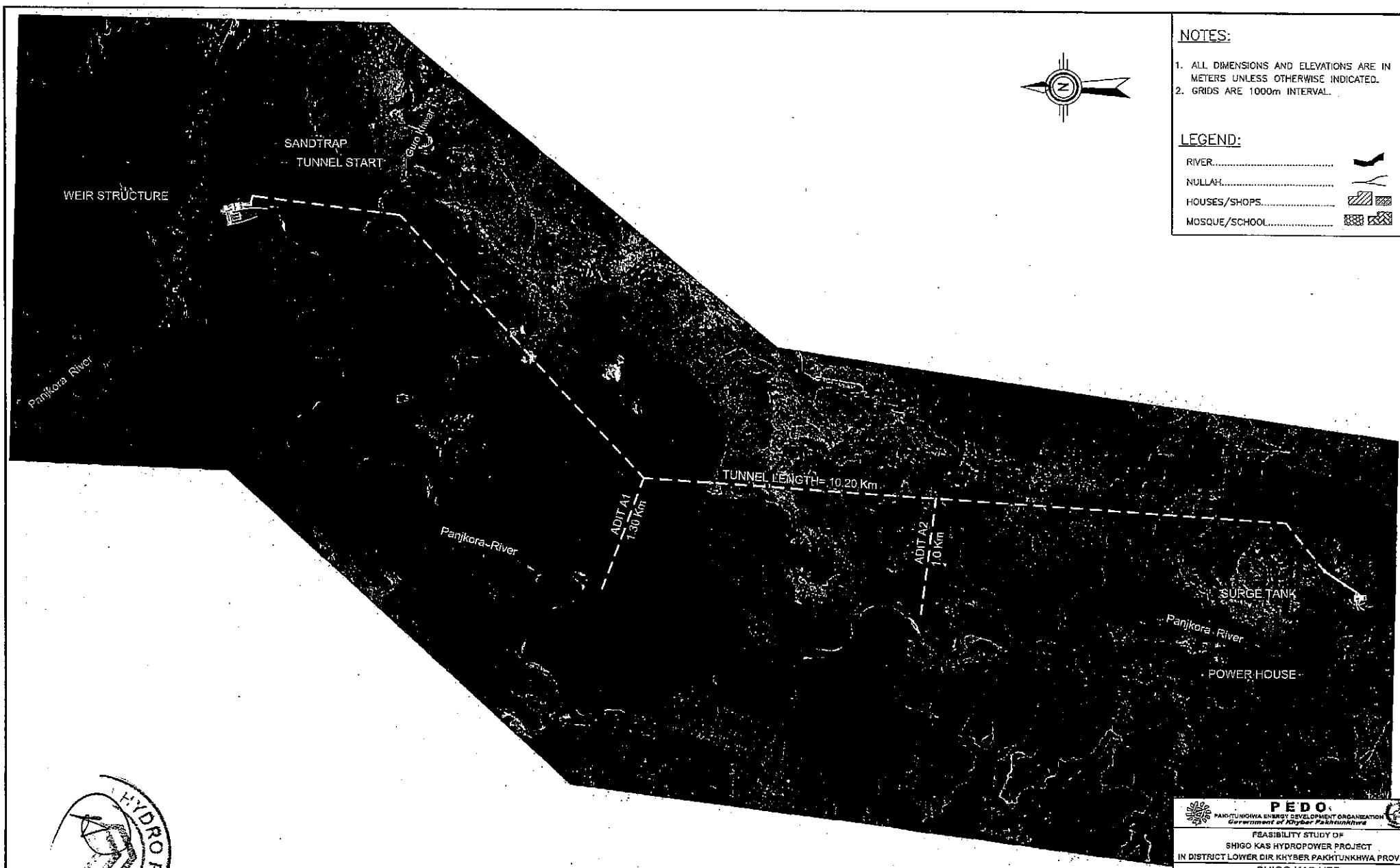
SHIGO KAS HPP

TOPOGRAPHIC SURVEY PLAN
POWER HOUSE AREA (OPTION-II)

(SHEET 2 / 2)

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	April, 2013
SURVEYED:	SHIRAZ	FIGURE NO.	SKS-005-02
CHECKED:	HADI	SCALE	1 : 2500
APPROVED:	M.H.F		



NOTES:

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.
2. GRIDS ARE 1000m INTERVAL.

LEGEND:

RIVER.....

NULLAH.....

HOUSES/SHOPS.....

MOSQUE/SCHOOL.....

HYDRO POWER LIMITED

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FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

SATELLITE IMAGERY
PROJECT LAYOUT PLAN

(SHEET 1 / 1)

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	SK-S-01
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE.	1 : 20,000



N

NOTES:

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.

LEGEND:

RIVER.....

NULLAH.....

HOUSES/SHOPS.....

MOSQUE/SCHOOL.....

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

SATELLITE IMAGERY
WEIR STRUCTURE, INTAKE AND TUNNEL INLET PLAN
(SHEET 1 / 1)

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION (PRIVATE) LIMITED

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	SK-S-02
CHECKED:	M.H.F	SCALE.	1 : 4000
APPROVED:	M.H.F		



N

NOTES:

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.

LEGEND:

RIVER.....

NULLAH.....

HOUSES/SHOPS.....

MOSQUE/SCHOOL.....

PENCO HYDRO POWER LIMITED

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

SATELLITE IMAGERY
SURGE TANK, POWER HOUSE AND COLONY PLAN

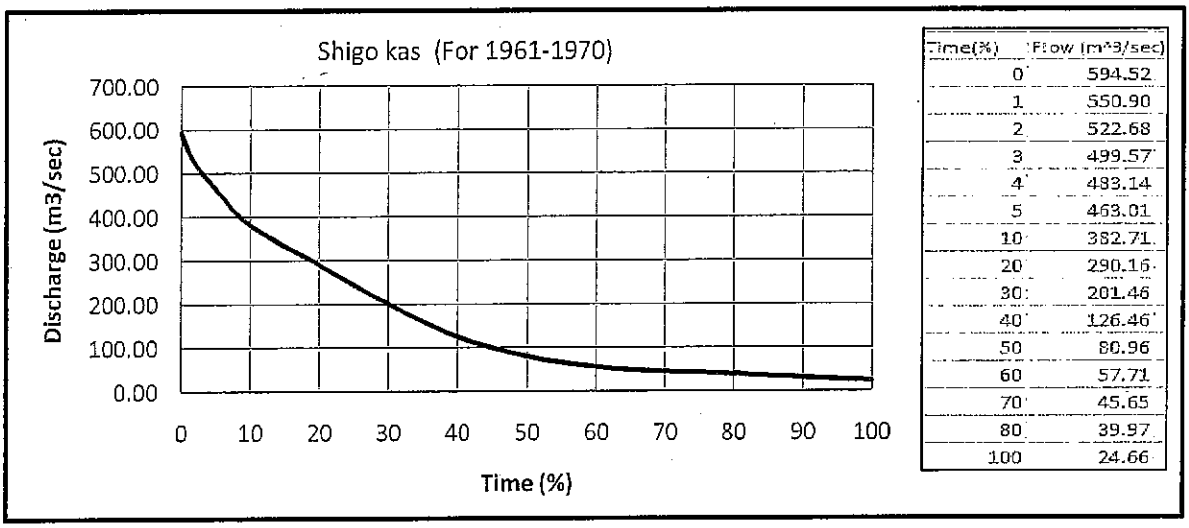
(SHEET 1 of 3)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	SK-S-03
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE.	1 : 4000

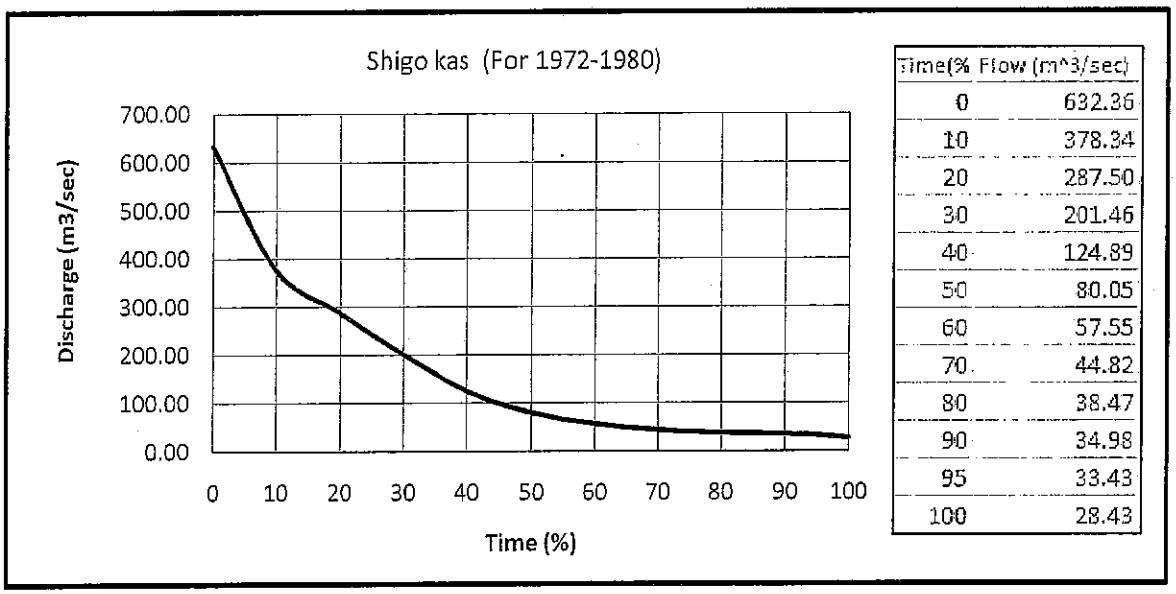
ANNEXURE 4A

Flow Durations and Yearly Hydrograph Shigo-kas HPP



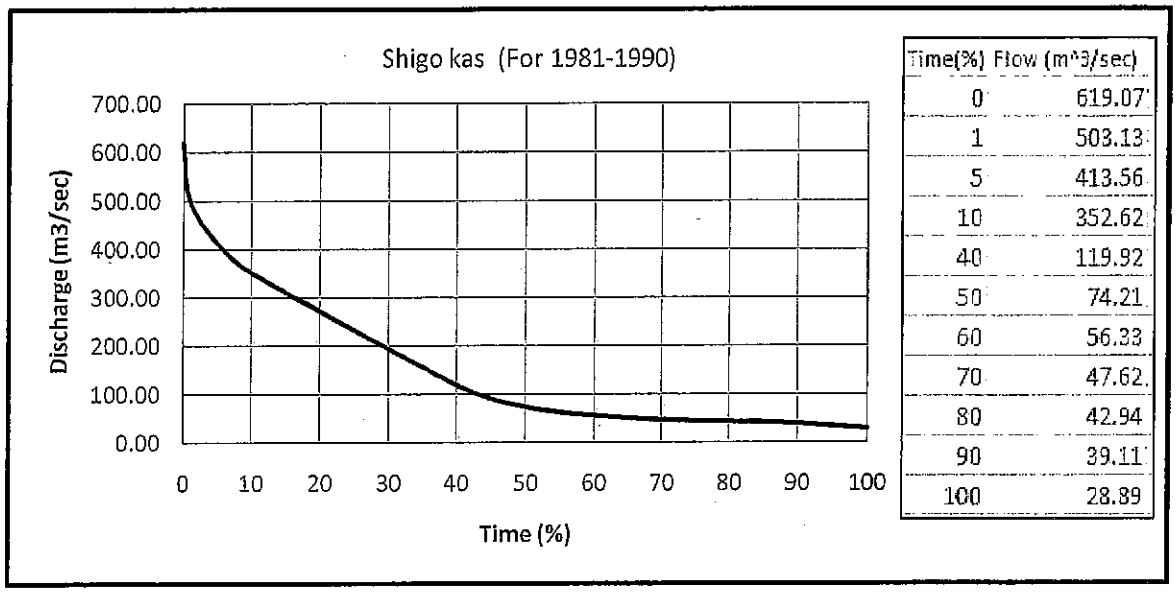
Time(%)	Flow (m^3/sec)
0	594.52
1	550.90
2	522.68
3	499.57
4	483.14
5	463.01
10	382.71
20	290.16
30	201.46
40	126.46
50	80.96
60	57.71
70	45.65
80	39.97
100	24.66

Figure A-4.1: Flow Duration Curve For Each 10 Years Segments Starting From 1961-1970



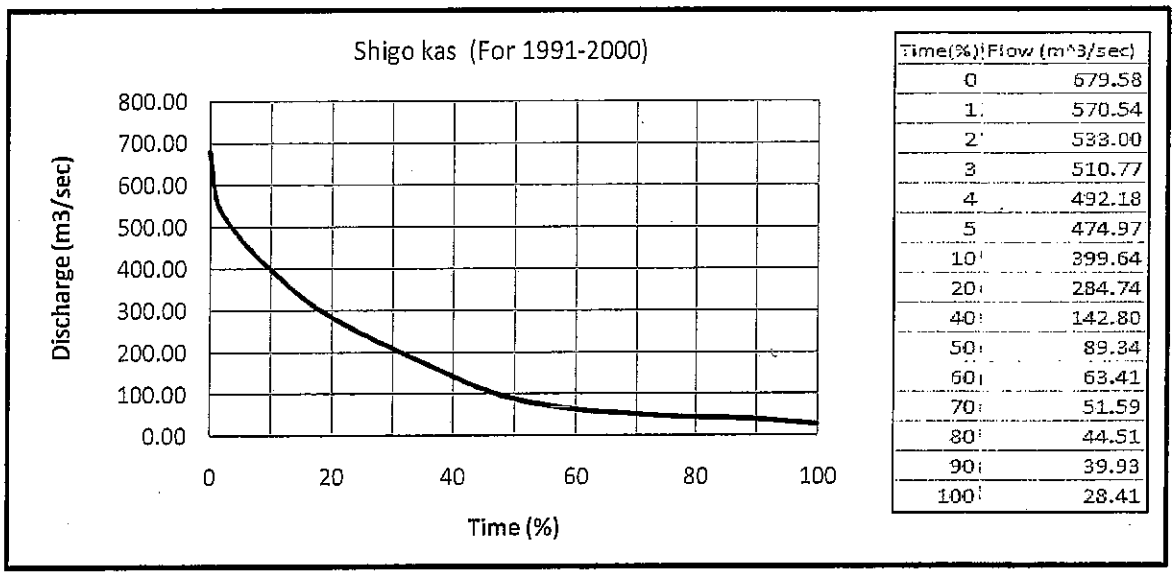
Time(%	Flow (m^3/sec)
0	632.36
10	378.34
20	287.50
30	201.46
40	124.89
50	80.05
60	57.55
70	44.82
80	38.47
90	34.98
95	33.43
100	28.43

Figure A-4.2: Flow Duration Curve For Next 10 Years Period 1972-1980



Time(%)	Flow (m^3/sec)
0	619.07
1	503.13
5	413.56
10	352.62
40	119.92
50	74.21
60	56.33
70	47.62
80	42.94
90	39.11
100	28.89

Figure A-4.3: Flow Duration Curve For Each 10 Years Segments Starting From 1981-1990



Time(%)	Flow (m^3/sec)
0	679.58
1	570.54
2	533.00
3	510.77
4	492.18
5	474.97
10	399.64
20	284.74
40	142.80
50	89.34
60	63.41
70	51.59
80	44.51
90	39.93
100	28.41

Figure A-4.4: Flow Duration Curve For Next 10 Years Period 1991-2000

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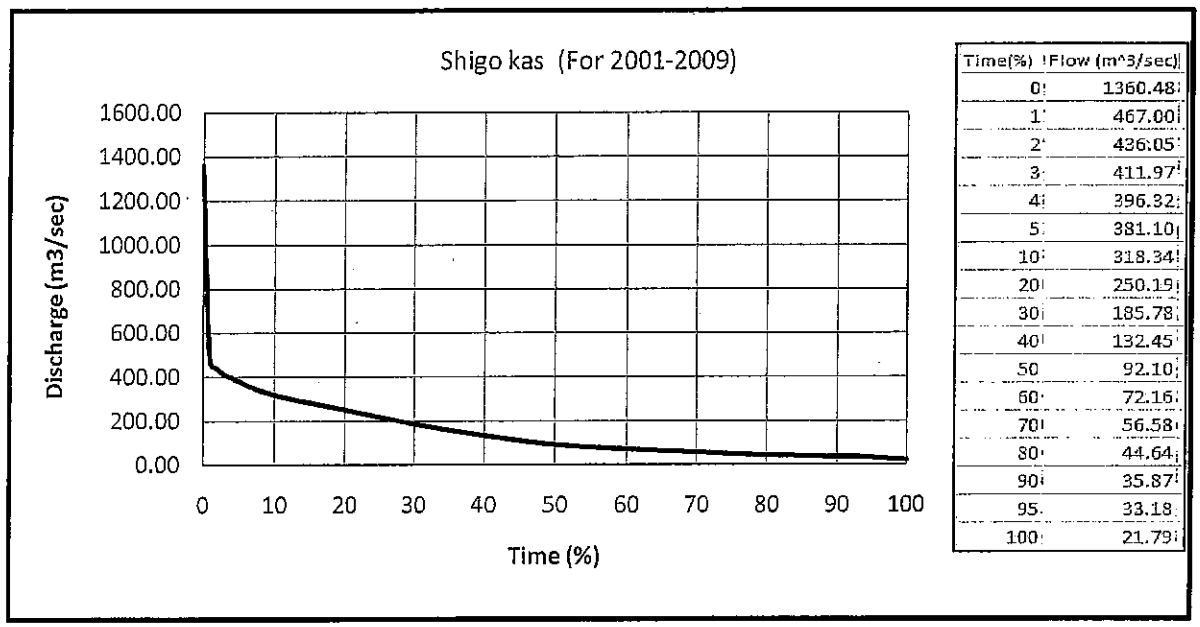
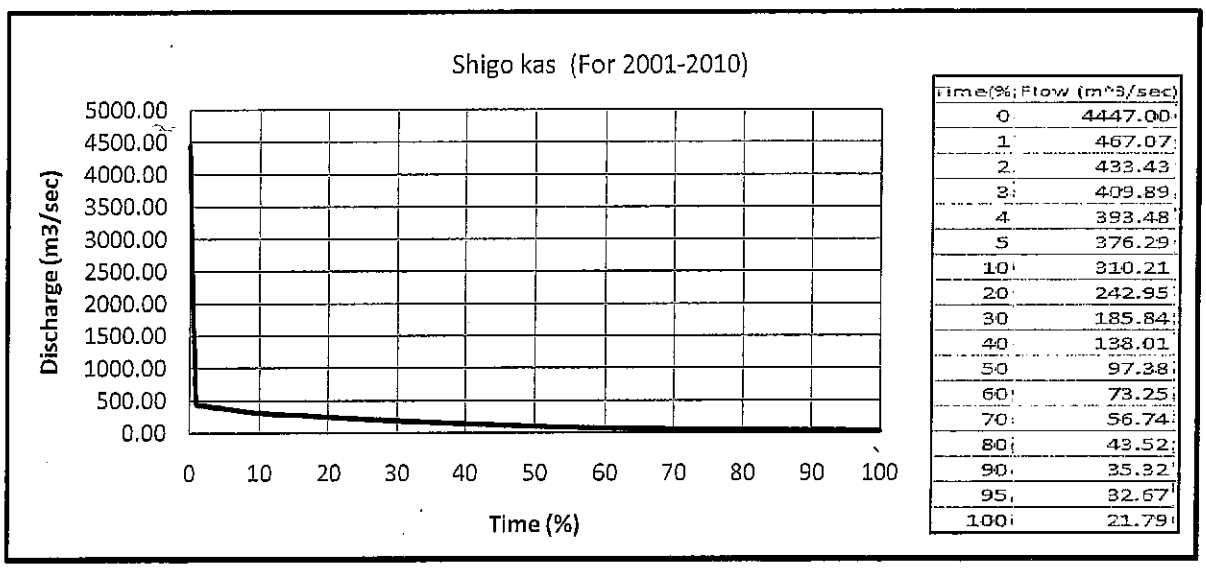


Time(%)	Flow (m^3/sec)
0	1360.48
1	467.00
2	436.05
3	411.97
4	396.32
5	381.10
10	318.34
20	250.19
30	185.78
40	132.45
50	92.10
60	72.16
70	56.58
80	44.64
90	35.87
95	33.18
100	21.79

Figure A-4.5 : Flow duration curve for next 10 years period 2001-2009



Time(%)	Flow (m^3/sec)
0	4447.00
1	467.07
2	433.43
3	409.89
4	393.48
5	376.29
10	310.21
20	242.95
30	185.84
40	138.01
50	97.38
60	73.25
70	56.74
80	43.52
90	35.32
95	32.67
100	21.79

Figure A-4.6: Flow duration curve for next 10 years period 2001-2010

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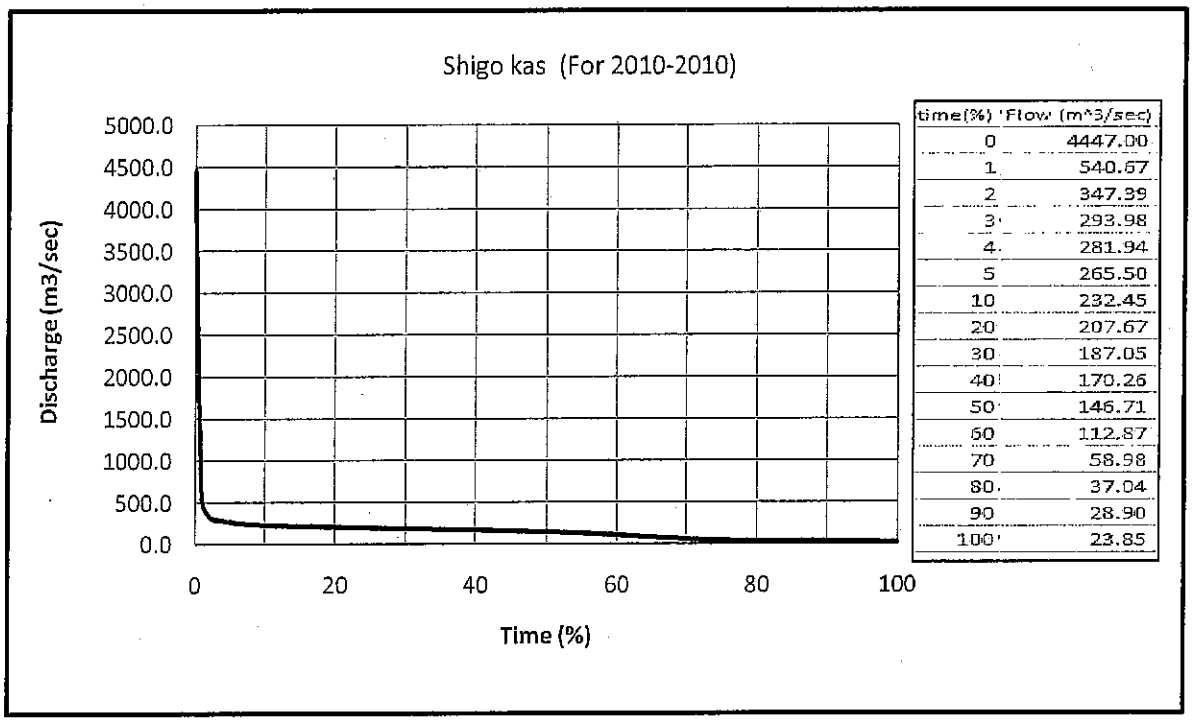
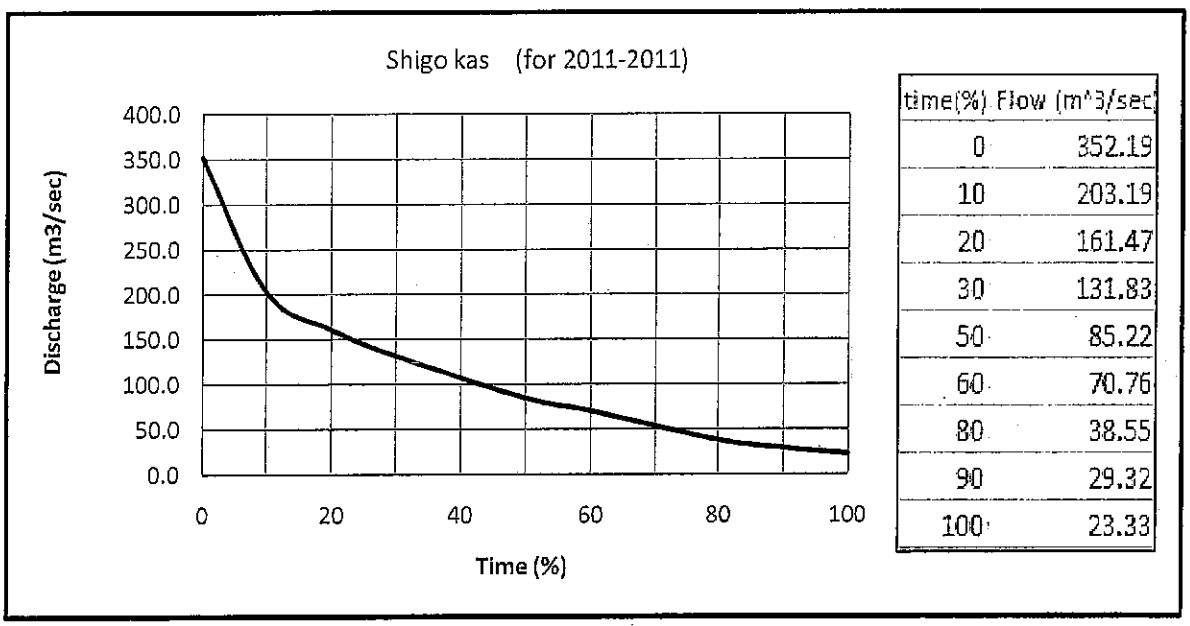


time(%)	Flow (m^3/sec)
0	4447.00
1	540.67
2	347.39
3	293.98
4	281.94
5	265.50
10	232.45
20	207.67
30	187.05
40	170.26
50	146.71
60	112.87
70	58.98
80	37.04
90	28.90
100	23.85

Figure A-4.7: Flow duration curve for 2010



time(%)	Flow (m^3/sec)
0	352.19
10	203.19
20	161.47
30	131.83
50	85.22
60	70.76
80	38.55
90	29.32
100	23.33

Figure A-4.8: Flow duration curve for 2011

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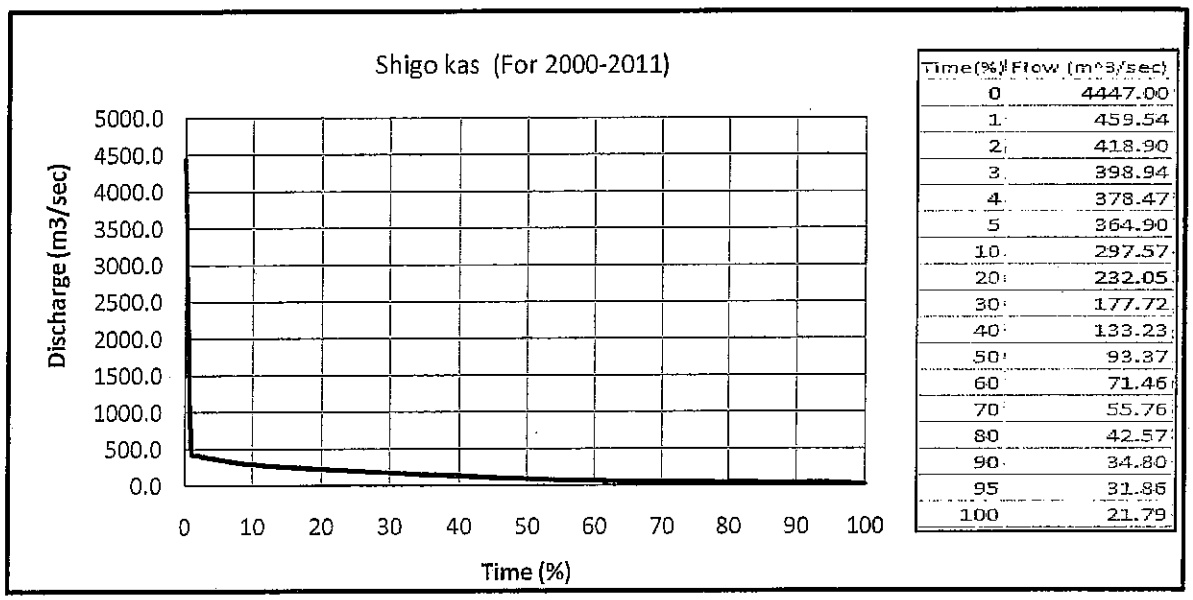
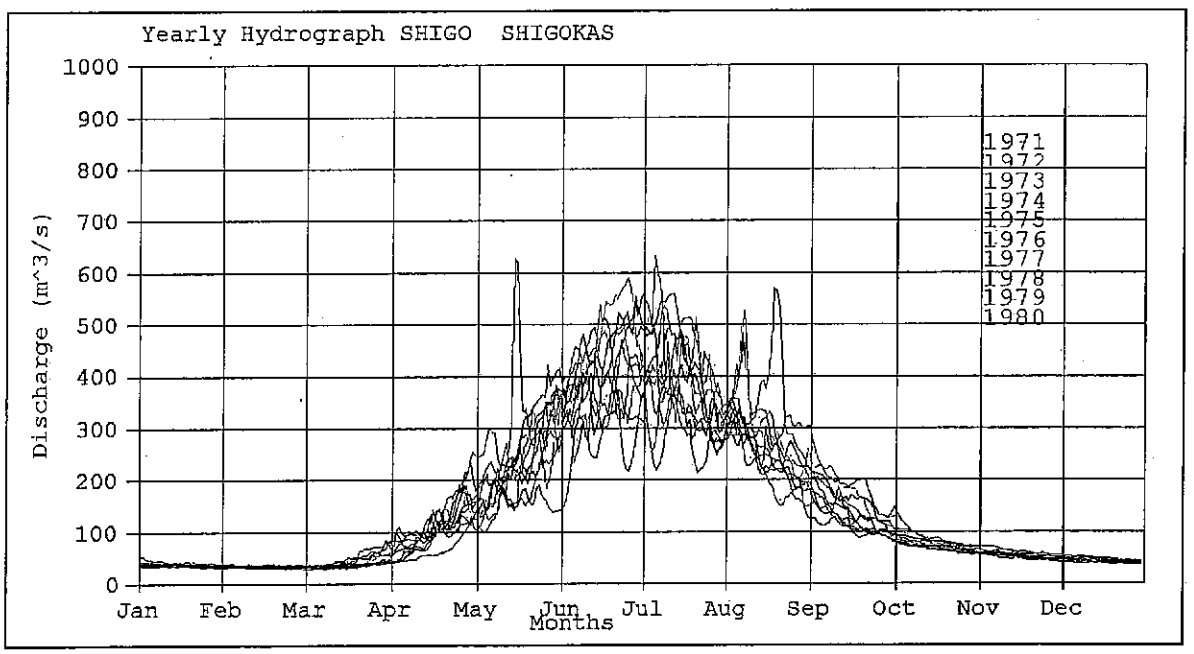


Time(%)	Flow (m^3/sec)
0	4447.00
1	459.54
2	418.90
3	398.94
4	378.47
5	364.90
10	297.57
20	232.05
30	177.72
40	133.23
50	93.37
60	71.46
70	55.76
80	42.57
90	34.80
95	31.86
100	21.79

Figure A-4.9: Flow Duration Curve For Last 12 Years

Period 2000-2011



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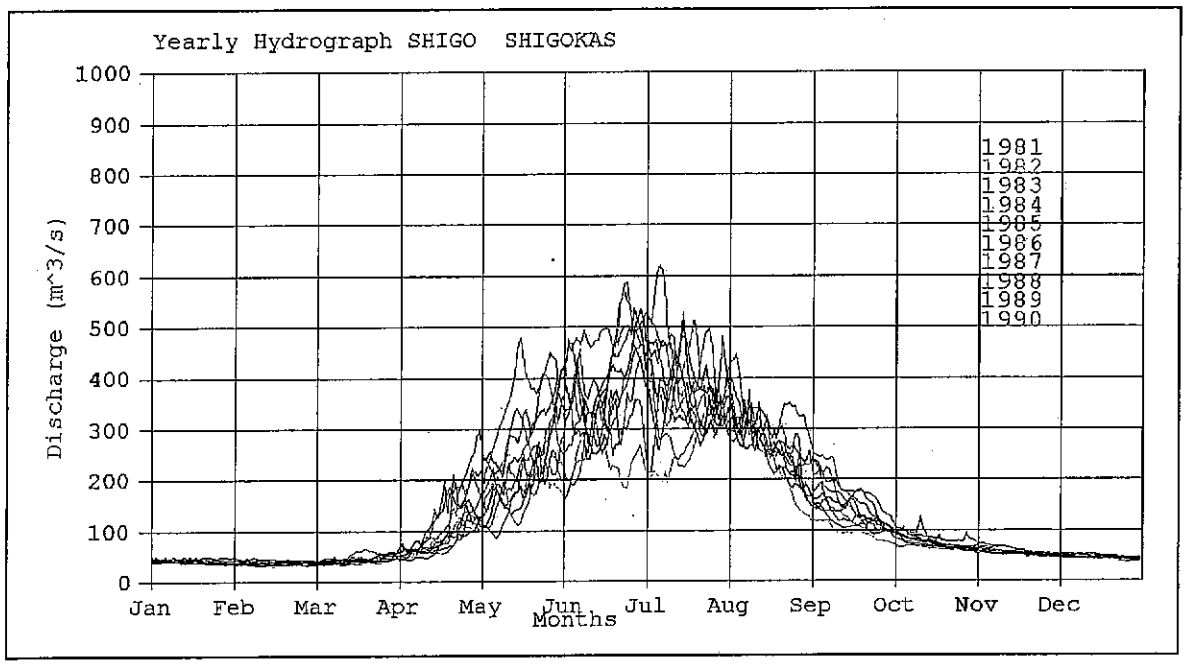
Shigo-kas At Proposed HPP



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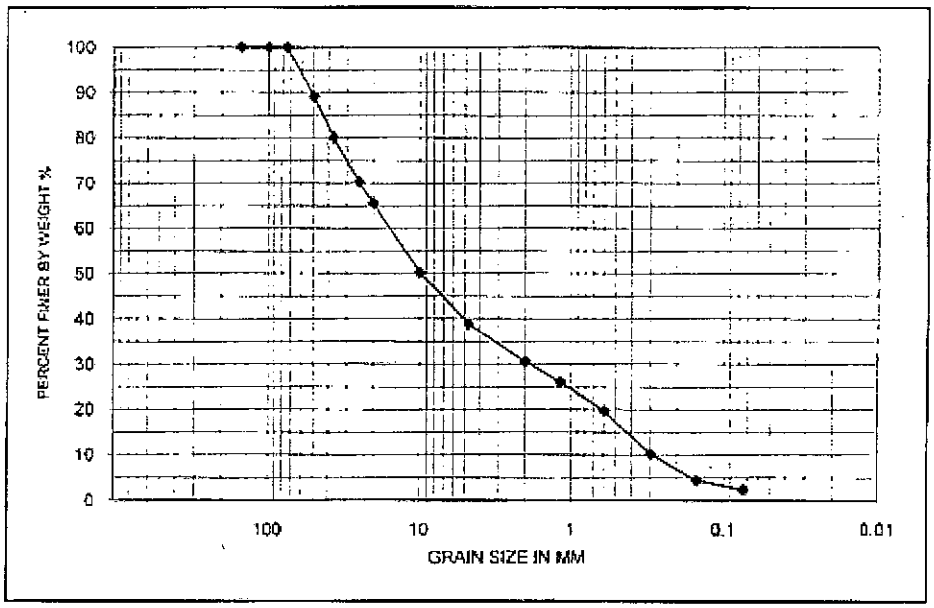
Shigo-kas At Proposed HPP

Annexure 4C

Lab Results of Grain Size Analysis

CMTL WAPDA LAHORE
Test Results of Grain Size Analysis
ASTM D-422

Project:-	Shigo Kas Hydropower Project in Distt Dir	LAB.No:-	4408
Location:-		B.H/T.P No:-	NIL
Client:-	Pacific Engineering and Geotechnical Services	S.No:-	1
Date:-	06.06.13	Depth:-	NIL M



L.L		%	Gravel	61	%
P.L		%	Sand	37	%
P.I		%	Passing#200	2	%

Tested By:- MUHAMMAD SALEEM
LAB.ASSISTANT

Checked By:- MUNIR AHMAD
R.O.

SE... ...EER
Cent... ...al Testing
Laboratory WAPDA Lahore

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CHAPTER 4

HYDROLOGY& SEDIMENTATION

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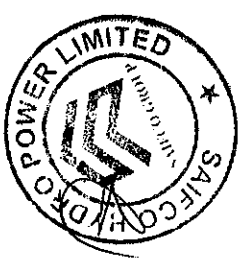

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HYDROLOGY& SEDIMENTATION

4.1 INTRODUCTION

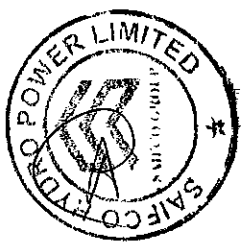
The proposed site is located near Shigo-Kas village. It is located 10 km downstream from Timergara Town, where Panjkora River becomes narrow again and passes a bottleneck. This bottleneck is located 13 km upstream the Junction of Panjkora River with Swat River. The flows of Shigo-Kas are proposed to be diverted with a gated weir to a tunnel which carries the water upto penstock which will bring these flows down to the powerhouse to generate hydropower. The main function of this Hydro Power Project is the production of cheaper power and will be connected to national grid.

This chapter deals with hydrological studies of the proposed Shigo-kas Hydropower Project (HPP). The chapter on hydrology describes the main input variable relevant for hydropower plants, namely the occurrence and availability of river flow, flood estimation for the design of Gated weir site. Following is detail of work involved.

- High flood estimation, 10 year, 100 year, 1000 year flood and 10,000 year flood.
- Definition of flood during construction.
- Estimation of low discharges and development of flow-duration curves with historic data.
- Collection of sediments samples round the year and analysis of the same.
- Analysis of suspended load and bed materials, estimate on sedimentation.

Based on the present study that includes available information, data collection and analysis, the following has been described in subsequent sections.

- Long term extreme climatological conditions
- Long-term flow parameters
- Flow duration and water availability
- Mean monthly flows
- Low flow analysis
- Flood estimation
- Sedimentation study



4.2 DESCRIPTION OF THE CATCHMENT

Proposed Gated weir site is located on Shigo-kas. The Panjkora River is the main tributary of Swat River. It rises high in the Hindu Kush at lat. 35.45, flows south through Upper Dir and Lower Dir Districts and joins the Swat River near Chakdara, Malakand, Khyber Pakhtunkhwa. The project is located in Dir region. The gated weir site lies at latitudes 34° 45' 30.15 E and longitude 71° 48' 12.19" N. The catchment lies in Digital Elevation Model (DEM) in srtm_51_05 and srtm_51_06.

4.2.1 Regional Setting

The district is surrounded by Afghanistan in the West, Kohistan district in the NE and Swat districts in the East. Dir region has high mountain ranges and deep valleys. It is surrounded by the Hindu Kush range in the North & West, Mushamber range in the East and the Hindu Raj range in the South. There are about one hundred mountain peaks above 6,000 meters in this range. Regional setting of Panjkora River is shown in **Figure 4.2.** The drainage area of the river at proposed weir site is 5816 km^2

4.2.2 The Catchment

As given before, the drainage area of Panjkora River upto proposed gated weir site is about 5816 km^2 shown in **Figure 4.3**, several streams drain into the Panjkora River upstream of proposed site and contribute appreciable amount of water for hydropower. The valley of Dir descends from an elevation of 5563 meters above mean sea level (masl) at weir site the bed level of river 639. The average slope in the watershed is about 1.2 %. The length of the main stream is 160 km.

Maximum area of Dir Lower surrounds River Panjkora which gushes out in the Hindukush and joins the Swat River at Tehsil Adenzai. Lower Dir is rugged and mountainous except from its lower parts round Chakdara (Tehsil Adenzai) and Munda area in the south west. River Panjkora is one of the rivers in the country contribute and facilitate water sources for cultivation and power generation. Dir lower is a hilly area and there is a net of small streams that ultimately joins the River Panjkora at one point or the other ("Punj" means 5 in Urdu and "Kora" means streams. Mainly River Panjkora is consist of two main streams i.e. one flows from Kohistan area and other from Ushairai Dara. Beside this there is net of relatively small streams that joins it in different places like, Toormang stream, Rabat stream, Shalfalam Stream, Kunai Stream (emerges from Maidan), and River Bajaur (Rodh) joins it from Bajaur. These streams in common routine remain dry but in summer (Moon Soon) April-August it flooded high when it rains and brought huge destruction and gated weirage to the cultivated lands and commercial properties. River Panjkora and River Swat join each other at Chakdara and ultimately fall into River Indus. River Panjkora flows through nine Union

Council, which include Toormang, Shalfalam, Khall, Munjai, Timergara, Koto, Khungai, Balambat, and Bandagai. **Figure 4.4 showing** land cover stream meandering of Panjkora River. **Figure 4.5** shows 3D View of Topography of Panjkora River catchment.

The people of these union councils have dependency on the river for drinking water and water for cultivation. A substantial piece of land lies on the bank of this river which it facilitates for watering the crops. The major crop which is the identification of this part of land is Mota Rice. This crop is the main source of food for these people. Agricultural land near Shigo Kas weir site shown in **Figure 4.1**

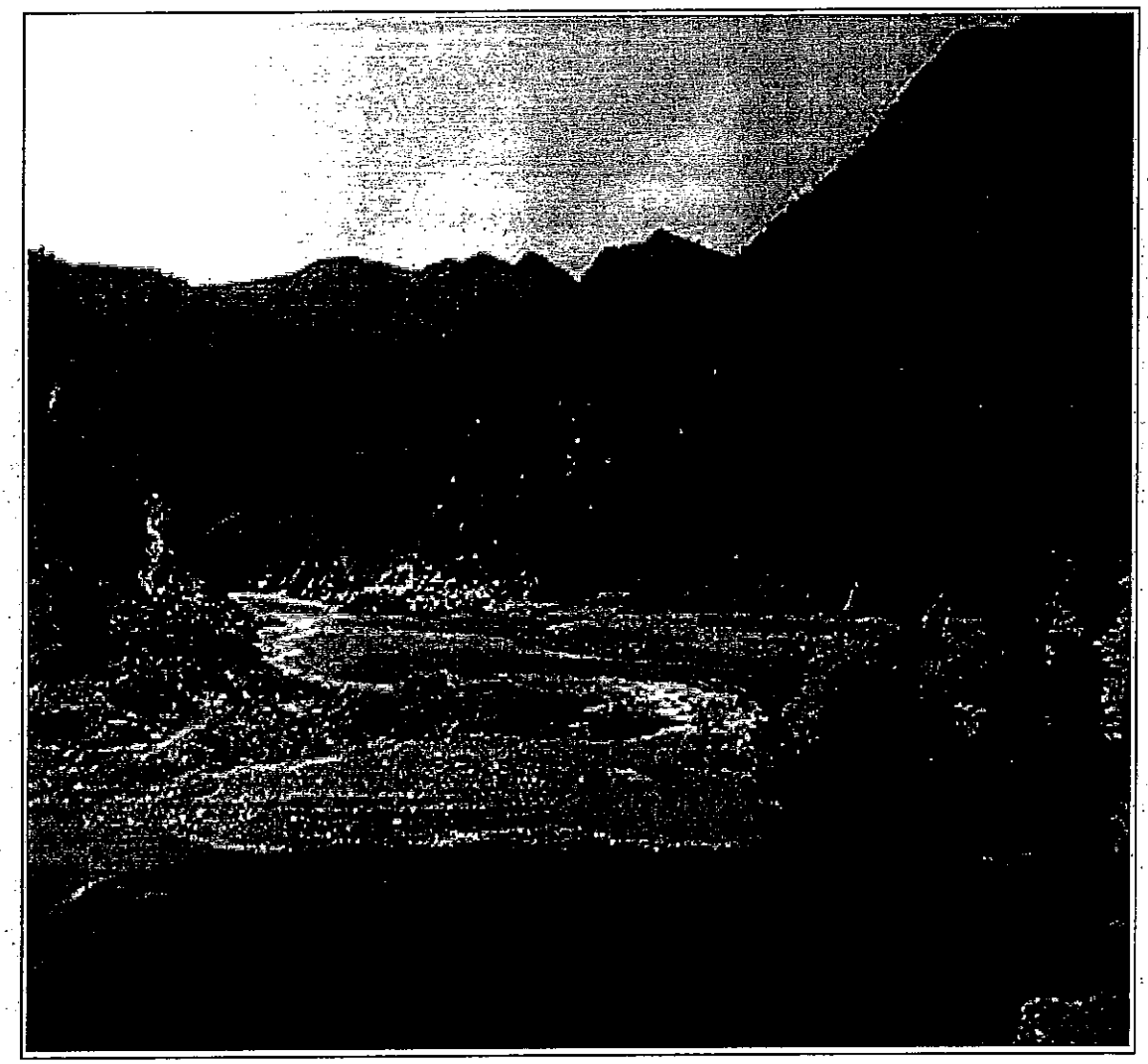


Figure 4.1: Panjkora River near Shigo-kas showing agricultural land on banks

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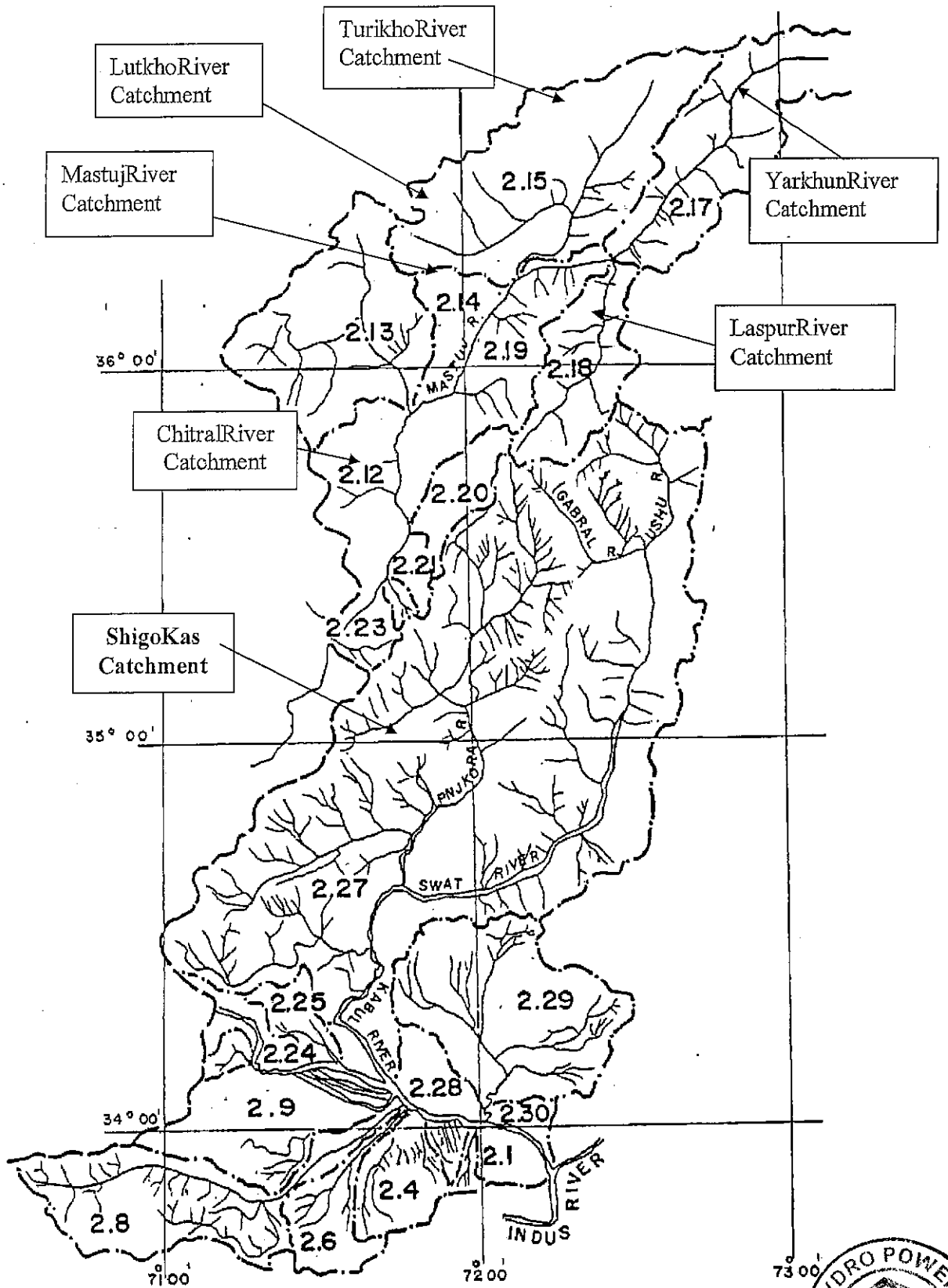

Figure 4.2: Punjkora River Catchment Regional Setting

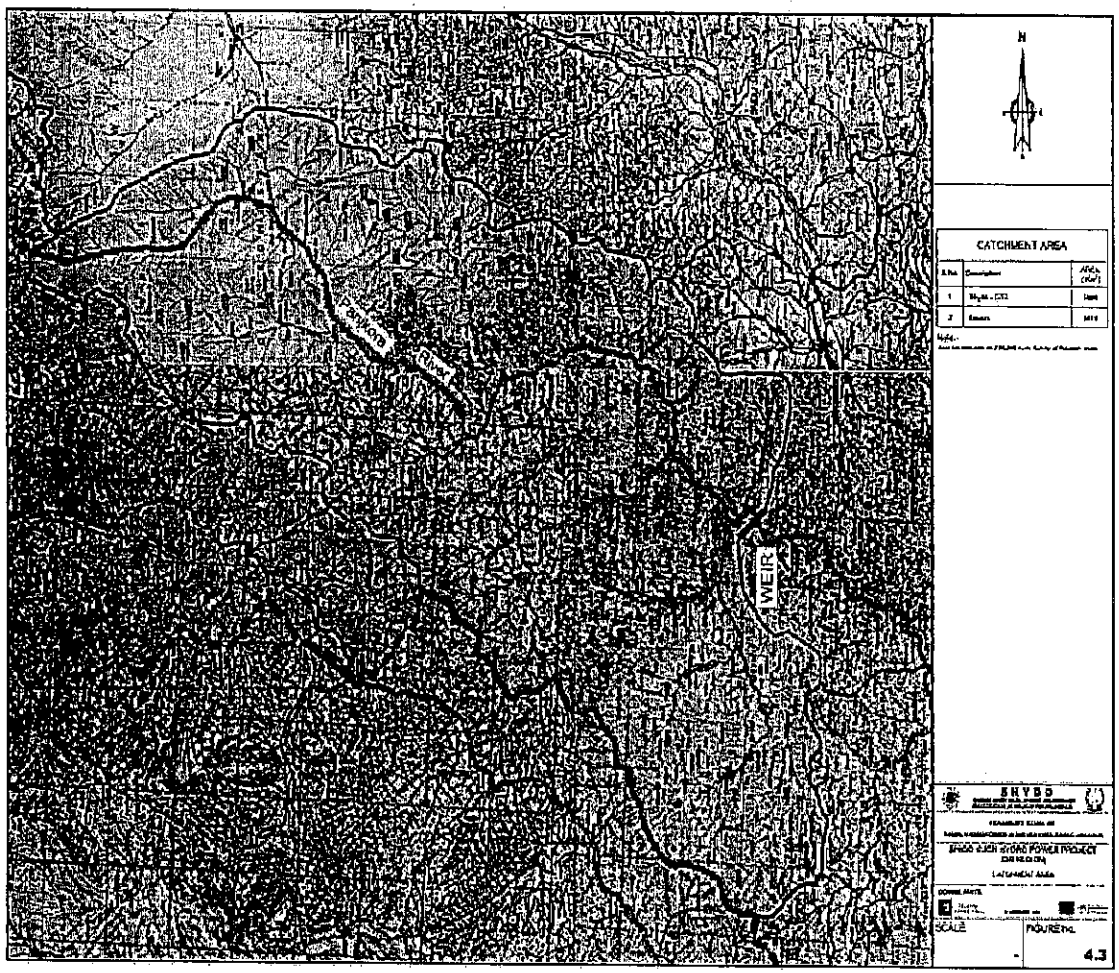

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Figure 4.3: Catchment Area of Panjkora River at Shigo-Kas HPP site

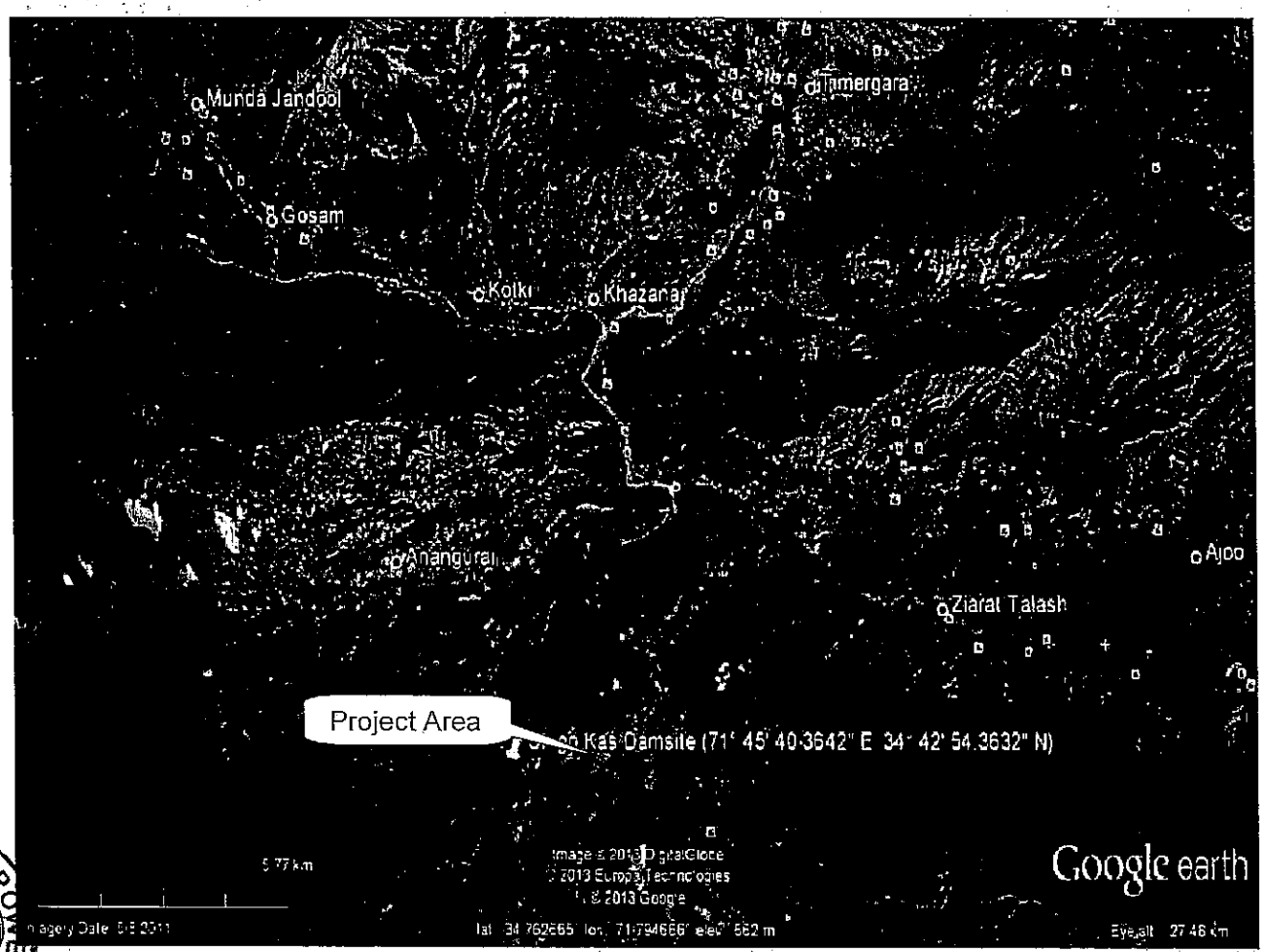

Figure 4.4: Map showing land cover stream meandering of Pnajkora River (Source: Google Earth)

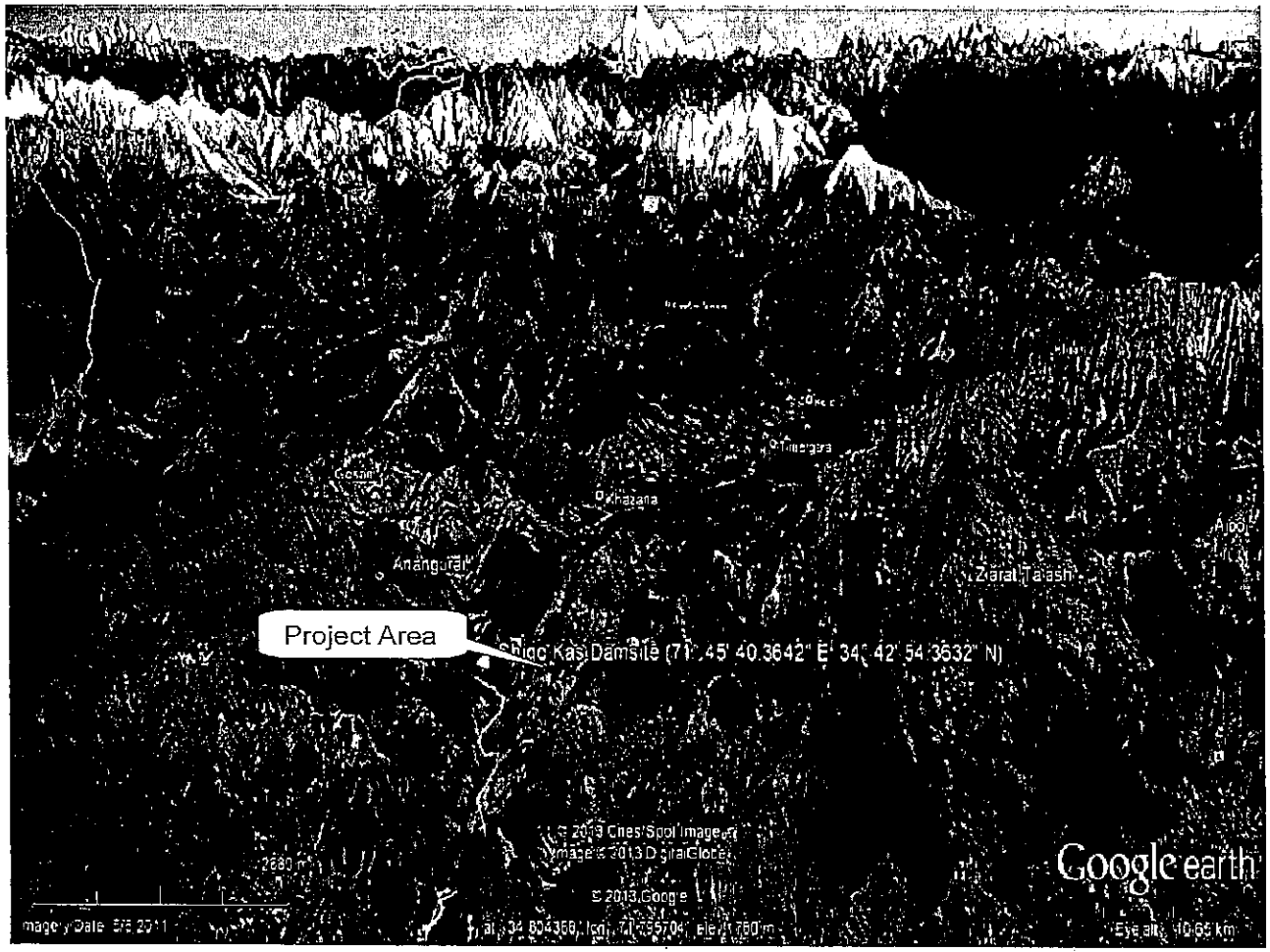

Figure 4.5: 3D View of Topography of Panjkora River catchment (Source: Google Earth)

4.3 CLIMATE

4.3.1 Collection of Climatological Data

Climatological data was collected from Pakistan Meteorological Department (PMD) and WAPDA for the feasibility studies. All the data was processed in computer and any omissions, errors and its consistency was checked before to use.

4.3.2 Hydrometeorological Stations

The hydro meteorological stations in and nearby the project area for which the data has been calculated and processed are shown in the following **Table 4.1**. Location of PMD stations are shown in **Figure 4.6**.

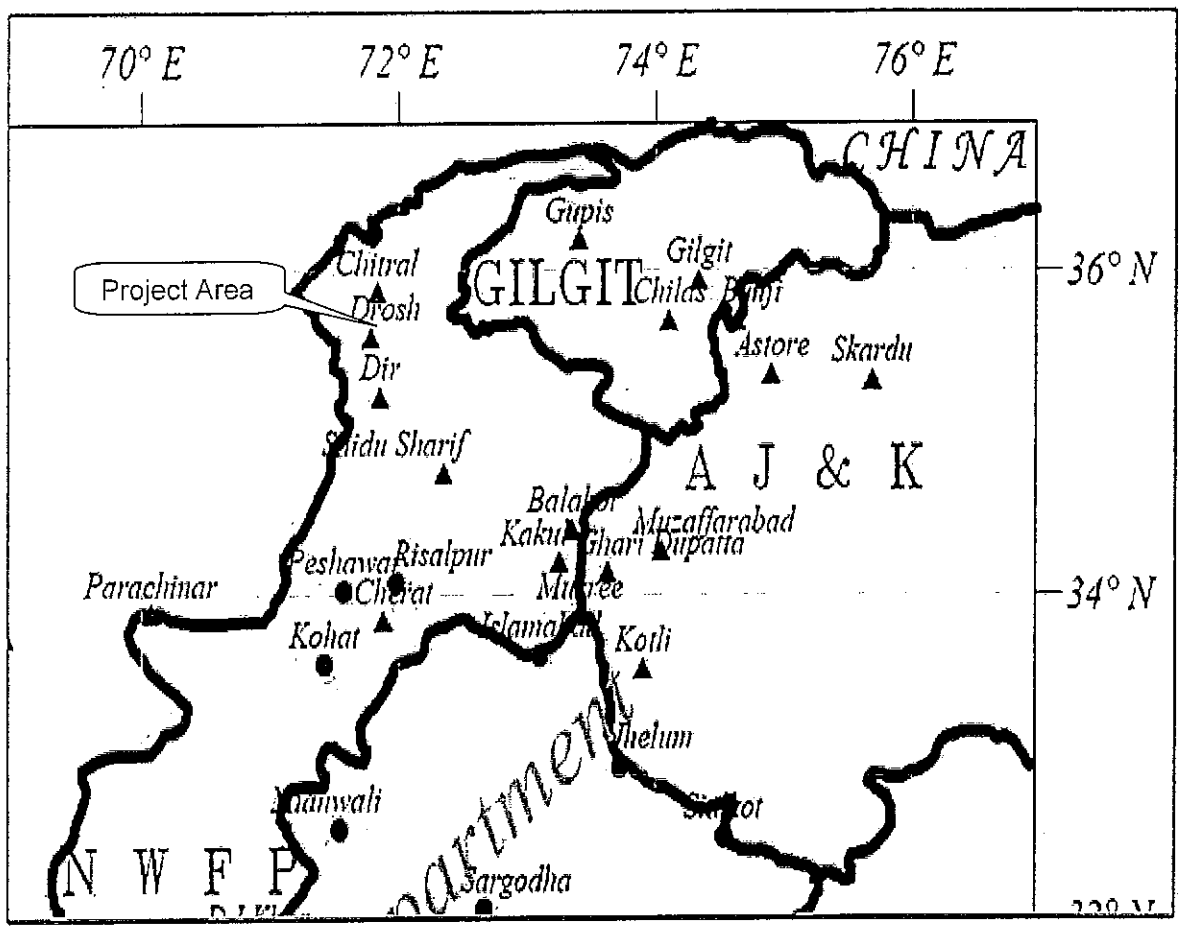

Figure 4.6: Locations of PMD Stations

Table 4.1: Inventory of Climatological Stations

Station	Latitude	Longitude	Elevation (m)	Available Record Period	Variable	Interval	Agency or Source
Chitral	35 51 N	71 40 E	1499	1964-10	P	Monthly	1
Dir	35 12	71 51	1425	1967-10	P,T	Monthly	2
Drosh	35 34	71 47	1465	1931-10	P,T	Daily	2
Kalam	35 28	72 35	1921	1978-09	P,T	Daily	3
Saidu Sharif	34 44	72 33	949	1974-04	P,T	Monthly	2
Variable:	P=Precipitation		T=Temperature				
Agency:	1=PMD, Lahore		2=PMD, Gilgit 3=WAPDA 4=SIHP (Wapda's Snow and Ice Hydrology Project)				

4.3.3 Climate

The weather of the area is characterized by moderate summer and severe winter. The monsoon penetrates into the project area but the main mechanism for producing rain is western disturbances .The winter season starts from November and extends up to May. The summer season begins in June and ends in October.

4.3.4 Precipitation

Rainfall record at Dir station is available in the catchment. In the upper boundaries of catchment, the rainfall data of Kalam and Drosh climatological stations is available for the period 1964 to 2010 and 1931 to 2007 respectively. The available data has been processed using Excel package to achieve annual, monthly and % age monthly distribution of rainfall at Dir and Kalam. The results so achieved are presented in **Table 4.2.** The comparison of the rainfall amounts at different stations is done in **Figure 4.7**. It is inferred from the Figure that rainfall at Dir is higher as compared to 4 other stations. Dir station is located within the Panjkora River catchment and others are outside but nearby. Therefore high flows/floods are expected at gated weir site.It is also inferred that more rainfall occurs in the month of March and then in July and August. Lowest rainfall is recorded in June. At Dir station, being within watershed is analyzed and mean, minimum and maximum long term rainfall was computed and presented in **Figure 4.8.**

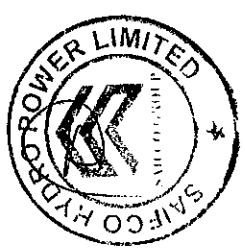

Table 4.2: Distribution of Rainfall

Long Term Areal Precipitation, Shigo Kas HPP

Month	Station			
	Dir	Kalam	Saidu Sharif	Areal Shigo Kas
	(mm)			
Jan	115.7	76.7	79.3	99.2
Feb	165.2	121.6	108.3	142.7
Mar	238.9	194.0	162.3	211.2
Apr	169.4	153.5	116.1	153.1
May	89.4	82.9	64.6	82.0
Jun	53.9	30.1	52.7	49.0
Jul	144.8	36.0	154.6	126.2
Aug	145.3	36.5	122.8	118.7
Sep	82.0	35.7	67.2	69.4
Oct	66.7	47.5	51.5	59.2
Nov	51.8	53.0	30.2	46.7
Dec	78.5	50.8	46.6	65.2
Annual	1401.7	918.4	1056.3	1222.7

Source: WAPA, Pakistan Meteorological Dept.

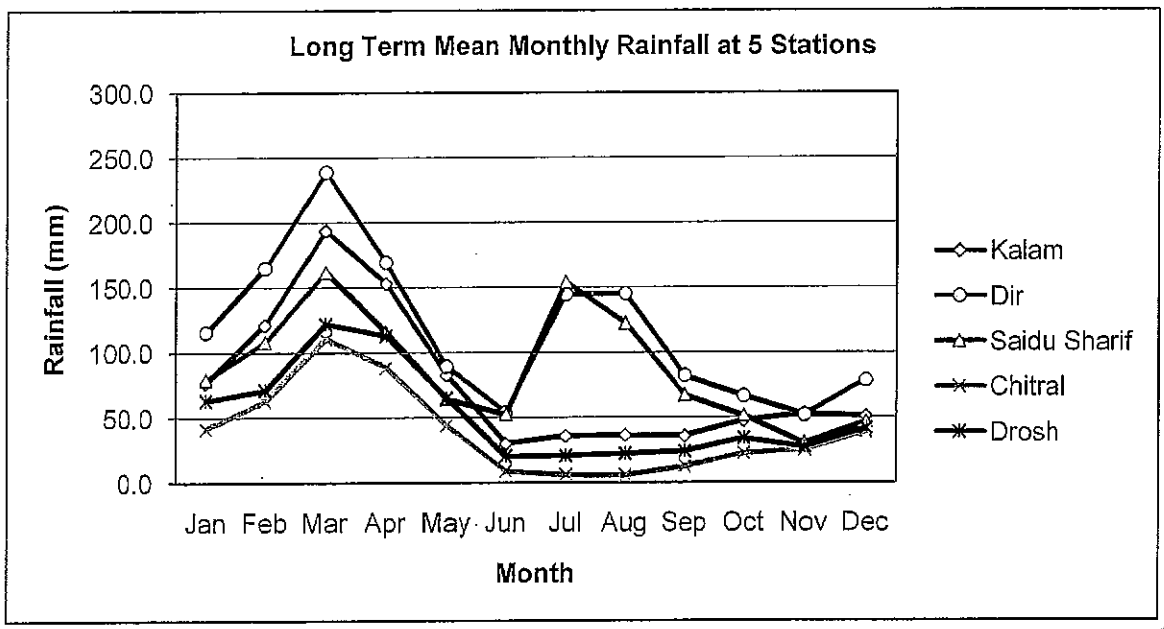

Figure 4.7: Comparison of the Rainfall Amounts at Different Stations

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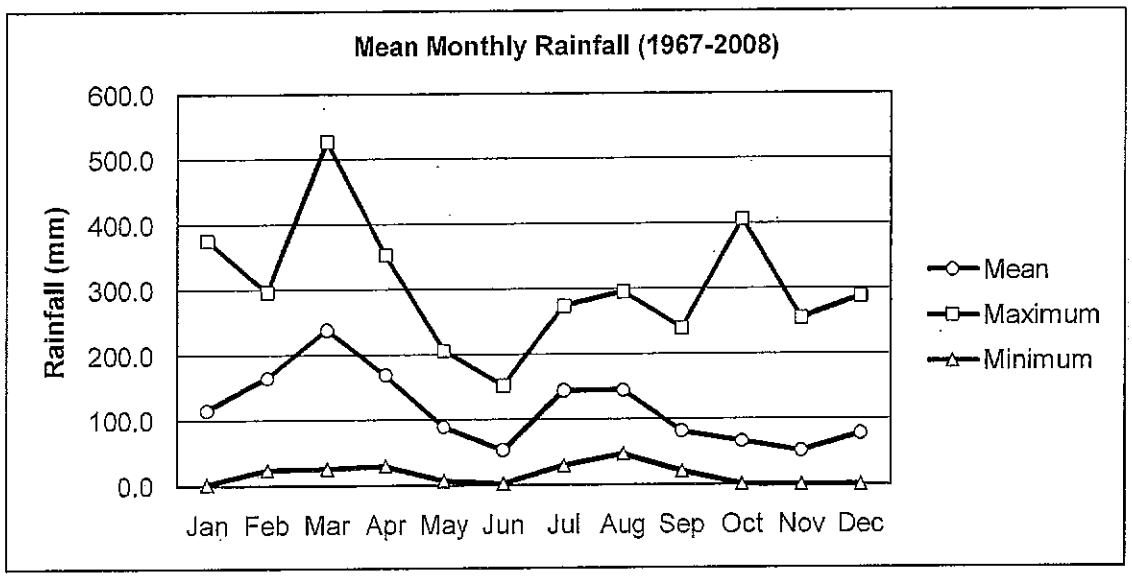

Figure 4.8: Comparison of Minimum, Mean and Maximum Rainfall at Dir

With the help of 3 stations vs. Dir, Kalam and Saidu Sharif, areal precipitation over Shigo-kas watershed was calculated using Theissen Polygon method **Figure 4.9** The mean annual areal precipitation for the period 1967 to 2010 comes to be 1223 mm (**Table 4.2**). Mean monthly precipitation for Panjkora River watershed is presented in **Figure 4.10**. In winter February, March and April are the months of maximum rainfall. In summer, July and August receive more rainfall while the lowest rainfall occurs in the month of June. The maximum daily precipitation recorded during the historic period is 187 mm in 2010.Long Term Annual Areal Precipitation for Shigo-kas HPP was calculated and presented in **Figure 4.11**. The bar chart indicates the annual distribution of rainfall, minimum and maximum annual rainfall. Annual precipitation ranges from 717 to 1710 mm in the area. Upper part of the mountains is covered by snow. Snowmelt contributes an appreciable proportion of the total run-off into the river.

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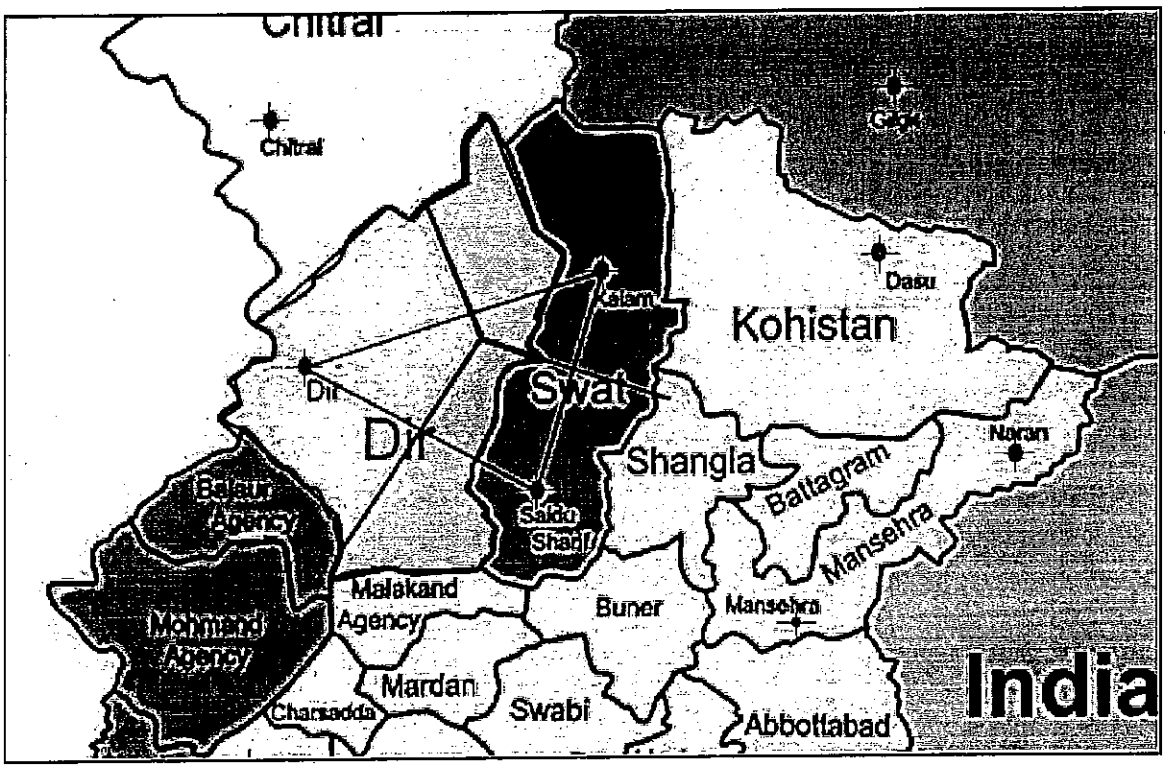

Figure 4.9: Thiessen Polygon Map, Shigo-kas HPP

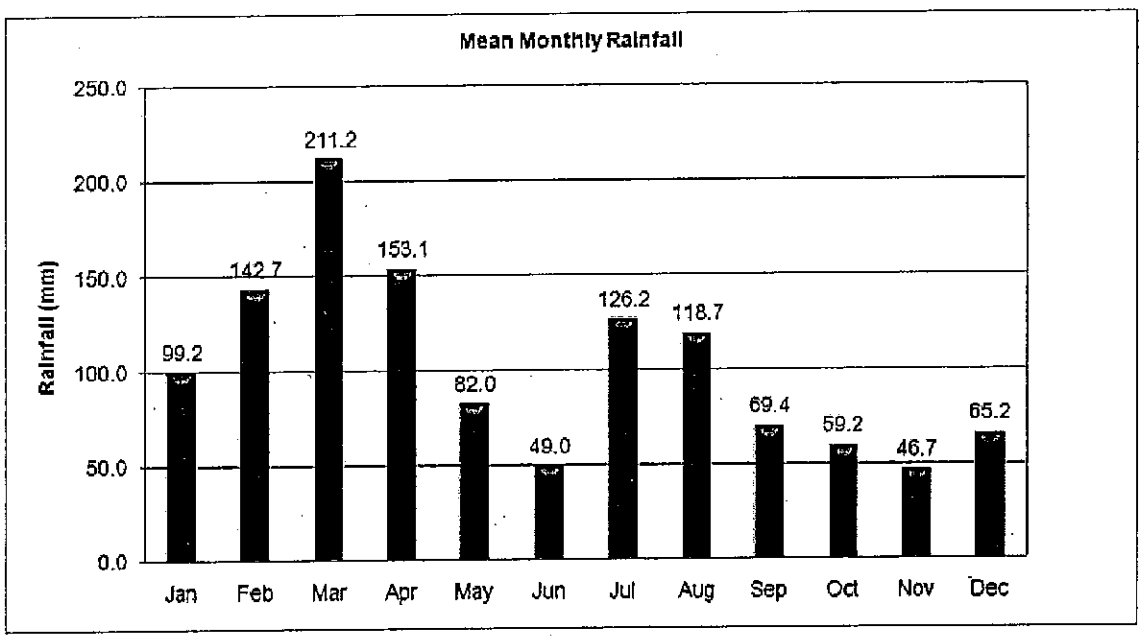

Figure 4.10: Mean Monthly Areal Precipitation, Shigo-Kas HPP

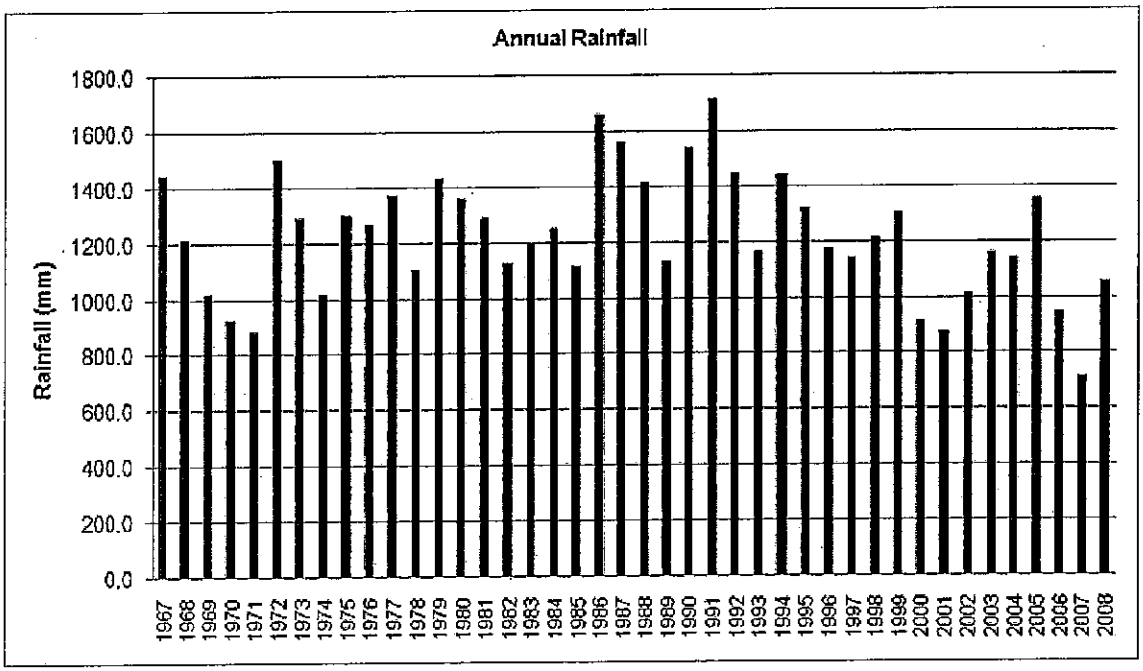

Figure 4.11: Long Term Annual Areal Precipitation Shigo-Kas HPP

4.3.5 Temperature

As regards the temperature data, it is also available for the period 1967 to 2004 at Dir. The same has been processed to compute mean, maximum and minimum temperatures. The results are presented in the **Table 4.3**. Mean monthly variation of temperature at Dir is shown in **Figure 4.12**. Recorded lowest and highest temperature at Dir is shown in **Figure 4.13**. According to the available record, the minimum temperature is -2.5 C° in the month of January while the maximum temperature is 32.4 C° in the month of June.

The weather of the area is characterized by moderate summer and severe winter. Therefore there are two climatic seasons. Summer season lasts for 6 months from April to September and winter season from October to March. In general the climate of watershed is very cold, sub-humid and arid.

The climate is hot in summer at low altitudes with cold winters having wide variations between extremes of temperatures. Since 1994, WAPDA under Snow and Ice Hydrology Project aimed for flow forecasting for Tarbela and Mangla reservoirs, has established a network of automatic climatological data observation platforms at higher elevation bands. The observations recorded at these platforms indicate occurrence of higher precipitation and severer temperatures at higher altitude as compared to those recorded at recording stations at lower altitudes in the valleys.

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Table 4.3: Recorded Mean Temperature

Recorded Mean Temperature at Dir			
Month	Station: Dir (1967-2004)		
	Mean	Minimum	Maximum
	(degree centigrate)		
Jan	4.8	1.8	7.1
Feb	5.9	1.3	9.7
Mar	9.7	5.5	13.8
Apr	15.2	12.6	17.6
May	19.7	16.6	23.6
Jun	24.0	21.8	26.8
Jul	25.3	23.0	26.9
Aug	24.5	21.8	26.7
Sep	21.4	19.1	23.1
Oct	16.2	14.3	18.6
Nov	11.4	9.1	13.0
Dec	7.0	3.5	12.2

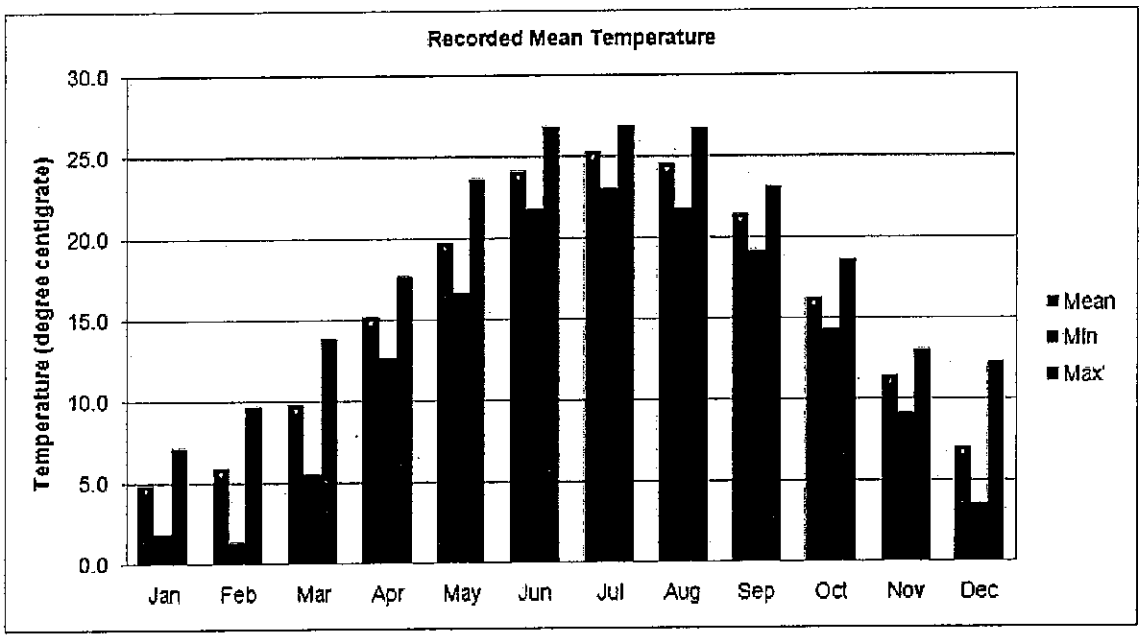


Figure 4.12: Recorded Mean Temperature at Dir

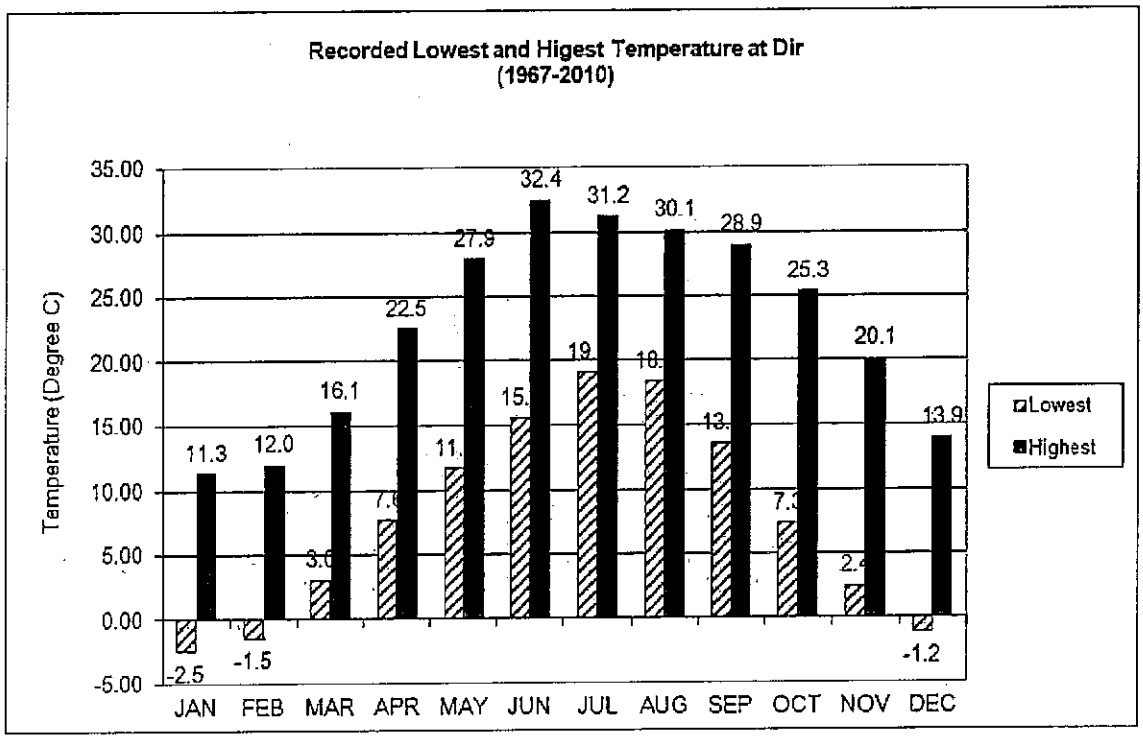


Figure 4.13: Recorded Lowest and Highest Temperatures at Dir (1967-2010)

4.4 ESTIMATION OF FLOWS

4.4.1 Available Information

A stream gauging station has been installed on Panjkora River at Zullam Bridge just upstream of Shigo-kas by PEDO and intermittent data is available. The discharge data and the water level records of this hydrological station are thus available for small period. Keeping in view the limited record of flow data of Zulam Bridge, the recorded daily flow data of nearby stations has been utilized for extension of flow series for further use in Shigo-kas HPP.

4.4.2 Collection Of Data

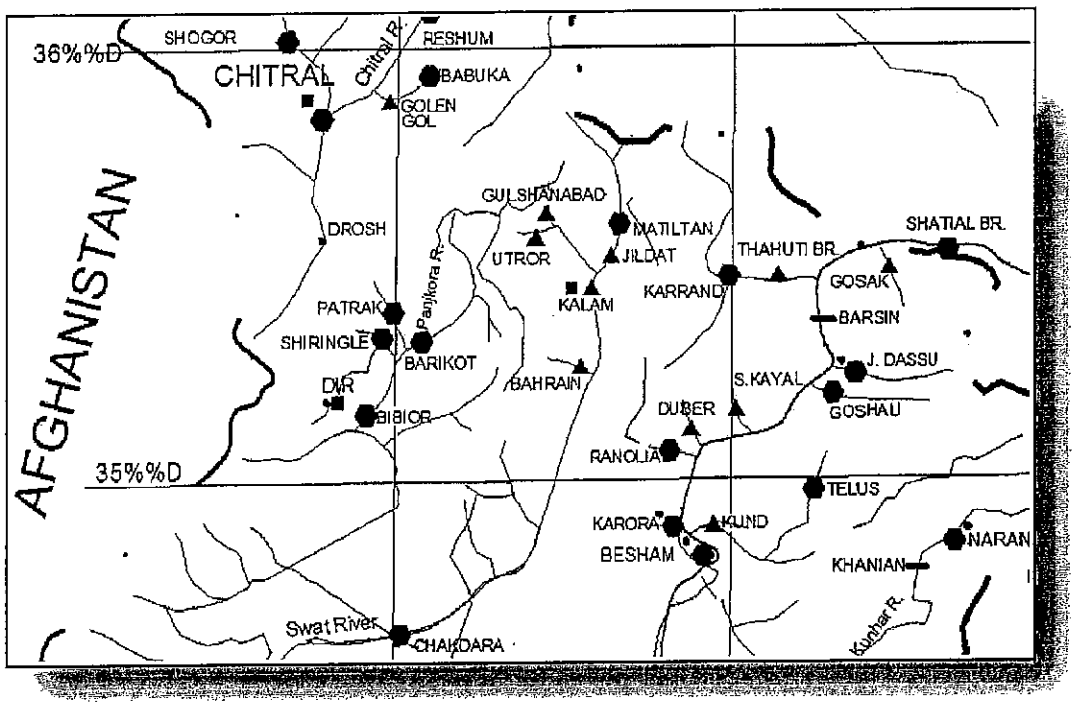
4.4.2.1 Water Levels

A staff gauge has been installed at Zulam Bridge by PEDO and daily flow data is available from year 2000 to 2004 and 2010 to 2011. The gauge data is normally observed 9 times every day i.e. from 0800 hrs to 1600 hrs. Whereas, In high flow from June to September, water levels are observed on hourly basis round the clock. The recorded water level data of this river has been collected for the recorded period.

4.4.2.2 Discharge Data

Flow measurements are being performed on Panjkora River at hydrological station since the installation of the gauge. The same has been collected from PEDO for further processing to study the behavior of the flows. Keeping in view the missing data series of this stream from

August 1961 to Oct 2009, the flows of Panjkora River were extended with the help of runoff relationship of nearby rivers with long term recorded data. Location of hydrological stations are shown in **Figure 4.14**. Nearby rivers with long term record include Panjkora at Zulam Bridge, Koto, Bibior, Sharmai and Swat at Kalam.



Automatic Gauging Stations ▲ Staff Gauging Stations ● Main Cities ■

Figure 4.14: Location of Hydrological Stations

4.4.3 Processing of Flows

Although the recorded data at Zulam Bridge, Koto, Bibior and Sharmaii limited but it is very important to know the behavior of the stream and for the extension of time series. The collected flow and water level data of this Panjkora River at the above stations were entered into the Computer by using DBHYDRO software of GTZ. Hydrographs of daily flows were calculated with the help of this software. The mean monthly flows of this historic series are presented in **Table 4.4** and **Figure 4.15**. Yearly hydrographs of recorded daily flows of Panjkora River and computed at proposed HPP site were plotted and shown in **Figure 4.16, Figure 4.17 and Figure 4.19**. Flow duration curves for the recorded years were also determined and shown in **Figures 4.18 and 4.20**.

As the flow data of hydrological sites on Panjkora River is available for intermittent period to July to 2011, therefore daily flows data of nearby rivers were used for the same period to develop a relationship for extension of flow series at the project site.

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Table 4.4: Mean Monthly Flows

Catchment Area =	5860 Sq km												Annual
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Volume
	m3/sec												(mcm)
2009	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	26.365	22.975	-
2010	21.203	70.269	130.870	130.591	177.010	139.387	298.625	196.756	122.057	56.665	31.160	27.260	3684.06
2011	25.436	55.773	95.011	115.233	146.684	104.778	69.695	60.408	54.843	41.094	39.543	22.808	2184.67
Mean	23.320	63.021	112.941	122.912	161.847	122.082	184.160	128.582	88.450	48.879	32.356	24.347	2934.37

Note: -1 shows data not available.

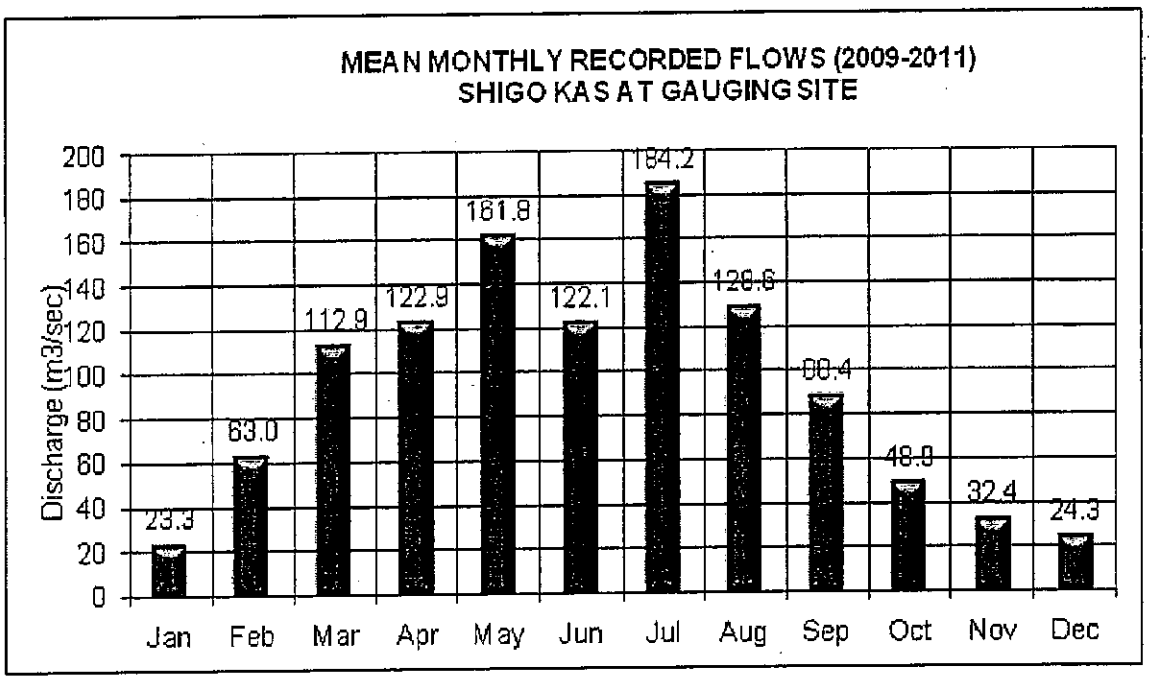

Figure 4.15: Mean Monthly Flows

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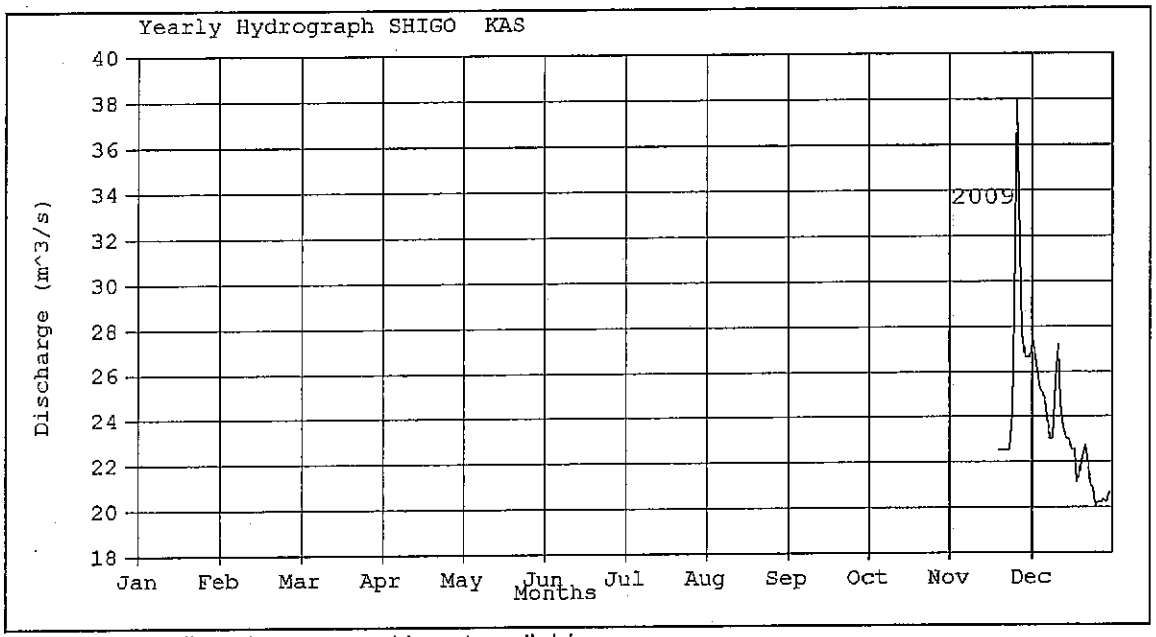


Note: Missing line shows record is not available

Figure 4.16: Recorded Yearly Hydrographs –Shigo-kas(Zulam Bridge) At Gauging Site (2009)

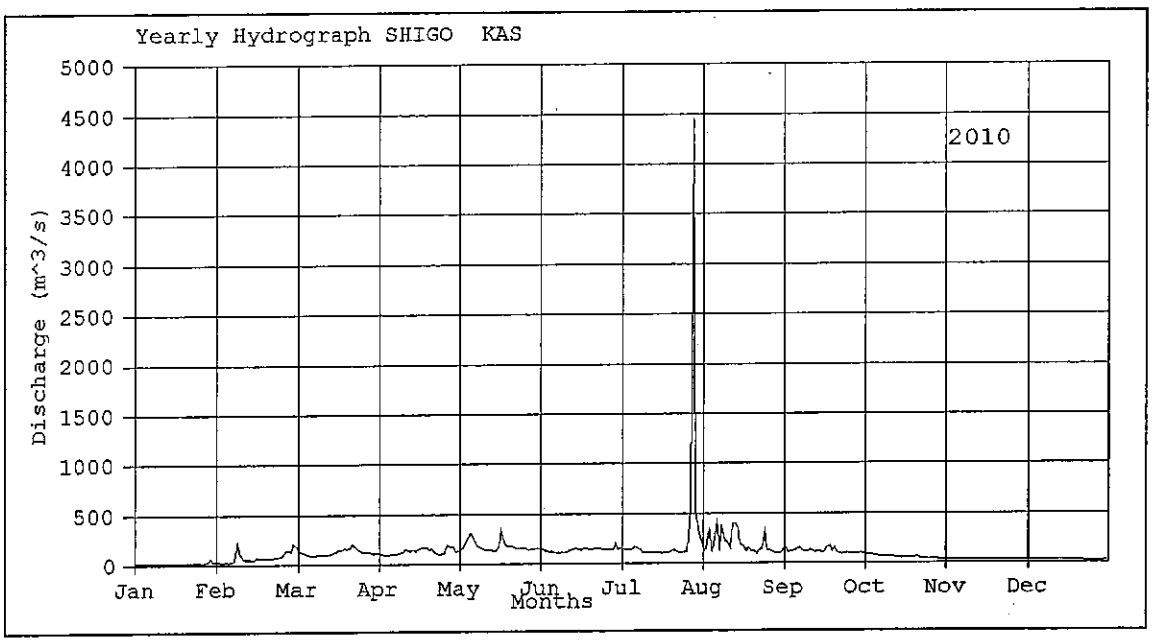
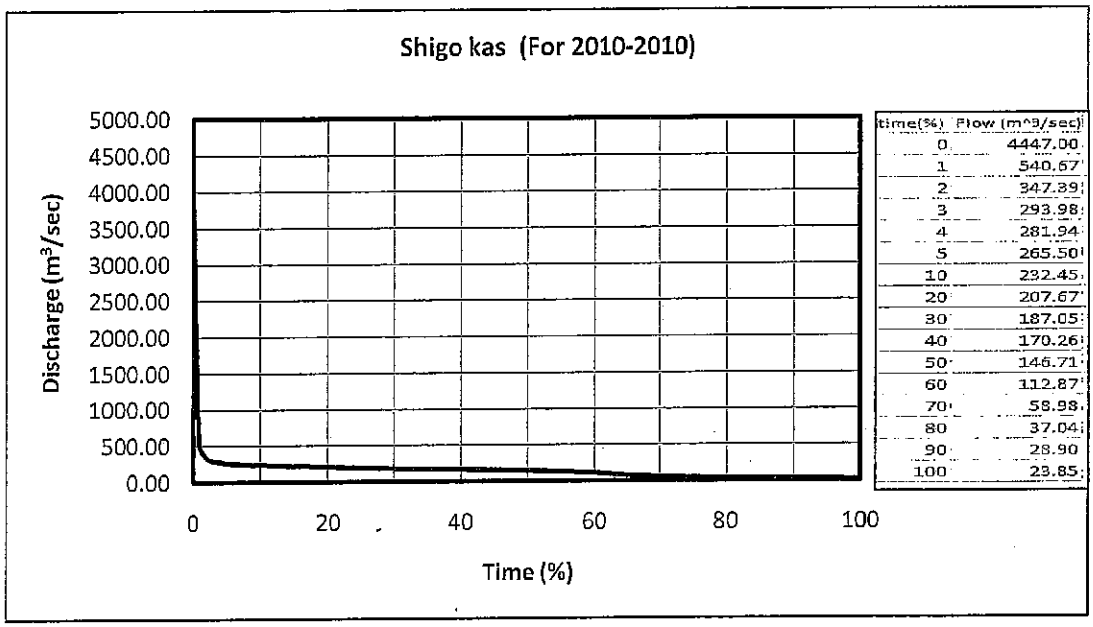


Figure 4.17: Recorded Yearly Hydrographs –Shigo-kas (Zulam Bridge) At Gauging Site (2010)



time(%)	Flow (m^3/sec)
0	4447.00
1	540.67
2	347.89
3	293.98
4	281.94
5	265.50
10	232.45
20	207.67
30	187.05
40	170.26
50	146.71
60	112.87
70	58.98
80	37.04
90	28.90
100	23.85

Figure 4.18: Flow Duration of Recorded Flows 2010

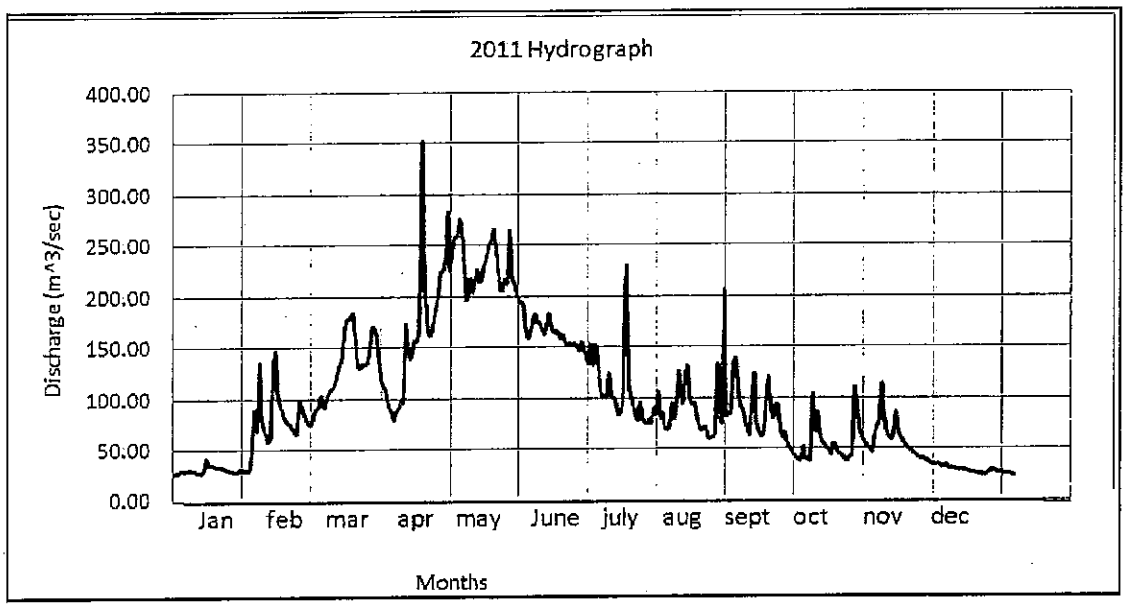


Figure 4.19: Recorded Yearly Hydrographs –Zulam Bridge at Gauging Site (2011)

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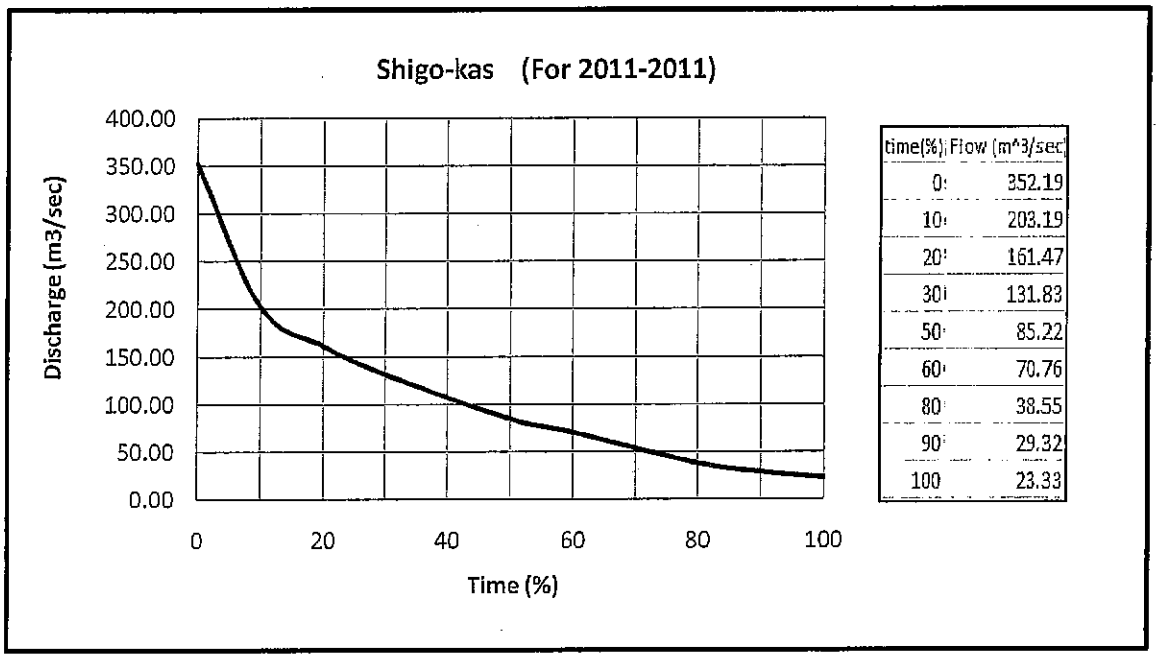


Figure 4.20: Flow Duration of Recorded Flows 2011

4.5 EXTENSION OF FLOW SERIES

Extension of flows in case of Panjkora River can be made with the help of available long term recorded daily flows of nearby station of homogeneous characteristics. In this regards nearby gauging stations like Zulam Koto & Bibior on Panjkora, Swat River at Kalam were considered and relationships were investigated. Further to the available record at Panjkora River flow measuring site, runoff relationships were estimated by using flow data for the corresponding recorded period for further lengthening the flow series of Panjkora River for the final selection of flow pattern for water availability.

4.5.1 Relationship Between Daily Flows of Panjkora River and Nearby Rivers

Runoff relationship has been developed between the recorded daily flows of Panjkora River and Swat at Kalam with the help of corresponding data of the two rivers. The relationship with the help of regression analysis was developed and presented in **Figure 4.21.**

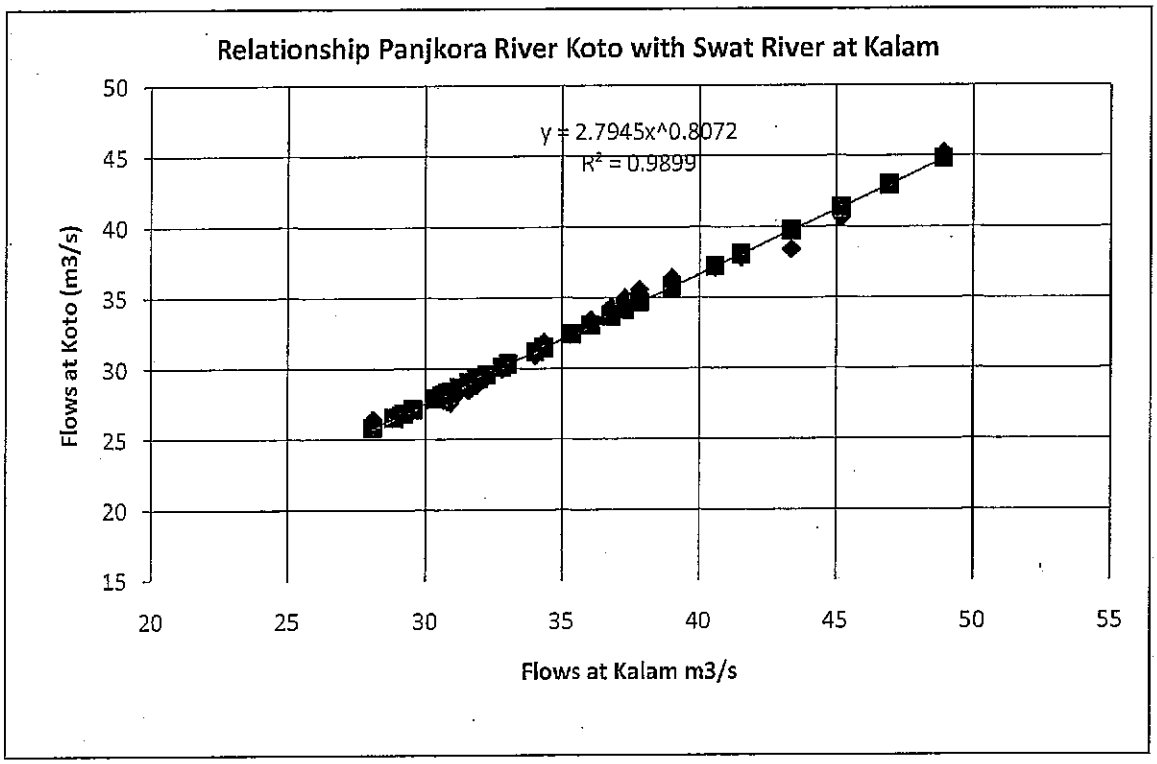


Figure 4.21: Relationship Panjkora River Koto with Swat River at Kalam

Refer to **Figure 4.21,** correlation was found between Koto at Panjkora and Swat River at Kalam with R^2 value 0.9899. The equation so obtained is given below:

$y = 2.7945x^{0.8072}$
$R^2 = 0.9899$
Where
y = Estimated Daily flow at Gauging Site in m^3/sec
x = Daily recorded flow in m^3/sec
R^2 = Coefficient of Correlation

Putting the value of recorded daily flows, the flows at shigo kas can be computed for the period when record is not available. Selecting the best fit relationship, above equation was therefore used for the extension of flows in Koto at Gauging site. The catchment area at Shigo site is 5816 km2. The proposed HPP is located just downstream of gauging station. At this location, the catchment area of the river is also 5816 sq.km. Area reduction factor [5816/5816] comes to be 1.0. If the location of gated weir site is different than gauging site, this factor can then be used to compute the flows at proposed gated weir site.

4.5.2 Mean Monthly and Annual Flows at Shigo-kas River Gauging Site

Using the procedure describe in the previous section mean monthly flow series was extended at Shigo-kas gauging site and given in **Table 4.5.** Annual volume of flows in million m^3 (mcm) is also given in the same table. The long term average monthly values are presented

graphically in **Figure 4.22**. To evaluate the fitness of good of extended flow series, comparison between recorded and computed mean monthly flows were made and presented in **Figure 4.23**. The graph shows fair comparison between the computed and observed values. However, the computed flows are little higher than limited recorded flows. It is due to the wet and dry years present in the historic series from where the data was extended. It confirms that extension of flow series is accurate. The monthly values show that the maximum flows occur in the month of July (364.5m^3/sec) whereas the month of January gives the lowest (40.0m^3/sec).

4.5.3 Mean Monthly And Annual Flows At Proposed Gated weir Site

As discussed in previous section, proposed weir is located very close to gauging site. At this location, the catchment area of the river is 8516 km. An area reduction factor [8516/8516] becomes 1.0. Therefore flows are unchanged as no reduction in area was found. Extended daily flows 1961-2011 are placed in **Annexure-2**.

Annual water available at proposed Gated weir site is computed and given in **Figure 4.24**. It shows that dry year was 2011 and wet year was 1991. Standard deviation (643) of annual flows shows that the variation in water available in the river during different years is not so high. It varies between 2184 and 5728 mcm.

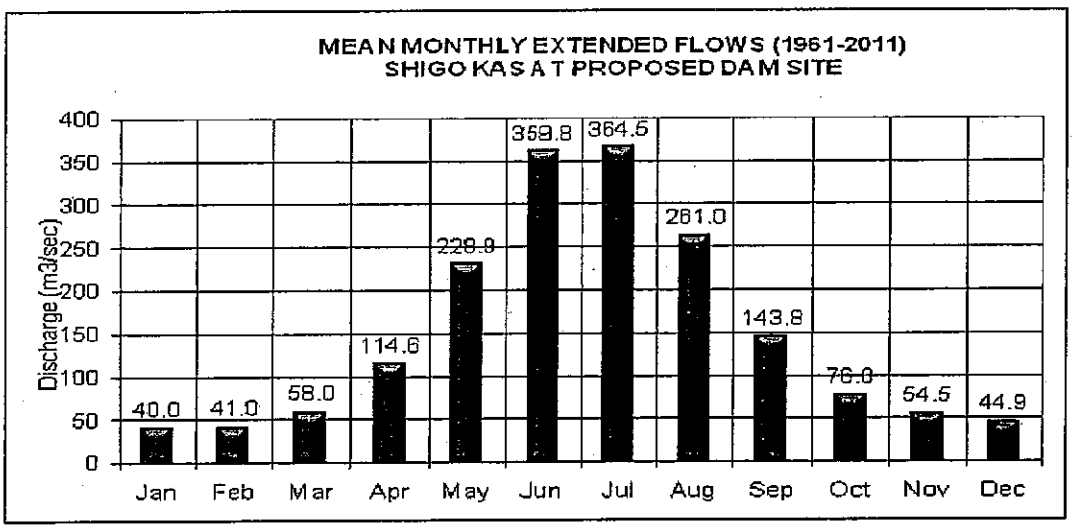


Figure 4.22: Long Term Average Monthly Flows

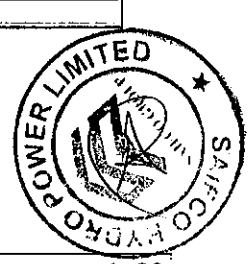
Table 4.5
Extended long term mean monthly flows
Shigo-kas at gated weir site

MEAN MONTHLY FLOWS, SHIGO KAS AT PROPOSED HPP (m3/sec)

Catchment Area = 5860 Sq km

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Volume
						m3/sec							(mcm)
1961	37.624	31.928	36.300	76.485	214.431	366.022	400.599	304.928	218.620	102.935	60.571	49.680	4993.53
1962	41.987	38.170	40.619	73.191	140.691	302.652	334.878	249.936	137.316	72.962	53.527	42.928	4017.84
1963	35.819	32.421	41.882	91.096	178.213	404.106	385.687	275.569	157.815	78.983	53.560	43.096	4673.23
1964	37.764	35.449	41.660	88.069	208.628	361.493	433.129	306.182	170.230	75.992	47.924	41.037	4855.38
1965	35.299	31.137	37.360	81.208	223.491	488.635	467.229	300.757	166.233	84.526	55.986	42.348	5293.34
1966	36.665	36.939	48.947	87.735	183.931	422.032	360.763	301.519	170.716	79.794	53.647	42.950	4797.78
1967	37.285	32.883	34.758	70.155	175.069	386.428	490.925	307.445	174.086	73.575	52.371	43.126	4933.03
1968	39.186	36.250	44.947	102.974	208.069	380.619	387.202	308.267	163.124	78.749	54.970	44.572	4832.70
1969	37.543	36.464	55.127	108.549	189.533	409.586	524.552	382.469	146.925	84.438	61.601	48.557	5480.29
1970	40.798	36.691	39.014	98.014	216.733	360.165	316.025	297.505	193.126	87.279	57.998	46.370	4700.75
1971	39.540	36.402	45.300	111.199	241.439	373.523	287.801	260.474	126.737	65.703	47.796	38.844	4398.64
1972	36.345	31.812	39.904	95.108	218.522	466.035	423.608	295.080	175.755	77.977	52.446	41.946	5131.27
1973	35.238	31.306	36.657	115.894	259.903	459.254	407.774	335.006	193.459	88.000	52.459	41.873	5405.39
1974	35.261	32.875	47.984	111.841	177.186	310.713	343.370	246.782	120.744	70.446	49.497	40.897	4180.09
1975	34.771	33.503	34.416	92.319	291.346	407.739	384.033	349.519	164.743	81.606	62.481	47.680	5214.36
1976	38.836	35.683	38.342	63.764	244.357	382.483	451.744	283.827	154.577	84.059	55.504	42.913	4930.36
1977	37.096	35.897	45.520	101.529	191.211	337.968	345.107	248.745	127.824	72.177	51.100	42.363	4300.82
1978	37.929	35.235	36.206	89.299	234.807	396.390	390.296	236.992	108.482	71.438	53.531	46.537	4562.58
1979	37.509	34.398	35.524	109.783	175.112	378.808	436.763	246.649	126.470	66.582	51.599	40.106	4568.25
1980	43.029	36.602	36.265	92.089	230.954	391.807	340.469	224.257	126.294	73.755	56.784	45.656	4459.61
1981	43.381	41.063	46.226	122.378	301.105	361.773	395.491	241.842	117.576	69.393	51.234	43.978	4823.53
1982	38.801	36.387	36.512	79.685	176.008	238.797	255.349	242.510	97.138	63.449	63.187	47.587	3585.67
1983	42.073	38.943	40.634	68.886	190.077	311.339	332.506	279.056	146.963	77.533	60.905	50.002	4307.07
1984	42.262	36.600	43.583	88.720	218.184	471.075	330.333	295.299	161.948	69.907	50.283	42.427	4831.89
1985	38.921	36.331	39.986	77.575	175.188	313.192	336.861	266.354	128.421	76.484	53.506	44.444	4173.95
1986	39.291	34.897	41.404	97.574	202.802	365.180	446.919	285.349	128.784	79.285	53.968	42.739	4778.21
1987	40.926	40.568	46.385	107.266	222.332	365.941	410.160	317.779	176.670	86.598	62.356	48.480	5060.11
1988	47.365	43.569	46.710	137.095	299.366	394.430	404.877	256.248	132.834	73.619	51.423	44.250	5076.73
1989	39.110	35.467	40.549	64.083	179.401	400.587	354.585	263.362	149.295	75.897	55.740	46.045	4479.48
1990	40.425	38.511	49.085	83.448	336.217	384.912	381.559	271.084	177.948	80.285	54.983	42.608	5101.12
1991	39.446	41.387	49.463	99.670	203.397	446.150	526.982	364.481	205.499	91.515	61.245	51.668	5728.79
1992	44.232	43.334	44.947	89.400	187.978	376.152	490.576	342.791	203.830	106.773	76.351	55.183	5417.74
1993	49.112	42.236	42.527	116.345	277.896	368.958	372.733	249.284	199.121	93.740	64.380	56.606	5079.76
1994	48.413	45.128	66.102	89.422	234.744	419.768	487.594	321.566	177.320	87.564	64.791	54.517	5481.82
1995	40.553	41.967	43.508	89.464	209.157	398.029	488.265	318.143	138.979	83.976	56.351	46.016	5136.14
1996	40.513	39.005	45.575	107.618	200.636	467.057	419.076	330.018	178.350	93.745	62.253	46.771	5336.46
1997	52.814	47.271	45.662	108.723	189.297	405.139	545.358	316.623	148.389	86.434	56.769	44.426	5384.52
1998	37.291	36.239	37.983	123.937	265.409	305.001	444.475	248.378	167.133	80.425	58.498	41.708	4852.54
1999	36.277	35.205	41.685	127.550	287.105	413.037	346.917	245.237	152.803	78.303	56.129	44.276	4899.97
2000	37.551	32.535	37.966	108.985	271.126	258.194	239.072	177.197	123.078	76.061	50.545	39.413	3815.13
2001	33.485	34.116	41.173	77.383	221.295	259.971	243.985	193.217	116.933	69.730	50.908	37.852	3626.77
2002	34.096	32.227	49.567	121.496	266.852	387.931	278.818	222.624	117.401	71.019	49.202	40.371	4392.98
2003	32.049	31.603	40.633	113.336	238.115	453.665	402.651	228.093	147.807	83.680	62.905	47.179	4945.15
2004	41.527	35.521	63.974	139.569	291.851	386.942	288.476	229.467	131.762	79.342	71.951	60.161	4781.73
2005	37.708	63.560	252.326	260.856	264.649	352.237	279.712	149.638	80.358	64.392	49.953	41.737	4985.64
2006	46.960	76.112	91.144	168.929	238.601	140.994	127.550	183.805	92.582	63.540	68.806	74.105	3556.02
2007	87.478	110.471	258.402	354.118	312.439	289.617	222.060	153.398	120.124	69.841	54.073	58.264	5493.24
2008	40.411	34.264	103.628	286.030	331.747	290.715	165.127	126.242	63.315	47.800	36.139	48.615	4133.93
2009	46.292	69.532	140.122	240.729	357.630	293.704	298.598	173.211	74.081	39.491	26.365	22.975	4658.73
2010	21.203	70.269	130.870	130.591	177.010	139.387	298.625	196.756	122.057	58.665	31.160	27.260	3684.06
2011	25.436	56.773	95.011	115.233	146.684	104.778	69.696	60.408	54.843	41.094	39.543	22.808	2184.67
Mean	39.998	40.963	58.021	114.615	228.940	359.806	364.497	261.027	143.835	76.030	54.515	44.862	4696.525
Min	21.203	31.137	34.416	63.764	140.691	104.778	69.696	60.408	54.843	39.491	26.365	22.808	2184.672
Max	87.478	110.471	258.402	354.118	357.630	488.635	545.358	382.469	218.620	106.773	76.351	74.105	5728.788
St.Dev	8.607	14.161	46.073	55.458	50.452	81.486	99.540	63.249	26.447	13.141	8.801	8.153	643.104
Coeff.Skew	3.267	3.166	3.468	2.804	0.699	-0.289	-0.662	-0.769	0.286	0.607	0.702	0.287	-1.399

Note: In Blue Color Recorded Flows, Blank Column data not available



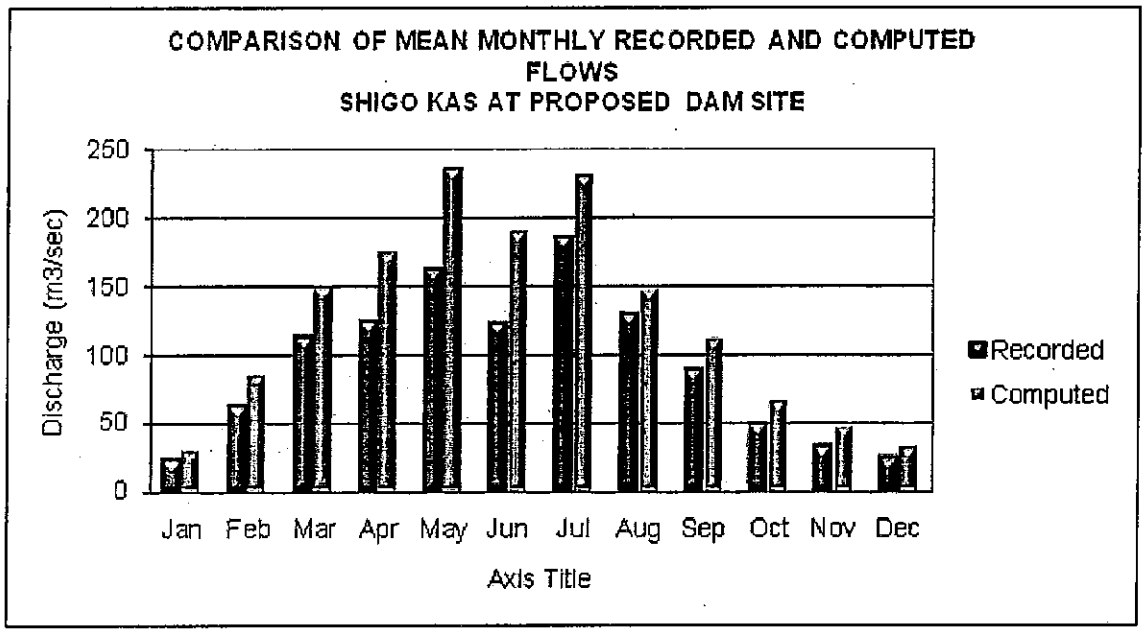


Figure 4.23: Comparison of Mean Monthly Recorded and Computed Flows

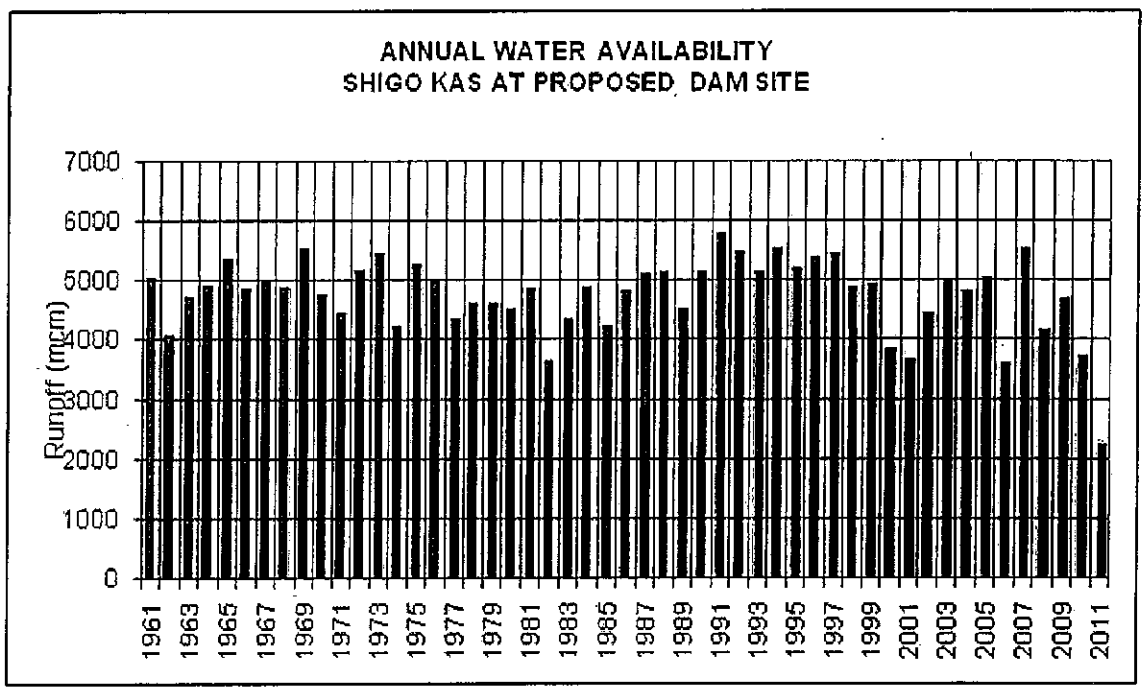


Figure 4.24: Water Availabity at Gated weir Site

4.5.4 Flow Duration

In order to check the availability of flows at the proposed gated weir site, a flow duration analysis was carried out. The flow duration curve of the simulated series has been computed

and plotted by combining the data of all the years i.e. 1961 to 2011. The flow duration curves estimated from simulated series of daily flows are shown in **Figure 4.25** (Post 2010 Flood) and **Figure 2.27** (Pre 2010 flood) and its hydrograph in Bar Chart in **Figure 4.26 and Figure 4.28**.

The flow duration curves for the dry year (2011), average year (2009) and the wet year (1991) have also been plotted separately in **Figure 4.29, 4.31 and 4.33**. The flow duration data is also tabulated in these figures. The corresponding mean monthly discharges are shown in **Figure 4.30, 3.32 and 3.34**. Flow duration curves for 10-years segments starting from 1961-2011 along with their mean monthly discharges have been computed. These graphs are presented in **Annexure-1.Table A-4.6** shows summary results of flow duration and mean monthly flows.

4.5.5 Yearly Hydrograph

Variation of flow in the river can be well observed from the hydrographs, which were plotted with the help of daily flow data. Yearly hydrographs for the dry year (2011), average year (2009) and the wet year (1991) and their comparison were plotted separately in **Figure 4.35** to **Figure 4.38**. Yearly hydrographs for each 10 year segments are compared in **Figure 4.39** to **Figure 4.41.** Hydrograph of year 2010, exceptionally high flood is plotted and shown in **Figure 4.42**. Remaining hydrographs are presented in **Annexure-1**.

Table 4.6

a. Flow Duration

Time (%)	Discharge (m^3/sec)			
	Mean 1961-2011	Average Year 2009	Dry Year 2011	Wet Year 1991
0	4447.00	547.71	352.19	658.22
3	476.06	396.26	249.91	559.75
5	433.01	378.57	227.61	527.97
10	363.91	333.48	203.19	480.20
20	272.38	277.37	161.47	365.29
30	197.10	228.77	131.83	236.92
40	130.22	168.66	99.41	144.14
50	85.08	96.32	85.22	91.86
60	61.28	66.01	70.76	68.45
70	48.93	50.73	55.91	54.44
80	41.92	42.97	38.55	44.02
90	36.73	36.21	29.32	41.28
95	34.54	33.40	26.80	38.99
100	21.79	27.90	23.33	36.71

b. Mean Monthly Flows

Month	Mean 1961-2011	Average Year 2009	Dry Year 2011	Wet Year 1991
	(m^3/sec)			
Jan	40.00	46.29	25.44	39.45
Feb	40.96	69.53	55.77	41.39
Mar	58.02	140.12	95.01	49.46
Apr	114.62	240.73	115.23	99.67
May	228.94	357.63	146.68	203.40
Jun	359.81	293.70	104.78	445.15
Jul	364.50	288.60	69.70	526.98
Aug	261.03	173.21	60.41	364.48
Sep	143.84	74.08	54.84	205.50
Oct	76.03	39.49	41.09	91.52
Nov	54.51	26.37	39.54	61.24
Dec	44.86	22.97	22.81	51.67
Annual	(mcm)			
Volume	4696.5	4658.7	2184.7	5728.8

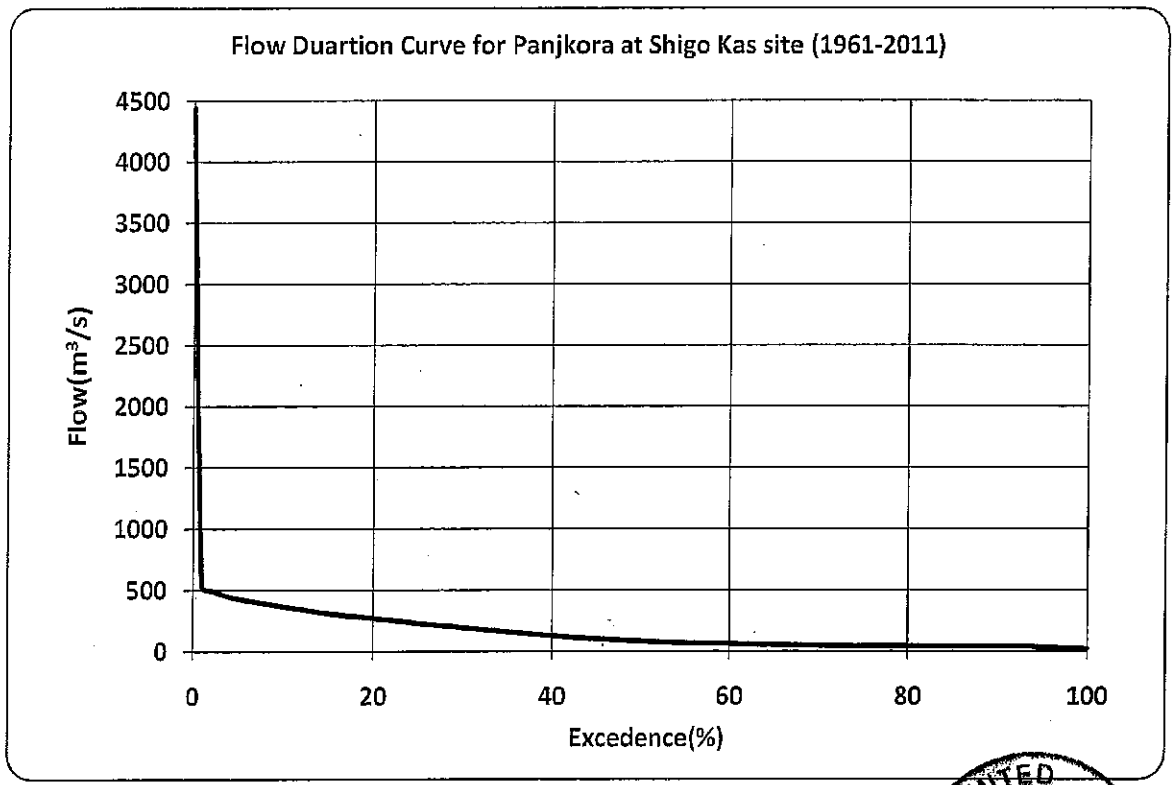


Figure 4.25: Flow Duration Curve, Shigo-kas At Proposed Gated Weir Site For Period 1961-2011 Post 2010 Flood

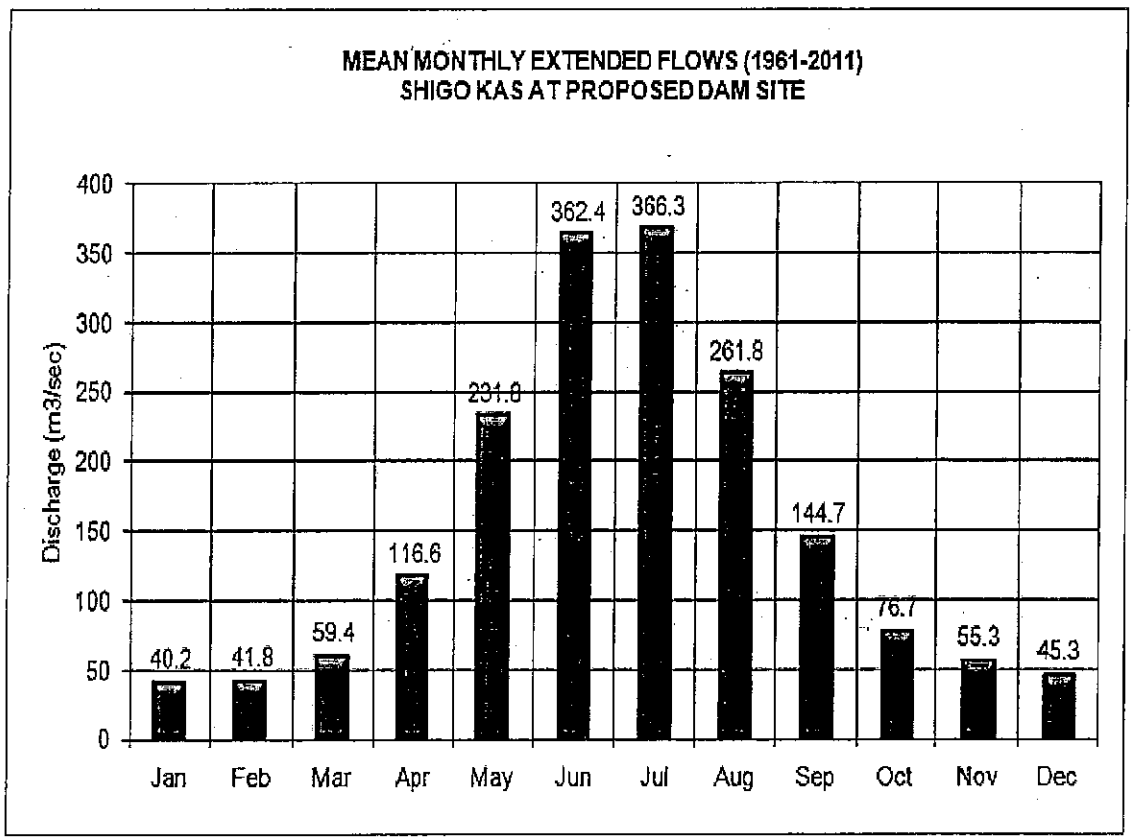


Figure 4.26: Mean Monthly Extended Flows

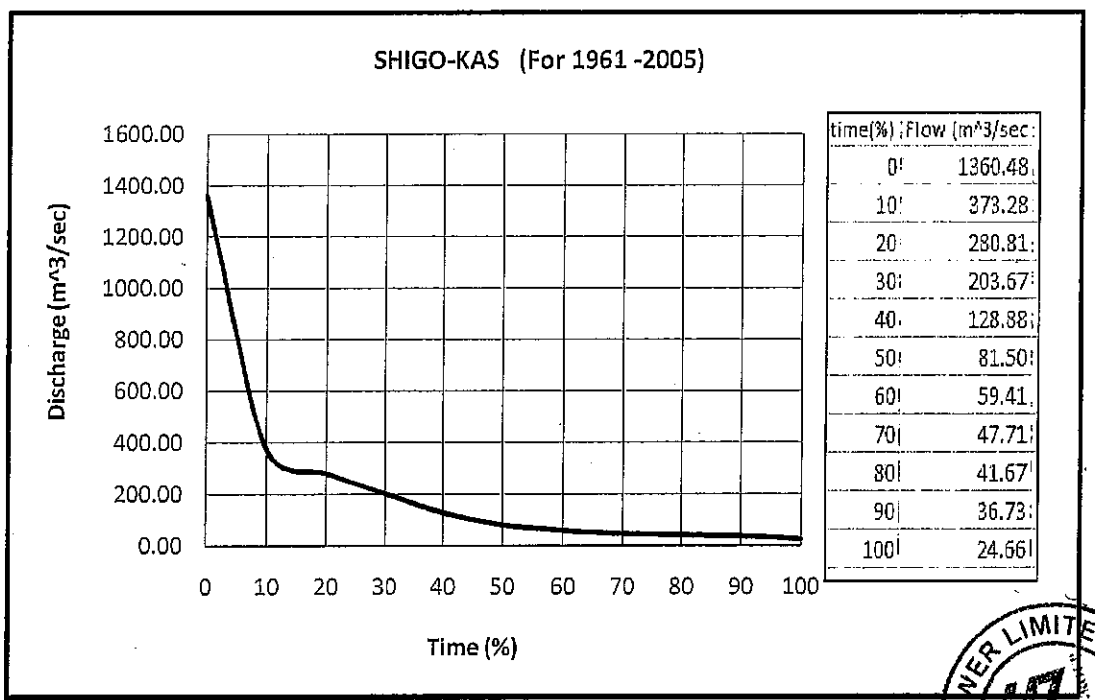


Figure 4.27: Flow Duration Curve, Shigo-kas At Proposed Gated weirSite For Period 1961-2005 Pre 2010 Flood

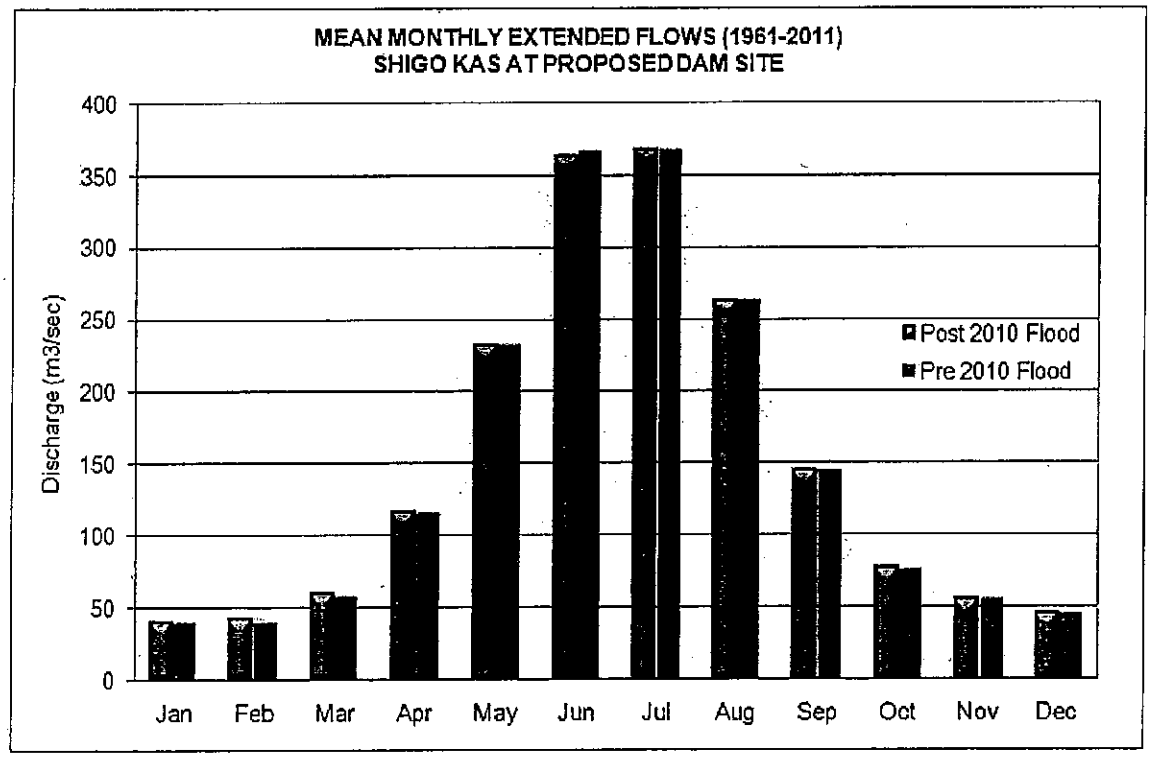
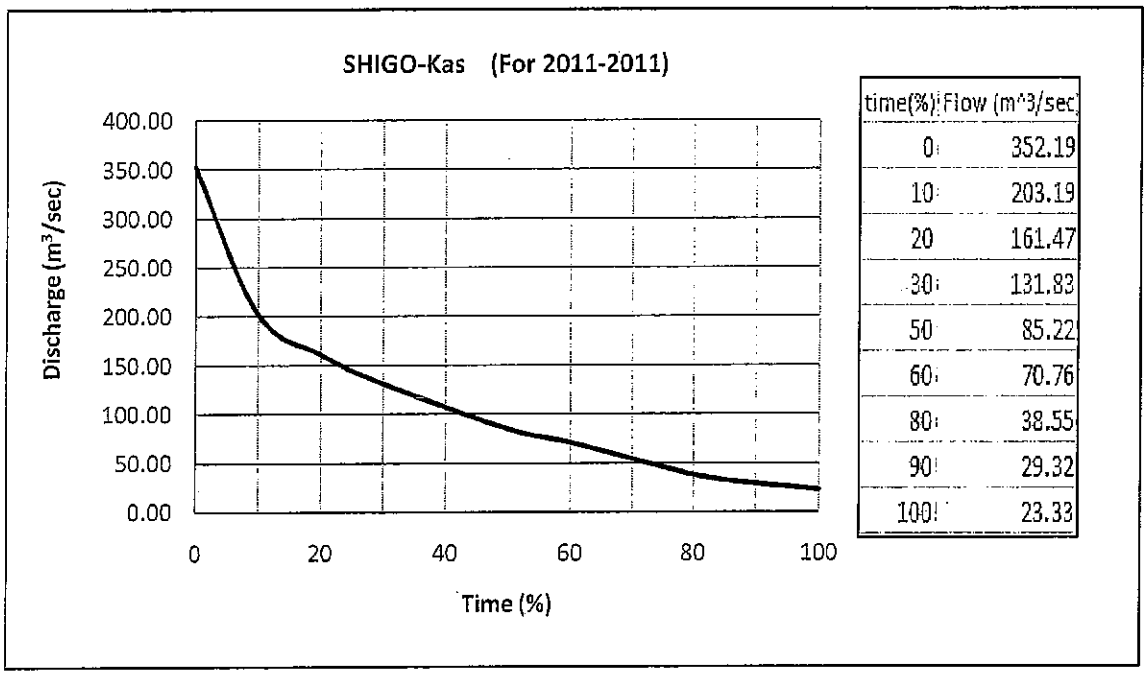


Figure 4.28: Mean Monthly Extended Flows(1961-2011)



time(%)	Flow (m^3/sec)
0	352.19
10	203.19
20	161.47
30	131.83
50	85.22
60	70.76
80	38.55
90	29.32
100	23.33

Figure 4.29: Dry year - Flow Duration Curve at Proposed Gated weir Site Year 2011 (Dry year in 51 year of extended data)

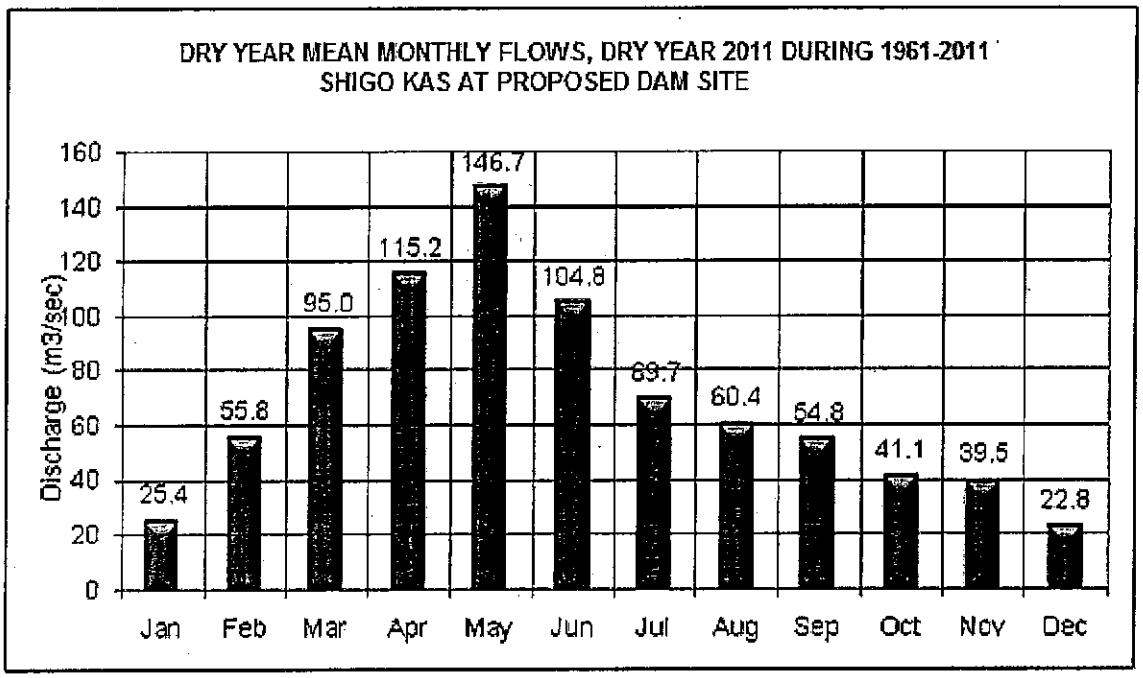


Figure 4.30: Dry Year Mean Monthly Flows 2011

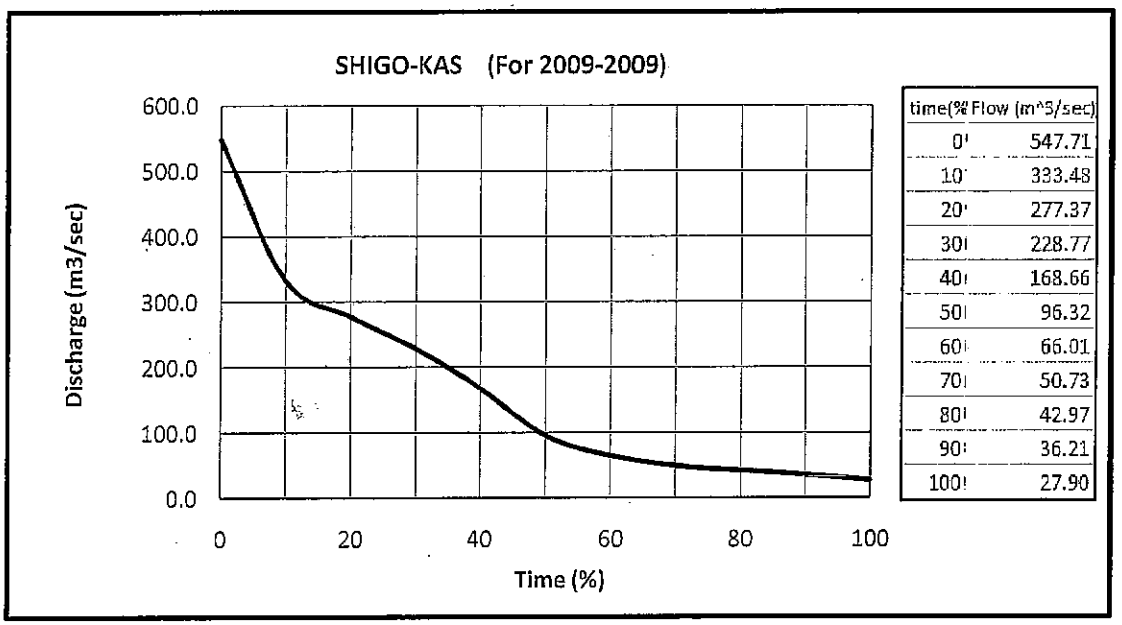


Figure 4.31: Average Year - Flow Duration Curve at Proposed Gated weir Site Year 2009
(Average year in 51 years of extended data)

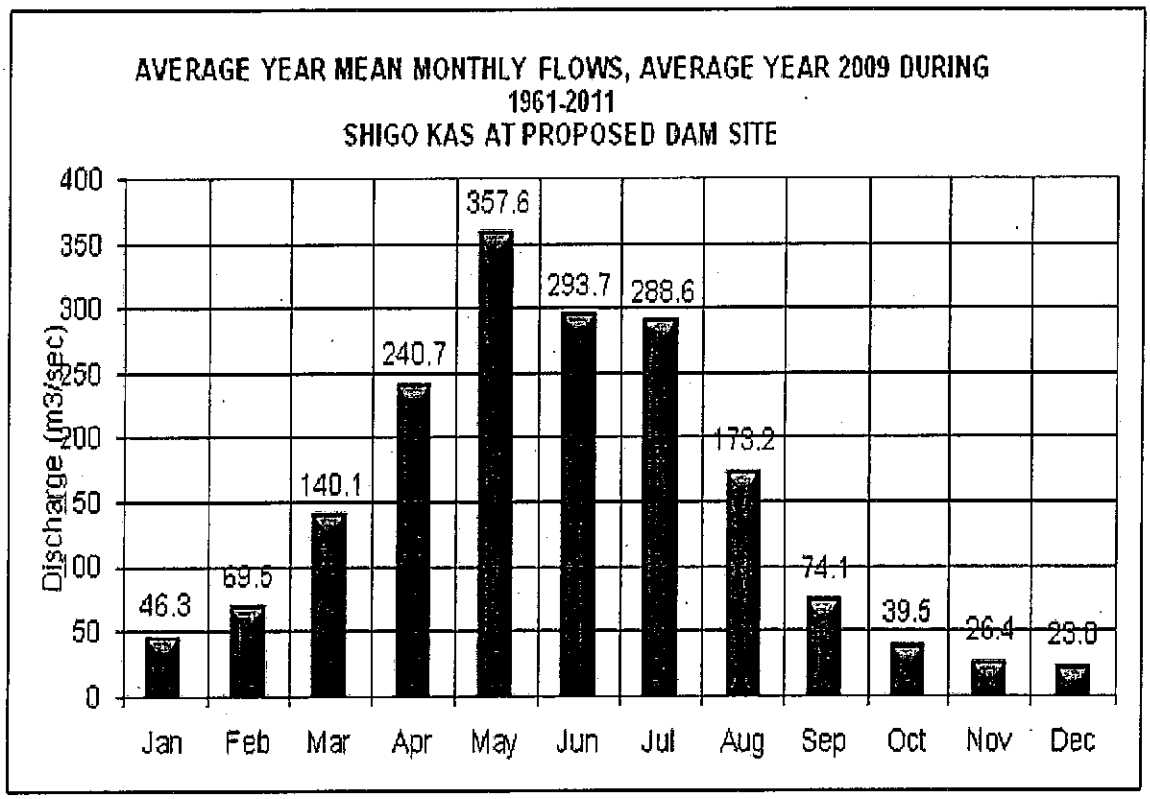


Figure 4.32: Average Year Mean Monthly Flows, 2009

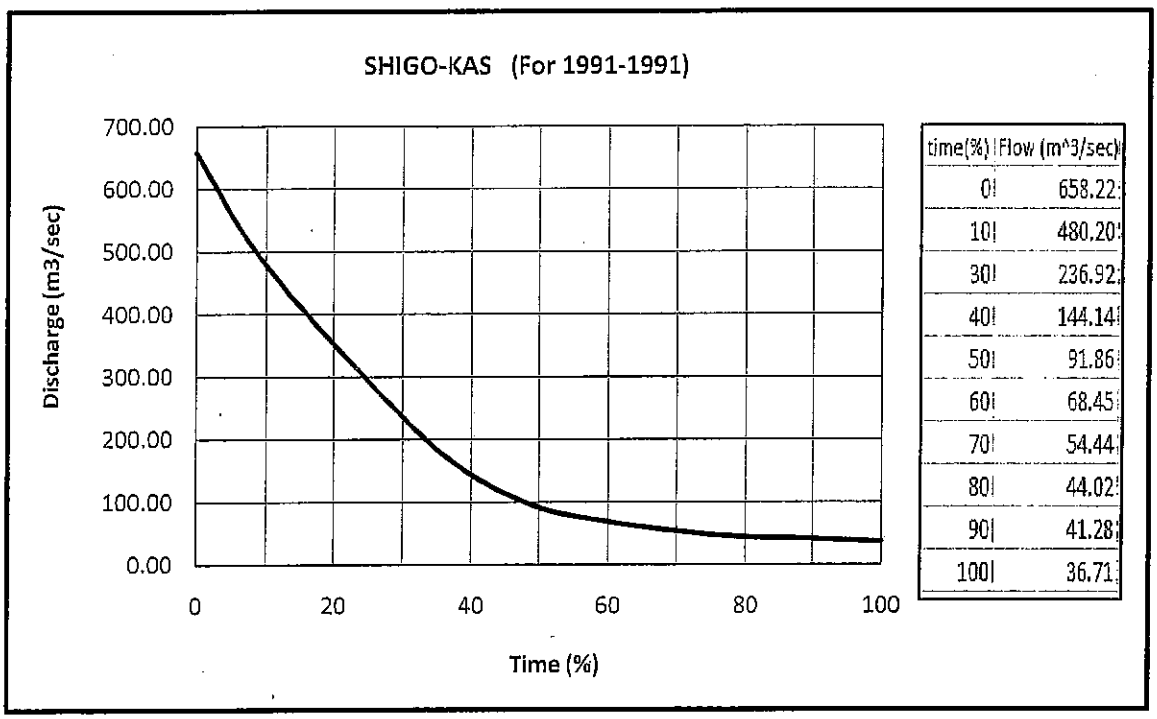


Figure 4.33: Wet Year-Flow Duration Curve at Proposed Gated weir Site, Year 1991 (Wet Year In 51 Year Extended Data)

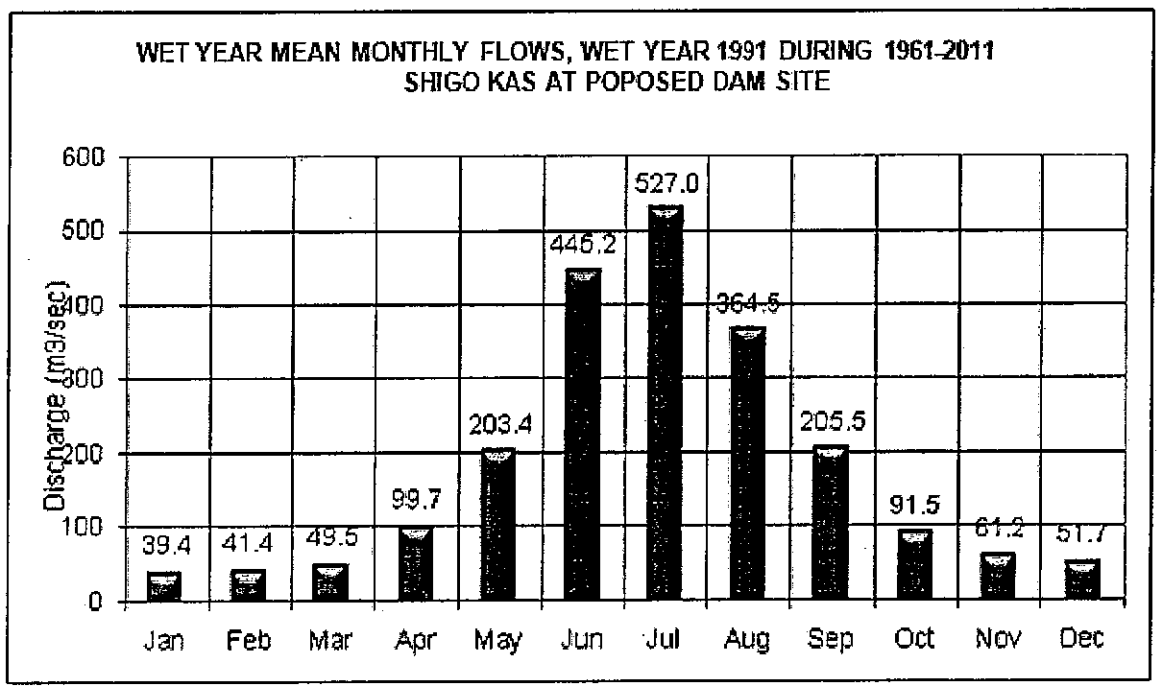


Figure 4.34: WET YEAR MEAN MONTHLY FLOWS, 1991

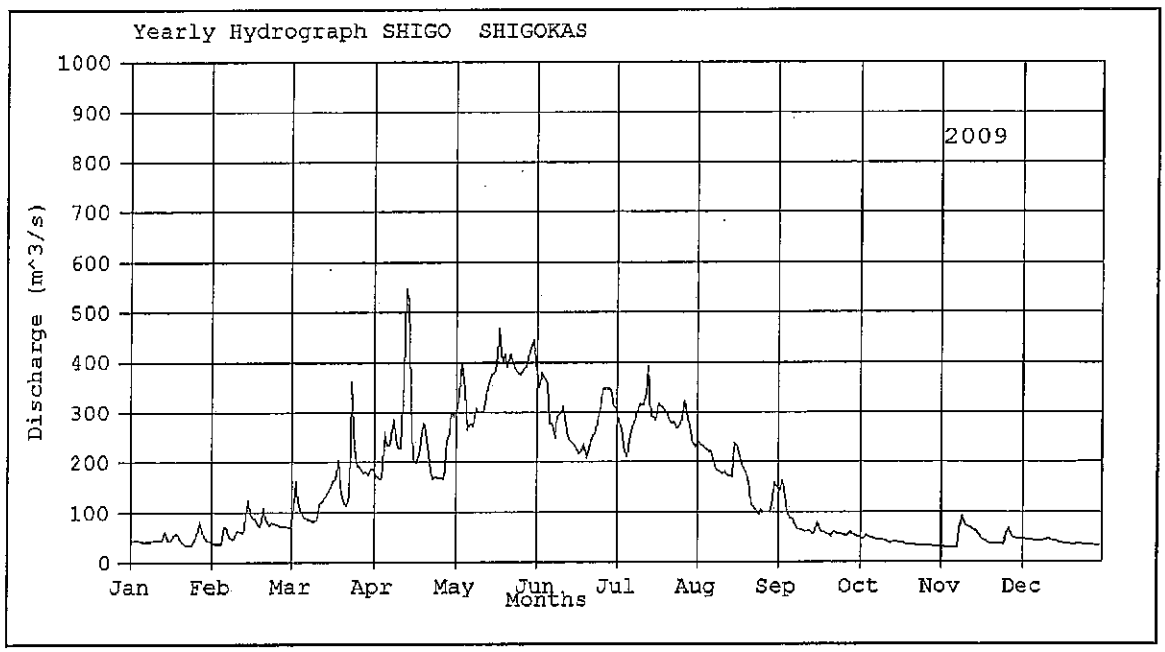


Figure 4.35: Average Year Hydrograph 2009 at Proposed HPP

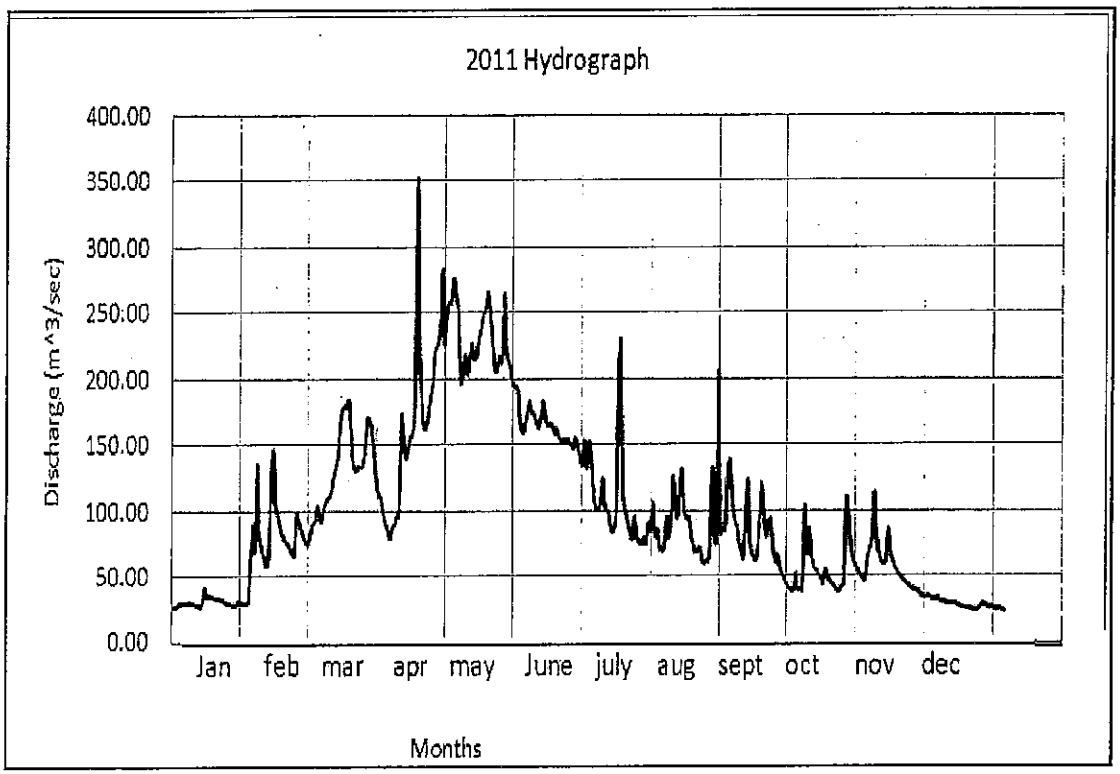


Figure 4.36: Dry Year Hydrograph 2011 at Proposed HPP

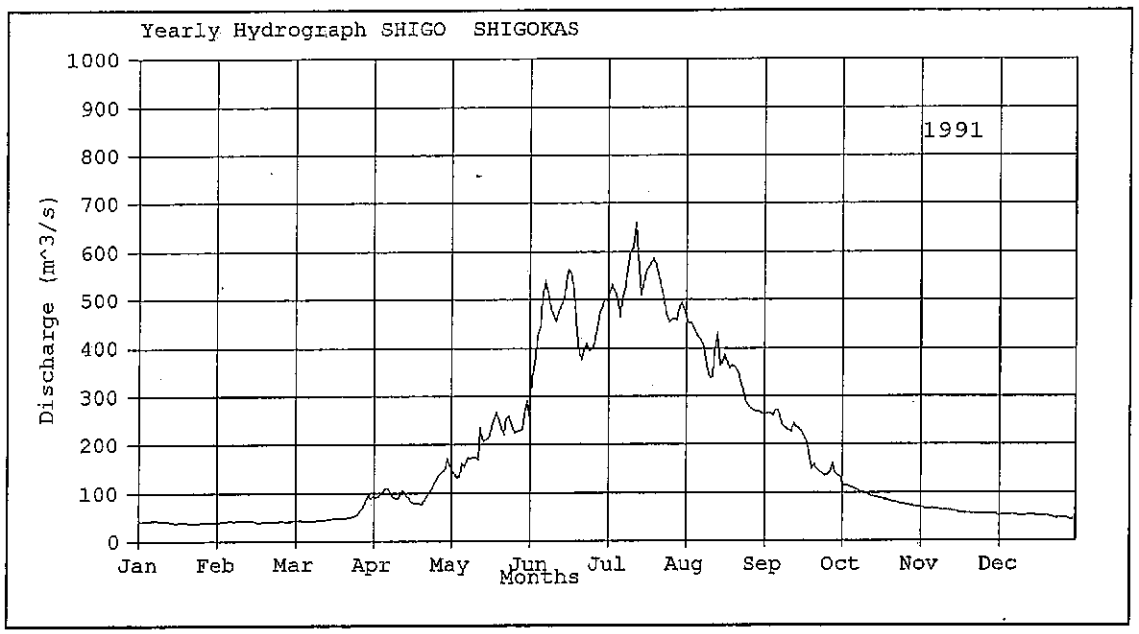


Figure 4.37: Wet Year Hydrograph 1991 at Proposed HPP

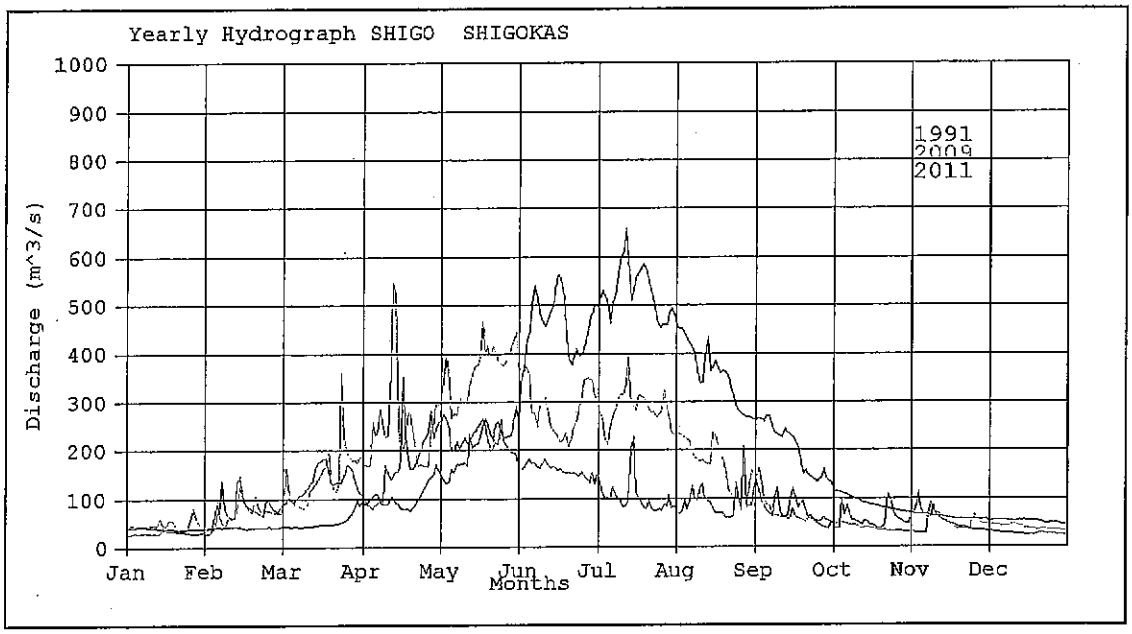


Figure 4.38: Comparison Of Dry, Average and Wet Year Hydrographs

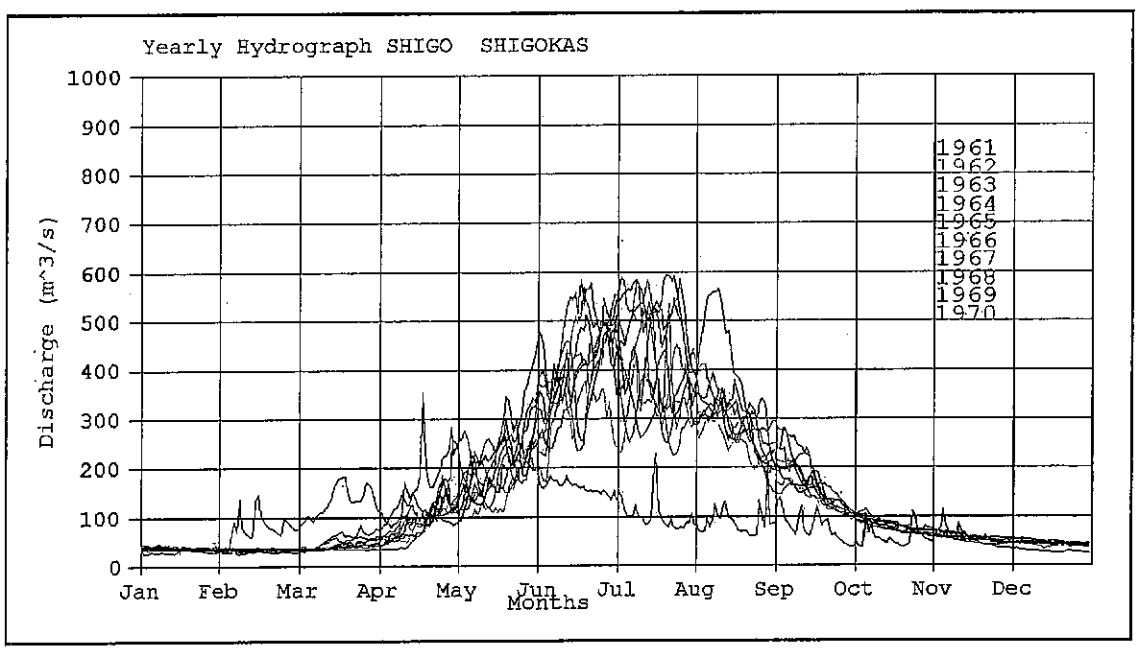


**Figure 4.39: Comparison of First 10 Years Hydrographs (1961-70)
At Proposed HPP**

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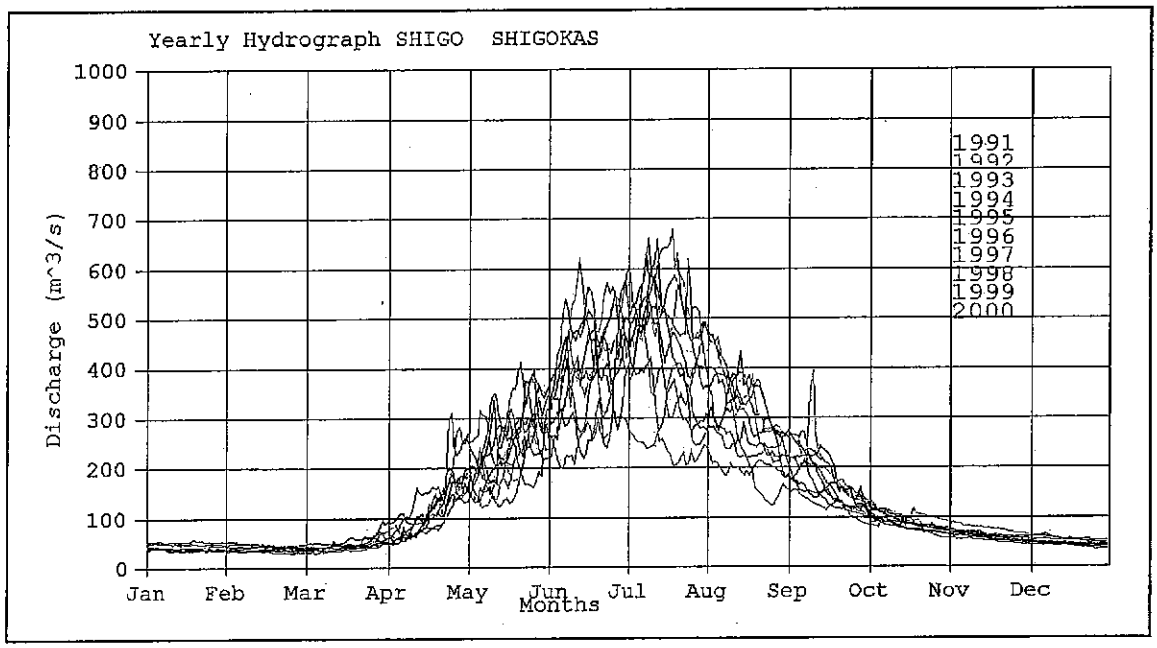


Figure 4.40: Comparison Of Next 10 Years Hydrographs (1991-2000) At Proposed HPP

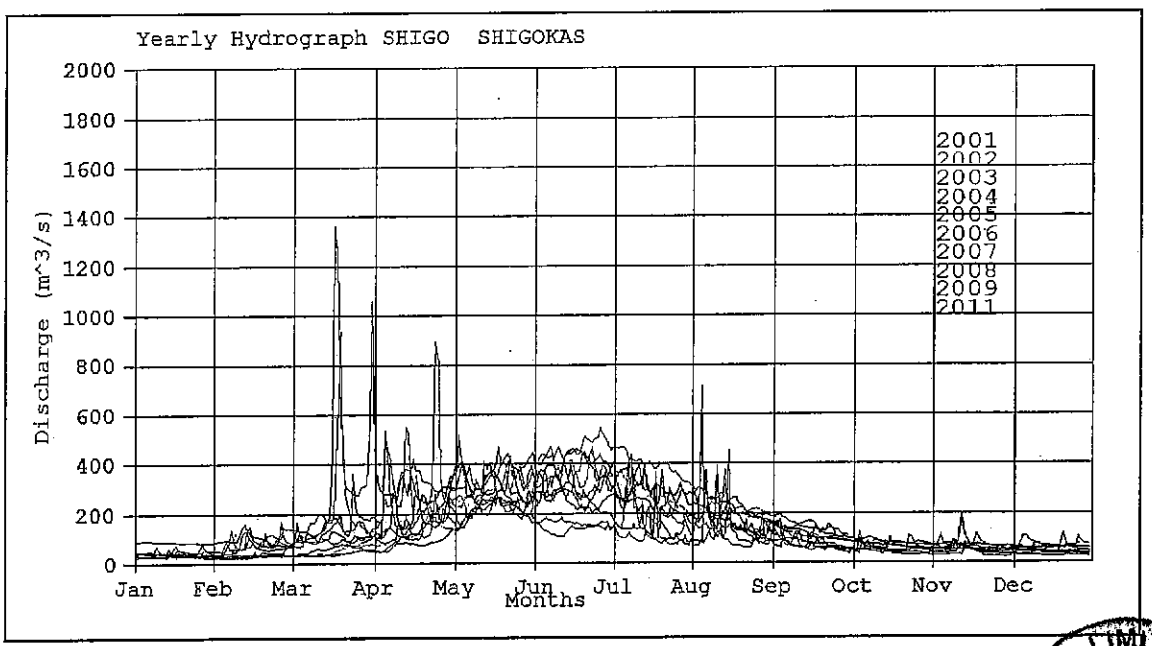


Figure 4.41: Comparison Of Next 10 Years Hydrographs (2001-2009 And 2011) At Proposed HPP

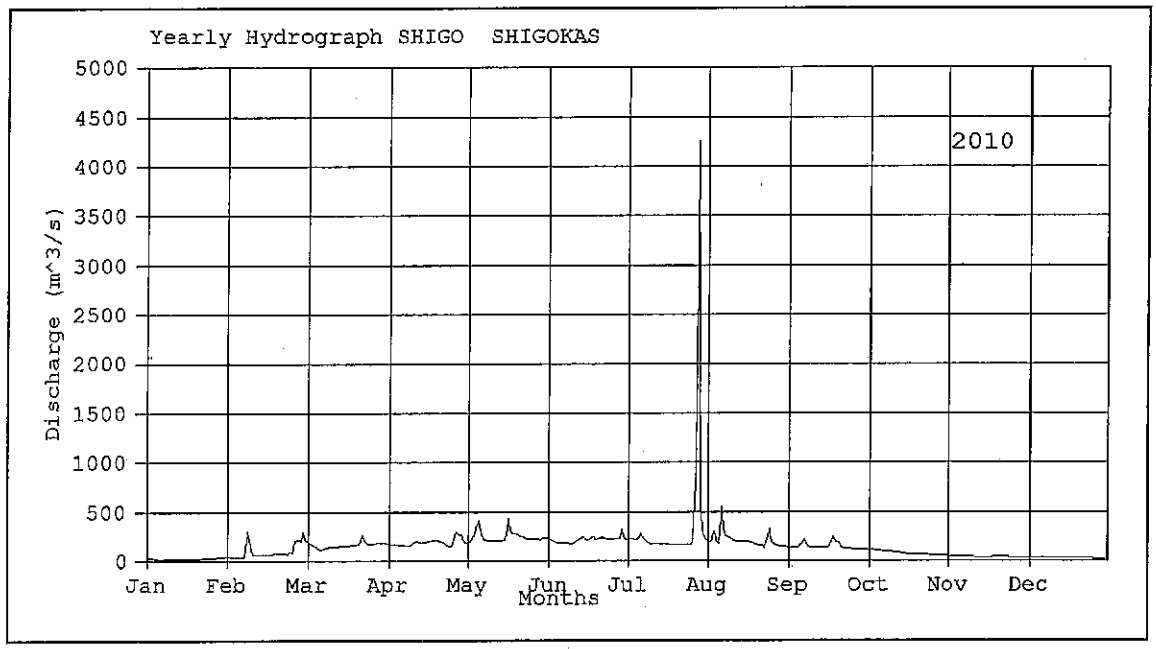


Figure 4.42: Hydrograph 2010 (Exceptionally High Flood)
Shigo-kas At Proposed HPP

4.5.6 Low Flow Analysis

This type of analysis is carried out to ensure adequate water supply for power generation. Series of low flow events was selected by computation and arranging in order of magnitude. The minimum independent flow rate of certain duration will be determined and then Sequential Mass Curve Analysis of inflow and power demand will yield a rough estimate of water required to meet the power demand. The analysis will determine the deviation of flows around its mean values.

Mean daily flows at proposed gated weir site were extended for 51 years (1961-2011). Low flow analysis was carried out on this long term inflow series. Mean monthly minimum flows during the recorded period were extracted from the long term series and plotted in **Figure 4.43**. It shows the minimum of the minimum flow occurs in the month of January and it is 21.2m^3/sec. To have a comparison with maximum mean monthly flows for 51 years, mean monthly maximum flows were also plotted in **Figure 4.44**. Minimum variation of flow in the river can be well observed with the help of **Figure 4.29, 4.30, 4.36** and **4.43**.

4.5.7 Conclusions

The present study reveals that the mean flow in Shigo kas at proposed gated weir site varies between 40m^3/sec in January and 366 m^3/sec in July (See **Figure 4.26**). It is recommended that flow duration curve for the extended period 1961-11 (**Figure 4.25**) may be adopted for design purpose. The mean monthly flows (1961-2011) and flow duration given in **Table 4.7** are recommended for the project.

Table 4.7 Recommended Mean Monthly Flows and Flow Duration

Month	Extended Flows			Flow Duration	
	Mean	Minimum	Maximum	Time (%)	Discharge (m^3/sec)
	(m^3/sec)				
Jan	40.00	21.20	87.48	0	4447.00
Feb	40.96	31.14	110.47	3	476.06
Mar	58.02	34.42	258.40	5	433.01
Apr	114.62	63.76	354.12	10	363.91
May	228.94	140.69	357.63	20	272.38
Jun	359.81	104.78	488.64	30	197.10
Jul	364.50	69.70	545.36	40	130.22
Aug	261.03	60.41	382.47	50	85.08
Sep	143.84	54.84	218.62	60	61.28
Oct	76.03	39.49	106.77	70	48.93
Nov	54.51	26.37	76.35	80	41.92
Dec	44.86	22.81	74.10	90	36.73
Annual	(mcm)			95	34.54
Volume	4696.5	1759.7	8042.8	100	21.79

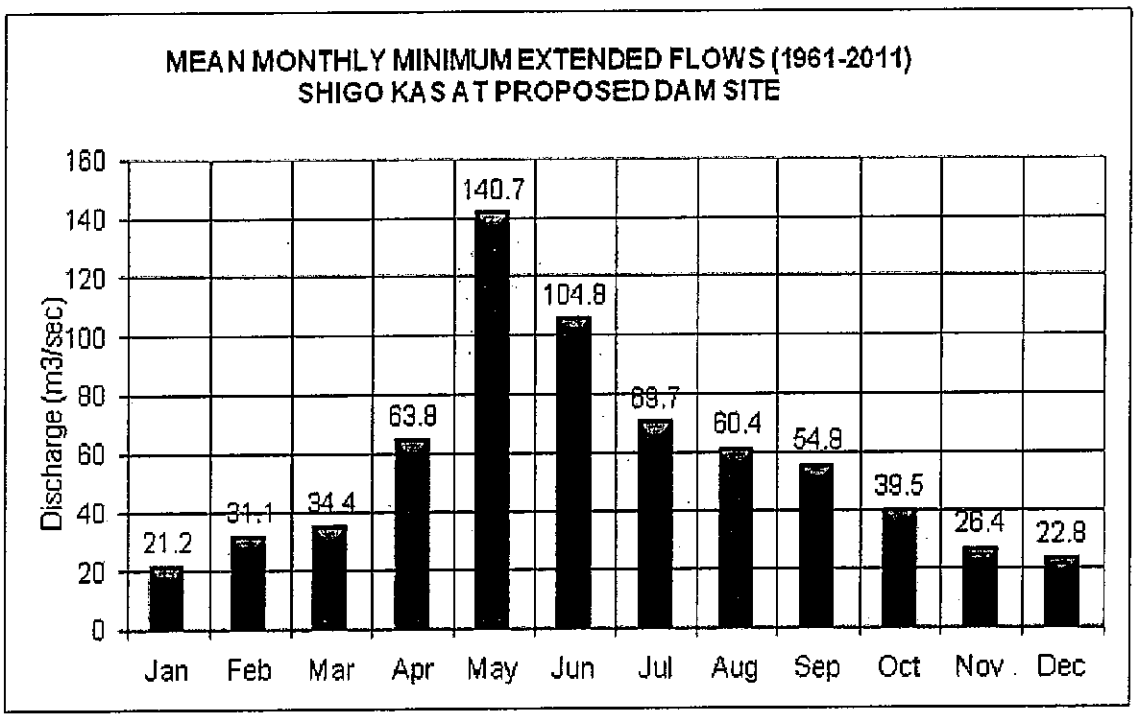


Figure 4.43: Mean Monthly Minimum Extended Flows



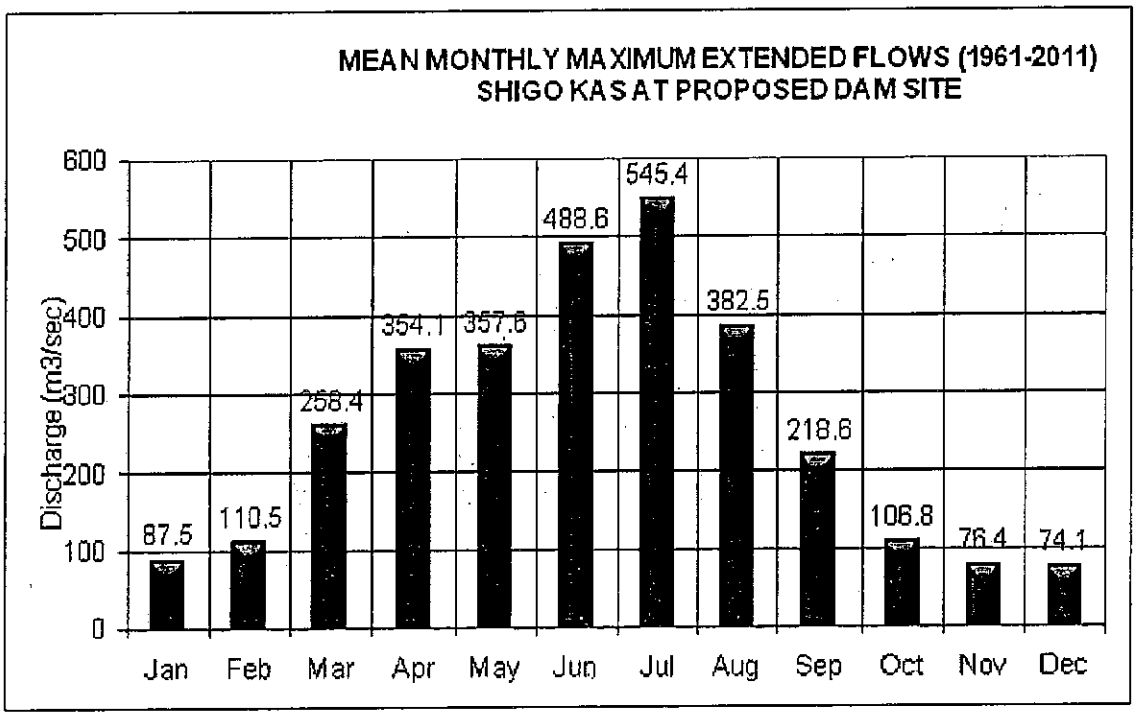


Figure 4.44: Mean Monthly Maximum Flows

4.6 ESTIMATION OF PEAK FLOODS

4.6.1 General

Estimation of peak discharge is important for making the hydropower structures safe from gated weir age due to flooding at proposed site. These floods are computed by analyzing the available peak flows in the catchment. If the recorded data is limited, the flood series may be extended at proposed HPP with the help of recorded long term flood data of main river. Maximum flood discharge at Shigo-kas HPP is available for limited period 1986-87 and 2005-06. However a long-term flood data in Chital River at Chitral and Swat River at Kalam has been available since 1961. In addition long term rainfall data is also used to find peak discharge at proposed site.

With the already published literature, a regional analysis of floods has been conducted to develop empirical relationships between morphological parameters of the catchments and the maximum floods. The regional analysis of floods was used to confirm the results of the flood analysis.

4.6.2 Relevant Floods

Limited recorded flood data on Panjkora was available as mentioned in **Sec 4.4**. During this period maximum instantaneous discharge in Shigo kas was not recorded. However maximum daily flows were observed and is given in **Table 4.8**.

Table 4.8: Recorded Peak Flood on Panjkora River at Gauging Sites

STATION NAME	RIVER NAME	YEARS	DATE	INSTANTANEOUS FLOODS (m3/sec)	DATE	Maximum Daily Flow (m3/sec)	DATE	Minimum Flow (m3/sec)
Zulam Bridge	Panjkora	2001-04 & 2009-11		Incomplete Year		4447		
Koto	Panjkora	1995-2011	29 -Jul	-	29 -Jul	4217		17.11
Bibior	Panjkora	1995-1999						

Flood data on the other hand has been recorded in Panjkora River at Zulam bridge since 1999. Relevant floods with maximum peak values recorded in Panjkora River at Zulam bridge are given below:

Table 4.9
Max Instantaneous Discharge
Panjkora River at Zulam bridge

Years	Date	Discharge (m^3/sec)
1999	12-May	308.50
2000	30-Mar	411.88
2001	23-Jul	1141.54
2002	12-Aug	356.60
2003	16-Apr	652.66
2004	10-Oct	1173.11
2005	18-Mar	2088.83
2006	5-Aug	1562.00
2010	July	4447

The limited data shows that July 2010 is the year with maximum flood in the basin during recorded period. The data also shows that peak flood usually occurs in the month of March, July and August.

4.6.3 Estimation of Floods by Frequency Analysis

The available information of Panjkora River at Shigo-kas HPP is not available, whereas, floods have been recorded in the main river at Panjkora River and adjacent river Swat at Kalam. Extrapolation of the observed floods record from a catchment is not so accurate because the floods in smaller catchments usually show larger specific discharges than the ones of the larger catchments. Therefore relationships have been developed to determine the specific maximum discharge at Shigo-kas HPP for accurate estimation of peak discharge.

4.6.4 Estimation of Relationship Between Specific Maximum Floods In Different Watersheds In The Basin

Maximum Instantaneous recorded floods of Panjkora at Zulam, Chitral at Chitral, and Swat at Kalam have been collected to derive relationships for estimating peak discharge series at Shigo-kas HPP. These are plotted with their catchment area as shown in **Figure 4.45**. The Figure shows correlation between the maximum floods between maximum index flood and catchment areas with R^2 value of 0.967. These results indicated that the maximum index floods in the watersheds comprising Panjkora, Chitral and Swat have correlation with their area and estimation at ungauged location may be made with the help of relationship between the Index maximum flood and the watershed areas. An indication is found that the floods in smaller catchments showed bigger specific discharges than the ones of the larger catchments. Exponent 'n' for the Maximum Index discharge at Shigo-kas HPP with respect to that of developed relationship and using Kalam peak floods, was estimated due to the difference in watershed size. This relationship has been then used to generate maximum instantaneous discharges in Shigo-kas at Shigo-kas HPP where recorded data is not available.

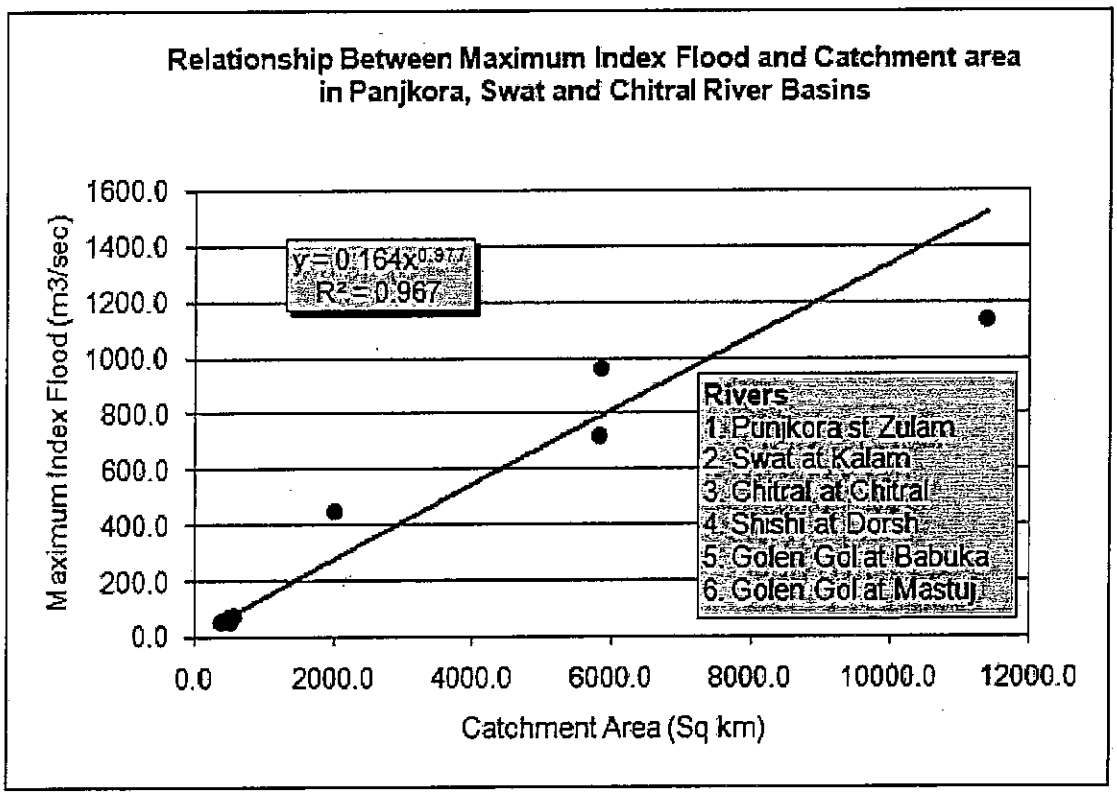


Figure 4.45: Relationship b/w Max. Index Flood and Catchment Area at Different River Basins

Relationship applied for converting the data of Kalam gauging station to the project gated weir site shall be as under

$Q1 = Q2 (A1/A2)^n$

Where:

Q1 = Estimated peak discharge required at the gated weir site on Shigo-kas (m^3/s)

Q2 = Recorded peak discharge at the Kalam gauging station on Swat River (m^3/s)

A1 = Catchment area of Zulam upstream of the proposed gated weir site (km^2)

A2 = Catchment area of Kalam River upstream of Kalam stream gauging station (km^2)

Universally, n values ranging from 0.3 to 0.8 have been applied. Generally the following values for n are recommended for similar situations:

n = 0.75 (Mostly used in Northern and Central India and Pakistan)
n= 0.70 (USBR recommendation)
n= 0.50 (Others)

The value of n should be calibrated for the area under study. This was done by using above Figure and the relationship is

$y = 0.164 (x)^{0.977}$
$R^2 = 0.967$

Using the relationship the index maximum discharge for the Swat at Kalam gauging station and gated weirsite was calculated and the transposition factor was determined. The value of n is then calculated by rewriting previous equation:

$n = \log(Q1/Q2) / \log(A1/A2)$

The estimated transposition factor by above relationships comes to 0.52. Comparing with the given range of n values (see above) this factor is within the specified limit. So transposition factor of 0.52 is used for the estimation of peak discharge. Based on the transposition factor of 0.52, instantaneous peak discharges at proposed gated weir site were transposed and flood frequency analysis has been carried out for different probability distributions.

4.6.5 Estimation of Design Flood Using Flood Frequency Analysis

With the help of derived relationship, series of maximum instantaneous discharges in Panjkora River at Shigo-Kas HPP is estimated and given in **Figure 4.46**. The figure shows maximum of maximum instantaneous flood of 5291 m^3/s in 2010 which was the highest flood year in the area. The missing bar shows data not available for that year. The observed flood frequency is computed and plotted in **Figure 4.47** to evaluate the pattern of maximum floods

with different return periods. The data was checked for outliers and its consistency. The flood value of 2010 was indicated as an outlier by the model, **Figure 4.48**. But the value of 2010 was retained in the analysis as it was actually occurred in 2010. Data was found consistent.

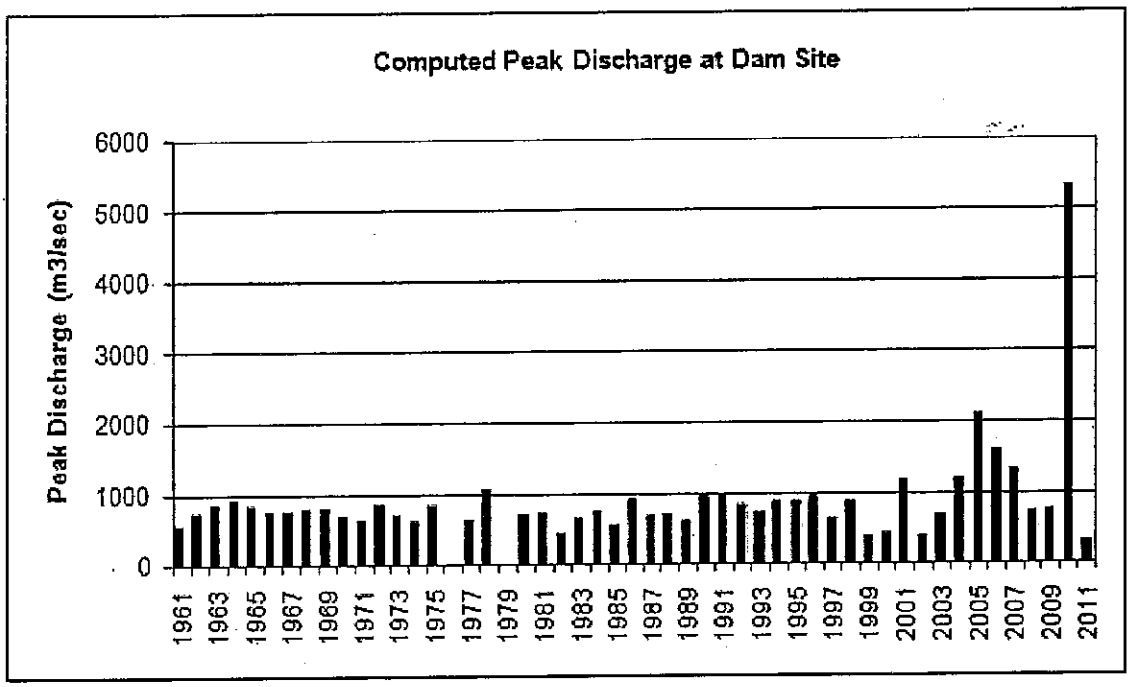


FIGURE 4.46: Computed Peak Discharge at Dam Site

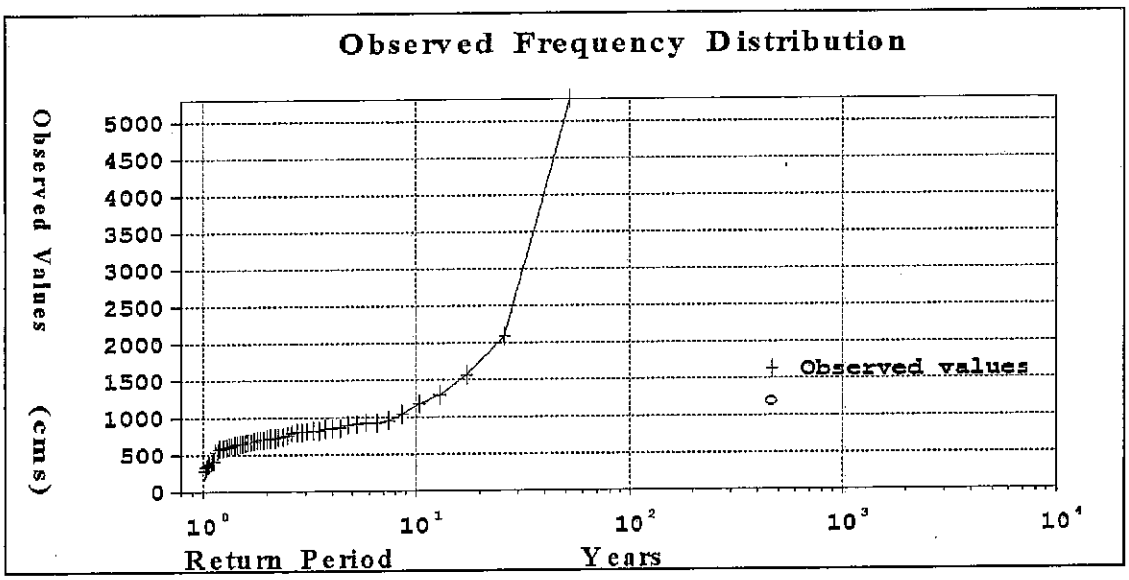


FIGURE 4.47: Observed Frequency Distribution

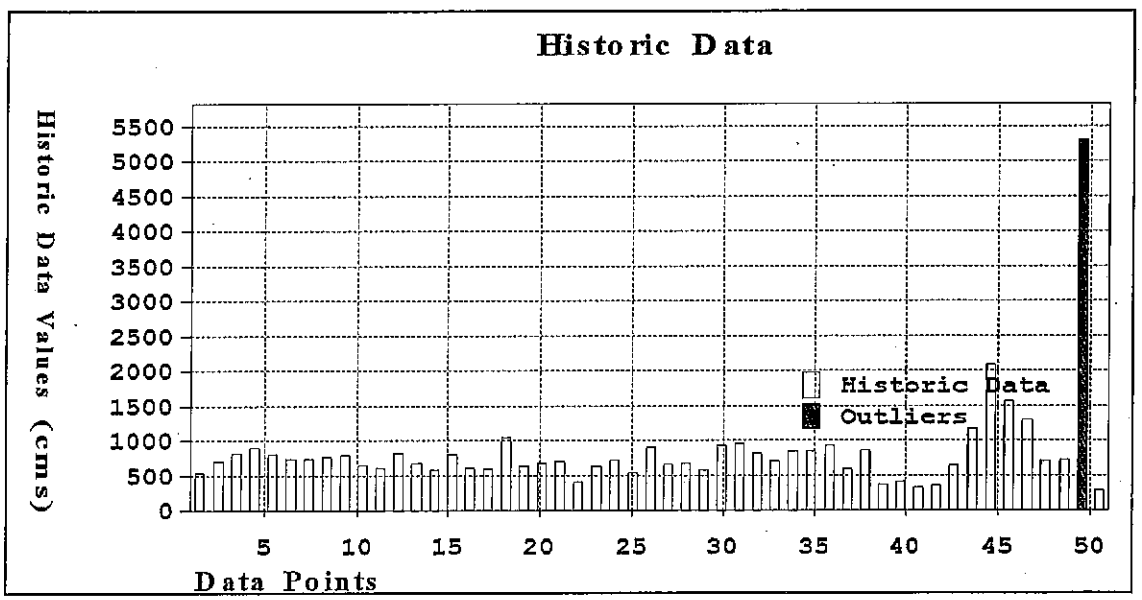


FIGURE 4.48: Historic Data

Alternatively the extended flow series computed in previous sections was used to derive flood series at proposed site. The daily annual maximum flow was extracted from the data. To convert the maximum flood to instantaneous flood, relationship has been developed with the help of recorded data of adjacent river, Swat at Kalam. The relationship so developed is given in **Figure 4.49**. The extended flood series is compared with the previous one to verify the results. The comparison in **Figure 4.50** shows that the results of extended series by two methods are quite comparable. The flood series computed by Swat and Panjkora instantaneous floods were selected for further analysis being slightly higher than other series.

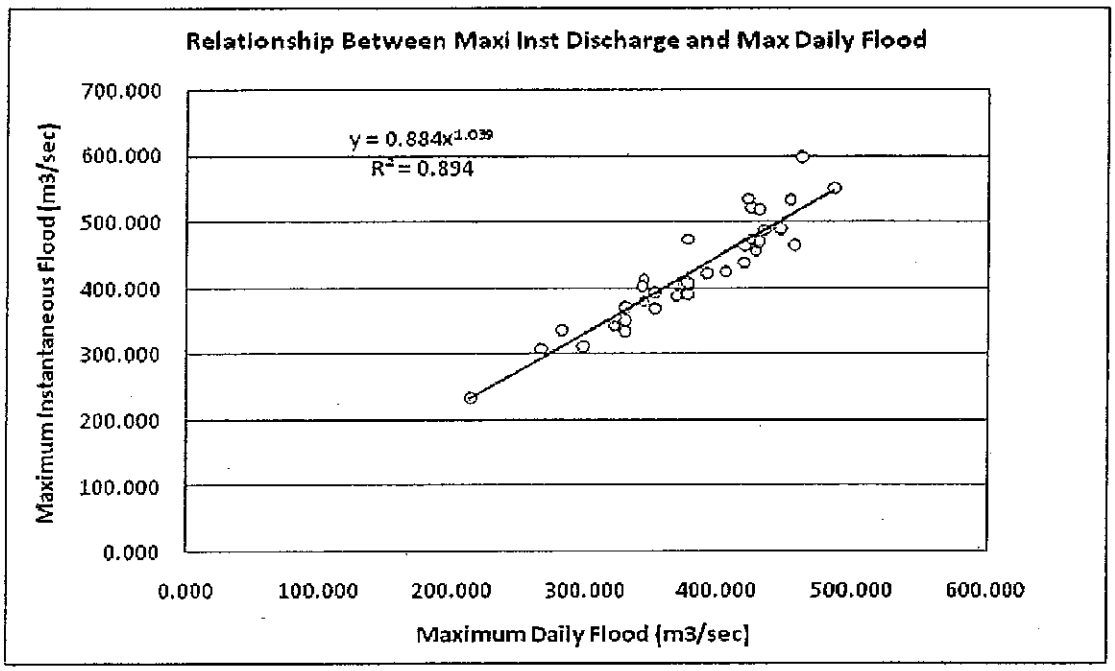
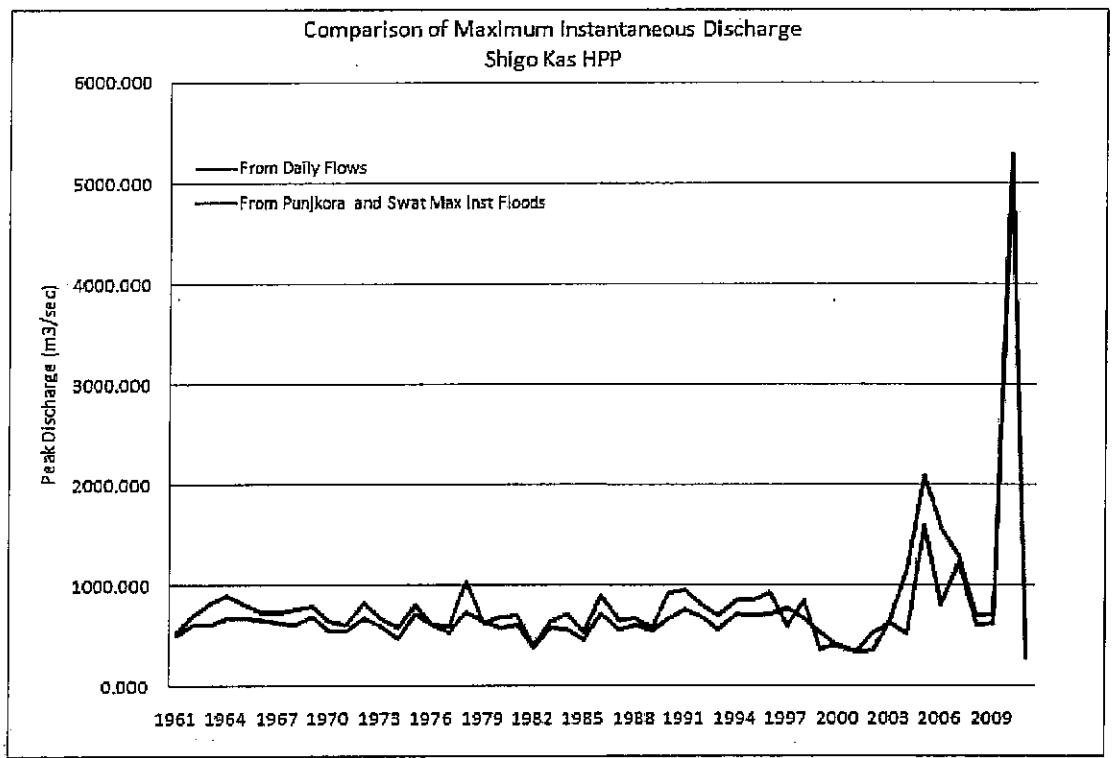


Figure 4.49: Relationship B/W Max. Instantaneous Discharge & Max. Daily



Flood

Figure 4.50: Comparison of Max. Instantaneous Discharge

Flood frequency analysis was then carried out on the flood series at Shigo-kas HPP site. To evaluate the best-fit frequency model for the observed flood series various distributions have been selected and their results and standard errors have been compared using computer software "Design Flood for Windows (DFW), Ver. 2011)[9]. Summary results for Shigo-kas HPP are given in **Table 4.10**. Chi Square values of the frequency distributions are given in **Table 4.10** indicating lowest for Log Pearson and Gumbel Distributions. This test indicated that Log Pearson as well as Gumbel is best fit. Comparison of flood frequency analysis curves is shown in **Figure 4.51**. Some selected flood frequency curves of these distributions are shown in **Figure 4.52 to 4.54.**

Table 4.10: Summary Results of Flood Frequency Analysis

Shigo-kas HPP

	Method of Moments				Method of Max Liklihood				
Return Period (Years)	Gumbel Type I	Pearson Type-III	Log Pearson Type-III	Log-Normal	Gumbel Type I	Pearson Type-III	Log Pearson Type-III	Log-Normal	Mean
	(m3/sec)				(m3/sec)				(m3/sec)
2	728	620	654	648	755	736	700	713	694
5	1349	728	1126	1194	1064	1146	1032	1068	1088
10	1759	1052	1539	1643	1268	1433	1292	1339	1416
25	2278	1791	2196	2310	1526	1801	1668	1717	1911
30	2380	1977	2345	2453	1577	1874	1748	1796	2019
50	2664	2558	2798	2878	1718	2076	1986	2024	2337
100	3046	3483	3508	3507	1908	2349	2337	2351	2811
200	3427	4553	4347	4203	2098	2622	2727	2702	3335
500	3929	6171	5690	5233	2347	2984	3313	3202	4109
1000	4309	7537	6916	6103	2536	3259	3815	3611	4761
5000	5214	11140	10645	8458	2975	3901	5214	4671	6527
10000	5569	12864	12723	9630	3163	4180	5934	5178	7405
Chi Square Test	79.0	-	35.5	44.5	18.2	25.7	17.0	22.5	

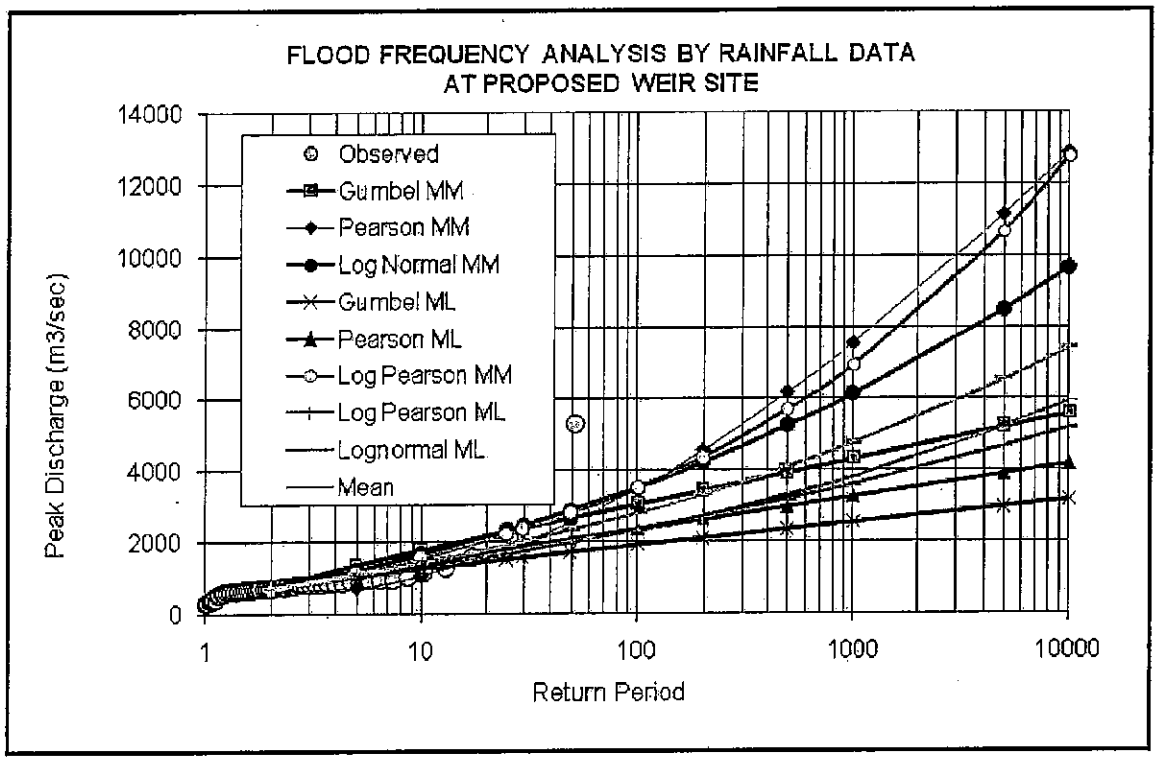


Figure 4.51: Comparison of Flood Frequency Analysis Curves

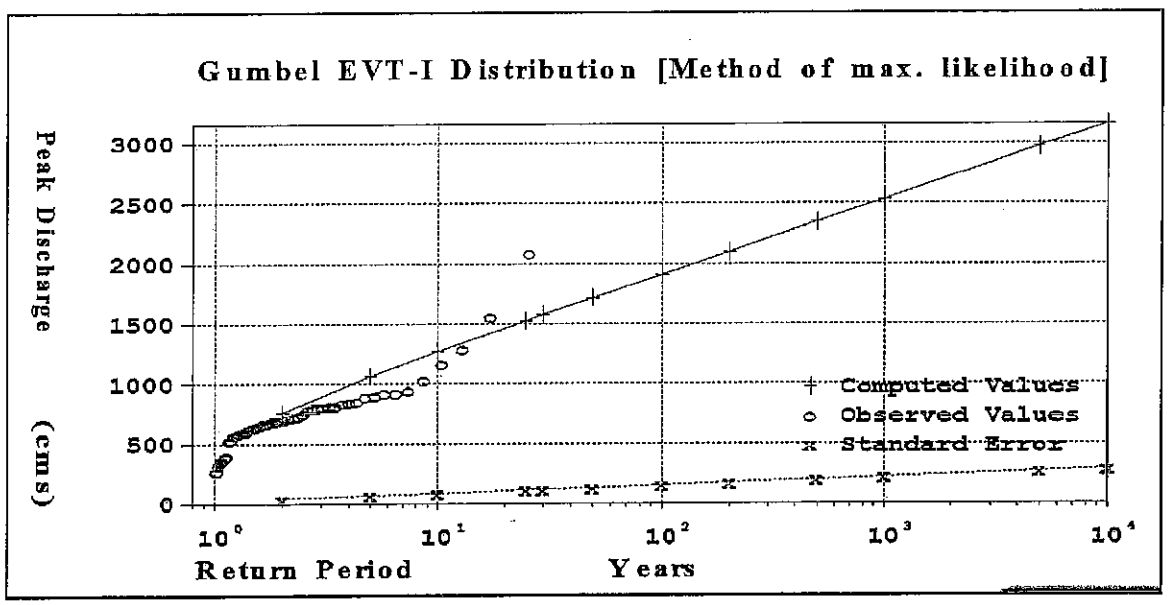


Figure 4.52: Flood Frequency Curves

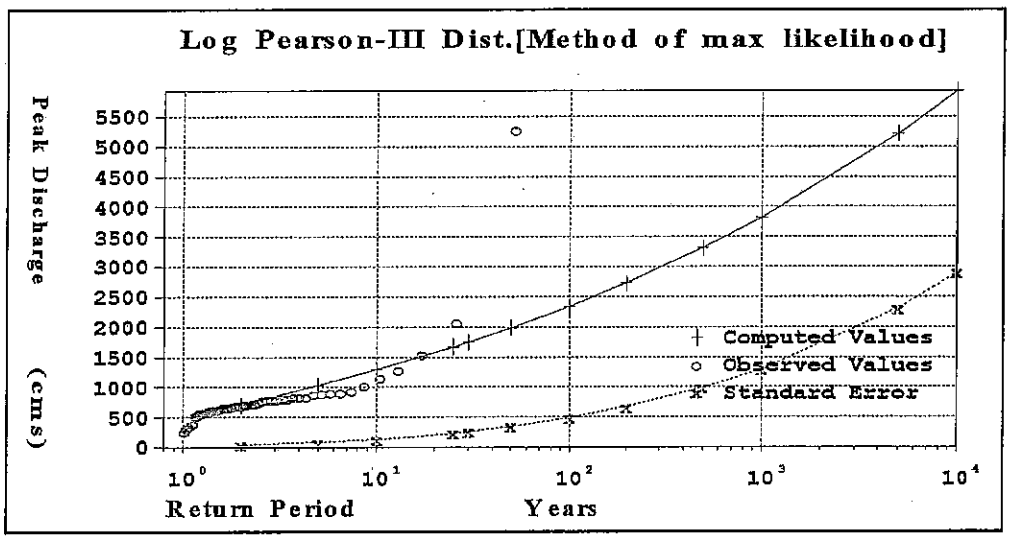


Figure 4.53: Flood Frequency Curves

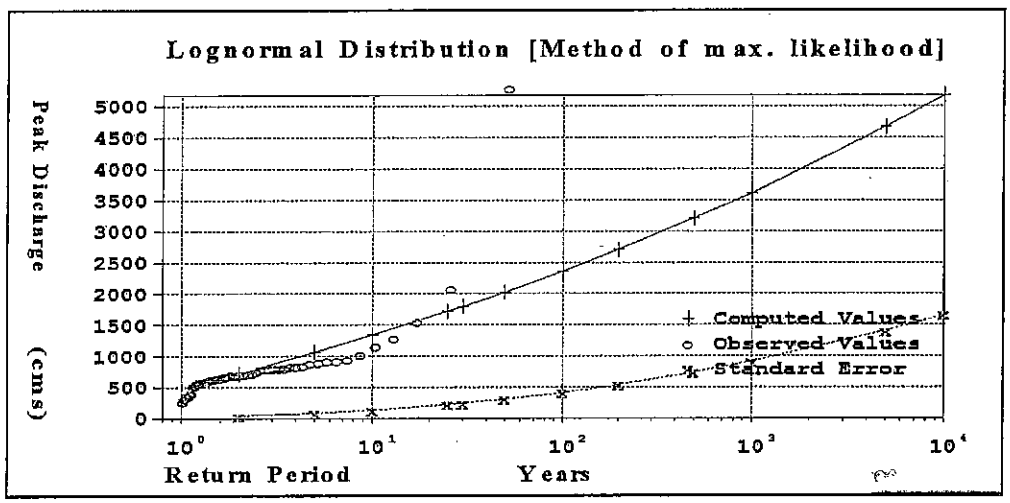


Figure 4.54: Flood Frequency Curves

4.6.6 Estimation of Floods by Maximum Rainfall Method

4.6.6.1 Rainfall Records

Maximum rainfall records are available at Dir, Kalam, Chital, Drosh and Saidu Sharif stations. The data is available since the station was established. The data include maximum annual rainfall in day from 1962-2010. Records of Dir, Kalam and Saidu Sharif have been plotted in **Figure 4.55** and it is used in this study. The maximum rainfall at Dir is higher as compared to other stations.

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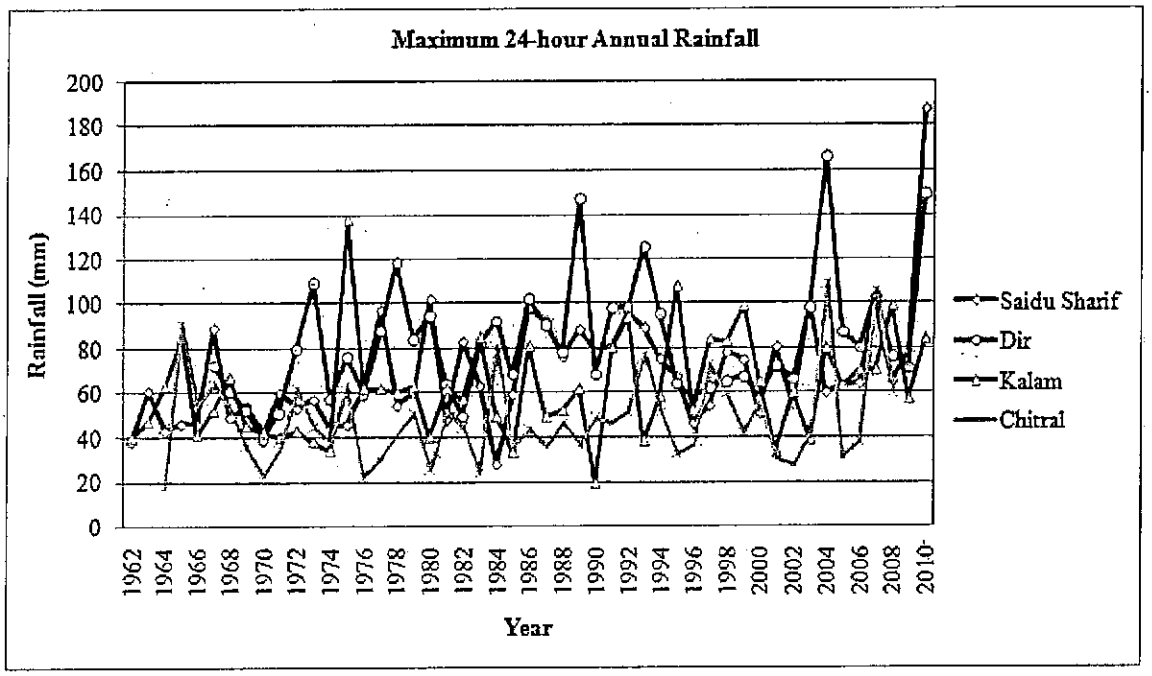

Figure 4.55: Maximum 24-Hour Annual Rainfall

4.6.6.2 Extreme Rainfall in 2010

2010 was the worst year of flooding in Pakistan. About 75% area of Pakistan was under flooding. Moonsoon started on 15th of July 2010. The series of rainfall started on 27th of July 2010, and continued for more than 40 hours without any break. More than 312 millimeter rain was recorded in 40 hours. The overflowing rivers, streams and massive floods caused by heavy monsoon rains and thunder storms had claimed thousands of human lives, displacement of population and destruction to the basic infrastructure of roads, bridges, electricity, water supply schools and hospitals.

4.6.6.3 Rainfall Frequency Studies

Frequency analysis of maximum one-day rainfall data has been carried out. Computer program Design Flood [9] along with excel has been used. This program is capable of using four commonly used flood frequency distributions to cover all possible aspects employed during a frequency analysis. These distributions include:

a) Gumbel Extreme Value Type-I

b) Pearson Type-III

c) Log Pearson Type-III

d) Lognormal

The parameters of the distributions can be estimated by 'Method of Moments' or more precisely by 'Method of Maximum Likelihood'. Design Flood offers both options. The

Goodness of fit of these frequency models to the observed data depends upon the standard error, 95% confidence limits and Chi test.

Frequency analysis of maximum one-day rainfall data has been carried out for Dir and Kalam using different distributions. However, Gumbel Extreme Value Type-I along with Weibull plotting position formula have been adopted for this study according to their suitability to the observed data. The individual frequency curves have been fitted by least square method and maximum one-day rainfall for 2, 5, 10, 30, 50, 100, 200, 500, 1000 and 10000-year frequencies have been estimated. **Table 4.11, 4.12 and 4.13** give results of frequency analysis at three stations. Rainfall frequency analysis curves for Dir, Saidu Sharif and Kalam is presented in **Figure 4.56, 4.57 and 4.58** respectively.

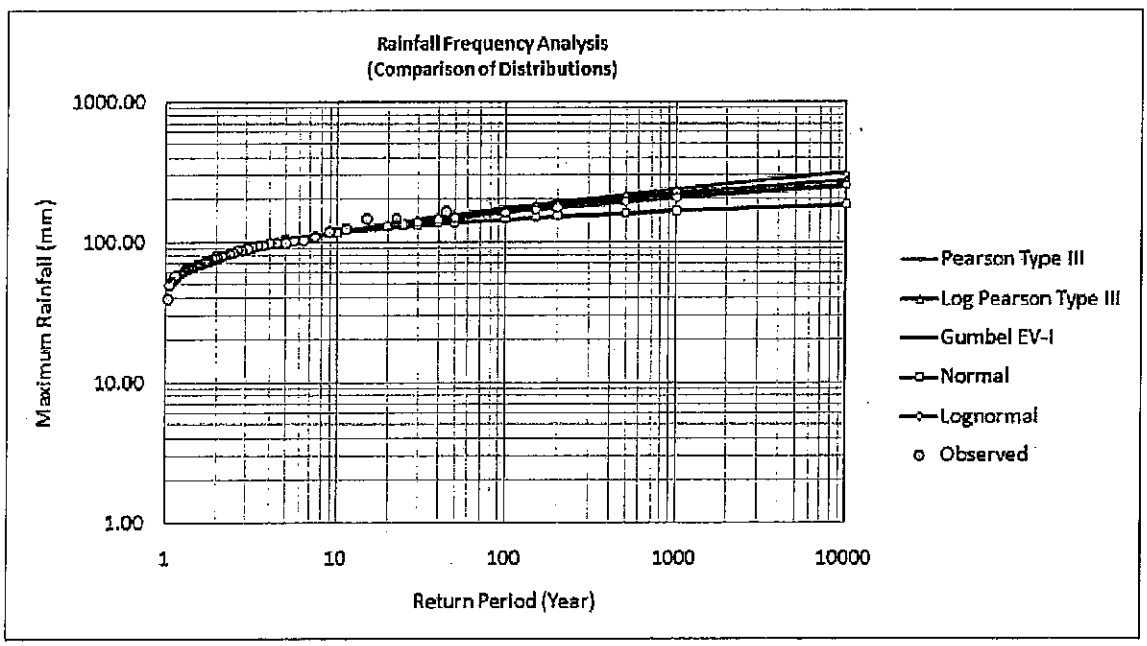

Figure 4.56: Station: Dir

Table 4.11: Results of Frequency Analysis

Return	Max Rainfall					
Period	Gumbel EV I	Normal	Lognormal	Pearson III	Log Pearson III	Mean
(year)	mm					
2	78.38	82.65	78.77	74.53	77.45	78.35
5	101.34	105.62	102.16	99.69	101.51	102.06
10	116.54	117.65	117.04	116.93	118.12	117.26
20	131.12	127.57	130.96	133.52	134.56	131.54
25	135.74	130.46	135.31	138.78	139.89	136.04
30	139.51	132.73	138.84	143.05	144.27	139.68
40	145.42	136.18	144.35	149.76	151.25	145.39
50	149.99	138.74	148.60	154.93	156.72	149.80
100	164.13	146.18	161.66	170.92	174.08	163.39
150	172.38	150.23	169.24	180.22	184.55	171.33
200	178.22	152.99	174.61	186.81	192.13	176.95
500	196.81	161.24	191.70	207.76	217.23	194.95
1000	210.86	167.03	204.68	223.60	237.26	208.69
10000	257.51	184.20	248.57	276.43	311.45	255.63
Skew	1.424	1.424	0.329	1.424	0.329	

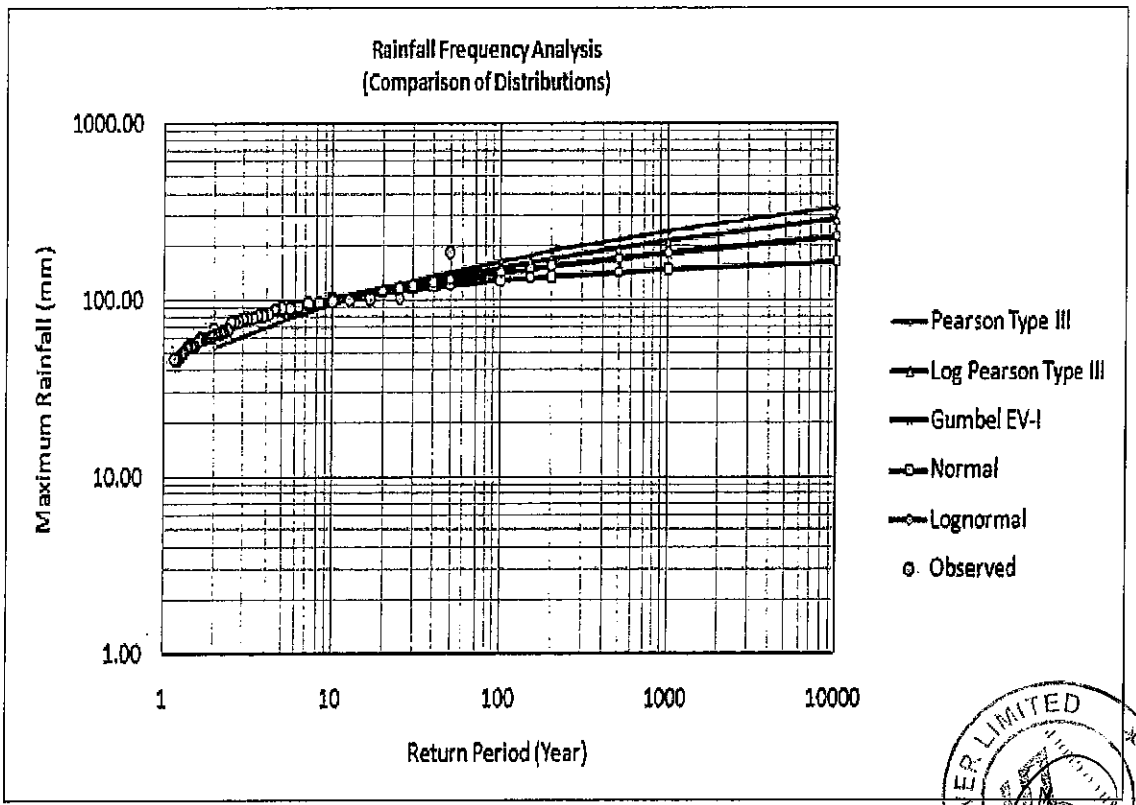

Figure 4.57: Station: Saidu Sharif

Table 4.12: Results of Frequency Analysis

Return	Max Rainfall					
Period	Gumbel EV I	Normal	Lognormal	Pearson III	Log Pearson III	Mean
(year)	mm					
2	65.11	68.92	65.10	53.98	63.99	63.42
5	85.63	90.51	86.25	76.21	85.71	84.86
10	99.21	101.81	99.93	94.99	100.87	99.36
20	112.24	111.14	112.85	114.97	116.01	113.44
25	116.38	113.86	116.91	121.63	120.95	117.94
30	119.74	115.99	120.21	127.14	125.01	121.62
40	125.03	119.23	125.39	135.97	131.49	127.42
50	129.11	121.64	129.38	142.92	136.59	131.93
100	141.75	128.63	141.73	165.08	152.82	146.00
150	149.12	132.44	148.94	178.41	162.65	154.31
200	154.35	135.03	154.06	188.02	169.79	160.25
500	170.96	142.79	170.44	219.47	193.52	179.44
1000	183.52	148.23	182.96	244.04	212.57	194.27
10000	225.21	164.36	225.76	330.06	283.81	245.84
Skew	2.578	2.578	0.309	2.578	0.309	

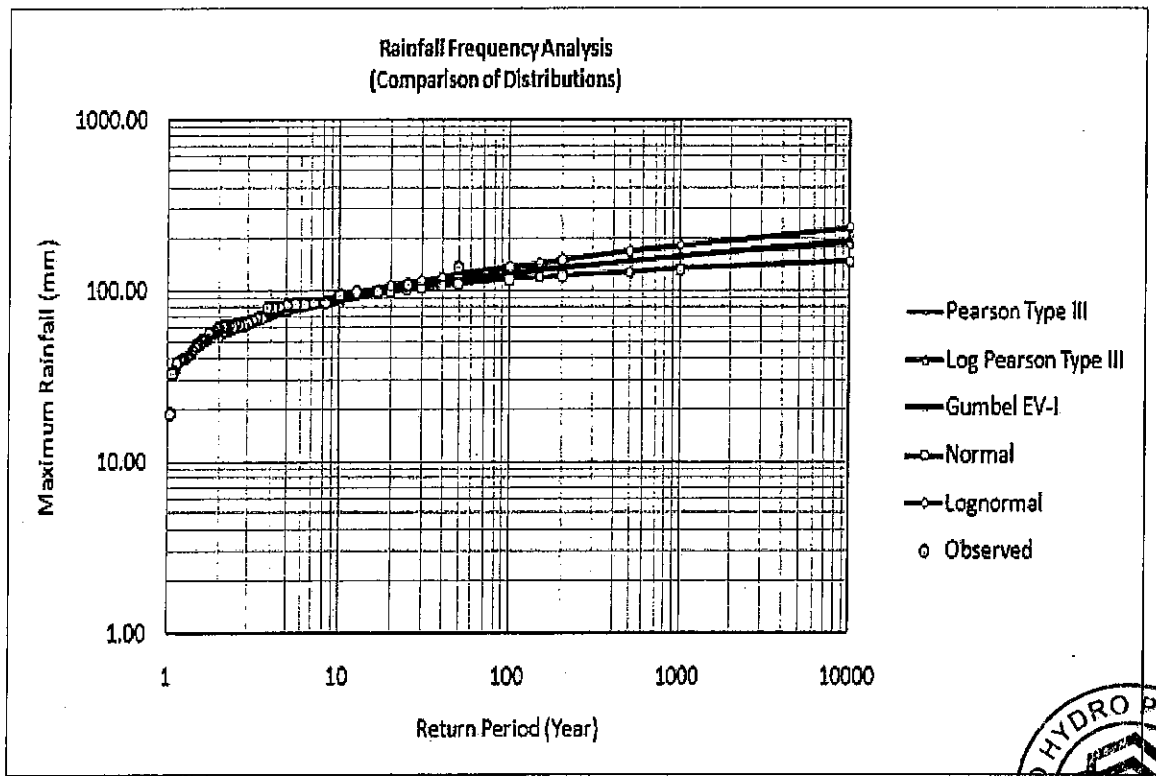

Figure 4.58: Station: Kalam
Table 4.13: Results of Frequency Analysis

Return Period (year)	Max Rainfall mm					
	Gumbel EV I	Normal	Lognormal	Pearson III	Log Pearson III	Mean
2	58.46	61.76	57.78	51.60	58.75	57.67
5	76.17	81.02	79.15	73.09	79.44	77.77
10	87.89	91.11	93.31	87.94	92.19	90.49
20	99.14	99.43	106.89	102.29	103.78	102.30
25	102.71	101.85	111.21	106.84	107.33	105.99
30	105.61	103.76	114.72	110.55	110.19	108.97
40	110.17	106.65	120.26	116.37	114.61	113.61
50	113.70	108.79	124.55	120.87	117.98	117.18
100	124.60	115.04	137.92	134.78	128.16	128.10
150	130.96	118.43	145.78	142.89	133.94	134.40
200	135.47	120.75	151.40	148.64	137.97	138.84
500	149.81	127.67	169.51	166.93	150.50	152.89
1000	160.65	132.52	183.50	180.79	159.72	163.43
10000	196.62	146.92	232.12	227.11	189.06	198.37
Skew	-1.470	-1.470	-0.266	-1.470	-0.266	

4.6.6.4 Peak Flood Estimation

4.6.6.5 Unit Hydrograph Approach

Flood hydrograph/peaks for the Shigo-kas catchment have been estimated using rainfall values of various frequencies and applying the unit hydrograph technique. Computer program HEC-HMS is used for this study that utilizes the U.S. Soil Conservation Service (SCS) unit hydrograph method for free drainage areas where volume of runoff, for example in English units, may be estimated as:

$$P = \frac{[P - 0.2S]^2}{P + 0.8S}$$

where

$$S = \frac{1000}{CN} - 10$$

Q = Rainfall Excess in inches

CN = Estimated Curve No.

P = Precipitation in inches

Peak Discharge in cfs is given by

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$$Q_p = \frac{484AQ}{T_p}$$

Where,

T_p = Time to peak in hours

A = Catchment area in sq. miles

The flood hydrographs for various return periods have been computed. 10000-year flood hydrograph using rainfall method has been given in **Figure 4.59**.

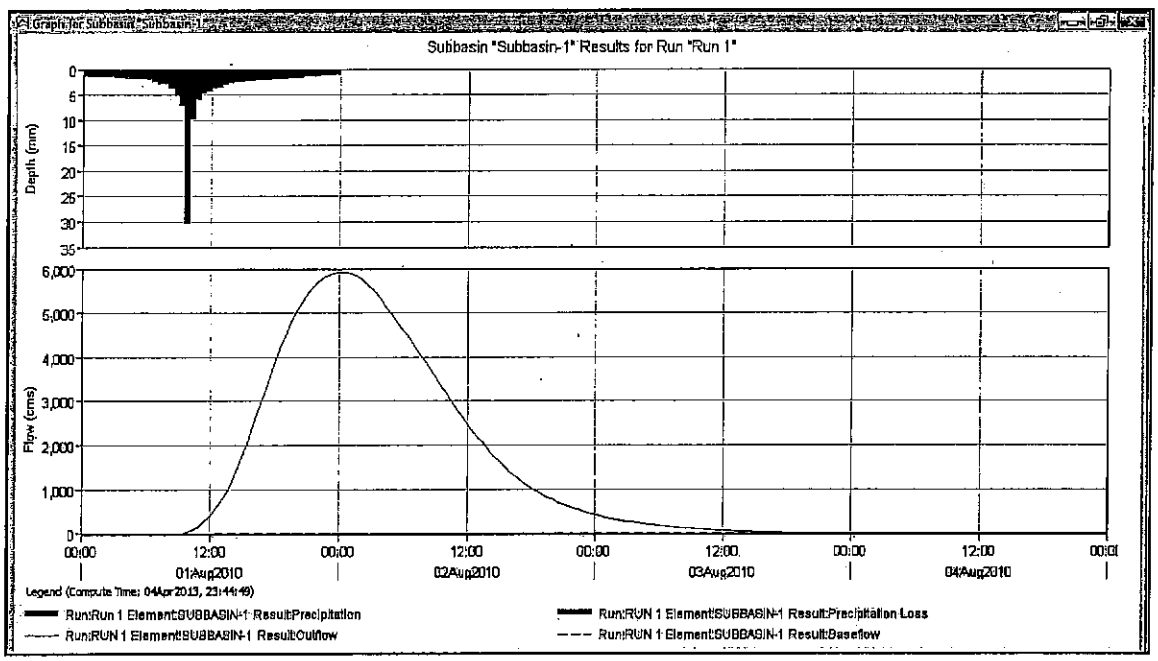

Figure 4.59: 10000-Year Flood Hydrograph Using Rainfall Method

4.6.7 Estimation of Floods by Regional Method

Based on the previous investigations in Northern areas, a regional method has been derived by GTZ for the estimation of floods. Empirical relationships with morphometric parameters of the watershed have been established for determining the maximum flood. The morphometric parameters comprise catchment area and mean elevation. To establish the empirical relationships, the maximum floods for various periods of return were estimated from the available series of maximum floods at the gauging stations in hilly areas located in the Northern Areas of Pakistan.

The method for estimation of flood was developed as follows:

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1. Flood frequency analysis was performed for all available stations in the area.
2. Specific discharge of estimated 5, 10, 100, 1,000 and 10,000-year floods were calculated.
3. An enveloping curve was drawn to each set of specific discharges (5, 10, 100, 1,000 and 10,000-year floods), and a mathematical function was fitted to the curve.
4. Estimation of floods for Panjkora River at Shigo-kas HPP at the Intake was undertaken.

Stations for which flood frequency analysis was performed are presented on **Table 4.14**, along with the estimated 5, 10, 100, 1,000 and 10,000-year floods. The specific discharge of the 5, 10, 100, 1000 and 10,000-year floods have been plotted on **Figure 4.60**.

The mathematical function fitted to the enveloping curve is of the form:

$$Q_{max} = C \times A^n \qquad [1]$$

Where,

Q_{max} = maximum instantaneous discharge for the return period in m^3/s.

C, n = coefficients.

A = catchment area in km^2.

The mathematical function fitted to the enveloping curves are presented below:

$$Q_5 = 11.97 \times A^{0.59} \qquad [2]$$

$$Q_{10} = 15.60 \times A^{0.57} \qquad [3]$$

$$Q_{100} = 40.45 \times A^{0.50} \qquad [4]$$

$$Q_{1000} = 64.05 \times A^{0.47} \qquad [5]$$

$$Q_{10000} = 84.85 \times A^{0.46} \qquad [6]$$

Where, Q_5, Q_{10} , Q_{100}, Q_{1000} , Q_{10000}= Maximum instantaneous discharges for return periods of 5, 10, 100, 1,000, and 10,000 years in m^3/s.

A = Catchment area in km^2.

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TABLE 4.14
Estimated 5, 10, 100, 1,000 & 10,000 Year Floods (Gumbel)

Station Name	Area (km^2)	Q_5 (m^3/s)	Q_{10} (m^3/s)	Q_{100} (m^3/s)	$Q_{1,000}$ (m^3/s)	$Q_{10,000}$ (m^3/s)
Shyok at Yugo (78-83)	65025	2622	2851	3570	4275	4979
Indus at Kachura (73-83)	146100	5869	6437	8215	9961	11704
Hunza at Dainyor Br (74-83)	13925	2520	2817	3749	4663	5576
Gilgit at Gilgit (80-85)	12800	1354	1476	1857	2232	2606
Gilgit at Alam Br (73-83)	27525	3305	3561	4360	5145	5929
Indus at Partab Br (73-83)	176775	9179	9942	12331	14677	17018
Astore at Doyian (74-87)	3750	839	967	1368	1762	2155
Gorband at Karora (75-84)	625	515	627	978	1322	1666
Indus at Besham Q (73-83)	196425	11990	12947	15942	18883	21819
Brandu at Daggar (70-86)	598	356	444	718	988	1257
Siran at Phulra (73-83)	1057	696	811	1170	1522	1873
Chitral at Chitral (73-84)	12425	1286	1430	1878	2319	2759
Swat at Kalam (73-85)	2024	481	547	754	957	1160
Swat at Chakdara (73-85)	5400	1171	1365	1973	2570	3166
Bara at Jhansi P (73-83)	1846	490	651	1156	1652	2148
Kabul at Nowshera (73-88)	88540	4308	5003	7179	9316	11449
Haro at Khanpur (73-83)	777	918	1191	2044	2883	3719
Jhelum at Chinari (70-90)	13735	1330	1573	2332	3078	3823
Jhelum at Domel (80-90)	14490	1462	1691	2408	3111	3813
Neelum at Muzaffar (63-90)	7275	1737	1918	2486	3043	3600
Kunhar at Naran (60-90)	1036	386	457	680	899	1117
Kunhar at Garhi H U (60-88)	2382	873	1040	1562	2075	2587

Station Name	Area (km^2)	Q_5 (m^3/s)	Q_{10} (m^3/s)	Q_{100} (m^3/s)	$Q_{1,000}$ (m^3/s)	$Q_{10,000}$ (m^3/s)
Jhelum at Kohala (65-90)	24769	3651	4188	5869	7520	9168
Jhelum at Azad P (79-90)	26289	3808	4296	5822	7320	8816
Kanshi at Palote (79-90)	1111	1340	1653	2633	3595	4556
Shishi at Drosh (61-90)	3177	6405	7920	12662	17319	21967

The coefficients of the equations presented above, are in good agreement with the values obtained by other authors in previous studies. Creager in his remarkable work on floods found, with data available in 1926, a value of 0.5 for the exponent "n" of equation (1). The values obtained for the same exponent through the regional analysis presented in this document are 0.59, 0.57, 0.50, 0.47 and 0.46 for the 5, 10, 100, 1,000, and the 10,000-year flood equations respectively (equation [2], [3], [4], [5], and [6]). Creager remarks that the value of the exponent "n" of equation [1] have ranged between 0.3 and 0.8.

The coefficients of equations [2] to [6] are also comparable with the coefficients of formulas obtained in Europe. The Illwerke-formula assigns a value of 0.83 to the exponent "n", and a value of 5.5 to the coefficient "C" for the estimation of the 100-year flood. The value of "n" in the Illwerke formula is larger than the value presented in the corresponding formula (2), while the "C" value of the Illwerke formula is smaller than the one given in formula (2). However, estimated floods from both equations are comparable for catchments with area up to 700 km^2.

The Hofbauer-formula, developed in Europe, is remarkably similar to the 100-year flood obtained in this document. The values of the coefficients "n" and "C" as given by Hofbauer are 0.5 and 42 respectively, the exponent "n" being the same as presented in formula [4], and the "C" coefficient very close to the value given in formula [4].

Similar relationships have been used in Pakistan in the past to estimate floods. Direct estimation of floods from the records by statistical methods has been considered to be inadequate, because the records may not include floods caused by extremely severe Monsoon events that could penetrate the upper valleys including the Swat valley. This extreme events have been considered here by including stations in areas where maximum floods are produced by Monsoon rains. Stations in areas moderately affected by the Monsoon and included in this analysis are: Swat river at Chakdara, Gorband river at Kandia, Siran river at Phulra, Brandu river at Daggar and Bara river at Jhansi Post.

However, floods for areas affected by extreme Monsoon rains cannot be calculated with these formulas. Stations on rivers recording such floods include Punch river at Kotli, Kanshi river at Palote in the Jhelum catchment, and Haro river at Khanpur in the Indus catchment. The estimated 5, 10, 100, 1,000 and 10,000-floods estimated for those stations fall above the enveloping curves. Consequently, floods caused by extreme Monsoon rains are higher than the values estimated with these formulas.

The watershed of Shigo-kas falls in the areas those are affected by the Monsoon. The regional method covers both, the floods originated by rains and snow melt; it may be used for the estimation of maximum floods as a comparison with flood frequency analysis. The estimated 5, 10, 100, 1,000 and 10,000-year floods of Shigo-kas at proposed intake site are included in **Table 4.15** and shown in **Figure 4.61.**

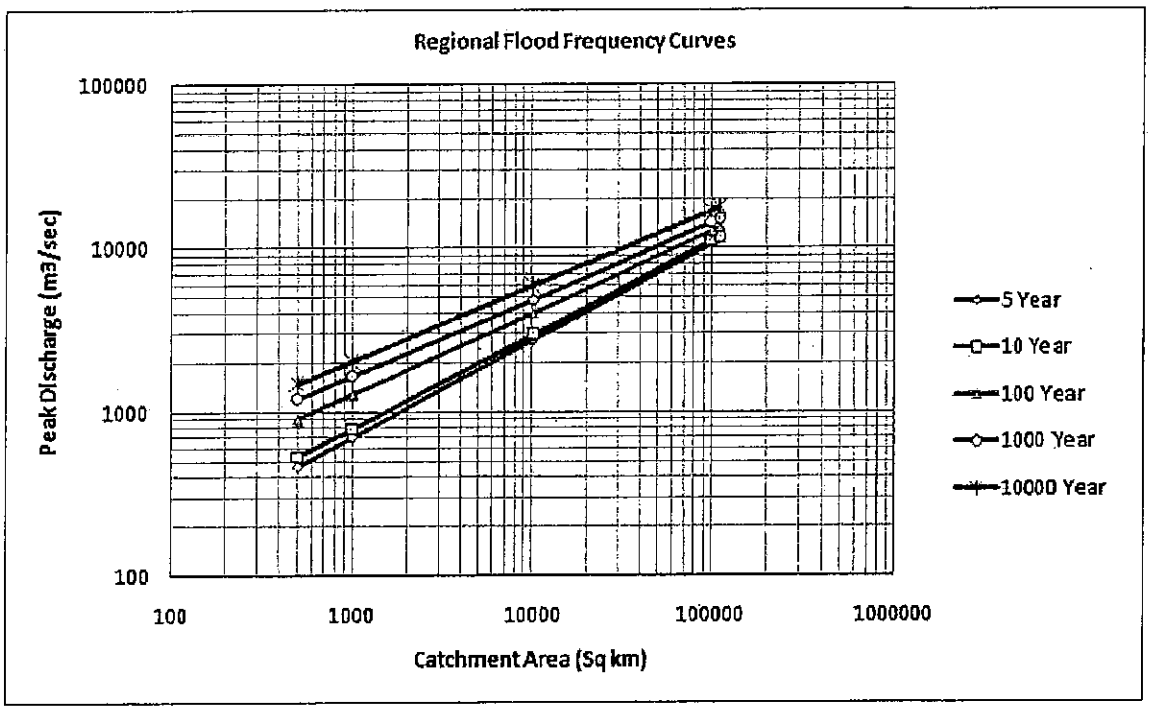

Figure 4.60: Specific Discharge of the 5, 10, 100, 1000 and 10,000-Year Floods

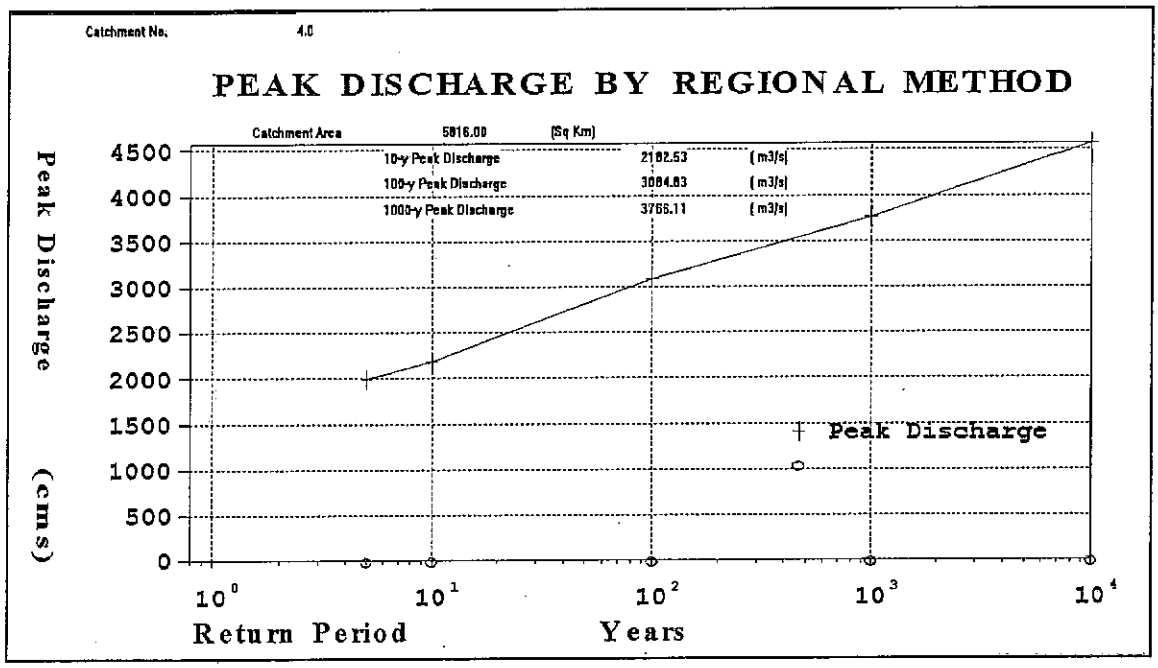

Figure 4.61: Peak Discharge By Regional Method

Table 4.15
Estimation of Floods by Regional Method
Shigo-kas HPP

Return Period Year	Maximum Flood m3/s	Maximum Flood (ft3/s)
5	1992	70346
10	2183	77087
100	3085	108956
1000	3766	133018
10000	4575	161584

4.6.8 Relationship With Peak Floods In Sub Catchments

Studies have been carried out by GTZ for estimation of floods in Chitral river basin (Refer to report "Hydropower investigations in Chitral River") and results of this analysis is given in the following **Table 4.16.** Panjkora River is adjacent to Chitral and Swat River Basins.

Table 4.16: Estimation of Floods in Chitral River Basin

Sr No.	Region	Reigon	Scheme	River	Catchment Area (Sq km)	Mean Ele (m AMSL)	Peak Discharge 10-year (m3/Sec)	100-year (m3/Sec)	1000-year (m3/Sec)
1	A	Mastuj	Yarkhun River Alternate-1	Yarkhun	1793	4409	510	1480	2710
2	A	Mastuj	Laspur Rive Muri Gram HPP	Laspur	571	4368	290	860	1500
3	A	Mastuj	Turkho River Istaru-Buni	Turkho	3373	4249	700	2030	3700
4	B	Turkho	Trichi Gol ShushGhai	Trichi Gol	785	4765	396	980	1790
5	B	Turkho	Golen Gol TurTonas	Golen Go	383	4064	235	588	978
6	B	Turkho	Mastug River Karog Parait	Mastuj	8300	4149	1100	2730	4550
7	C	Chitral	Lutkho River-Darban-Burbunu HPP	Mastuj	474	4272	261	653	1088
8	C	Chitral	Lutkho River MujiGram-Shogo HPP	Mastuj	963	4008	375	930	1550
9	C	Chitral	Lutkho River Shogo-Sin HPP	Mastuj	2348	3921	580	1450	2420
10	C	Chitral	Arkari River Uchhatur-Andakht HPP	Lutkho	995	4038	700	2030	3700
11	C	Chitral	Chitral River Kari Muskhui	Chitral	9861	4038	1200	3100	6300
12	C	Chitral	Chitral River Gahirat-Swir	Chitral	11409	3924	1400		7400
13	C	Chitral	Chitral River Torkam-Gobubar HPP	Chitral	11410	3865	1440		7700
14	C	Chitral	Shishi Gol Loo Nissar Lawi	Chitral	394	3440	238	695	1270

With the help of estimated peak discharges, relationships between peak discharge and return period with in sub-catchments have been developed and shown in the **Figures 4.62 to 4.64.**

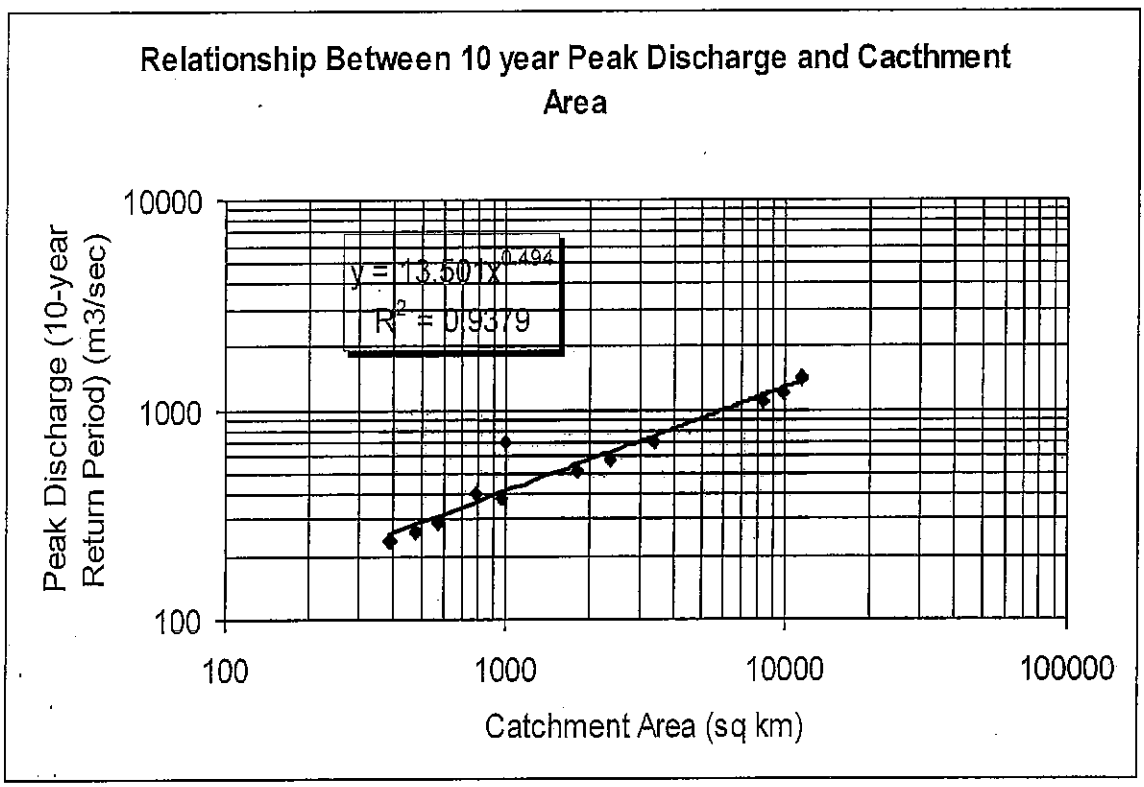

Figure 4.62: Relationships B/W 10 year Peak Discharge and Catchment Area

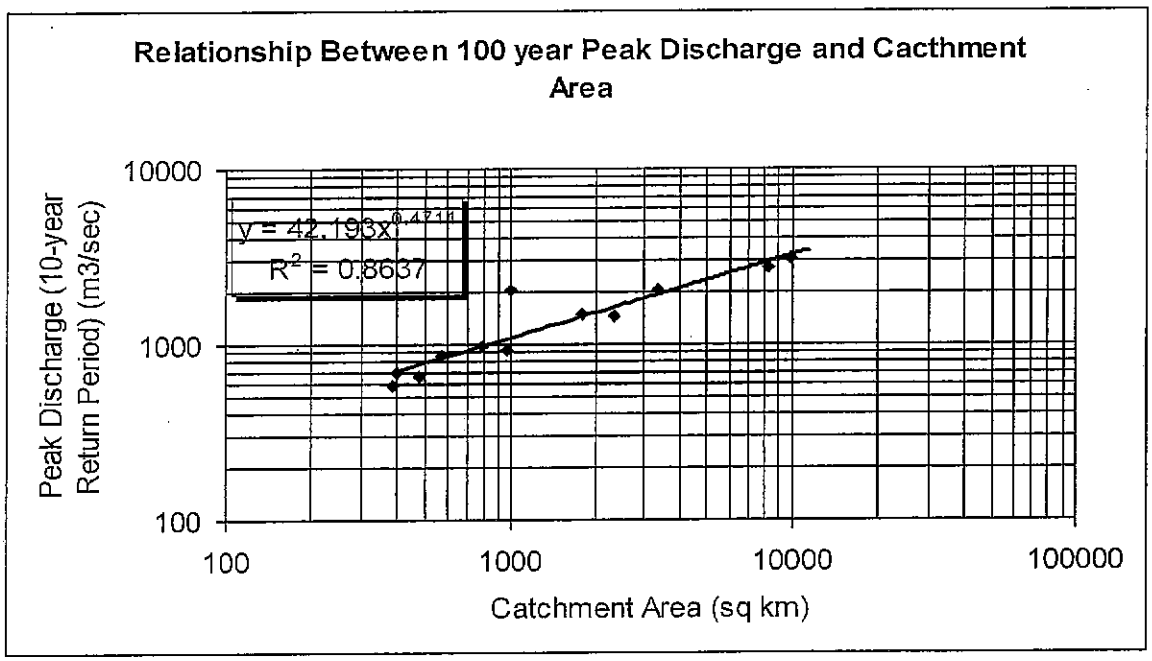

Figure 4.63: Relationships B/W 100 year Peak Discharge and Catchment Area

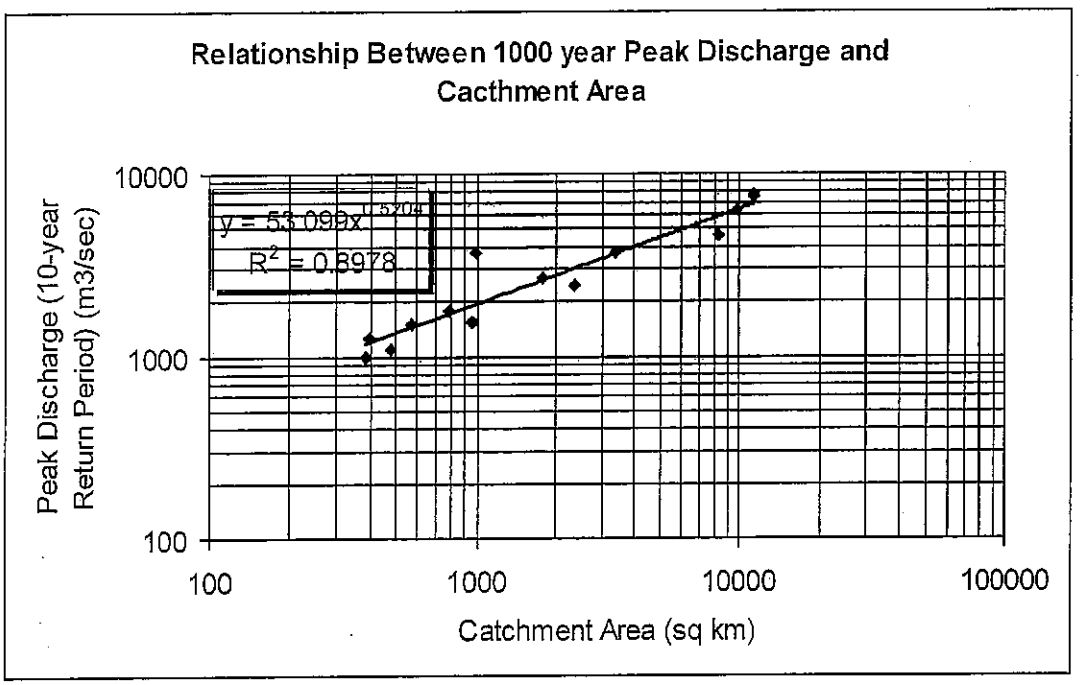

Figure 4.64: Relationships B/W 1000 year Peak Discharge and Catchment Area

Table 4.17, Present analysis gives following values of peak discharges for different return periods:

Table 4.17: Peak Discharges for Different Return Periods

River	Location	Catchment Area (Sq km)	Peak Discharge (m3/sec) 10-year	100-year	500-year	1000-year
Chitral	Chitral	11396	1363	3439	-	6858
Swat	Kalam	2020	580	1522	-	2787
ShigoKas	Weir Site	5816	977	2505	3669	4833

4.6.9 Slope Area Method

Peak discharge was also calculated with the help of slope area method. Cross sections **Figure 4.66** at proposed gated weir site **Figure 4.65,** downstream and upstream of gated weir site were recorded during present field survey and HFL was marked on each section.



Figure 4.65: X-Sec of Shigo-kas Gated Weir Site Looking Upstream

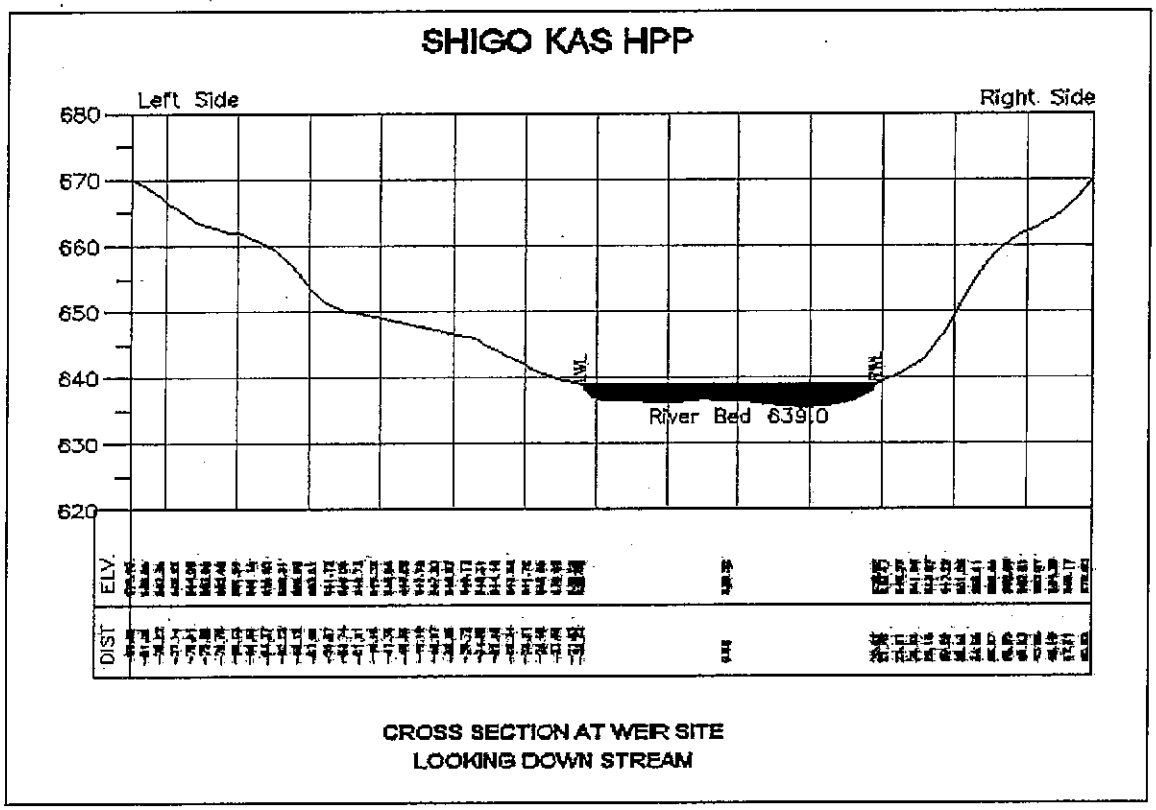

Figure 4.66: X-Sec of Shigo-kas Gated Weir Site Looking Upstream

Computations were carried out with the help of Manning's formula and results are shown in **Figure 4.67**. Summary results are given below:

Table 4.18
Summary Results of Slope Area Method

At Gated weir Axis

Sec No.	Area (m2)	Wetted Perimeter (meter)	Bed Slope	Manning's n	Velocity (m/s)	Peak Disch (m3/s)
1	527.0	79.9418	0.01200	0.0400	9.63	5074.42

The results obtained by slope area method are comparable with other methods. But the return period of peak discharge estimated by slope area method is unknown and therefore these were not recommended for the Design Flood of the project.

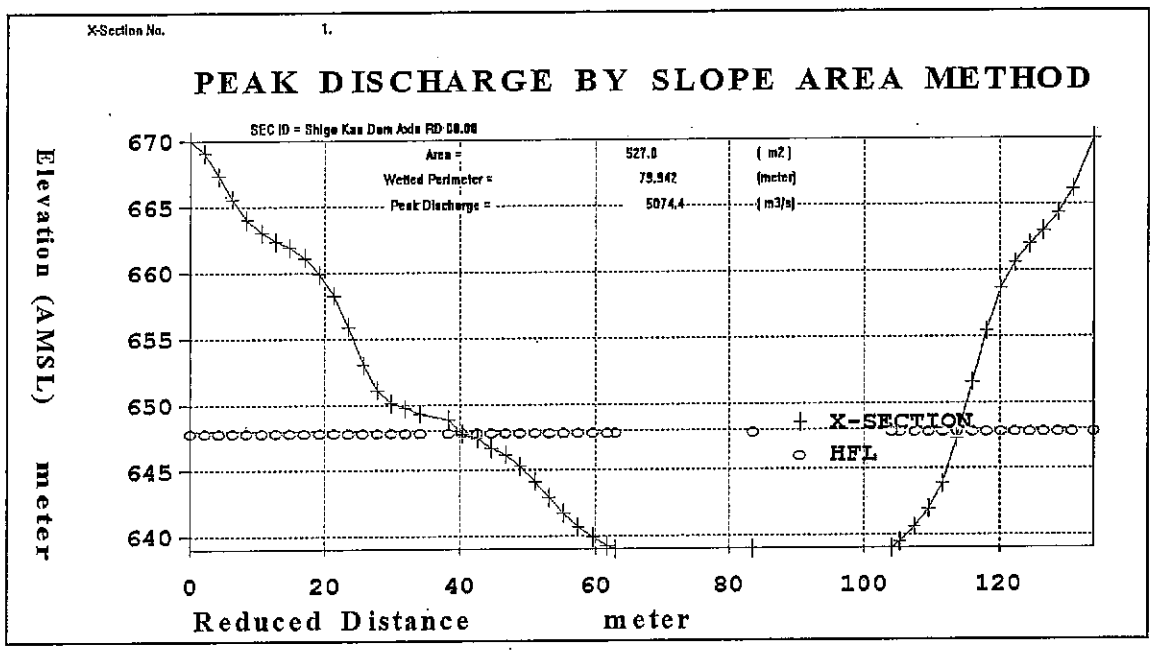

Figure 4.67: Software Computation

4.6.10 Design Floods

The floods estimated by the frequency analysis (**Table 4.10**) give reliable estimation of the maximum floods, due to the following reasons.

- The frequency curve of the floods correlates with the geomorphology of the catchments and the maximum flows at site
- The values of the maximum floods are greater than the maximum, given by the regional method.
- The results are comparable with other techniques.

Comparison of the flood analysis by the five alternate methods is given in **Table 4.19** and shown in **Figure 4.68**. The results computed by flood frequency analysis are found more accurate for the design purpose.

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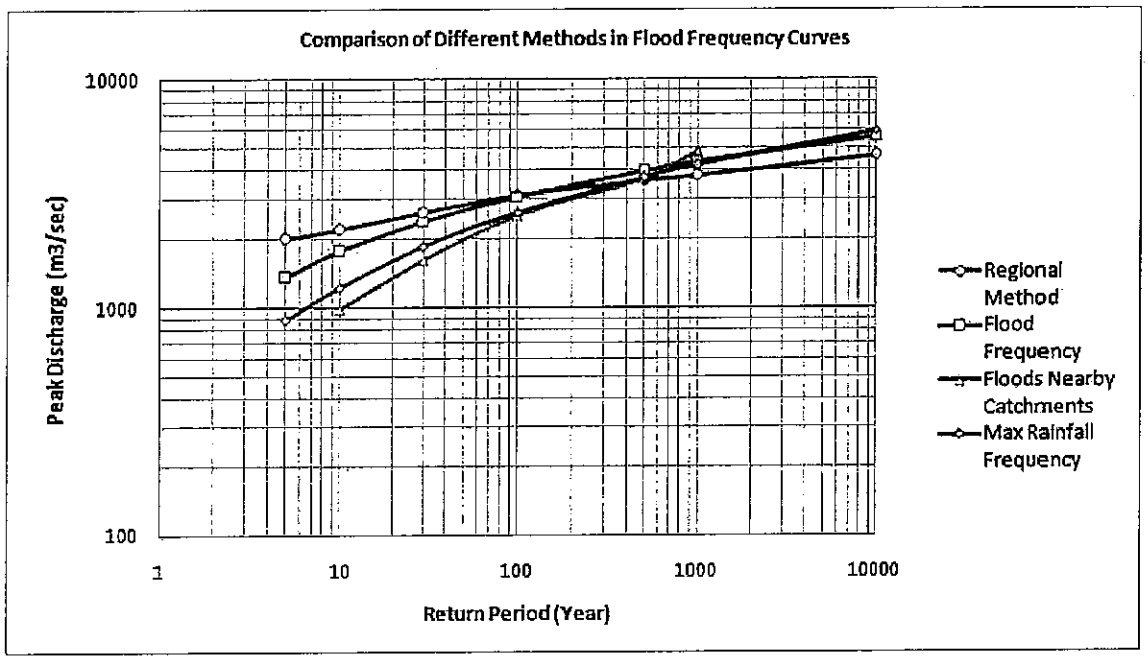


Figure 4.68: Comparison of the Flood Analysis by Alternate methods

Table 4.19: comparison of results (m^3/sec)

Recurrence Interval (Years)	Method of Estimation			
	Regional Method GTZ	Flood Frequency Analysis	Floods in Nearby Catchments	Max Rainfall Frequency
5	1992	1349	-	880
10	2183	1759	977	1220
30	*2600*	2380	*1600*	1851
100	3085	3046	2505	2611
500	*3600*	3929	3669	3688
1000	3766	4309	4833	4193
10000	4575	5569	-	5924

Note: *In Italics are Interpolated values*

Recurrence Interval (Years)	Method of Estimation			
	Slope Area Method	2010 Peak Discharge		
Unknown	5074	4447		

4.6.11 Conclusions

The peak flood at proposed gated weir site may be adopted of the order of 5569 m^3/s for 10,000-year return period. The recommended peak discharges for other return periods are given in **Table 4.20**

Table 4.20: Recommended Peak Discharges At Proposed Gated weir Site

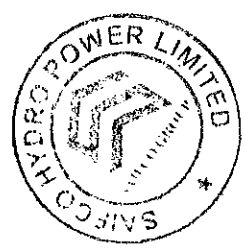
Return Period (Years)	Peak Discharge m3/sec
5	1349
10	1759
30	2380
100	3046
500	3929
1000	4309
10000	5569

4.6.12 Flood Routing Studies

Flood routing exercises was carried out for Inflow design flood. The area-elevation-capacity relationship was determined from topographic surveys and represented graphically in **Figure 4.69 and** Reservoir flood routing in **Figure 4.70**. The inflow design peak discharge of 10,000-year return period (5569 m^3/sec) was routed through the weir and maximum level was determined for design flood.

The following parameters have been used in the flood routing study:

Width of the river section	=	108.5 m
Overflow section	=	25 m
No. of gates	=	6
Width of gate	=	10 m
Height of gates	=	12 m
Type of gates	=	Radial
Gated section crest level	=	640.75 m
Weir crest level	=	650 m



Computer software HEC-HMS was used for routing purpose. In Peak discharge condition gated spillway can safely pass the Peak inflow discharge of 5569 m^3/sec at HFL of 654 m amsl. Results are shown in **Figure 4.69.** The following results have been obtained:

Inflow Peak discharge = 5569 m^3/sec

Flood passing through spillway gates = 5569 m^3/sec

HFL = 654 m

Therefore the 10,000-year flood can safely pass through the proposed spillway.

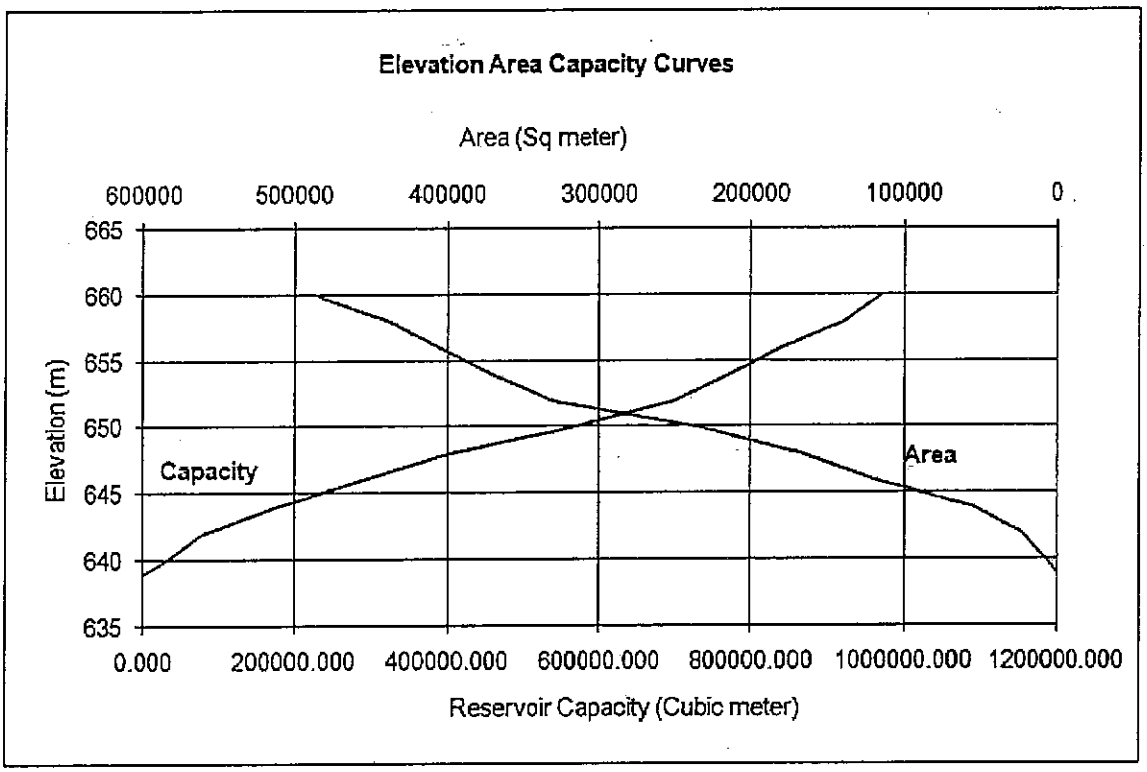


Figure 4.69: Elevation Area Capacity Curve

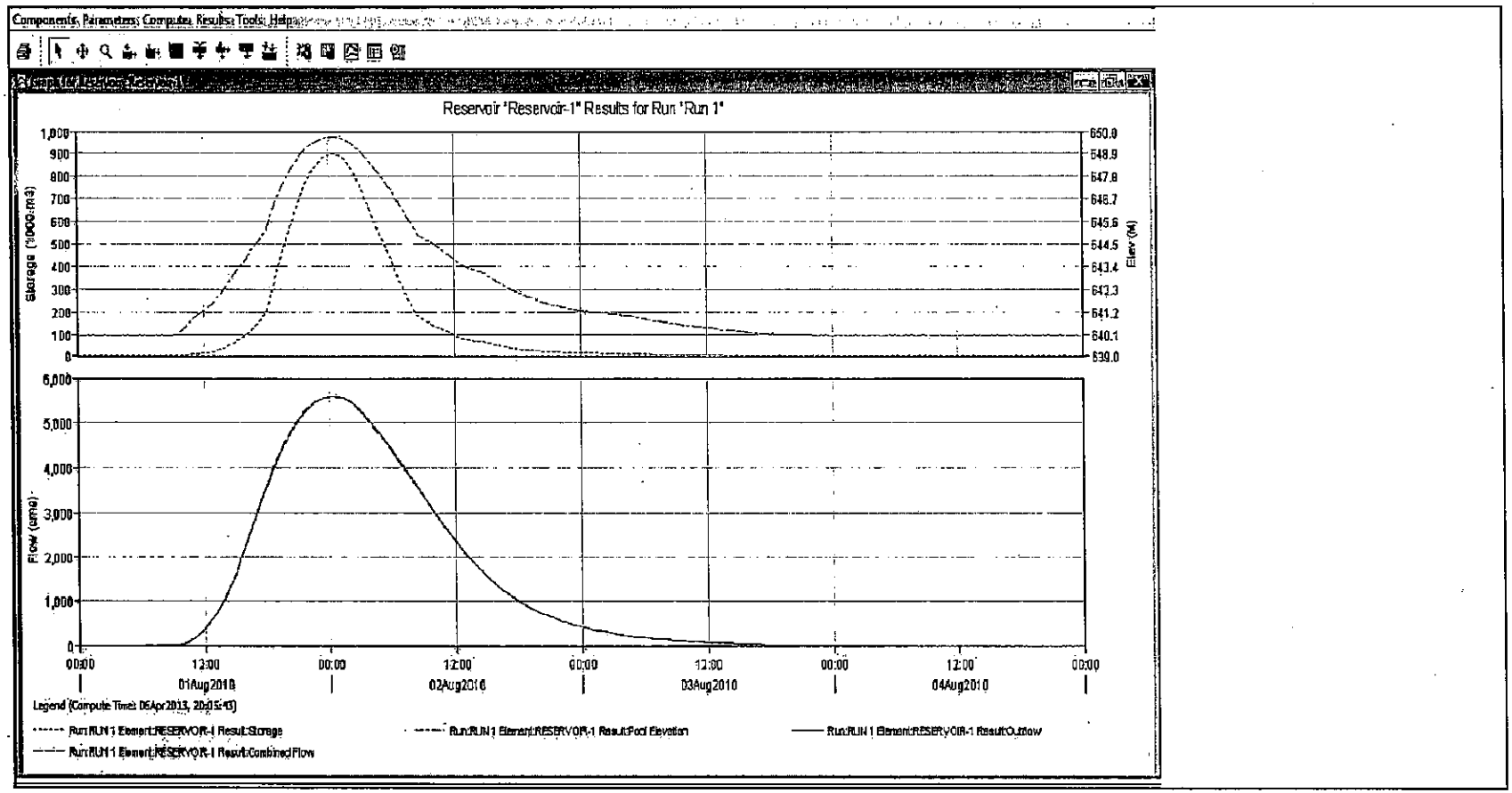


Figure 4.70: Reservoir Flood Routing

SEDIMENTAION

4.7 Introduction

The proposed site is located on Shigo-kas. It is located 10 km downstream from Timergara Town, where Panjkora River becomes narrow again and passes a bottleneck. This section deals with sedimentation studies of the proposed Shigo-kas Hydropower Project (HPP). Following is detail of work involved.

- Estimation of bed material.
- Grain size distribution.
- Estimation of bed load.
- Determination of suspended sediment rating curve.
- Estimation of suspended load and total load

4.8 Geomorphology and Topography

Proposed weir site is located on Shigo-kas. It is a tributary of Panjkora River which is the main stream of Swat River. Dir region has high mountain ranges and deep valleys. It is surrounded by the Hindu Kush range in the North & West, Mushamber range in the East and the Hindu Raj range in the South. There are about one hundred mountain peaks above 6,000 meters in this range. The drainage area of Panjkora River upto proposed gated weir site is about 5816 km^2, several streams drain into the Panjkora River upstream of proposed site and contribute appreciable amount of sediments. In context of topography, the valley has an elevation of 5563 meters above mean sea level (masl) at weir site the bed level of river 639. The average slope in the watershed is about 1.2 %. The length of the main stream is 160 km. Topographic conditions of the area are shown in **Figure 4.71.**



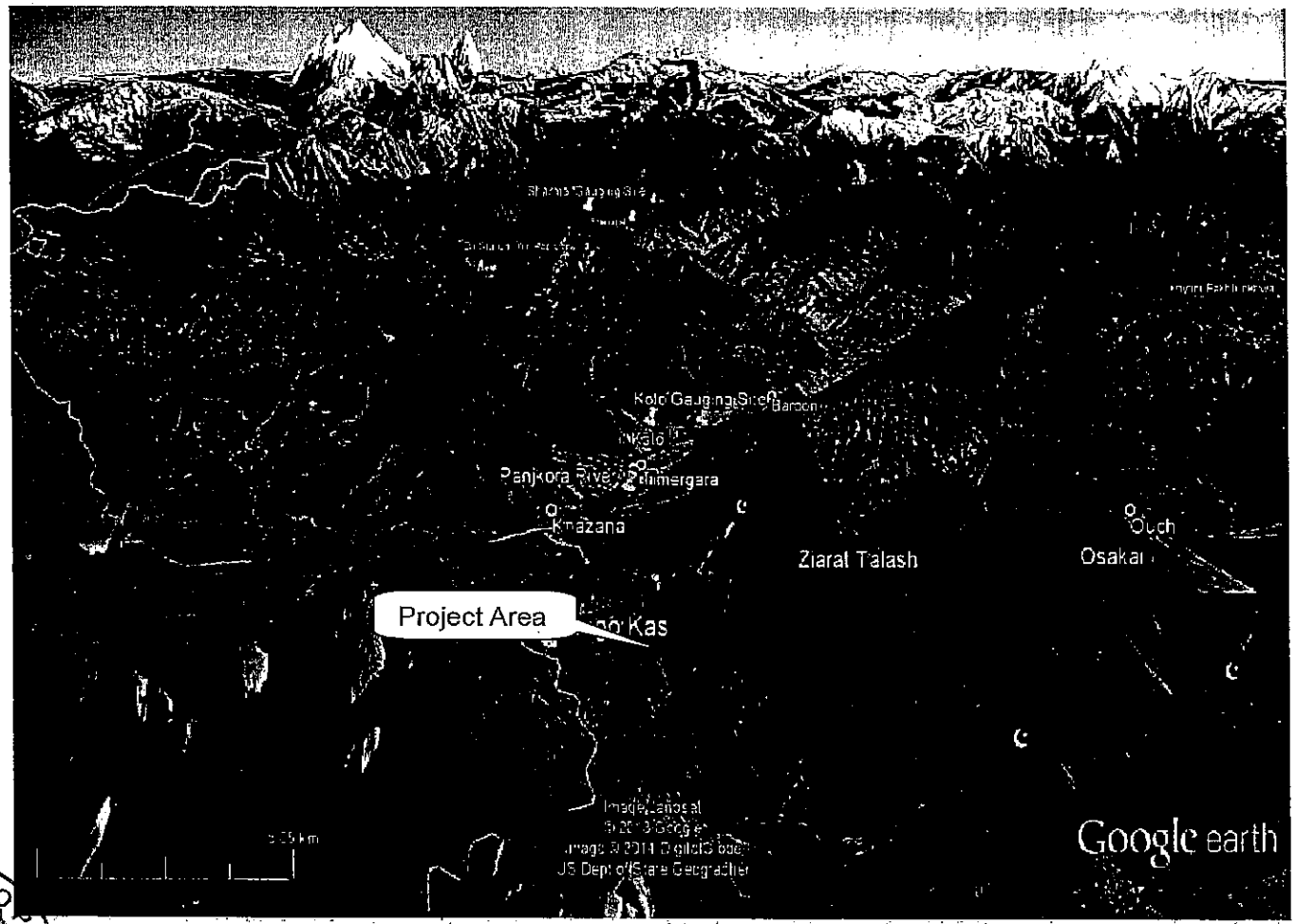


Figure 4.71: Map showing topographic conditions of Panjkora River at Shigo-kas (Source: Google Earth, 2014)

4.9 Available Data

4.9.1 Longitudinal Profile and Slope

Topography of watershed and steep slopes plays an important role in the sediment transport in a river. The longitudinal profile of the Shigo-kas at weir site **Figure 4.72** shows a mean gradient of approximately 0.44%. Slope at weir site is lesser as compared to average watershed slope of 1.2% as mentioned earlier. This value indicated that Shigo-kas is a steep river and carry appreciable sediment load. Hill slope map of the watershed is prepared to determine slopes in the watershed. The map is presented in **Figure 4.73.** Map showing digital elevation is also prepared to find the elevation difference in watershed **(see Figure 4.74).** These maps indicated that slope in the upper reaches towards NE is steep and comparatively high. Highest elevation in the watershed as determined from this map is 5748 m.a.s.l and lowest is 572 m.a.s.l. River bed level at weir site in Shigo-kas is 639 m.a.s.l. Not only gradient in Shigo-kas is higher, but also it receives more sediment due to its size of catchment area (5816 km^2).

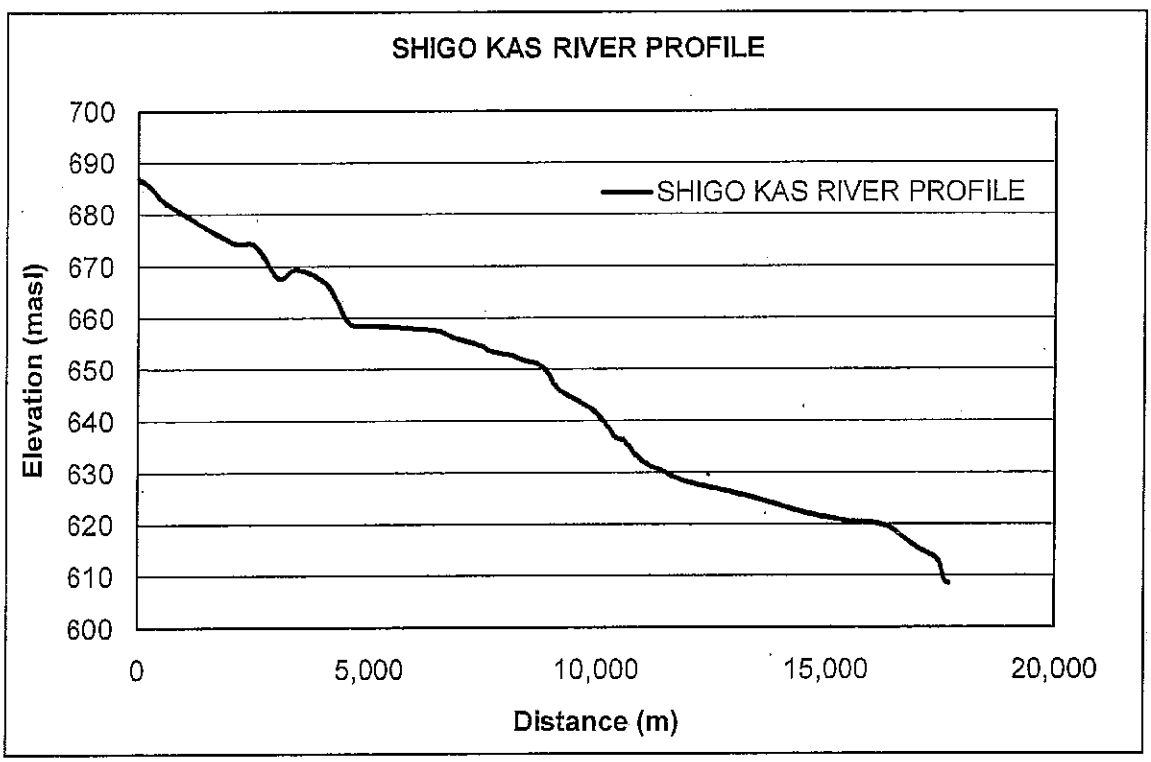


Figure 4.72: Longitudinal Profile of Shigo-kas

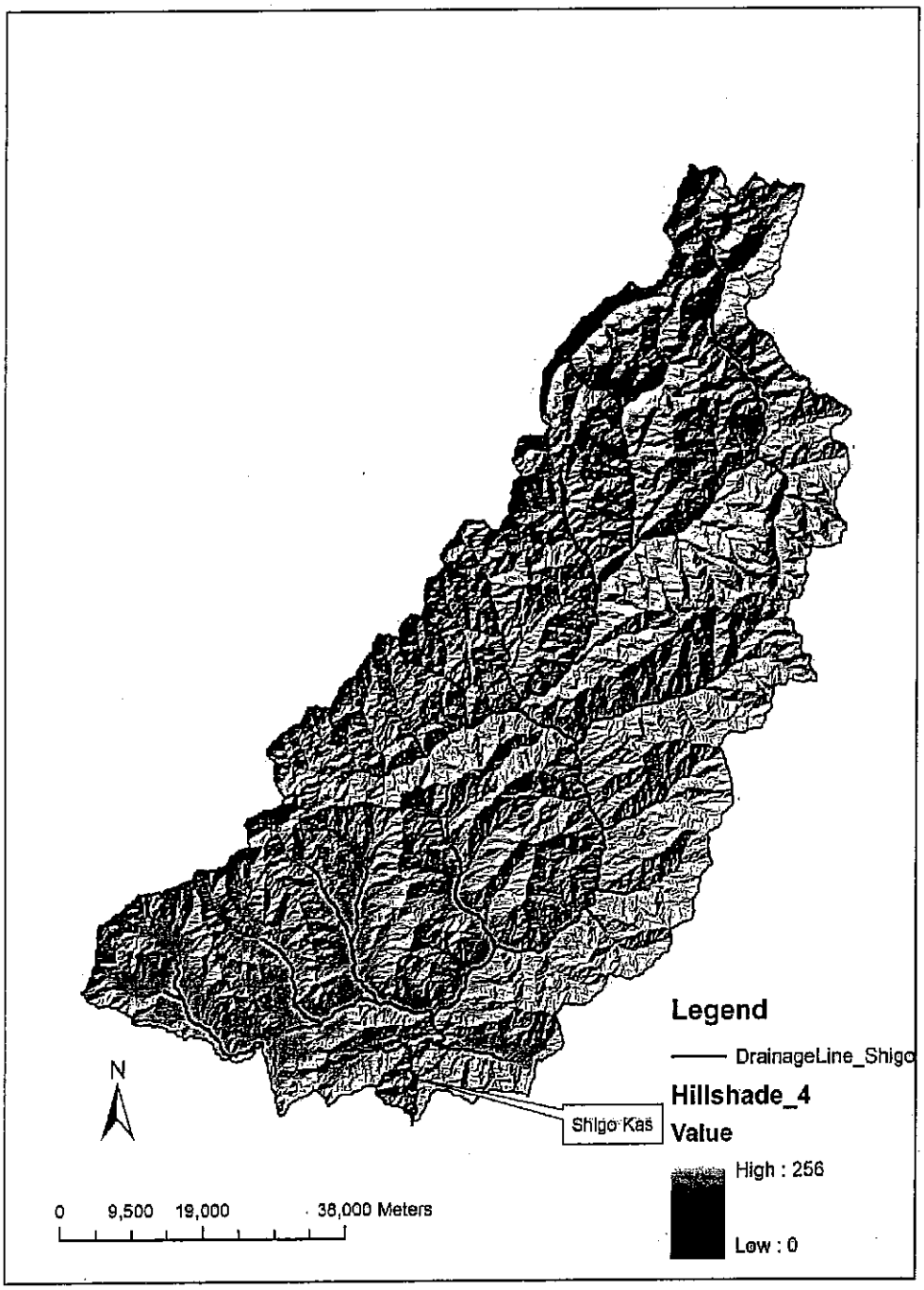


Figure 4.72: Slopes in the Watershed, Shigo-kas HPP

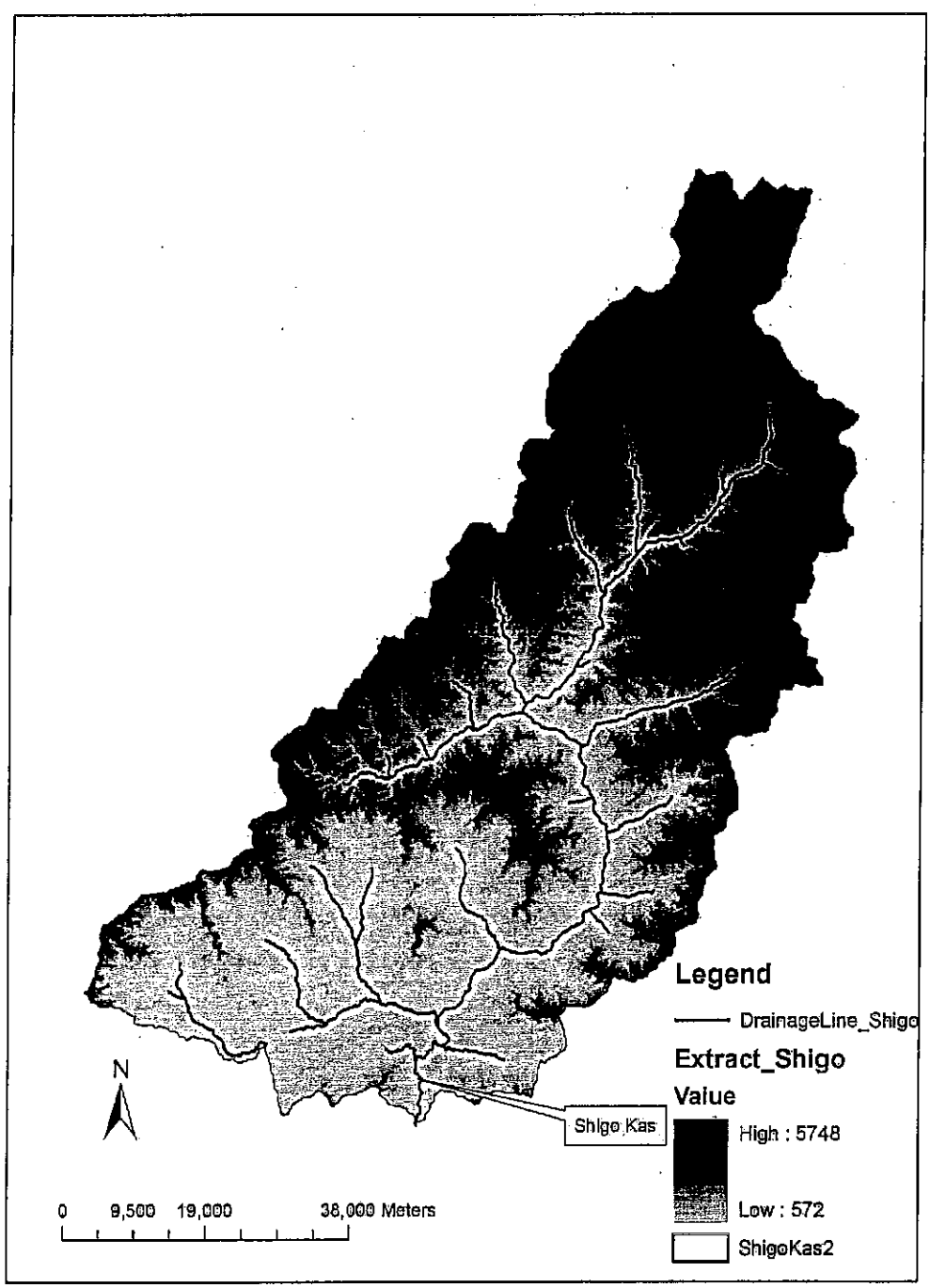


Figure 4.73: Ground Elevation (m) in the Watershed, Shigo-kas HPP

4.9.2 Bed Material

One of the important parameter for all 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 river is characterized by armouring

effects. The armour 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.

In case of Mountain Rivers, such as the Shigo-kas, with armoured layers, the riverbed surface consists of large cobbles and boulders with a size of more than 200 mm. The size of the boulders is too large for a typical mechanical sieve (dmax = 64 mm). Consequently, sieving might give misleading results. Therefore, the bed material grain diameters should be determined with help of the so-called 'Line-by-number-procedure', developed at the Technical University in Zürich, Switzerland.

4.9.3 Bed Load

Bed load measurements were not carried out on the Shigo-kas in the past because most bed load measurement devices developed in the past were designed for low land rivers only. The basket collecting the transported bed load material is usually too small for the size of stones existing in Mountain Rivers. A measurement with these bed load samplers would lead to misleading results. Therefore empirical formulas need to be applied for the estimation of the expected bed load.

4.9.4 Suspended Load

Suspended load measurements were carried out on Panjkura River during mean and high flows at the gauging station at Zulam bridge from 2000 to 2005.

The suspended measurements were carried out in connection with discharge measurements. The available data were considered for analysis and estimation of mean annual suspended load transport as well.

4.9.5 Data Base of Previous Studies

Feasibility study of Munda Dam Multipurpose Project was carried out by JICA and Nippon Koei Co. Ltd. The report dealt with analysis of sediment transport Swat River at Munda Dam site located 5 km upstream of Munda Headworks using SWHP flow and sediment concentration as observed at the gauging station at Kalam and Chakdara. SWHP WAPDA also carried out measurement in Panjkora River at Zulam Bridge upstream of Shigo-kas Weir Site. Location of gauging stations is shown in **Figure 4.75**. The data at these stations has been available since 1961. The average annual values of sediments at these locations are:

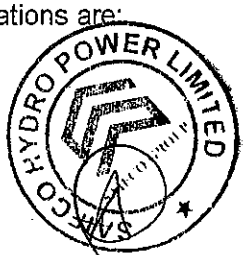


Table 4.21 Average Annual Sediment and Water Yield

Station	Catchment Area (km^2)	Annual Inflow (m^3/sec)	Suspended Sediment Load Million Short Tons/year	Suspended Sediment Inflow AF/Year
Panjkora at Zulam	N/A	110	37.30	27000
Swat at Kalam	2,020	92	0.339	266
Swat at Chakdara	5,776	180	2.150	1,770

Since the above analysis utilized authentic flow and sediment record of SWHP, the above value of sediment contents may be considered a reasonable estimate at these locations. Comparatively sediments in Panjkora River is quite high as compared to Swat river.

4.10 Bed Material

Once the armour layer is broken locally by a strong current, it is expected that the finer sediment material of the subsurface will also be transported. The armour layer develops naturally during low and mean flows, when fine sediments are washed out from the riverbed and cobbles and boulders with large weight remain on the surface of the riverbed. This phenomenon is strongly developed at steep slopes greater than 1%. The thickness of the armour layer is in the range of the mean grain diameter of the available sediments on the surface. Below the armour layer, a mixture of fine and coarse sediments is available as subsurface material.

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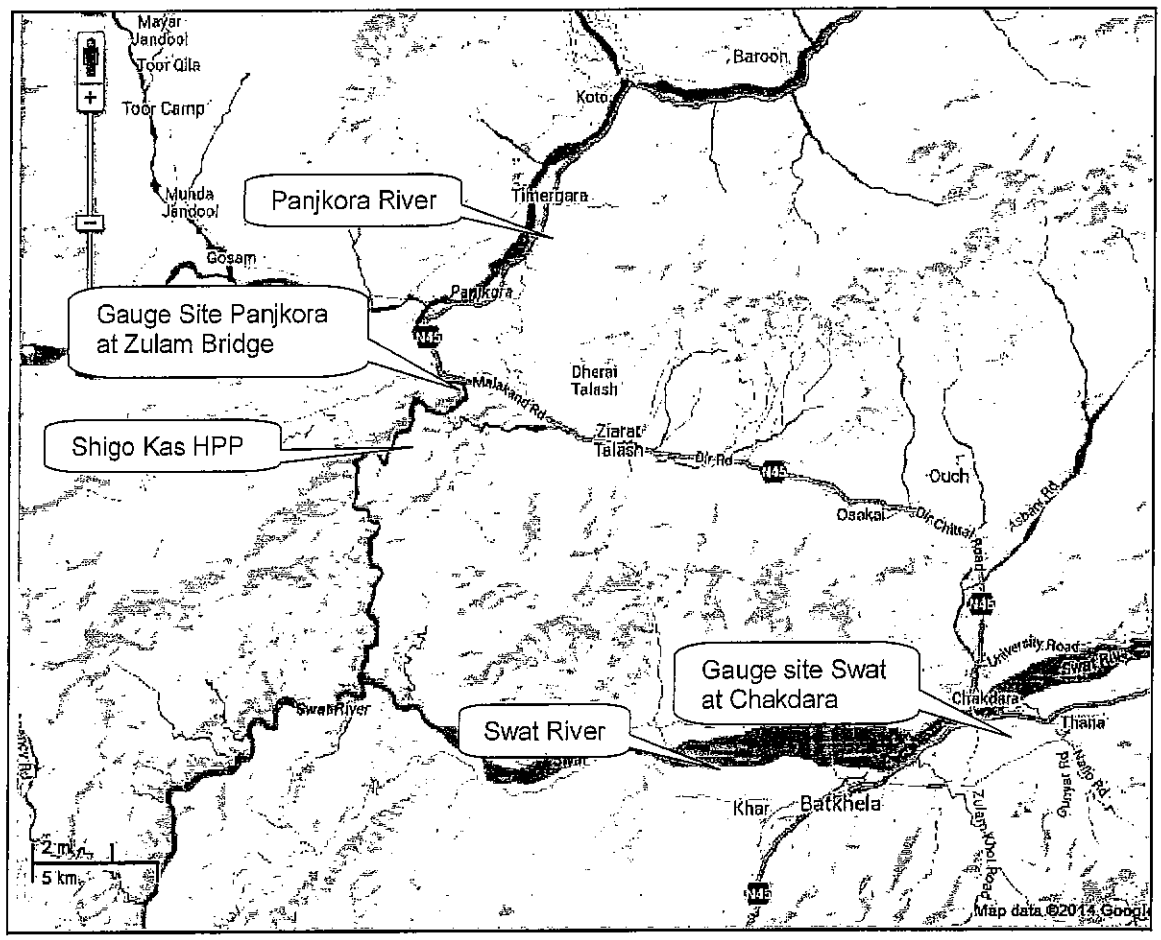

Figure 4.75 Location of gauging sites from weir site.

The grain distribution curve of the river bed material as well as subsurface material obtained from present investigations at Shigo-kas is presented in **Figure 4.76**. A view of armour layer bed material at weir site is shown in **Figure 4.77.**

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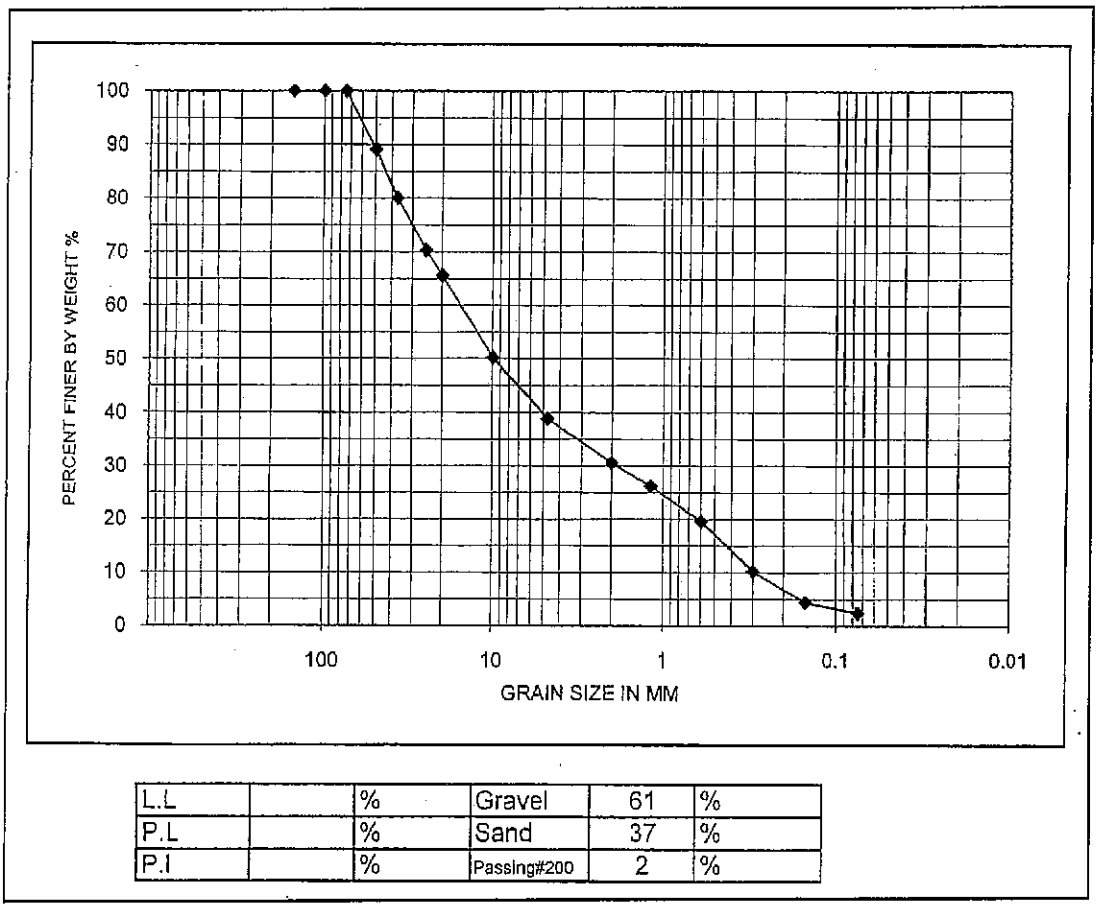

L.L		%	Gravel	61	%
P.L		%	Sand	37	%
P.I		%	Passing#200	2	%

Figure 4.76: Subsurface Materials at Shigo-kas

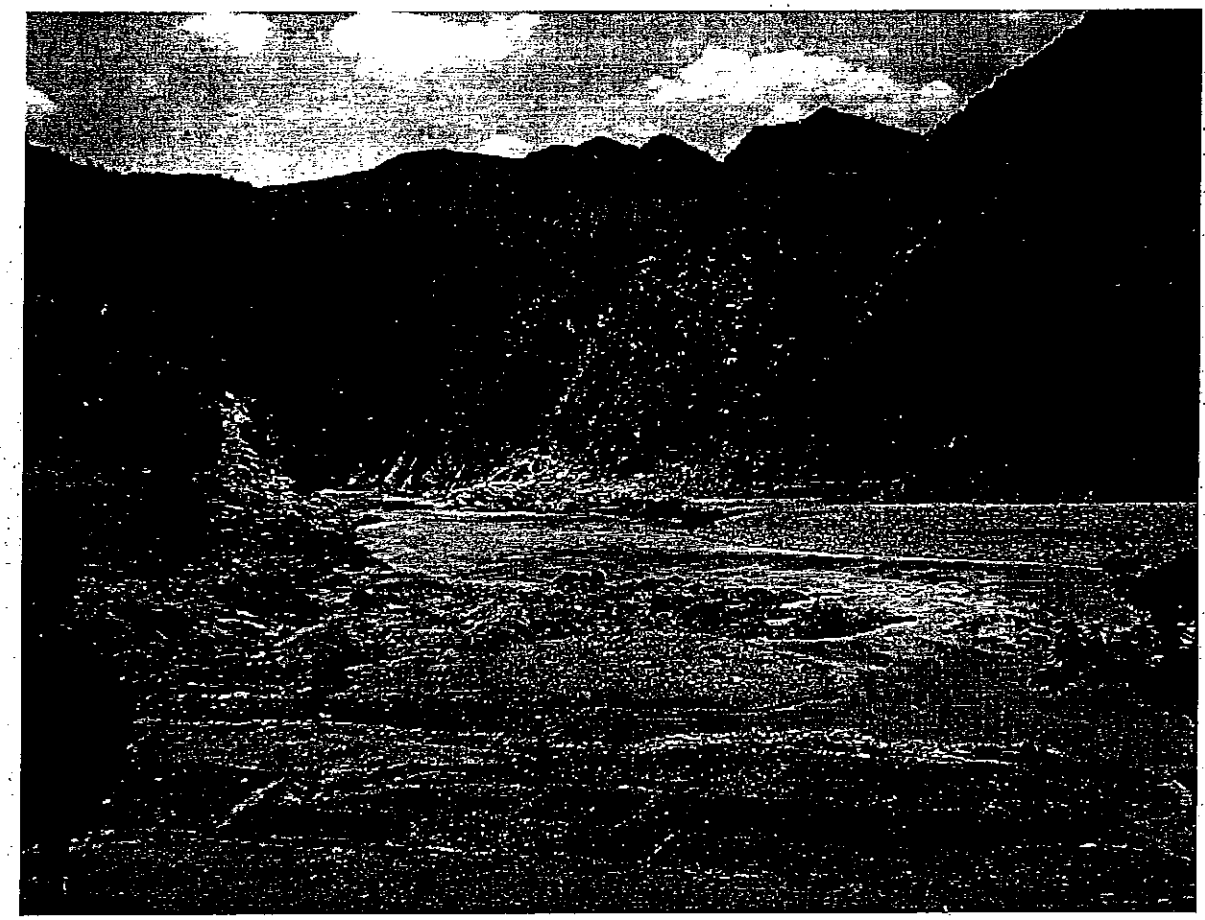

Figure 4.77: Armour Layer Bed Material near Shigo-kas Weir Site

Based on grain size analysis of the bed material following grain size parameters were estimated. These parameters are then used for the calculation of bed load of the Shigo-kas at proposed weir site.

Table 4.22 Grain parameters of the bed material, Shigo-kas at Weir Site

Analysis of Grain Size									
Sample No	Location/ Depth	D_{10}	D_{16}	D_{30}	D_{50}	Mean Dia D_m	D_{60}	D_{84}	D_{90}
		mm							
1	Sample 1	0.300	0.450	1.833	10.182	12.931	17.882	28.160	25.600

4.10.1 Sediment Sampling

4.10.2 Shigo-kas

No historic data of suspended sediment is available at proposed weir site. However SWHP/WAPDA has measured suspended sediments in Panjkora river at Zulam Bridge upstream of proposed weir site. These data has been used herein for the sediment estimation at weir site because the gauging site is located close to proposed site.

4.10.3 Panjkora River

Suspended sediment sampling was carried out in Panjkora river at Zulam Bridge for the period 2000-2005 by SWHP, WAPDA. All the measurements were taken along with discharge measurements of the river. Suspended sediment rating was developed with the help of recorded data of Panjkora river at Zulam bridge and it is displayed in **Figure 4.78**. The R^2 value [0.19] shows little correlation between discharge and suspended sediments. However same is the case in many rivers of Northern areas of Pakistan.

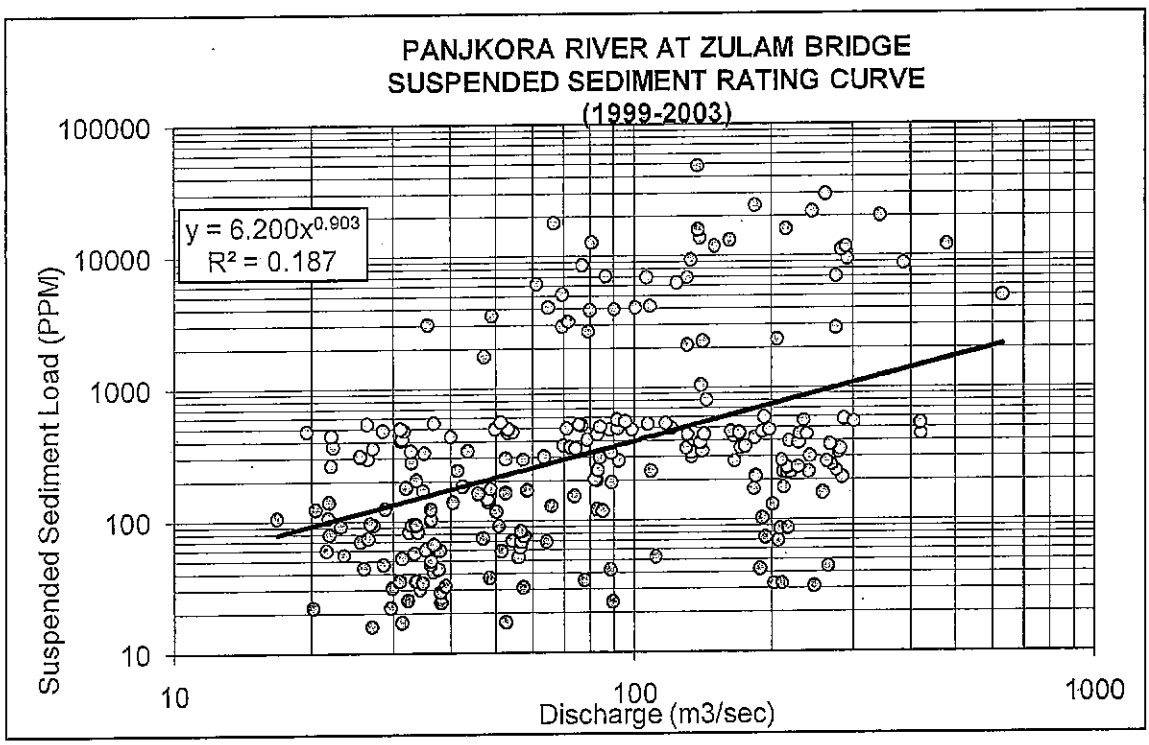

Figure 4.78: Suspended Sediment Rating of Panjkora River at Zulam Bridge

4.11 Sediment Yield In Panjkora River

Sediment yield in Panjkora river at Zulam Bridge was computed and published by SWHP/WAPDA. These results are presented in **Table 4.23**. Refer to Table 4.23 (second column) mean annual runoff in Panjkora river at Zulam bridge (2000-2005) was estimated to be 2,810,000 AF. Mean annual suspended sediment in Panjkora at Zulam Bridge comes to be 37.3 MST. Mean annual suspended sediment volume in Panjkora at Zulam Bridge is 27,600 AF. Annual suspended sediment distribution is given in **Figure 4.79.**

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Table 4.23: Sediment Data

19. PANJKORA RIVER AT ZULAM BRIDGE											
Year	Water Yield			Suspended Sediment			Sed./Dis. Ratio		Observed Concentration		Computed Concentration
	Total Runoff 10^3 Ac. Ft.	Maximum Discharge (Cusecs)	Minimum Discharge (Cusecs)	Million Short Tons	10^3 Ac. Ft.	Ac. Ft. Per Sq. Mile of D.A.	By Wt. (%)	By Vol. (%)	Max. PPM	Min. PPM	Max. PPM
1	2	3	4	5	6	7	8	9	10	11	12
2000	1980	13500	723	27.8	20.6		1.03	1.04	18000	17	26300
2001	1680	22000	528	12.50	9.26		0.547	0.552	16000	22	34500
2002	2340	10100	858	29.10	21.60		0.916	0.922	48700	25	21300
2003	3210	20900	725	40.70	30.10		0.933	0.938	15700	16	25600
2004	2510	29100	1150	16.50	12.20		0.484	0.487	19300	56	27400
2005	5120	67300	1050	97.30	72.10		1.400	1.410	22200	98	36900
Mean	2810			37.30	27.60		0.885	0.891			

Source: Surface Water Hydrology Project (SWHP), WAPDA

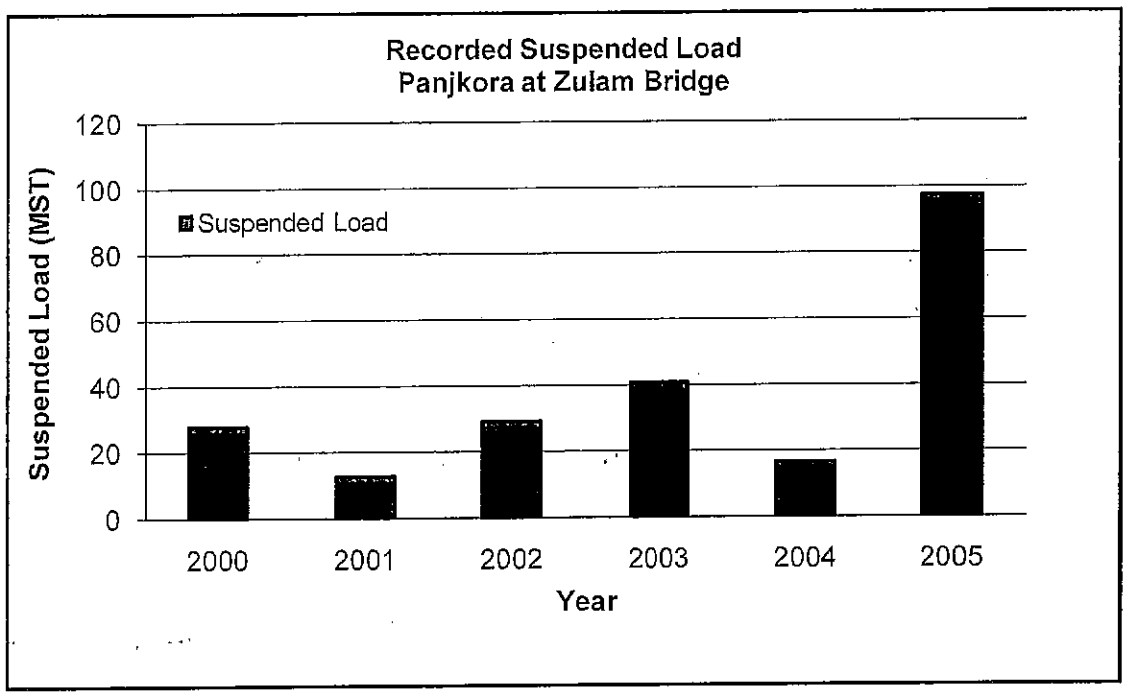

Figure 4.79: Annual Distribution of Suspended Sediments

4.12 Bed Load

Since bed load movement in the Shigo-kas was not directly measured, empirical formulae were used on the basis of available and measured parameters. Concerning the assessment of bed load, two aspects were considered:

- Initiation of motion, and
- Amount of transported material.

4.12.1 Initiation of Motion

As proved by field measurements in mountainous regions worldwide, the bed load in nature has to be distinguished between fine gravel in the range between 2 mm < d < 16 mm at the initiation of movement, and the incipient motion of cobbles and boulders of the armour layer. A critical condition is reached at the latter criterion, since the riverbed then starts to move and

no protection of the fine material in the subsurface layer is given any more. If this happens, deep scouring with enormous sediment transport is expected (Palt 2001). The empirical formulae use the dimensionless specific discharge q* as described below:

$$q_* = \frac{q}{\sqrt{g\left(\frac{\rho_s}{\rho_w} - 1\right)d_{65}^3}} = f(S)$$

With:

q = specific discharge = (Q/bw) [m3/sm]

ρs = specific density of sediment [kg/m3]

ρw = specific density of water [kg/m3]

d65 = grain diameter of armour layer at 65 % passage of weight

S = slope [-]

The incipient motion of fine gravel as well as the armour layer can be described by the following equations:

Incipient motion of fine gravel

$$\frac{q}{\sqrt{g\left(\frac{\rho_s}{\rho_w} - 1\right)d_{65}^3}} = 0.039 \cdot S^{-1.16}$$

Incipient motion of armour layer

$$\frac{q}{\sqrt{g\left(\frac{\rho_s}{\rho_w} - 1\right)d_{65}^3}} = 0.093 \cdot S^{-1.25}$$

i) Initiation of Motion at Shigo-kas

The mean width of the river was approximated with the help of river x-section recorded at site and shown in **Figure 4.80.** The mean width comes to be about 30 m. Considering the water surface slope of [S = 1.2 %(in catchment) and S = 0.44% (at weir site)] and a grain diameter at 50% passage of weight of 1.0 cm (for fine) to 5.0 cm (for coarse), following threshold discharges can be given for the three different stages of sediment load movement. They distinguish the grain size distribution of the transported bed load:

- no movement: Q < 3.6 m^3/s

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- movement of fine gravel (2 mm – 49 mm): 3.6 < Q < 163 m^3/s
- movement of bed material: Q > 163 m^3/s

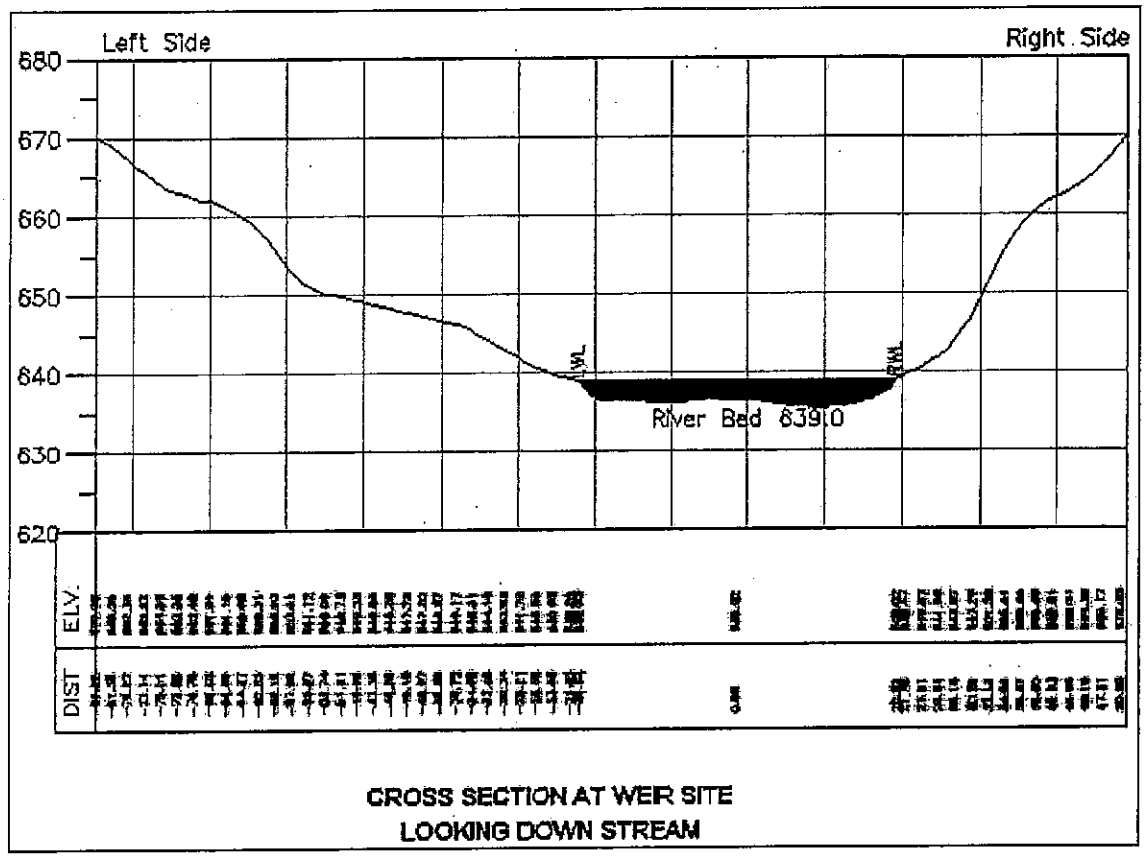

Figure 4.80: Panjkora River X-Section at Weir

The above analysis indicated that no bed load movement will be observed below discharge 3.6 m^3/s. The estimated discharge 163 m^3/s; where armour layer will start moving shows that this phenomenon is a common event. However, when it occurs, large bed load transport masses are expected. Nevertheless, the threshold discharge for armour layer movement has to be considered for the future operation of the hydropower plant.

4.12.2 Amount of Transported Material

Rating Curve

The rating curve is a relationship between the water discharge and the bed load discharge. If measurement at site reaches conditions where the layer is destroyed, the rating may be employed. Bed load consists of fine gravels, indicating the transport mechanism between initiation of motion an layer destruction. The bed load rating curve for this specific transport mechanism can be drawn. No recorded data of bed load is available in Shigo-kas or in Punkora River. However some measurements were carried out by GTZ in a nearby river, Kalam River at Utror which is quite away from the Shigo-kas. Therefore empirical formulae

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have been employed to estimate bed load at site. Computations were carried out with the given hydraulic and bed material characteristics of Shigo-kas and results are presented in **Figure 4.81**

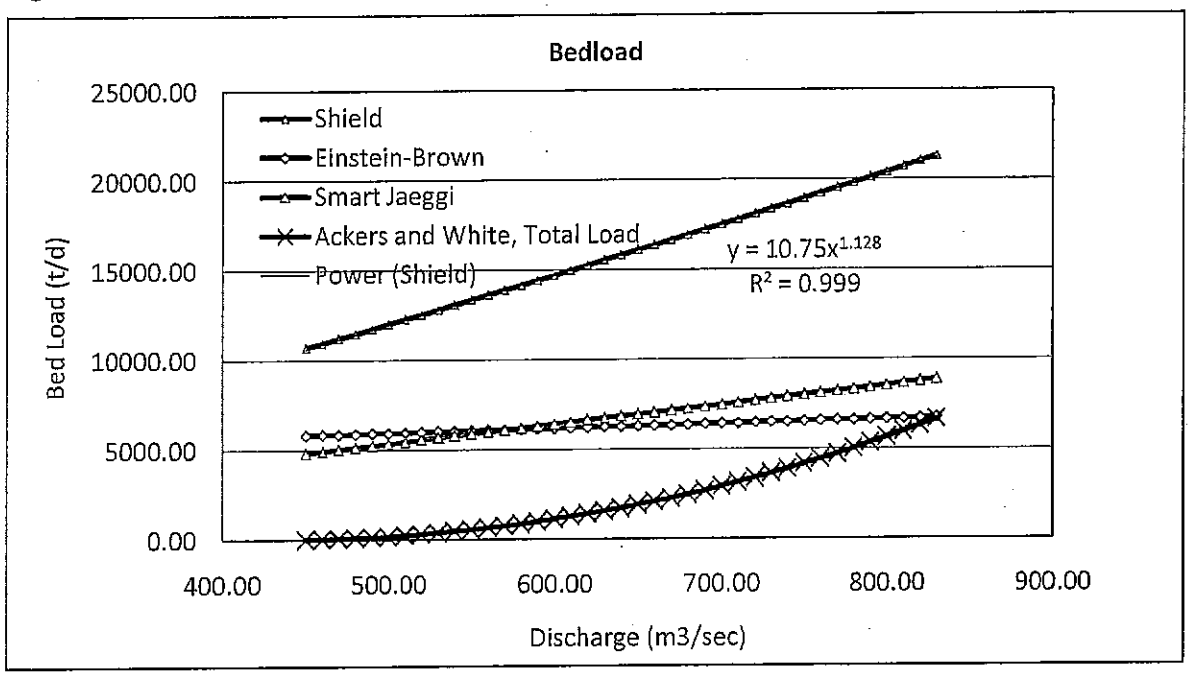

Figure 4.81: Estimation of Bed load using Empirical Formulae

The expected bed load was calculated on the basis of rating curves mentioned above. The mean yearly bed load in the Shigo-kas at weir site was calculated to be approximately 0.89 MST/year (**Table 4.24). Table 4.25** illustrates that the yearly bed loads vary according to flood conditions. In 1991, the yearly loads was maximum in Shigo-kas (1.17 MST/year). Distribution of yearly bed load in Shigo-kas at weir site and is presented in **Figure 4.82**. Mean monthly bed load at proposed weir site is shown in **Fig 4.83**.

Table 4.24: Mean Yearly Bed Load

Month	Bed Load (Ton)
Jan	0
Feb	542
Mar	8263
Apr	27382
May	138878
Jun	247256
Jul	259196
Aug	170525
Sep	40416
Oct	142
Nov	82
Dec	0

Total	892683

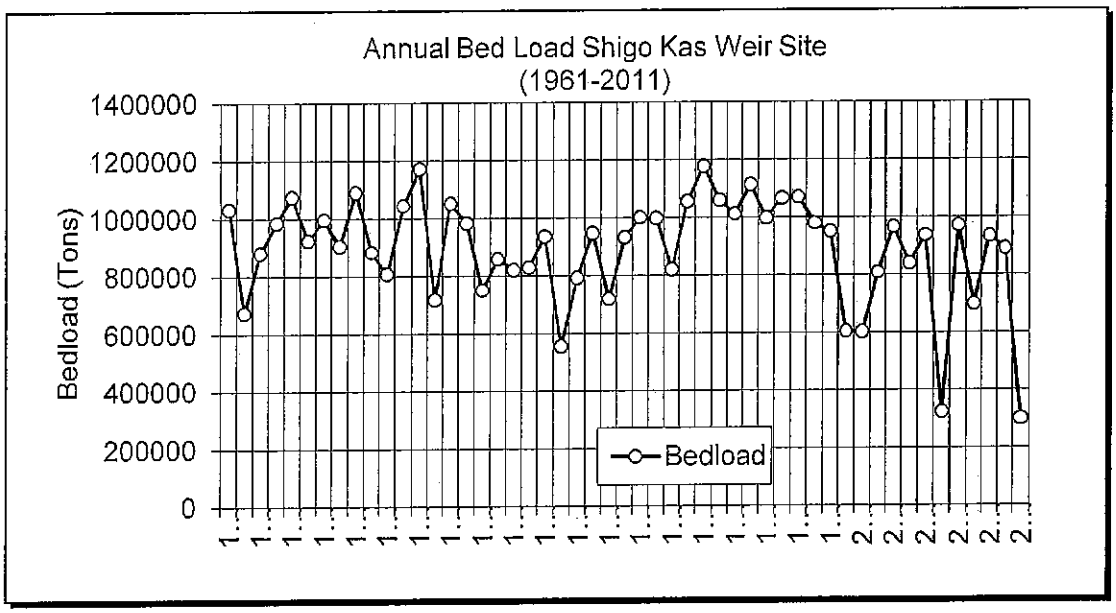

Figure 4.82: Distribution of bed load transport based on Shield Formula at Weir Site

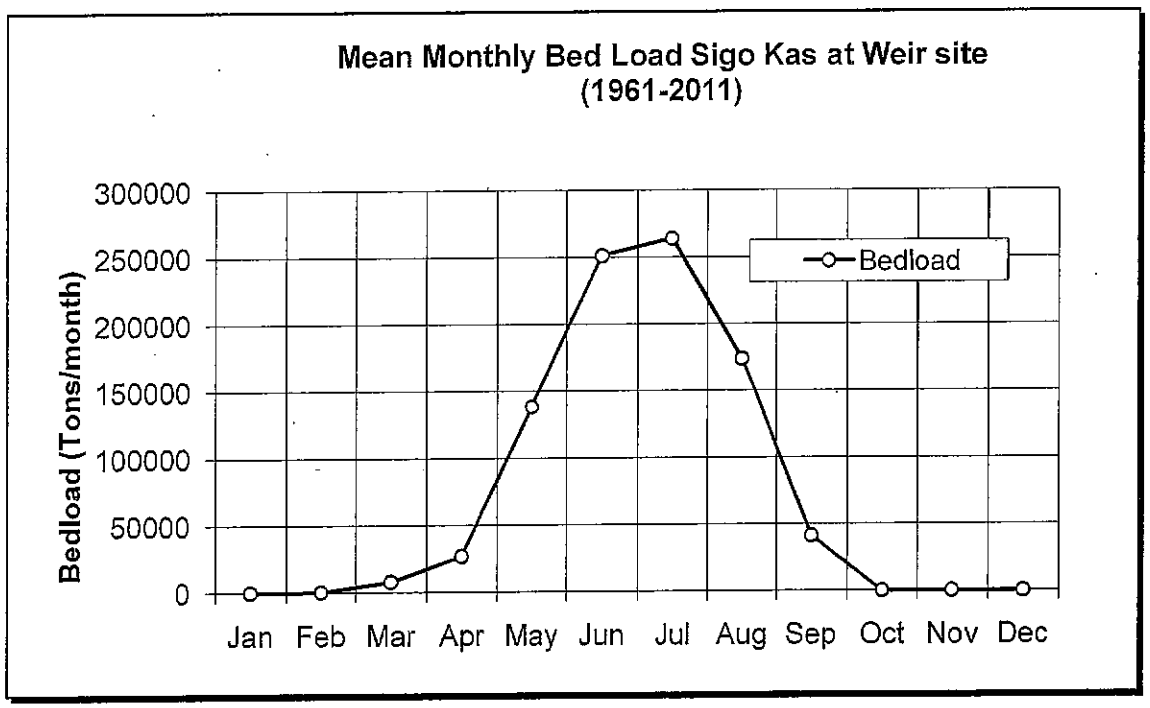

Figure 4.83 Distribution of monthly bed load transport based at weir site

Table 4.25: Variation of Yearly bed load in the Shigo-kas at Weir Site

Shigo-kas at Weir Site	
Year	Bedload (Tons)
1961	1031468
1962	672587
1963	880093
1964	984309
1965	1074243
1966	923096
1967	995017
1968	904048
1969	1089243
1970	883373
1971	807817
1972	1043560
1973	1170644
1974	718040
1975	1050453
1976	982184
1977	750707
1978	859035
1979	820571
1980	828817
1981	936516
1982	554389
1983	792172
1984	946929
1985	718813
1986	930648
1987	1001008
1988	998193
1989	820772
1990	1054634
1991	1177430
1992	1060224
1993	1011540
1994	1113981
1995	997945
1996	1065511
1997	1070925
1998	979378
1999	950309
2000	603804
2001	602081
2002	808384
2003	965967
2004	838885
2005	936768

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2006	324988
2007	971012
2008	697742
2009	934277
2010	891649
2011	300668
Mean	892683
min	300668
Max	1177430
St Dev	186315

4.13 Suspended Load

4.13.1 Amount of Transported Material

The development of a suspended sediment rating curve and its analysis showed that the suspended sediment concentration data has good correlation. **Figure 4.76** shows the correlation between discharge and suspended sediment concentrations in the Panjkora river at Zulam Bridge upstream of Shigo-kas HPP. **Table 4.26** shows the sand/silt/clay proportions and initial density of recorded data.

The sediment concentration in mountain rivers is highly dependent on the suspended sediment supply. Since the suspended load concentration was measured on a daily basis during the flood period (March to June/July) at the gauging station for the recorded period, this source of information was expected to provide the actual suspended load transport in the Shigo-kas. Therefore the available decade data for suspended load transport were used for the estimation of mean expected transport at weir site. Mean monthly suspended load at proposed weir site (1961-2011) is shown in **Fig 4.84 and Table 4.27**. Distribution of yearly suspended load in Shigo-kas at weir site and is presented in **Figure 4.85 and Table 4.28.**

Table 4.26: Sand/Silt/Clay Percentage and Initial Density

PANJKORA RIVER AT ZULAM BRIDGE Sand/Silt/Clay Percentage and Initial Density				
Year	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Initial Density (kg/m^3)**
1999	20	60	20	1213
2000	6	73	21	1159
2001	26	55	19	1241
2002	20	62	19	1215
2003	10	64	26	1165
Mean 1999-03	**16.3**	**62.7**	**21.0**	**1199**

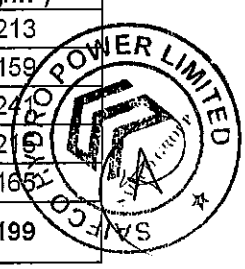

Table 4.27
Monthly Suspended Load Shigo-kas at proposed Weir site

Month	Suspended Load (Ton)	Specific Load (Ton/km²)
Jan	19510	3.4
Feb	21637	3.7
Mar	80334	13.8
Apr	187463	32.2
May	573476	98.6
Jun	1268894	218.2
Jul	1441252	247.8
Aug	717745	123.4
Sep	227796	39.2
Oct	66852	11.5
Nov	34316	5.9
Dec	24233	4.2
Total	4663508	802

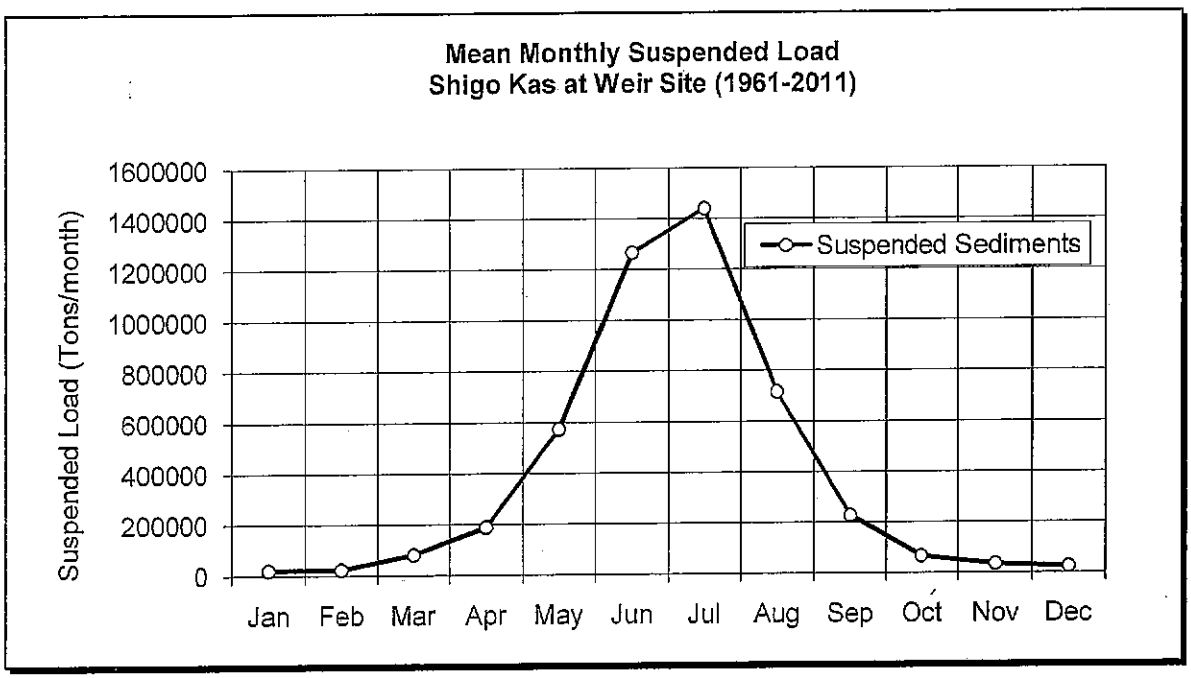

Figure 4.84: Distribution of mean monthly suspended load transport

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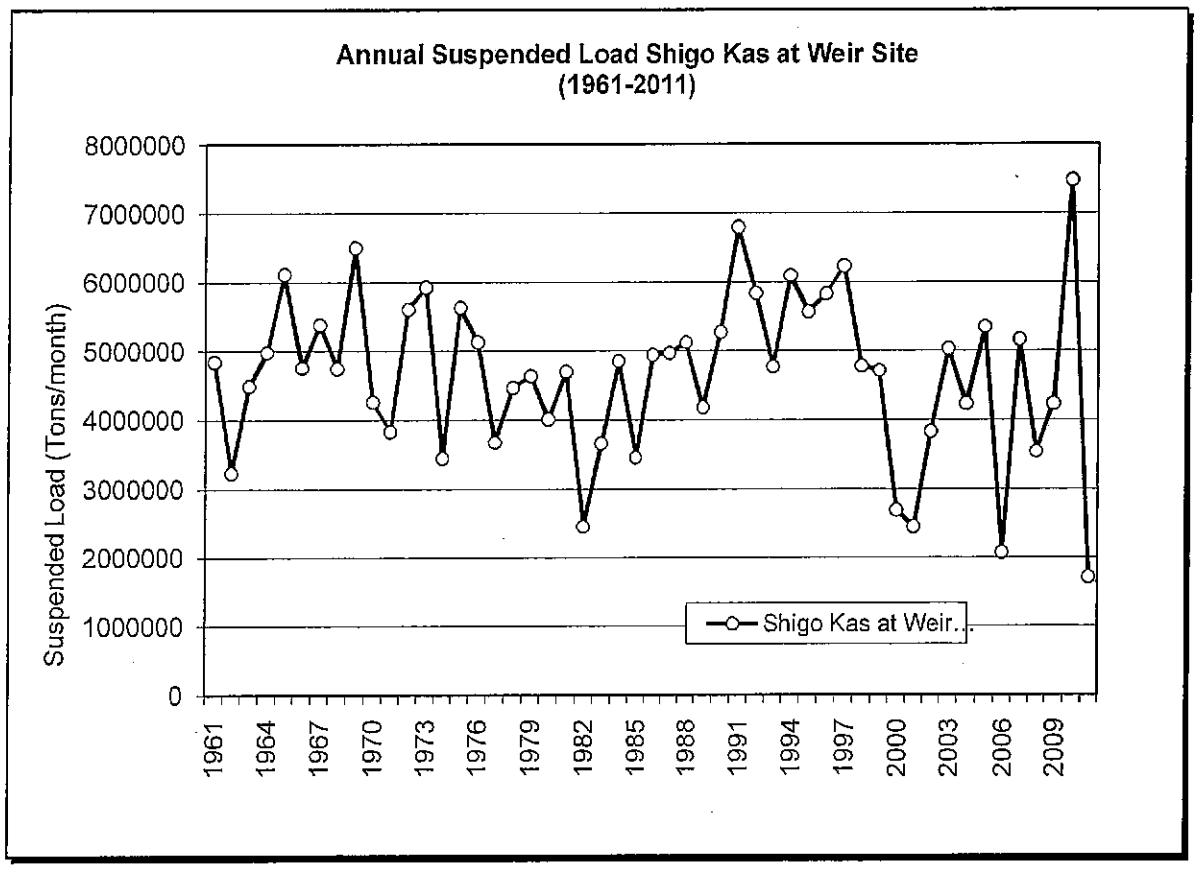

Figure 4.85: Distribution of annual suspended load based on decade data

Table 4.28: Yearly suspended load in the Shigo-kas at weir site

Year	Annual
1961	4846276
1962	3232300
1963	4491616
1964	4984817
1965	6121613
1966	4760663
1967	5385755
1968	4748795
1969	6503251
1970	4264995
1971	3833101
1972	5608277
1973	5928769
1974	3446311
1975	5637598
1976	5130011
1977	3676829
1978	4472989
1979	4638757

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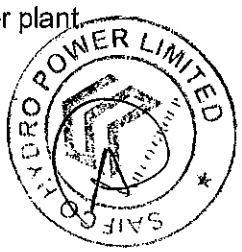
Year	Annual
1980	4014637
1981	4703083
1982	2456981
1983	3660851
1984	4856604
1985	3458226
1986	4947894
1987	4972191
1988	5128261
1989	4181594
1990	5276587
1991	6796482
1992	5842804
1993	4776722
1994	6096574
1995	5571598
1996	5835257
1997	6232064
1998	4782197
1999	4716704
2000	2697189
2001	2451025
2002	3829433
2003	5034441
2004	4234803
2005	5352875
2006	2075552
2007	5168244
2008	3542088
2009	4234083
2010	7482215
2011	1716927
Mean	4663508
Min	1716927
Max	7482215

According to the decade data, the mean annual suspended load transport was calculated to be 4.66 MST/year. **Figure 4.85** shows the variation of suspended load transport throughout the year. It can be seen that the transport is high during the flood season, while during low flow the transport of suspended loads is expected to be marginal. This result should be considered for design of the headworks, as well as for operation of the hydropower plant.



4.13.2 Amount of Total Sediment

Estimated suspended load and bedload at weir site were added to estimate total sediments in the River. **Table 4.29** shows estimated monthly and annual total sediment load for the period 1961 to 2011 at proposed weir site. **Figure 4.86 and 4.87** show distribution of mean monthly and annual total sediments at proposed site respectively. Mean annual total sediments (1961-2011) comes to be 5.639 MST. It is to be noted that SWHP, WAPDA has reported mean annual suspended sediment in Panjkora at Zulam bridge 37.3 MST (see section **4.11**). This figure is quit higher than the present work. It is recommended to continue sediment measurements at site to firm up these results.

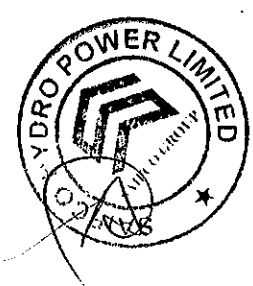


Table 4.29: Computed Monthly Total Sediment Load at Weir Site (Ton)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1961	16577	24313	31103	147002	653067	2709451	3984368	1797589	520602	125231	60225	43867	10113396
1962	20413	15363	19191	64260	257321	1081079	1326831	785547	223009	59047	31523	21303	3904887
1963	15092	11265	20760	92773	408001	1756211	1691471	939513	312194	69369	31595	21466	5371709
1964	16763	13331	20597	83648	574642	1503873	2152905	1117028	376572	64286	25617	19763	5969126
1965	14687	10440	16594	75335	668090	2486136	2374183	1084360	332035	78880	34348	20769	7195856
1966	15756	14453	27913	92061	445490	1964701	1506619	1114730	379251	69776	31715	21293	5683759
1967	16303	11700	14242	66763	404574	1655915	2568754	1144202	386463	60212	30185	21460	6380772
1968	17612	13320	19034	136310	450883	1600763	1999498	1050008	245096	67068	30419	22813	5652844
1969	16478	14081	36102	123946	491099	1825704	2909946	1768819	260233	77881	41215	26991	7592495
1970	19371	14245	17931	116598	623174	1462451	1207711	1056329	485290	83707	36889	24672	5148368
1971	18204	14035	24857	140562	762368	1536710	1009441	847747	195797	48230	25377	17589	4640918
1972	14692	10821	19014	106528	617362	2295371	1995175	1075608	398906	67645	30342	20374	6651836
1973	14692	10530	16878	196418	845319	2205831	1868488	1322474	479818	88314	30304	20347	7099412
1974	14643	11554	28739	156906	396845	1145335	1372770	776959	158475	55569	27082	19476	4164351
1975	14235	11983	14040	96696	1144363	1800184	1671281	1455020	339271	72580	42299	26101	6688052
1976	17607	13501	17186	48314	786246	1594317	2225929	982242	291845	77975	33715	21319	6112195
1977	16103	13680	24915	107190	493128	1304391	1386922	783311	190958	58324	28860	20756	4427535
1978	16818	13191	15429	92078	711938	1727959	1806529	713339	121558	56677	31572	24936	5332024
1979	16468	12604	15023	170609	387816	1680414	2143528	769115	166093	49470	29465	18724	5459328
1980	21502	13489	15491	104549	697874	1678074	1348653	657537	187257	59947	35147	23934	4843454
1981	21686	17670	24728	208192	1125079	1483713	1759757	751521	142206	53912	28867	22269	5639599
1982	17578	14022	15739	72772	401816	705294	823416	759827	99151	44893	30986	25876	3011370
1983	20478	15950	19222	55222	490986	1152547	1320811	960960	281840	66254	40283	28471	4453023
1984	20707	13481	22450	90874	638489	2301986	1273787	1046744	293405	52900	27893	20817	5803532
1985	17653	13254	18843	69139	399822	1123611	1342028	886321	186756	65477	31398	22736	4177039
1986	17987	12971	19979	126396	541225	1591171	2218344	1031183	196173	70019	31924	21169	5878542
1987	19426	17249	24782	165751	645886	1479987	1882996	1184644	401484	81767	42401	26825	5973200
1988	25637	19890	25221	281200	1085003	1738101	1830187	830694	178399	60511	29066	22546	6126455
1989	17856	13367	19159	47819	461463	1739341	1463134	865933	252270	63647	33990	24388	5002366
1990	18976	15620	28304	81310	1360765	1701673	1683329	907292	407946	71642	33404	20969	6331221
1991	18125	17913	29278	105359	538465	2118578	2923155	1535625	524424	91994	40632	30364	7973912
1992	22503	19549	23259	97802	461931	1578919	2566386	1382613	532169	121364	62011	34522	6903028
1993	27553	18643	20937	202287	961997	1502546	1601611	776956	498479	96575	44600	36078	5788261
1994	26729	21159	34674	98410	719588	1940815	2572100	1228035	406857	83109	45263	33815	7210555
1995	19085	18446	22772	92444	574806	1742413	2552831	1197267	212834	77605	34737	24303	6569543
1996	19055	16012	24040	157976	521826	2304210	1969891	1326249	398394	95775	42253	25086	6900767
1997	31543	23149	24033	170550	471196	1819891	3144509	1210939	267694	81238	35519	22727	7302989
1998	16274	13943	16922	243058	892750	1119898	2207214	771274	350901	71845	37291	20208	5761575
1999	15450	13174	20273	193827	1028743	1826988	1403682	771477	268668	67645	34471	22616	5667013
2000	16502	11410	17924	146492	911365	802706	722995	404521	156214	64424	28263	18176	3300993
2001	13254	12416	20067	65784	630288	811205	749045	500507	150670	54206	28854	16810	3053106
2002	13719	11145	30563	180598	903216	1637811	958288	642762	157908	55914	26921	16972	4637817
2003	12195	10756	19908	180925	726042	2167339	1808121	678138	251830	76690	42946	25521	6000408
2004	20000	13361	48470	223796	1079558	1626552	1031523	677252	189026	68651	55047	40453	5073688
2005	16640	45980	1483086	1041124	872456	1400548	981324	282111	70428	47937	27784	20224	6269643
2006	25815	65948	90340	325646	720852	214410	183186	515137	100708	32521	63988	61987	2400540
2007	82479	119153	1027298	1528860	1190367	976894	654906	286248	148086	54979	31924	38060	6139256
2008	19972	12676	115553	1006033	1297185	1006820	410237	254497	44890	26671	15347	29949	4239831
2009	25452	51787	271807	771524	1475863	1023356	1006678	411006	66551	18589	27356	18391	5168360
2010	9464	138027	350675	426462	765437	588476	5192993	574820	235962	64972	16263	10312	8373864
2011	11205	68468	208628	358662	669949	307686	137580	100165	71718	39312	35170	9053	2017595
Mean	19510	22441	88901	216369	771451	1540242	1743648	901847	266566	66926	34799	24542	5639243
Min	9464	10440	14040	47819	257321	214410	137580	100165	44890	18589	15347	9053	2017595
Max	82479	138027	1483086	1528860	1475863	2709451	5192993	1797589	532169	125231	63988	61987	10113396
St Dev	9943	25067	250510	279250	281703	527400	909159	365623	132711	19779	9751	8462	1511375



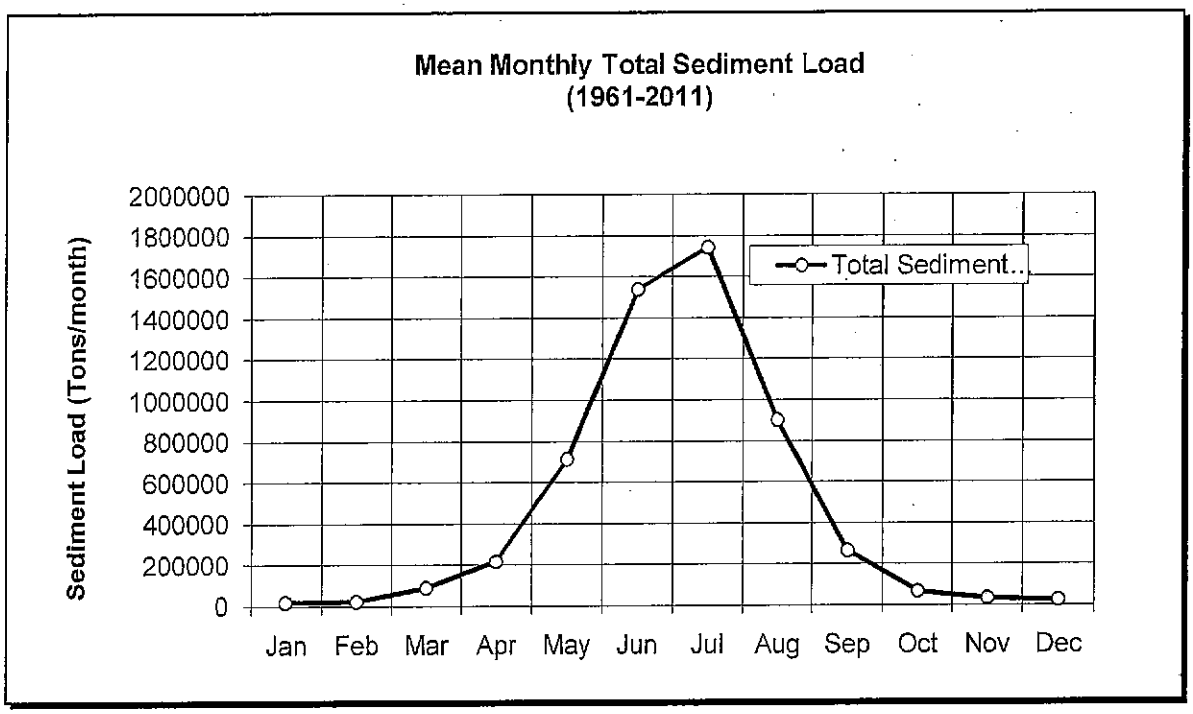


Figure 4.86: Distribution of mean monthly total sediment load

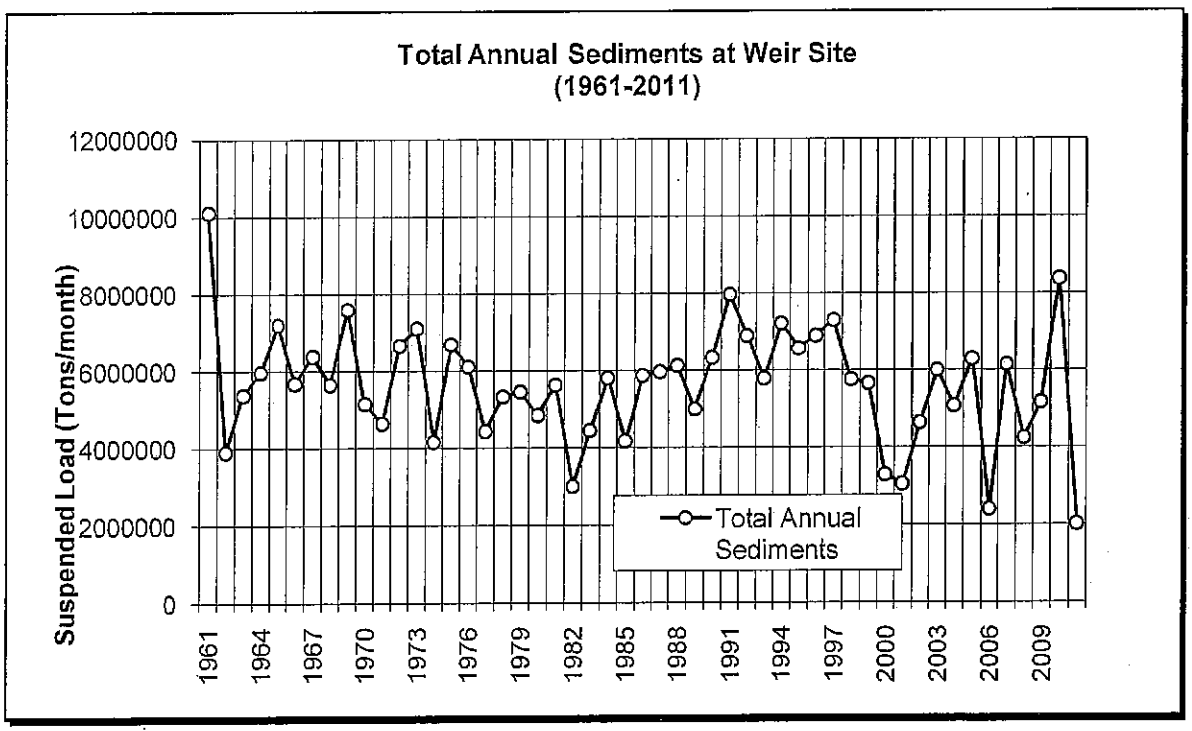


Figure 4.87: Distribution of annual total sediment load

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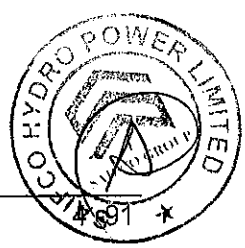

CHAPTER 5

GEOLOGY, GEOTECHNICAL INVESTIGATIONS & CONSTRUCTION MATERIALS

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GEOLOGY, GEOTECHNICAL INVESTIGATIONS & CONSTRUCTION MATERIALS

5.1 Background

Shigo Kas Hydropower project is a low head scheme and has been identified by PEDO/GTZ during the Master Plan studies preparation of the Northern Areas of Khyber Pakhtunkhwa in 1992-93 and falls within the Region No.7 "Dir Kohistan".

The project area is located 10 km downstream from Timergara Town, where Panjkora River becomes narrow again and passes a bottleneck. This bottleneck is located 13 km upstream the Junction of Panjkora River with Swat River. The project area got some affects at many places by the earthquake of October 08, 2005 and later disastrous floods in JULY 2010. The existing unpaved track which leads through agriculture fields which is the only access to weir site and upstream area is damaged at several places due to natural calamities.

PEDO AND GTZ carried out preliminary studies on the project in 1992, but details were not executed regarding geotechnical investigations for subsurface details and detailed geological mapping with reference to landslides and mass movements along Hydropower project. After careful review of the available geological and geotechnical reports, proposed layout of the Hydropower project and field observations, surface and sub-surface geological and geotechnical / laboratory investigations were identified and planned by the Consultants. All of the planned activities have been done with required field and laboratory testing keeping in view all requirements of the design. Geological mapping along Hydropower project area has been completed for reference see **Figure No. SKG-002-01 to SKG-002-22** sheets, attached with this report, Geological cross sections along all of the important structures are also included in the same figures for subsurface evaluation and further improvements have been done now after receiving the entire field and laboratory testing results. These all information has been provided to collect useful data for establishment of design criteria and layout planning and further parameters of geotechnical design have been evaluated based upon receiving results of field and laboratory. Geotechnical design parameters are included in chapter 6 of Geotechnical design.

5.2 Physiography of the Project Area

Shigo kas Project area lies in low to High Relief Mountains. The overall drainage system is "dendritic" i.e. drainage pattern is characterized by irregular branching in all directions with the tributaries joining the main stream at all angles. The project weir axis passes along the Shigo Kas and powerhouse site is located at left bank of Panjkora River near Utala Village.

The individual geomorphic forms of the region include natural rock slopes, scree, colluviums, debris covered slopes, debris – flow fans, somewhere in reservoir area alluvial fans and river terraces.

Natural rock slopes vary in form, depending upon the lithology and discontinuity patterns. Slopes angles vary from 25° to vertical depending upon the state of weathering and fractures.

The scree slopes and debris slopes result from accumulation of rock fragments (scree) and debris. The scree is a result of in place mechanical weathering. Whereas debris/Colluviums come from rock falls and in most of the areas the sliding zones consist of glacial moraines/Colluviums/Secree. Slope angles vary from 20° to vertical. In general scree/Colluviums slopes consists of big boulders and pieces of intact rock during the avalanching the fines which are intermixed with this type of matrix.

Along Panjkora river terraces characterized by flat to gently sloping land are situated at a level above the present flood plain, represents the previous levels of Panjkora River. These terraces consist of variety of valley infill materials intermix with glacio-fluvial and scree deposits.

Natural vegetation is largely confined to the lower part in the valley. The high mountains have thick vegetation as compare to the downhill. Small bushes and local trees are widely spread along the mountains. The fruit trees are rare. Wheat and maize are the main crops.

The population in the project area is sparsely distributed in the valley and along the Shigo Kas, Bagh, Sar and Utala areas. People living in the area are mostly engaged in the services and business professions in addition to agricultural activity and major population is serving in abroad especially in Middle East countries. Most common business of the area is transportation and selling the vehicles. Those who are living in the villages are generally poor but well hospitable. Most of them are farmers cultivating small holdings of land and few are running small shops of different kinds. Fishing is common along the Panjkora River.

Few springs and wells are the main water source of the entire project residents and well established Nalla and springs are present along the proposed tunnel area at down and up slopes as shown in attached figures of surface geological mapping.

5.3 Arrangement of this Report

This final findings report summaries review of the available literature on the Shigo Kas Hydro Power Project, brief comparison and joint discussions with the help of available data, the field investigations have been executed by Consultants for the scheme and Consultants have now been done all essential assessments for geotechnical parameters which have currently been

used in the geotechnical design. Geological study along the road has completed and its results are included in this final volume of report findings including detailed geotechnical investigations. The geotechnical investigation plan incorporated exploratory drilling, in-situ testing, disturbed and core sampling, laboratory testing, geologic logging, test pit excavations, seismic refraction survey along entire scheme. All activities of geotechnical investigations with final findings are being addressed in this final geotechnical report, geological mapping, joint study and rock mass characterization with details of all so far geological and geotechnical studies are part of this report.

5.4 Sources of Information

The available information at the start of the assignment was gathered from various agencies like PEDO, Geological Survey of Pakistan (GSP), and Electra Consultants main library also provided some useful documents.

5.4.1 Potential Hydropower schemes study by PEDO/GTZ (Year -1992)

This assessment Report was the main source of information and documents provided useful information for the current project pertaining to Feasibility studies. This report comprises all relevant sections with brief descriptions covering all the major events and aspects of the Project.

Numerous drawings and annexure have been obtained from this report. These include some very useful information regarding geological and geotechnical background of the project area but ground geotechnical investigations are lacking but important references of this report have a role of contribution in the present stage of feasibility studies.

5.4.2 Stratigraphy of Pakistan –Northern Area- Published Map and Book

The book and maps (Prepared by Geological Survey of Pakistan, published in 2008), comprise of different sections with details on regional geology and general geological history of the project area. The publication provided useful forehand information for the current Project.

5.5 Regional Geology

Northern Areas of Pakistan is well known for its three world famous mountain ranges viz., the Karakoram, the Himalayas and the Hindukush. The development of these mountain ranges is closely connected with the tectonic evolution of the domain lying between the Karakoram/Eurasian plate in north, and the Afro-Arabian and the Indo-Pakistan plates in south in Paleozoic time (Jaukovic, 1984).



The Karakoram-Kohistan terrain is part of the Karakoram Range. Geological setting is displaced by the process of continental collision, rock accretion, metamorphism, uplift and magmatic cooling during the past 100 Ma (Coward et al., 1982).

The suture zones, which separate the Indo-Pakistan and the Karakoram/Eurasian continents is divided into two parts, the Northern Suture and/or Main Karakoram Thrust (MKT) and the Indus Suture and/or Main Mantle Thrust (MMT).

5.5.1 Tectonic Settings

The Himalaya, Karakoram and Hindukush ranges of Pakistan are a dilemma due to their complex geology in modern plate tectonic theory. These northern mountain ranges of Pakistan (Brad et al., 1976: Ghazanfar et al., 1991) are the result of uplift caused collisional tectonics. Collisional tectonic history can be briefed by two major collisions occurred at 85 Ma between Asian plate and Kohistan island arc (Searle et al., 1999; Tahirkheli et al., 1979) and at 65 Ma between Indian plate and Kohistan island arc (Khan et al., 2009; Spencer, 1994; Chaudhry et al., 1994; Smith et al., 1994). This collision characterized by deformation, crustal thickening and surface uplift. First collision developed the Karakoram and Hindukush ranges. As a result of collision occurred at 65 Ma (Spencer, 1994; Chaudhry et al., 1994; Smith et al., 1994), Himalayas developed as young collisional orogen. The major tectonic elements of this orogen can be enumerated as Asian landmass (Searle et al., 1999), Northern suture/Main Karakoram Thrust known as MKT (Ghazanfar, 1993; Tahirkheli et al., 1979), Kohistan island arc (Khan et al., 2009, 2012, 2013; Khan et al., 2009; Chaudhry et al., 1994), Indus suture/Main Mantle Thrust known as MMT (Khan et al., 2012, 2013; Khan et al., 2009; Tahirkheli et al., 1979) and Indian plate (Ghazanfar, 1993; Chaudhry et al., 1994), from north to south respectively. Kohistan island arc is divisible into two blocks, Ladakh block and Kohistan block in east and west of Nanga Parbat syntaxis respectively. Furthermore, in the south of Kohistan island arc/MMT, Ganser (1964) subdivided the Himalayas (Indian plate) into Trans Himalayas, Higher Himalayas, Lesser Himalayas and Sub Himalayas from north to south respectively. Southern margin of Kohistan island arc is characterized by the amphibolites and ophiolites in the hanging wall of MMT (Khan et al., 2009, 2012, 2013) while the northern most margin of Indian plate is marked by the presence of gneisses metamorphosed to amphibolites and locally upper amphibolites facies or kayanite-silliminite grade (Chaudhry et al., 1994; Spencer, 1994).

5.5.2 General Geology

The project area lies at the margin of Kohistan island arc and Higher Himalaya near the Main Mantle Thrust, MMT. The southern part of project area is comprised of Higher Himalayan rocks while the northern part comprised of rock of Kohistan sequence.

5.5.3 Higher Himalayan Rocks

Higher Himalayan rocks are comprised of granite gneisses and its cover metamorphosed amphibolites and locally upper amphibolites facies (Chaudhry et al., 1994; Spencer, 1994). Chaudhry et al., (1994) assigned the nomenclature to these gneisses of basement and cover sequence as Kel group and Shardra group in upper Neelum valley, Purbinar group and Burawai group in upper Kaghan valley, Alpurai group and Slampur Formation in upper Swat valley. These units further extended westward to Dir, Bajaur and Afghanistan (Chaudhry et al., 1994). Two distinct varieties of gneisses can be characterized in the project area.

5.5.4 Granite Gneiss

It is light grey, dirty grey in colour and medium to coarse grained in texture. these gneisses are intruded by some younger tourmaline bearing lecugranites and pegmatites (Chaudhry et al., 1994). Gneisses are metamorphosed to amphibolites facies or Kayanite-silliminite grade and basically comprised of garnet rich and garnet free amphibolites. The rock is brittle and hard enough. It occupies the southern side of map area. Mostly alignment tunnel is passing through the gneiss and powerhouse and tailrace structure will be built on the gneiss rock. The rock is exposed at anticline axis and a flank.

5.5.5 Schistose Gneiss

It is dirty grey on weathering surface and white to light grey on fresh surface. Felsic and mafic bands are commonly found. Gneisses are generally folded, well bedded and having good exposure in the project area along the cliff forming deep "V" shaped valleys. The river cut the rock across the strike of beds in the vicinity of weir site area. Joints, fissure and cracks are found in the rock. The rock is moderate to hard for cutting.

5.5.6 Kohistan Sequence

Rocks of Kohistan sequences are found in the north of MMT and it is comprised of ultramafics-mafic rocks of ophiolites and Kamila amphibolites and volcanics.

5.5.7 Amphibolites

The amphibolites are found in the northern side of mapped area. These amphibolites are westward extension of Kamila amphibolites unit (Khan et al., 2009, 2012, 2013) of southeast Kohistan. Amphibolites are dirty grey to greenish in colour. These rocks have a fine to medium grained, hypidiomorphic and granular texture. Allotriomorphic and idiomorphic textures have also been observed. Amphibole, plagioclase, quartz and orthoclase are the main constituents while garnet, epidote, chlorite, sphene, calcite and biotite are the accessories. Towards south of

Dir, these amphibolites are much more uniform in texture (Chaudhary et al.,1984). The amphibolites are intruded by some acidic to intermediate composition bodies which are called as Thak intrusive complex in Kamila area west of Nanga Parbat syntaxis (Khan et al., 2009, 2012, 2013). The exposures show good bedding and mylonitization at places. The contact of the rock is faulted with the southern schistose rock. Calcite and quartz veins are abundant and the thickness ranges from few centimetres to some meters.

5.5.8 Scree

It is comprised of fallen materials by gravitational force, rock chips angular to sub angular usually found at the foot of vertical to sub vertical cliff or fur. It contains soil, clay, silt material drown/flown by weathering agent.

5.5.9 Alluvium

It comprises of sand grain, clay soil particles, organic materials and silt.

Tectonic Map of the Project Area is shown in **Figure 5.1** and General Geological settings are shown in **Figure 5.2.**

Regional Geological Map is shown in **Figure No. SKG-002-01 to SKG-002-022** and its Cross Section are shown in **Figure No. SKG-003-01 to SKG-003-03**

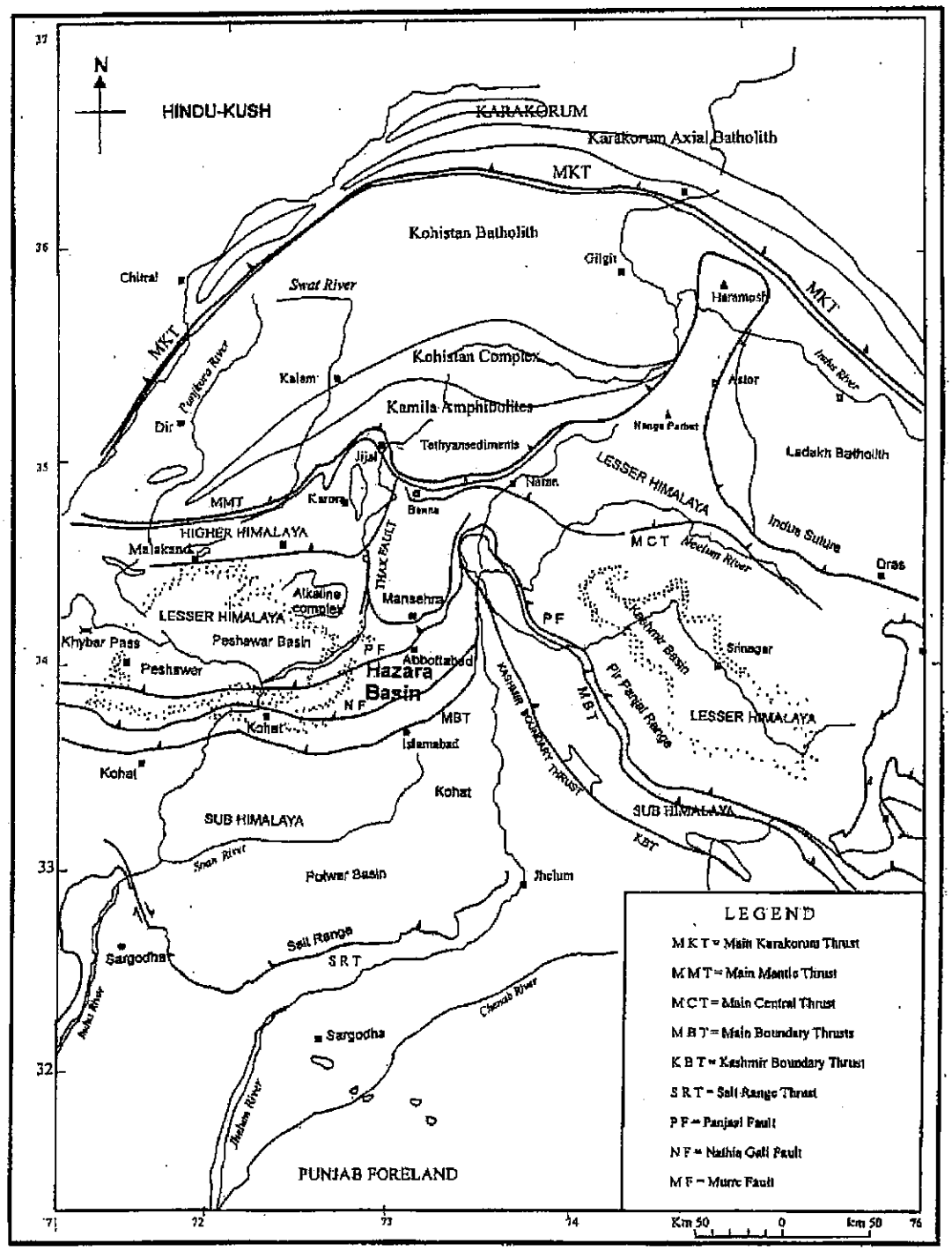

Figure 5.1: Tectonic Map of Pakistan (After Ghazanfar and Chaudhry, 1996)

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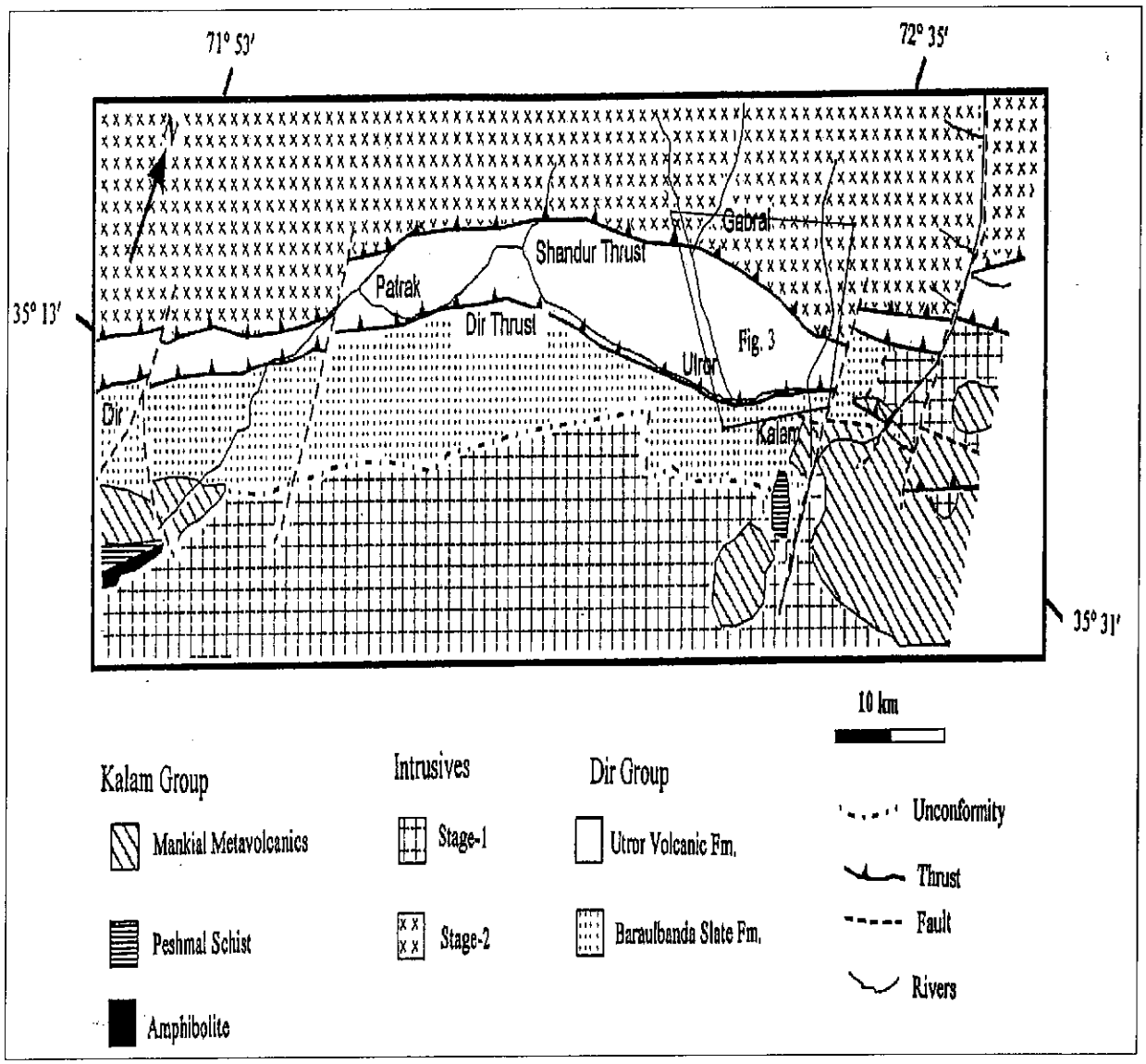


Figure 5.2: Geological Map of Dir Utror Area (after Sullivan et al., 1993)

5.6 Geology of the Project Area

Following are the main units of the soil / rock in the project area

Stratigraphic sequence of the project area consists of Indian mass rocks of lower Sawat Buner group mainly consists of granitic gneiss (Chakdara Granite Gneisses), it is granite with siliceous schist layers on the peripheries. These rocks are medium to coarse grained with association of Schistose Gneisses and Quartz mica Schist phyllitic gneiss, Phyllite and quartzite intercalations have been observed in the project area at higher elevations.

Major rock group of the project area are Granitic gneiss and widely spread along weir, Intake area, Sand trap, intake of tunnel, along the tunnel and power house areas. Poorly to well

outcropped in and around Tunnel and outlet portal, in most of the reaches along Tunnel, rock of the area is well exposed and widely distributed under thin to thick cover of Secree/Colluviums and terrace deposits, details are described in next relevant sections.

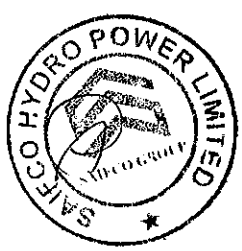
5.6.1 Granite Gneiss

The geological mapping indicates that the rock is light grayish white to whitish grey in colour at fresh surface and pale brown at weathered parts, coarse grained crystalline, banded metamorphic rock of Granitic composition. It may be defined as primary igneous Gneiss of Granitic composition very strong to strong in strength. Joint spacing is 60 mm to 200 mm i.e. very small to small. Mostly joints are open and somewhere filled with silty clays / clayey silt. In most part of the scheme, joints are dry but at some places joints are wet. Seepage can be observed at many points from the joints along the entire scheme. Some joints are filled with quartzite and calcite veins.

Weathering rate in some places is moderately weathered to highly weathered; however, maximum part of this rock along the components is slightly weathered. Three to four sets of joints have been observed and recorded from some good outcrops. Spheroidal weathering is common in the massive rock. Few of shear zones have been observed and marked within project area rock, which is the indication of faulting and evidences of intense folding at around weir axis along the sand trap and intake of tunnel areas.

In shear zones green mixture, due to chloritization of biotite is commonly present. Entire project area strike is North West generally and dipping to 15 to 75 degree North East. At section of same rock along the road at rock dip is 15° NE and slope is to upstream side which is reflecting favorable section and is favorable for rock cutting but other issues are included in the next relevant sections. At the upstream of weir axis shear part with highly weathered section of rock at left bank of Panjkora River has been marked and its strike is N80°W with dip of 65° NE. This shear zone is not critical regarding any seepage under the structures because of very tight conditions of joints and favorable strike and dip trend. Geotechnical design parameters have been discussed in chapter 6 of this report.

The Gneiss is a coarse grained irregularly banded rocks with discontinuous rather poorly defined schistosity. The gneissic fabric reflects predominance of Quartz and Feldspars and micaceous minerals. Gneisses are product of high grade regional metamorphism.



5.6.2 Over burden/Moraines/Colluviums

1) **Fluvial Deposit**

River bed is composed of medium to coarse grained sand, gravel, pebble, cobble even boulders. These materials belong to all three type crustal rock but especially at weir metamorphic with few igneous boulder and gravel material are dominated. Riverbed of Panjkora River itself is narrow to sufficiently wide at places. Hence deltas and meander are happening to exist at different area.

2) **Scree / talus/Colluviums/Debris**

These deposits are loose to semi consolidated material are present along the foot of mountain. These material are composed of angular to sub angular even rock fragments and chips. These deposits angular in shape have occurred by gradational action vertical to slope surface of the area. These deposits are still active at present time.

3) **Terraces/River Deposits/Cultivated Land Terraces**

Loose to semi consolidated deposits of alluvial, colluvial, and glacial origin occur at places throughout the region. Remnants of high and low level terraces exist along the valley sides and more recent gravel and boulder beds occur along Panjkora River.

Alluvium deposits of project area are mainly composed of Silty Sandy gravels, cobbles and boulders. Most of this deposit is heterogeneous in nature. At some places it is stratified due to gravels and some patches of intruded rocks or may be due to some ancient glacial activity. At some place, the stratification shows its ancient alluvium history. However, rather consistent usage of the term "alluvium" throughout its history makes it quite clear that alluvium is intended to apply to the deposits of comparatively recent time.

Cultivated land of the project area is flat to medium terraces on slopes composed of Silty Clayey Sand/Clayey Sandy Silt with gravels and occasional boulders at the surface.

The geological and geotechnical aspects of various components of the scheme have been fixed and considered during the present stage of geological/geotechnical investigations, with their possible solutions are individually described: And received details are incorporated based upon received geotechnical investigation results. Geological mapping and geological cross sections along all of the project components are the part of this report and further refinements have been done after receiving all of the field and laboratory results. After receiving all of the field geology,

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and geotechnical investigations with laboratory results, final geotechnical design parameters have been fixed with main emphasis has been taken for rock mass characterization along the tunnel area which is included in chapter 6 of this final report.

5.7 Geological Mapping of the Project Area

For the feasibility studies of the project, geological mapping of the project area has been carried out on a scale of 1:2000 for all project components and is presented in **Figure. Nos. SKG-002-01 to SKG-002-22** sheets and While geological cross sections along all of the structures are shown in **Figure No. SKG-003-01 to SKG-003-04.** Following major units and features have been described in the project area.

1. Granite Gneiss/Schistose Gneiss/Quartz mica Schist (Rock)
2. Overburden /Few Moraines Evidences/Colluviums/Scree
3. Terraces / River Deposits/Cultivated land terraces
4. Shear and Faulted zones
5. Sliding Zones

As identified, geological mapping has been done in the area upstream of proposed weir site, around weir, Gravel trap and Sand trap also, along the intake of tunnel, along tunnel stretch, Surge shaft, high pressure tunnel/Penstock and around power house area. All components have been mapped in detail covering important geological features like colluviums/Alluviums fans, terraces and river deposits, any sliding zones, discontinuity data, rock mass characterization, scan line survey of rock outcrops and identification of seepage / perennial and non-perennial Nalla along the tunnel and entire Hydro Power scheme.

Detailed geological mapping was carried out at power house with special reference to determine if there would be any potential land slide risks along the cut slopes of Power house. All possibilities were drawn on the geological map. Chances of land sliding are very rare due to very intact rock exposures at power house locations with 45° to 55° slope angle in outward direction of Power house. Detailed mapping has also been carried out along weir, power intake, sand trap, headrace channel. Headrace power Tunnel intake, along tunnel route, surge tank, high pressure tunnel/Penstocks and power house area especially to check potential for any landslides. There are some ancient slides and still active as well as some dormant ones but potential land sliding zones have also been established on geological map and remedial measures with safe cut slopes are described in chapter 6 of geotechnical design of this final report. Land sliding chances are almost negligible along about all of the structures except one of the big ancient history of Colluviums sliding along previous location of sand trap area has been observed and recorded, this location of sand trap area now is the part of tunnel, there are

very little chances of land sliding, only few colluviums movements have been observed but it is not much critical keeping in view the surface conditions and previous history of the area. Further details are incorporated in the next relevant sections and regarding safe cut slopes comprehensive details are included in relevant section of chapter 6 of geotechnical design.

Along weir axis, Power intake, sand trap area, headrace channel, inlet portal of headrace tunnel at left bank of Panjkora river, along tunnel route, surge shaft area and along High pressure tunnel/Penstock and at power house site details have been picked up regarding scanline survey for discontinuity data evaluation. Rock mass assessment has been made in accordance with the international standards. In discontinuity study number of potential joints with possibility of any failure and direction of failure is incorporated in the next relevant sections. Few analysis are included in this final geological & geotechnical investigation report but further detailed analysis are included in section of geotechnical design where details of rock mass characterization along the tunnel area are well elaborated with design considerations of all field and laboratory testing results of feasibility stage of completed geotechnical investigation works.

Shear zones have been picked at different locations and are marked accordingly as shown in geological mapping figures.

Through detailed surface geological mapping of the Shigo Kas valley, Rock, terraces/river deposits and scree features were also be picked up; land sliding zones have been picked and mapped for the better approach of understanding of any possibility of future hazard, with remedial measures. Along the components of the hydro power scheme, land sliding features have been picked up and details are included in next relevant sections but software model analysis have been done and models with interpretations are incorporated in geotechnical design section of this final report.

5.8 Discontinuity Data along Project Components

The behavior of rock mass depends upon structural attitude and the conditions of the discontinuities like tectonic / structural joints present in the strata of project area.

Discontinuity data collected in the field have been analyzed by computer software, Geo-orient. Rose diagram has been developed independently to check consistency of dominant joint sets in the weir area, along Power Intake, Sand trap, power channel and inlet portal area. While in geotechnical design section further exercises have been done by using softwares DIPS, Wedge, N-Wedge, PHASE, CADAM, GEO STUDIO 7, ROCK DATA and ROCK PLANE.

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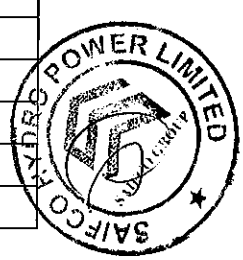
5.8.1 Discontinuity Data of Weir, Power Intake, Sand trap, Power channel and Inlet portal Area.

Joint sets measured in the field along downstream and upstream of weir axis and along all above mentioned structures and are presented in **Table 5.1**.

Table 5.1: Joints Data along above mentioned structures

Strike	Dip
N40W	30NE
N60W	69NE
N55W	66NE
N65W	60NE
N25W	15NE
N53W	67NE
N45W	52NE
N60W	50NE
N59W	62NE
N50W	47NE
N61W	60NE
N47W	39NE
N58W	52NE
N63W	57NE
N55W	82SW
N75W	57SW
N80W	35SW
N71W	50SW
N68W	59SW
N65W	61SW
N75W	52SW
N80W	55SW
N78W	57SW
N64W	65SW
N58W	62SW
N69W	54SW
N76W	70SW
N79W	68SW
N70E	80NW
N60E	77NW
N75E	80NW
N60E	65NW
N58E	69NW
N67E	66NW



Strike	Dip
N62E	72NW
N70E	70NW
N62E	65NW
N71E	74NW
N66E	70NW
N69E	80NW
N75E	61NW
N64E	79NW

Rose diagram along weir axis to Inlet portal structure are shown in the **Figure 5.3**.

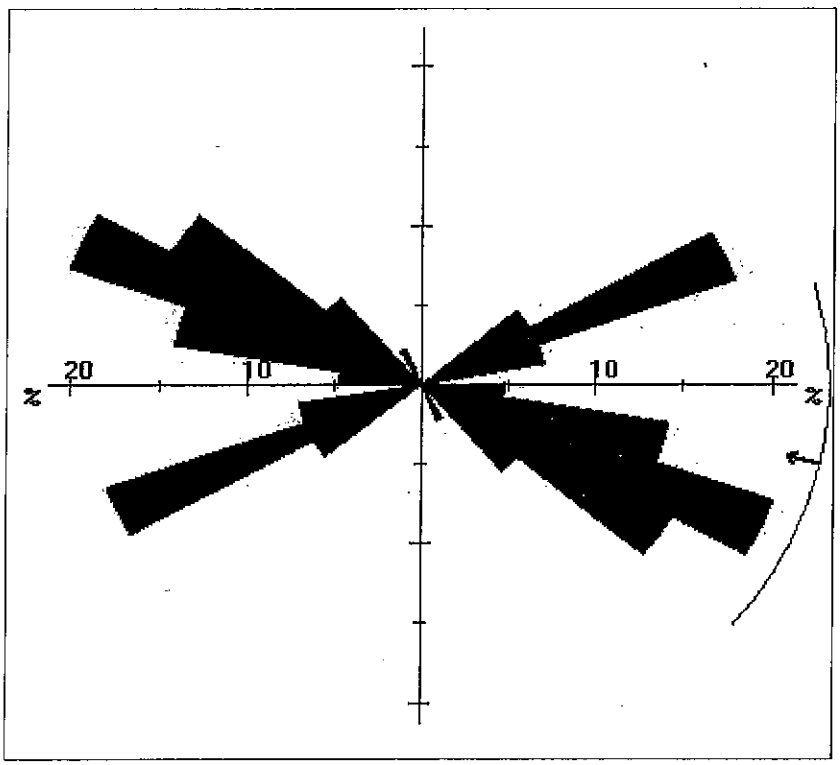


Figure 5.3: Rose Diagram along Weir Axis

Three sets of prominent joints have been observed in the area from weir axis to Inlet portal and mean resultant direction is North-West dipping towards North-East. Second prominent set of joint is in direction of North-West dipping towards South- West; third set of joint is North-East dipping North-West

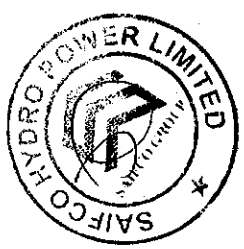
Mean resultant direction of strata in this area is N76W dipping in North-East from average 45° to 55°. Further analysis has been done and are included in geotechnical design section of the report.

5.8.2 Discontinuity Data recorded along Tunnel area.

Joint sets measured in the field along Tunnel alignment are presented in the **Table 5.2.**

Table 5.2: Joints Data along Tunnel Alignment

Strike	Dip
N50W	57NE
N30W	48NE
N27W	49NE
N47W	50NE
N44W	54NE
N38W	47NE
N38W	41NE
N29W	40NE
N32W	40NE
N55W	43NE
N57W	45NE
N55W	65SW
N58W	62SW
N59W	54SW
N71W	70SW
N71W	68SW
N62W	53SW
N67W	59SW
N58W	66SW
N60W	66SW
N55W	61SW
N35E	74NW
N40E	70NW
N39E	80NW
N45E	61NW
N50E	79NW
N52E	54NW
N54E	53NW
N57E	59NW
N61E	52NW
N65E	63NW



Rose diagram along Tunnel alignment is given in **Figure 5.4.**

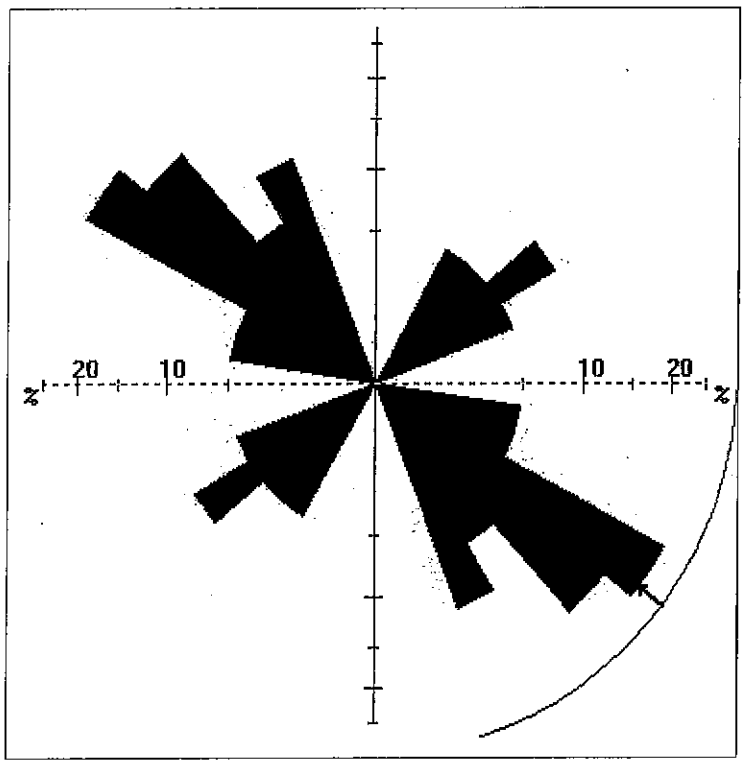


Figure 5.4: Rose Diagram along Tunnel alignment, preferred direction is N53W, 48NE

Three sets of joints have been observed in the exposed rock along Tunnel alignment. Mean resultant direction is North-West dipping towards North-East. Second prominent set of joint is in direction of North-East dipping towards North- West. All the joints along tunnel have favorable dips for excavation of the tunnel and tunnel drive is almost along the foliation plains which is also another favorable factor for tunnel drive, at inlet area excavation drive will across the strike while about after mid of the tunnel area tunnel drive will be along the foliation of rock. Further detailed analyses have been carried out and are appended in chapter 6 (Geotechnical Design) of final report volume with comprehensive evaluation along the tunnel area.

Joint sets arrangements with model analysis have been tied up with rock mass characterizations along the entire tunnel route.

Third joint of dipping South West trend has little hazardous due to its inward direction to excavation but joints spacing is narrow and very tight and very little chances of any slip along this direction. But findings of geotechnical design section will be followed against any failure and for any remedial measures and support systems.

5.8.3 Discontinuity Data along Power House area (Option-II)-Final layout

Joint sets measured in the field along power house area are presented in the **Table 5.3.**

Table 5.3: Joints Data along Power House area (Option-II)

Strike	Dip
N20W	45NE
N18W	44NE
N25W	45NE
N20W	43NE
N30W	48NE
N27W	49NE
N28W	50NE
N21W	54NE
N21W	47NE
N30W	41NE
N24W	40NE
N16W	40NE
N20W	43NE
N19W	45NE
N55W	58SW
N53W	60SW
N50W	61SW
N48W	55SW
N45W	58SW
N50W	54SW
N55W	59SW
N59W	62SW
N60W	65SW
N62W	53SW
N58W	59SW
N58W	66SW
N60W	66SW
N55W	61SW
N25E	55NW
N15E	54NW
N35E	55NW
N30E	63NW
N33E	65NW
N31E	68NW
N32E	68NW
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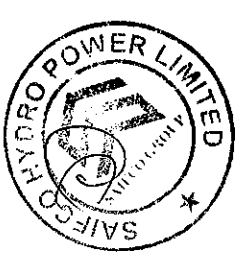
N25E	57NW
N20E	54NW
N18E	53NW
N15E	59NW
N21E	52NW
N24E	63NW



Rose diagram along Power house area is given in **Figure 5.5**.

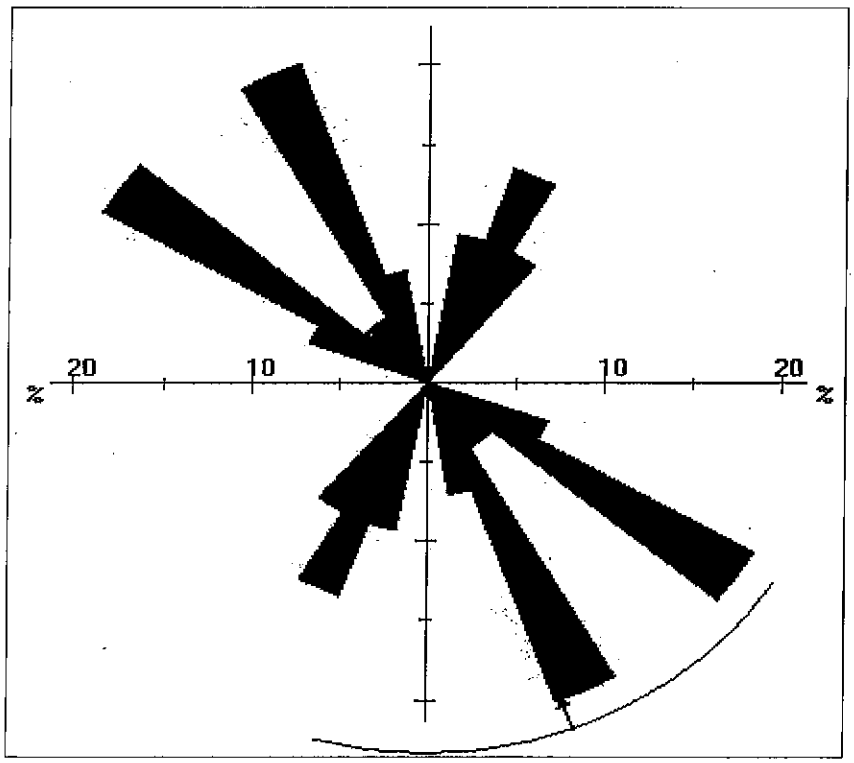


Figure 5.5: Rose Diagram along Power House area, preferred direction is N25W, 50NE and overall trend of rock is in NW dipping NE.

Three to four major and minor sets of joints have been observed in the exposed rock along power house area (Option-II) at left bank of Panjkora river near Utala village. Mean resultant direction is North-West dipping towards North-East. Second prominent set of joint is in direction of North-West dipping towards South- West. Third joint has trend of North-East dipping North-West and forth joint has trend of North -East dipping towards South – East, Slope failure analysis have been carried out in geotechnical design section with the help of different softwares as mentioned above and after receiving all testing results and model analysis safe cut slopes have been designed and are included in chapter 6 of final report. Such analysis by different softwares are describing all details and characteristics of all joint sets and safe cut slopes would be followed for excavation of Penstock area and finally proposed power house site as called option-II. During detailed design stage further comprehensive analysis are strongly recommended for re assessment of safe cut slopes as recommended in geotechnical design section and land acquisition must be followed accordingly with 25 % additional area keeping in view any possibility of abnormal zone in construction stage.

5.9 Geotechnical Investigations

5.9.1 General

The studies were aimed at providing the required surface and sub-surface information about the Rock, Overburden materials/Colluviums, terraces / river deposits (Alluviums) and Scree materials, sliding zones and the rock strata at the significant structures in the Project area and to develop the geotechnical design parameters for all the structures and most important part of this stage of study is to define the structures at sound and safe areas regarding geological and geotechnical conditions.

5.9.2 Field Investigations

Drilling activities commenced in 1st week of January, 2013 and was completed in February, 2014 and during this time about one year of investigations all planned activities have been carried out according to planned investigations in connection total 389 meters drilling in nine drill holes at all project components was done with all of the planned seismic refraction survey. Drilling activities including all required field and laboratory testing was done at weir, power intake, sand trap, intake of power tunnel, in tunnel area, near present location of outlet portal/Surge shaft, near along penstock area and at power house location. Drillings were initially planned at both options of power house but later after different evaluation analysis and studies power house option-II is selected and approved for further studies. Drillings at outlet portal and along penstock area was carried out along alternate option of sand trap at power house side instead of presently final layout where sand trap is at weir side. Accordingly as shown drillings of bore hole 07 & 08 (Option-II) now will be considered same at outlet portal and along penstock keeping in view the surface geological mapping. Around power house area bore hole # 09(Option-II) has been planned and executed, location of all drill holes are shown in figures of surface geological mapping and are attached.

First designed exploratory drilling comprised 14 boreholes / drill hole with 620 m of drilling quantum at both of the power house locations. But later after approval and better technical evaluation of power house option-II drillings and other all required field and laboratory testing was focused on the power house option-II and total 390 meters drilling with nine numbers of bore holes have been finalized and finally executed. Seismic refraction survey has been done accordingly and is attached with this report as **Annexure-F in volume 3** including interpretations.

The borehole / drill hole, test pits, trenches locations have been marked on the ground with the help of Total Station in areas of all structures and are shown in surface geological mapping figures. Final interpretations of all geotechnical investigations have been prepared and

executed activities are included in the final report with interpretations and technical evaluation of each structure. Quality characteristics have been discussed and included in section of geotechnical design.

The drilling program consists of vertical/Angle drillings; in-situ testing, sampling, laboratory testing and absolute geologic logging was carried out at site with the help of experienced geologists of Consultants. With the submission of this report, all of the planned geotechnical investigations have been completed and results are discussed in the next relevant sections of Chapter 5 & 6.

Corresponding of drillings, required laboratory testing was carried out from Central material testing laboratory (WAPDA) and results are attached as **Annexure-C & D Of Volume 3** of this report. Final interpretations are concluded by received laboratory results for different geotechnical design parameters of the project components.

Consultants has monitored all of the field and laboratory testing with preparation of testing programmes as per requirement of the study from start to end of investigations. After receiving all of the field and laboratory testing results, final interpretations with recommendation and conclusions are the part of final report as discussed in chapter 5 & 6 of this volume. **Tables 5.4 to Table 5.10** are showing proposed Testing Programs. **Table 5.11** is showing all of the planned Geotechnical Investigations for Shigo Kas Hydropower Project.

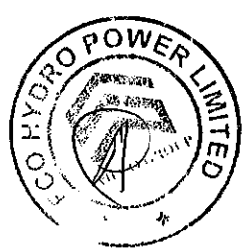


Table 5.4: Proposed Testing Programs

Table-5.4

SHIGO KAS HYDRO POWER PROJECT
LIST OF LABORATORY TESTS TO BE PERFORMED ON SELECTED SAMPLES

Description of Samples					Tests to be Performed								
Borehole	Depth (m)	Type of Samples	Location of Samples taken from	Material as per Log	Point Load	Density of Rock	Porosity of Rock	Direct Shear tests	Unconfined compressive strength	Thin Section Study(Petrographic Analysis	Triaxial Compression Test	Chemical Analysis of Rock sample for sulphate content	Modulus of Elasticity/Poission's Ratio
BH-01	3.5 to 5.0-RQD pieces of rock	Core sample	Weir Axis-Left Bank	Schist/Schistose Gneiss	1	1	1	1	1	1	1	1	1
BH-01	15 to 16.5 m-RQD pieces of rock	Core sample	Weir Axis-Left Bank	Quartz Mica Schist	1	1	1	1	1	1	1	1	1
BH-02	7.5 to 9.0 M-RQD pieces of rock	Core sample	Weir Axis-Right Bank	Quartz Mica Schist	1			1	1	1		1	1
BH-02	15 to 16-M-RQD pieces of rock	Core sample	Weir Axis-Right Bank	Quartz Mica Schist	1		1	1	1	1	1		
TOTAL TESTS TO BE PERFORMED					4	2	3	4	4	4	3	3	3

Note:
All tests are to be performed as per defined standards and provided scope of works

Table 5.5: Proposed Testing Programs

Table-5.5

SHIGO KAS HYDRO POWER PROJECT
LIST OF LABORATORY TESTS TO BE PERFORMED ON SELECTED SAMPLES

Description of Samples					Tests to be Performed								
Borehole	Depth (m)	Type of Samples	Location of Samples taken from	Material as per Log	Point Load	Density of Rock	Porosity of Rock	Direct Shear tests	Unconfined compressive strength	Thin Section Study(Petrographic Analysis	Triaxial Compression Test	Chemical Analysis of Rock sample for sulphate content	Modulus of Elasticity/Poission's Ratio
BH-03	5.0 to 6.0-RQD pieces of rock	Core sample	D/S Weir Axis-River bed	Schist/Schistose Gneiss	1	1		1	1			1	1
BH-03	9.5 to 11.0 m-RQD pieces of rock	Core sample	D/S Weir Axis-River bed	Schist/Schistose Gneiss			1				1		
BH-04	15.5 to 16.5 M-RQD pieces of rock	Core sample	Intake area	Quartz Mica Schist/Gneiss						1			
BH-04	21.5to 23.5 M-RQD pieces of rock	Core sample	Intake area	Quartz Mica Schist/Gneiss	1	1	1	1	1		1	1	1
TOTAL TESTS TO BE PERFORMED					2	2	2	2	2	1			

Note
All tests are to be performed as per defined standards and provided scope of works

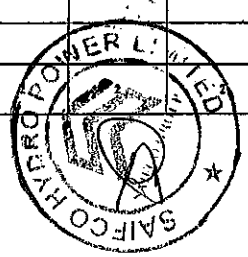


Table 5.6: Proposed Testing Programs

Table-5.6

SHIGO KAS HYDRO POWER PROJECT
LIST OF LABORATORY TESTS TO BE PERFORMED ON SELECTED SAMPLES

Description of Samples					Tests to be Performed								
Borehole	Depth (m)	Type of Samples	Location of Samples taken from	Material as per Log	Point Load	Density of Rock	Porosity of Rock	Direct Shear tests	Unconfined compressive strength	Thin Section Study/Petrographic Analysis	Triaxial Compression Test	Chemical Analysis of Rock sample for sulphate content	Modulus of Elasticity/Poission's Ratio
BH-05	21.6 to 24.6 RQD pieces of rock	Core sample	Tunnel area	Schistose Gneiss/ Quartz Mica Schist	1	1	1	1	1	1		1	1
BH-06	35.8 to 38.8 m-RQD pieces of rock	Core sample	Tunnel area	Quartz Mica Schist	1	1	1	1	1	1	1		
BH-08	24.0 to 28.80M- RQD pieces of rock	Core sample	Sand Trap/Gravel Trap	Quartz Mica Schist	1	1	1	1	1	1	1	1	1
TOTAL TESTS TO BE PERFORMED					3	3	3	3	3	3	2	2	2

Note:
All tests are to be performed as per defined standards and provided scope of works

Table 5.7: Proposed Testing Programs

Table-5.7

SHIGO KAS HYDRO POWER PROJECT
LIST OF LABORATORY TESTS TO BE PERFORMED ON SELECTED SAMPLES

Description of Samples					Tests to be Performed								
Borehole	Depth (m)	Type of Samples	Location of Samples taken from	Material as per Log	Point Load	Density of Rock	Porosity of Rock	Direct Shear tests	Unconfined compressive strength	Thin Section Study/Petrographic Analysis	Triaxial Compression Test	Chemical Analysis of Rock sample for sulphate content	Modulus of Elasticity/Poission's Ratio
BH-07	11.0 to 13.6 RQD pieces of rock	Core sample	Tunnel Outlet Portal area	Granite Gneiss	1	1	1		1			1	
BH-07	62.0 to 63.8 m-RQD pieces of rock	Core sample	Tunnel Outlet Portal area	Quartz Mica Schist	1	1	1	1		1			1
BH-08	24.60 to 28.60M-RQD pieces of rock	Core sample	Alternate option Sand Trap/Gravel Trap	Schistose Gneiss	1				1	1	1	1	
BH-08	30.60 to 32.0M-RQD pieces of rock	Core sample	Alternate option Sand Trap/Gravel Trap	Schistose Gneiss	1				1				
TOTAL TESTS TO BE PERFORMED					4	2	2	1	3	2	1		1

Note:
All tests are to be performed as per defined standards and provided scope of works

Table 5.8: Proposed Testing Programs

Table-5.8

SHIGO KAS HYDRO POWER PROJECT
LIST OF LABORATORY TESTS TO BE PERFORMED ON SELECTED SAMPLES

Description of Samples					Tests to be Performed								
Borehole	Depth (m)	Type of Samples	Location of Samples taken from	Material as per Log	Point Load	Density of Rock	Porosity of Rock	Direct Shear tests	Unconfined compressive strength	Thin Section Study (Petrographic Analysis	Triaxial Compression Test	Chemical Analysis of Rock sample for sulphate content	Modulus of Elasticity(Poisson's Ratio
BH-09	9.60 to 11.0 RQD pieces of rock	Core sample	Power House Option-II	Quartz Mica Schist	1	1	1	1	1		1	1	1
BH-05	37.5 to 39.0 m RQD pieces of rock	Core sample	Power House Option-II	Quartzose Gneiss	1	1	1			1			
TOTAL TESTS TO BE PERFORMED					2	2	2	1	1	1	1	1	1

Note:
All tests are to be performed as per related standards and project scope of works

Table 5.9: Proposed Testing Programs

TEST PITS

Table-5.9

SHIGO KAS HYDRO POWER PROJECT
LIST OF LABORATORY TESTS TO BE PERFORMED ON SELECTED SAMPLES

Description of Samples					Tests to be Performed									
TEST PIT #	Depth (m)	Type of Samples	Location of Samples taken from	Material as per Field Log	Particle Size Analysis-ASTM#22, 136 & AASHTO T-88(Fine & Coarse)	Liquid Limit/Plastic Limit & PI-ASTM-4253, AASHTO T-89 & 90-if applicable	Hydrometer Analysis-If applicable	Standard Proctor-T-AASHTO-180	Specific gravity of Aggregates	Soundness of Aggregates by Sodium Sulphate	Los Angeles Abrasion	Petrographic Analysis of Fine and coarse aggregates	Complete Chemical analysis of water	Chemical analysis of Salts(Sulphate, Chloride,Organic Impurities
1	0.0 TO 1.82	Composite sample	Borrow area U/S of Weir	Clayey Sandy Silt with gravels and Boulders	1	1	1	1	1	1	1			1
2	0.0 TO 2.13	Composite sample	Borrow area U/S of Weir	Sandy Gravels and Boulders	1	1	1		1					1
3	0.0 TO 1.89	Composite sample	Borrow area U/S of Weir	Silty Sand with gravels and Boulders	1	1	1		1	1	1	1		1
4	0.0 TO 1.84	Composite sample	Borrow area U/S of Weir	Silty Sand with gravels and Boulders	1	1	1	1	1	1	1	1		1
5	0.0 TO 1.43	Composite sample	Borrow area U/S of Weir	Silty Sand with gravels and Boulders	1	1			1					
6	0.0 TO 0.88	Composite sample	Borrow area U/S of Weir	Silty Sand with gravels and Boulders	1	1		1	1	1	1			
7	0.0 TO 0.81	Composite sample	Just UP STREAM OF Water sediment study	Silty Sand with gravels and Boulders	1	1	1							1
Three number of water samples, one from bore hole, 2nd from river water and 3rd from project surrounding established well													3	
TOTAL TESTS TO BE PERFORMED					7	7	5	3	6	4			3	5

Note: Composite samples of test pits were collected from top to bottom as representative and tests are to be performed by proper method and standards.

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Table 5.10: Proposed Testing Programs

TEST PITS

Table-5.10

SHIGO KAS HYDRO POWER PROJECT

LIST OF LABORATORY TESTS TO BE PERFORMED ON SELECTED SAMPLES

Description of Samples					Tests to be Performed										
TEST PIT #	Depth (m)	Type of Samples	Location of Samples taken from	Material as per Field Log	Particle Size Analysis ASTM(D2...) & AASHTO T(specify) & Curve	Liquid Limit/Plastic Limit & PI, ASTM-(D4...); AASHTO T(89 & 90 applicable	Hydrometer Analysis if applicable	Lab. Density	Specific gravity of Aggregates	Soundness of Aggregates by Sodium Sulphate	Los Angeles Abrasion	Fineness modulus	Petrographic Analysis of River sand as well as aggregates	Complete Chemical analysis of water	Chemical analysis of Salts (Sulphates, Chlorides & Organic Impurities
8	0.0 TO 1.83	Composite sample	300 meters D/S of Power House	Gravelly Sand	1				1	1		1			1
9	0.0 TO 2.29	Composite sample	Borrow area 500 meters D/S of Power House	Gravelly Sand	1				1		1				1
10	0.0 TO 2.1	Composite sample	Borrow area 300 meters D/S of Power House	Gravelly Sand	1			1	1	1			1		1
Three number of water samples, one from intake, 2nd from inter water and 3rd from project surrounding established well														3	
TOTAL TESTS TO BE PERFORMED					3	0	0	1	3	2	1	1	1	3	3

Note: Composite samples of test pits were collected from top to bottom as representative and tests are to be performed by proper method and standards. Atterberg limits and Hydrometer analysis are to be performed upon receiving % of passing for silt and clays

Table 5.11: Planned Geotechnical Investigations

Table-5.11

SHIGO KAS HYDROPOWER PROJECT

Proposed Geotechnical Investigation Plan

Serial Number	Bore hole number	Drilling depth (m)	Progress (m)	Peizometer m	Lugeon test	Permeability test	Location	Coordinates		Remarks
								Easting	Northing	
1	BH-01	35	35	35	3		Weir Axis-Left Bank-D/S of Existing alternate	3091270.931	1170856.769	As per attached location plan
2	BH-02	20	20		3		Weir Axis-Right Bank-D/S of Existing alternate	3091191.371	1170895.807	
3	BH-03	30	30		3		D/S Weir Axis-River bed-D/S of Existing alternate	3091249.956	1170817.678	
4	BH-04	35	35	35	2		Intake area	3091284.108	1170889.997	
5	BH-05	60	60		3		Tunnel area	3091343.908	1170887.979	
6	BH-06	30	30		0		Tunnel area	3091346.773	1170736.313	
7	BH-07	85	85	85	5	1	Near Outlet Portal Area / Surge Shaft	3088365.393	1162072.409	El 679.0 m
8	BH-08	44	44		1	2	Penstock	3088269.226	1161880.077	El 648.0 m
9	BH-09	50	50	50	2		Power House	3088183.220	1161473.340	El 586.0 m
10	Test pits (Nos)		10							
11	Reservoir Area					9				
TOTAL DRILLING		389	389	205	22	12				

The actual carried out principal quantities of fieldwork are given in **Table 5.12**

Table 5.12: Principal Quantities – Fieldwork

Fieldwork Activity	Quantity
Rotary Drilling - land based (Vertical & Angle holes)	390 m
Constant Head Permeability Test	12 No.
Packer / Lugeon / Water Pressure Test	22 No.
Piezometers Installation	205 m
Collection of core samples as per requirement	As required
Trial Pits in Project Area	10 No.
Borrow Area aggregate testing & Other Laboratory Testing	As required
Collection of undisturbed and disturbed samples of Soils	15No.
Standard Penetration Testing (SPT) & Cone Penetration Testing (CPT)	30
Surface Geological Mapping / Discontinuity Scanline Survey	Base Map 1:2000 Scale

5.9.2.1 Boreholes / Drill hole

Nine (09) numbers of boreholes have been drilled during present stage of feasibility studies in the project area while no borehole data is available in previous studies and during present stage of studies investigation locations are shown in same figures of surface geological mapping. Earlier four numbers of boreholes had been proposed at powerhouse site with 190 meters drilling but later after approval of Powerhouse option-II. one number of borehole BH-09 was planned and executed accordingly for required geotechnical design parameters.

Finally nine (09) numbers boreholes have been proposed to get sub-surface information at project structures location. Data from all of planned exploratory holes have been collected and included in **Annexure – A of Volume 3** and geotechnical parameters have been discussed in relevant section of geotechnical design.

The boreholes were planned by rotary diamond drilling in the bedrock as well as in the overburden / Scree/Colluviums and river bed strata. In-situ testing in the boreholes was carried out on regular intervals or on as-required basis, which comprised permeability tests in soil materials and water pressure / Packer / Lugeon tests in rocky strata. The waxed core samples from the rock strata were preserved as per requirement of the study.

The Consultant's team of Engineers and geologists, besides directly supervising the field activities, also prepared the relevant record of the drilling activities and lithological and structural logs of the borehole soon after the retrieval of core from the holes.

After the core was being retrieved from the boreholes, it was being placed in core boxes with all the relevant details mentioned on core boxes such as location, borehole number, box number, depth, etc. Core box photographs were taken from vertically above the box and include a scale and color chart. These photographs are included in **Annexure-E of Volume 3**. Same practice was being continued till completion of all investigation works.

Details of executed and designed boreholes / drill hole are given in **Table 5.13** proposed investigation plan of exploratory works along with the location of each borehole is shown in attached surface geological mapping figures.

Table 5.13: Location of Boreholes / Drill holes (Present stage of Feasibility Studies)

Borehole / Drill hole No.	Depth (m)	Inclination from Vertical (Degree)	Easting (m)	Northing (m)	Elevation (m asl)
BH-01	35	0	3091270.931	1170856.769	649
BH-02	20	0	3091191.371	1170885.807	642
BH-03	30	0	3091249.956	1170817.678	640
BH-04	35	0	3091294.108	1170889.997	668
BH-05	60	0	3091343.908	1170687.979	676
BH-06	30	30°	3088365.140	1161811.810	680
BH-07(Option-II)	85	0	3088365.393	1162072.409	679
BH-08(Option-II)	45	0	3088365.40	1161643.78	646
BH-9(Option-II)	50	0	3088183.220	1161473.210	586
TOTAL DRILLING	**390**				

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All of the above investigations have been completed and after receiving all of the geotechnical investigation data, detailed interpretative report is presented including all design and foundation parameters and details are included in chapter 6 Geotechnical design.

5.9.2.2 Test Pits and Trenches

Ten (10) test pits at project structures and for borrow areas of construction materials have been planned. Seven numbers have been executed for descriptions of entire borrow area sites around Weir axis while remaining three have been applied around power house area for almost same purpose of construction materials.

Test pits data is available in **Annexure – B of Volume 3.** Testing programs for all excavated test pits have been prepared and required testing have been done in Central Materials Testing Laboratory (CMTL-WAPDA). All results have been received and its results interpretations are included in evaluation of construction materials.

Location plan of test pits is shown on surface geological mapping drawings and presented in **Table 5.14.**

Table – 5.14: Location of Test Pits

Test Pit / Trench No.	Depth (m)	Easting (m)	Northing (m)	Location
TP-01	1.52	3091069	1171260	Up Stream of proposed Weir
TP-02	2.13	3090884	1171264	Reservoir area
TP-03	1.83	3090417	1171270	Reservoir area
TP-04	1.84	3090209	1171305	Reservoir area
TP-05	1.43	3090186	1171558	Reservoir area
TP-06	0.65	3090131	1171719	Reservoir area
TP-07	0.61	3091228	1171159	Reservoir area
TP-08	1.7	Power House Area-200 meters D/S		
TP-09	2.3	Power House Area-500 meters D/S		
TP-10	2.1	Power House Area 700 meters D/S		

One number of test pits has been excavated up stream of proposed Weir axis for sediments study of river bed materials and six numbers of test pits were excavated in Reservoir area for estimation of construction materials. Later three test pits were excavated in power house area for same purpose of construction materials evaluation. Laboratory testing results have been received and attached as **Annexure-D of Volume 3**, after receiving all of the required results, interpretations are included in section of construction materials evaluation. Issued laboratory

testing programs of drilled bore holes and excavated test pits are attached in **Annexure-D of Volume 3.**

5.9.2.3 In-Situ Testing and Sampling

The in-situ testing within boreholes has conducted during the course of drilling operations at regular intervals or on an as-required basis. The testing comprised performance of water pressure / lugeon tests in bedrock, constant head permeability tests in overburden and standard penetration test (SPT) / dynamic cone penetration test (CPT) to determine relative density of soil and overburden material consisting of boulders and gravel.

5.9.2.3.1 Constant Head Permeability Testing

A total of twelve (12) Constant Head Permeability tests were performed during present stage of studies from which nine were conducted in seven numbers of test pits just upstream of weir axis for evaluation of permeability in and around the weir axis and in reservoir area. While three numbers have been conducted in borehole number 07 & 08. Results are attached as **Annexure-C of Volume 3** in which analysis have carried out and values range is 10^{-2} cm/Sec to 10^{-1} cm/Sec in and around weir axis area as per general interpretations of the given results, values are at higher level of water inflow through river bed sediments and keeping in view, seepage analysis have been carried out at weir axis for any recommendation of grouting and anchor blocks against uplift would be provided, details of such all measures are included in chapter 6 "Geotechnical design". While in upper soils of BH-07 & 08, fines are more than the materials of test pits around weir axis. Permeability value range in soils of tunnel outlet portal and along penstock area is from 10^{-4} cm/Sec to 10^{-3} cm/Sec. Received values of constant head permeability are included in evaluation of geotechnical design studies.

5.9.2.3.2 Water Pressure Test

Twenty two numbers of water pressure tests were performed in boreholes, Borehole BH-01 at left bank of weir axis Lugeon values were calculated at 10 meters, 20, & 30 meters, Lugeon values are 49, 29 & 7 respectively. Three numbers in drill hole BH-2 at right bank of weir axis and Lugeon values range is 53, 5 and 5 at 10, 15 and 20 meters depth respectively. In river bed hole number BH-03 values range is 6, 3 & 2.47 at 10, 20 and 30 meters depth respectively. Banks holes are showing some open conditions of the rock while river bed rock is sparsely open joints and reflecting tight conditions regarding permeability. In borehole number BH-04 at power intake Lugeon values range at 15 and 30 meters depth are 0.45 and 6.14 respectively which are also showing moderately strong rocks at and around power intake area.

In the tunnel area drill hole number BH-05 was drilled and Lugeon values are 0.01, 13.66 & 12.90 at 15, 35 & 40 meters depth. No water pressure testing was carried out in bore hole # 6, presently location is coming in tunnel area and previously it was within sand trap location. Now sand trap location has been shifted about 200 meters up stream.

In borehole # 07 five numbers of water pressure tests were carried out at depths of 13, 23, 30.50, 50.0, 55.0 and received values are less than 1Lugeon which is the indication of very tight conditions of joints and fractures in tunnel outlet area reflecting good conditions of subsurface rock of tunnel outlet/Surge shaft area.

In borehole # 08, water pressure testing was carried out at 26.0 meters depth which has lugeon value is .002 less than 1 reflecting very good conditions of subsurface rock along proposed penstock area of the scheme.

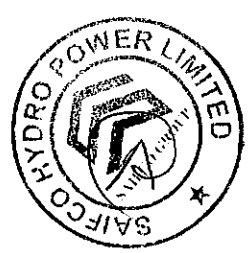
In borehole # 09 water pressure tests were carried out at depths of 23.0 & at 35.0 meters and same lugeon value .007 less than 1 Lugeon is reported which is the indication of good quality of subsurface rock under the foundation of power house area.

Water pressure results interpretations have incorporated in final geological and geotechnical investigation report with different comparisons like joint studies and laboratory testing results. Conditions of rock mass discontinuities associated with Lugeon values have also been incorporated in relevant sections of final report keeping in view on receiving all of field and laboratory results. Results of water pressure tests are attached as **Annexure-C of Volume 3.**

5.9.2.3.3 Standard Penetration Test (SPT)/Cone Penetration Test (CPT)

To assess the in-situ packing and compactness of overburden / fill material, the standard penetration tests (SPT) was planned in the exploratory boreholes.

However, as SPT has an open sampler at the tip which is not suitable for coarse grained gravels, therefore the dynamic cone penetration tests (CPT) with a closed tip has been used in the gravelly strata as required. Standard penetration resistance and material consistency in boreholes is not determined by SPT tool during present stage of studies while 30 tests have been carried out by Dynamic Cone Penetration and results are appended in attached borehole logs for ready reference.



5.9.2.3.4 Dynamic Cone Penetration Test (CPT)

The dynamic cone penetration test (CPT), modified form of SPT, was developed by Palmer and Stuart (1957) mainly for gravelly strata. The tests would be performed in boreholes by replacing the standard split spoon shoe of SPT with a conical massive tip having an angle of 60° in the vertex as shown in **Figure 5.6.** The testing procedure is exactly the same as SPT test and blow count for every 6 inches penetration are recorded. Nc values can be derived from CPT tests in boreholes if required. CPT values are referred in bore hole logs for ready reference.

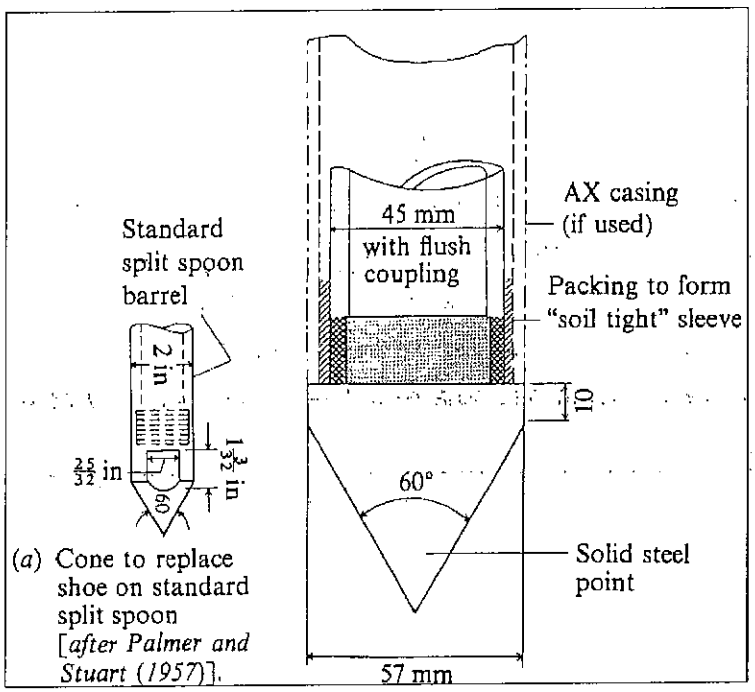


Figure 5.6: Illustrative Sketch of 60° Cone used for Dynamic Cone Penetration Test

5.9.2.3.5 Water Level Measurement in Boreholes and Test Pits

For the monitoring of ground water table, standpipe piezometers have been installed in the selected boreholes and total 205 meters installation depths have been achieved in four numbers of bore holes.

As methodology for the installation of piezometer, the base of the borehole shall be first filled with gravel pad and then the perimeter gap between the PVC pipe and the hole would be filled in sequence with gravel, coarse sand, bentonite pellets and cement & sand grout. To avoid chocking of PVC perforated pipe at the base, it would be wrapped with a cotton cloth. A typical sketch of standpipe piezometer designed and has been installed especially at weir axis and Power intake area while around power house area and around power tunnel outlet

area one piezometer each has installed; typical sketch of piezometer is presented in **Figure 5.7.**

In selected bore/ drill holes piezometer has been installed and later monitoring of fluctuation of water during low and high flood periods for better assessment of the ground water conditions were being continued and finalized depths of ground water with statistical analysis are included in this final report findings for consideration of the required geotechnical design parameters.

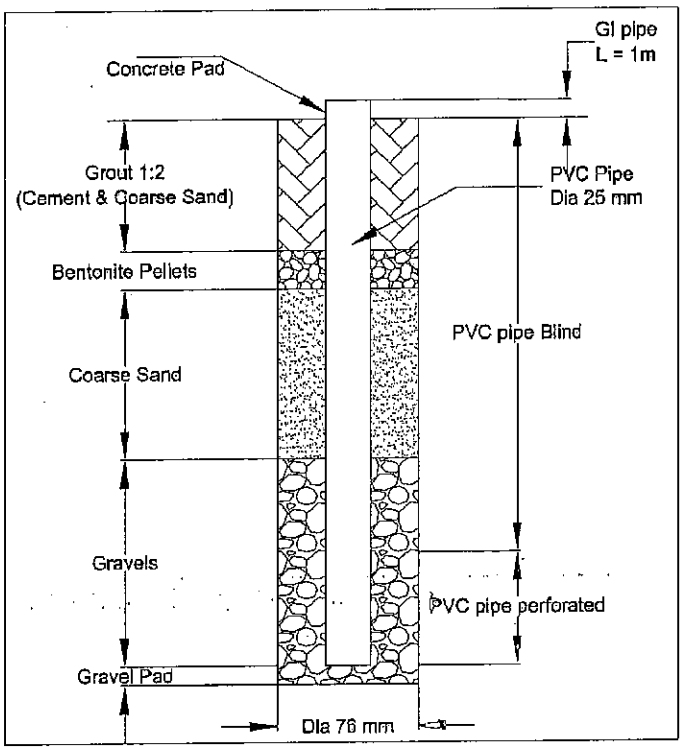


Figure 5.7: Typical Sketch of Standpipe Piezometer

Depth of ground water table in boreholes / drill hole is presented in **Table 5.15** and graphically presented in **Figure 5.8 & 5.9**.

Table 5.15: Depth of Ground Water Table in Boreholes and Drill hole

Borehole / Drillhole No.	Location	Borehole / Drillhole Depth (m)	Borehole / Drillhole Surface Elevation (masl)	Borehole / Drillhole End Elevation (masl)	Ground Water Table Depth from NSL (m)	Ground Water Table Elevation (masl)
BH-01	Weir Axis	35	649.0	314.0	6.3	642.7
BH-02	Weir Axis	20	642.0	622.0	2.0	640.0
BH-03	Weir Axis-River bed	30	640.0	630.0	0.2	639.8
BH-04	Power Intake area	35	668.0	633	20	648
BH-07	Outlet of Power tunnel/Surge shaft	85	679.0	594	19.5	659.50
BH-09	Power House area	50	586.0	536.0	15.5	570.50

Tunnel area of bore hole number BH-05 has no any ground water level up to drilling depth of maximum 60.0 meters, In Sand trap area of hydro power scheme ground water up to explored depth of 30 meters was not encountered. Along bore hole number 08 water table is not encountered which is the one abnormal behavior observed within the zone because tip of this bore hole is at elevation of 602.0 meters while water table is encountered just uphill side in hole BH-07 of around outlet portal area at 659.50 meters which can be a trapped water of one perennial Nullah just downhill of BH-07.

At power house area ground water table is encountered at depth of 15.50 meters from NSL at elevation of 570.50 meters which is about 12 meters higher than the Panjkora river bed within the vicinity of Power house. It is the indication that power house area rocks have adequate ground water reservoir.

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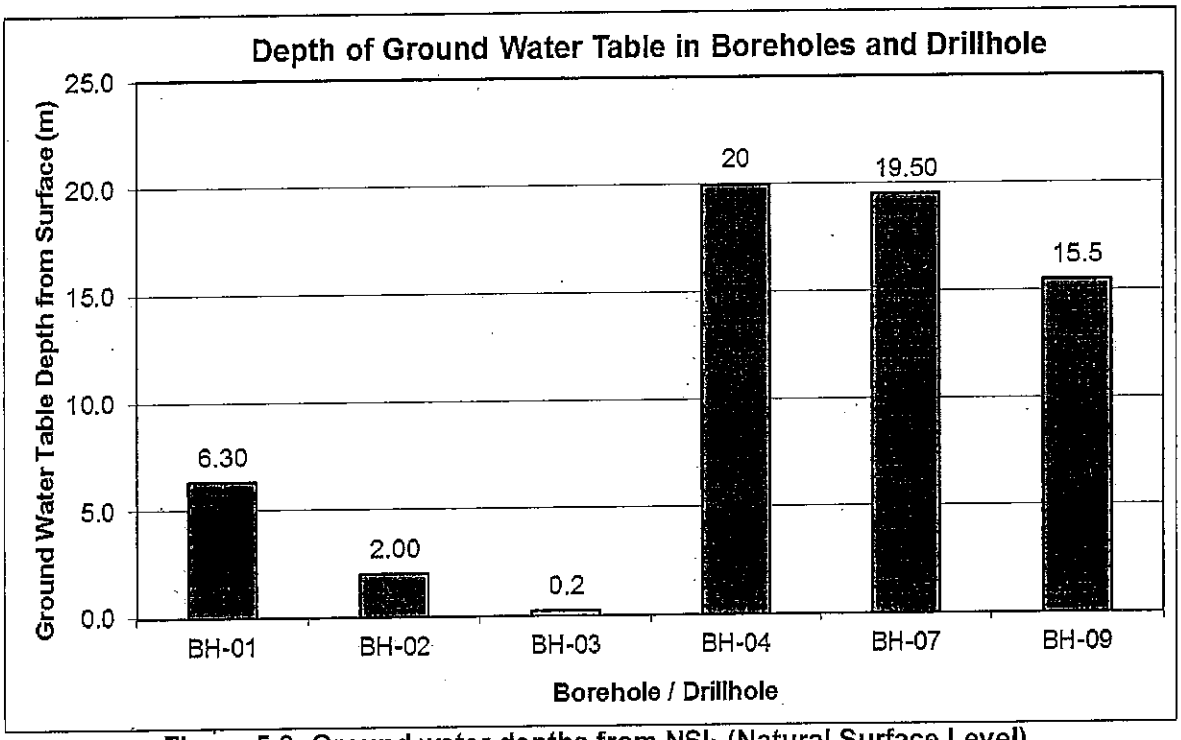


Figure 5.8: Ground water depths from NSL (Natural Surface Level)

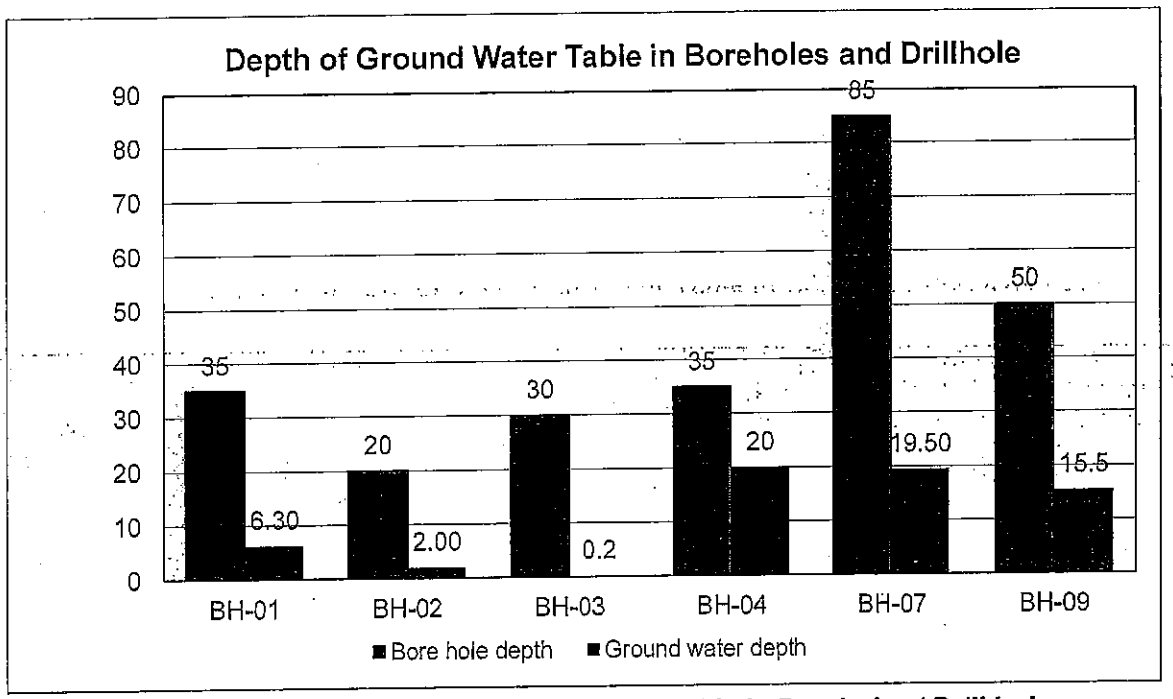


Figure 5.9: Depth of Ground Water Table in Boreholes / Drill hole

Ground water table is encountered in few of test pits out of the seven (7) test pits excavated up stream of weir axis and in reservoir area for construction materials and identification of the river bed materials. Similarly the same conditions have been encountered in three test pits around power house site. Ground water conditions for reservoir area are prepared and included in final

geology/geotechnical investigation report as **Annexure-B of Volume 3** of test pit logs for reference.

5.10 Collection of Rock and Soil Samples

For the construction materials availability, the bulk soil samples including boulder, gravel and sand from borrow area test pits have been collected. Main source of concrete aggregates is Panjkora river deposits and up stream of weir axis at about 8 Km near Timergara, one crusher has been installed by private group and production of all types of materials is in progress with sufficient quantities from the almost same borrow area of Panjkora river bed deposits where we have been investigated during present stage of studies. All the laboratory testing results of construction materials borrow areas are included as **Annexure-D of Volume 3**, later interpretations have been applied in evaluation of construction materials for required parameters within best permissible limits. Testing programs have been established as per BOQ and required specifications. Project area rocks will also involve for large excavation, therefore, rock cores have also been tested considering it an aggregate source. All of the quality testing is reflecting the borrow area materials to best level of use and same is addressed in details of all construction materials and final findings and recommendations are included in this final geology and geotechnical investigation report. After receiving all required laboratory results, final findings have been incorporated for selection of all types of construction materials.

5.11 Laboratory Testing

To determine the engineering characteristics and design parameters comprehensive laboratory testing programs were issued to investigation agency for required laboratory testing as per study requirements, testing programs had been issued to testing agency keeping in view the particular requirement of the project components and all of the testing programs were prepared for testing the rock core samples and disturbed/undisturbed samples obtained from test pits respectively. Rock core samples from drill hole BH-01, 02 & BHP-03 of weir axis area at different depths were selected for laboratory tests. The selected rock cores were properly preserved using wax, sealed packed, labeled and transported to laboratory. Similarly as per attached testing programs all of the core samples were preserved properly for required testing in laboratory.

Laboratory testing has been carried out in CMTL, WAPDA Lahore as per attached testing programs at all of the project components. Final findings and recommendations are prepared after receiving all of the laboratory results and statistical analysis have been done for accurate approach of geotechnical design studies. Laboratory testing results are attached as **Annexure-D of Volume 3.**

5.12 Geological and Geotechnical Evaluation of Project Structures

5.12.1 Weir Site, Power Intake area, Gravel Trap/Sand Trap, Power Channel & Inlet Portal

The weir site alternative-I has been investigated by 3 boreholes (BH-01, BH-02 and BH-03) at left, right and river bed of weir axis respectively; details are discussed in the relevant sections and comprehensive analysis have done after receiving of all field and laboratory testing results which details are included in chapter 6 "Geotechnical design".

The valley upstream of the weir is comparatively wide with significant agriculture on the left bank terraces. At weir axis in the river section top 2 to 3 meters materials are Silty Sandy gravels with sufficient boulders (Alluviums).At abutments moderately strong to strong rock is well exposed. At left bank few meters cover of Scree or overburden can be observed and recorded in present stage of studies. Downstream of the weir site at right and left abutments strata is same as of metamorphic rock and same is accumulated up to Sand trap. In Sand trap area Scree/Debris thickness is comparatively more than of the entire zone which need to be deeply investigated during detailed Engineering design stage. Some small scale slides can be observed and have been plotted in geological mapping around the weir. Some local shears and small Nalla have been observed and recorded during Surface geological mapping and all features have been marked on geological map of the area and details are included in geology/geotechnical investigation section.

Three numbers of drill holes were planned for proposed weir site (alternate-I) and have been drilled accordingly with required number of permeability tests/Water pressure tests and other field tests like cone penetration test in river bed deposits/alluvium. Later location of weir site (Alternate-I) has been shifted about 200 meters upstream including complete layout of intake and sand trap structure. Geological cross sections of shifted location have been appended with this report as sections of Alternate-II, considering without any change of anticipated depths of bed rock.

At weir site, Panjkora River has narrow valley and foundation of the weir would be founded on metamorphic rock after excavation of alluviums and river bed deposits up to maximum three meters as per present stage of investigations.

In the light of encountered strata, foundation of weir axis shall be founded on metamorphic rock.

The grout curtain and cut off wall for the weir have been designed to reduce seepage volumes and pressure head in both abutments and beneath the foundation as per the considerations of

designer. Keeping in view values of permeability and joints patterns, special emphasis has been given for the design of grout curtain. The grout curtain can be basically a single row, split-spaced, high-pressure curtain. Further details of joint patterns and permeability analysis are included in relevant sections. Geotechnical design considerations are included in chapter 6 of the final report.

Intake area and Sand trap foundation is also coming on metamorphic rock by surface geological mapping, one number of drill hole each has been proposed for Sand trap and Intake area and have been drilled accordingly but presently both structures have been moved with weir just about 200 meters upstream and conditions of present intake and sand trap are even more favorable regarding bed rock as per surface geological mapping.

One number of drill hole was proposed for tunnel area and has been drilled accordingly. Tunnel area has been classified based upon rock mass characterization; details are included in section of geotechnical design. As for as concern of surface geological mapping data for layout alternatives almost 100 % excavation would be carried out in metamorphic rock (Class A, B & C) along tunnel area. Very little percentage will fall in very poor conditions of rock (Class D) especially along Nullah and shear zones. These all interpretations with tunnel route are the part of geotechnical design studies as separate section.

Comprehensive assessments regarding Weir, Intake area, sand Trap and power tunnel have been incorporated in relevant sections.

Construction and permanent slopes at weir axis should not be more than 1:3 (1 Horizontal: 3 Vertical). As per present apparent conditions of surface geological mapping, weir would be founded on metamorphic rock (Schistose Gneiss & Quartz Mica Schist). Further studies regarding final cut slopes are recommended during detailed design stage. In situ shear test is also recommended for accurate assessments of the shear factors.

Sand Trap Excavation can be executed with 1:4 (1 Horizontal & 4 Vertical) in rock section while 1:2 (1 Horizontal & 2Vertical) in loose scree and debris; it can be 1:1 slope as per anticipated conditions of excavated materials. Excavation would be done in slope and berms method and complete geotechnical analysis and further required investigations at detailed design stage are strongly recommended. Some joints can create some issues of planner failure; rose diagram and preferred directions of rock movements are included in this report, complete analyses of anticipated joints with remedial measures like safe cut slopes are included in final section of geotechnical design. Rock of Sand trap area is metamorphic Mica Schist/Quartz mica Schist, moderately to highly weathered, highly fractured, rock is moderately strong to strong.

Project photographs are attached as **Annexure-E of Volume 3** and Seismic Refraction Survey report is attached as **Annexure-F of Volume 3** as autonomous volume of report by third party.

After receiving data of field, laboratory testing results and by different geotechnical analysis, Better assessment has been predicted for weir, Power intake, sand trap, and power channel including inlet portal of tunnel foundation. However further details can be evaluated during detailed design stage for complete set of true applications. The graphical presentation of test results is shown in **Figures 5.10 to 5.12.**

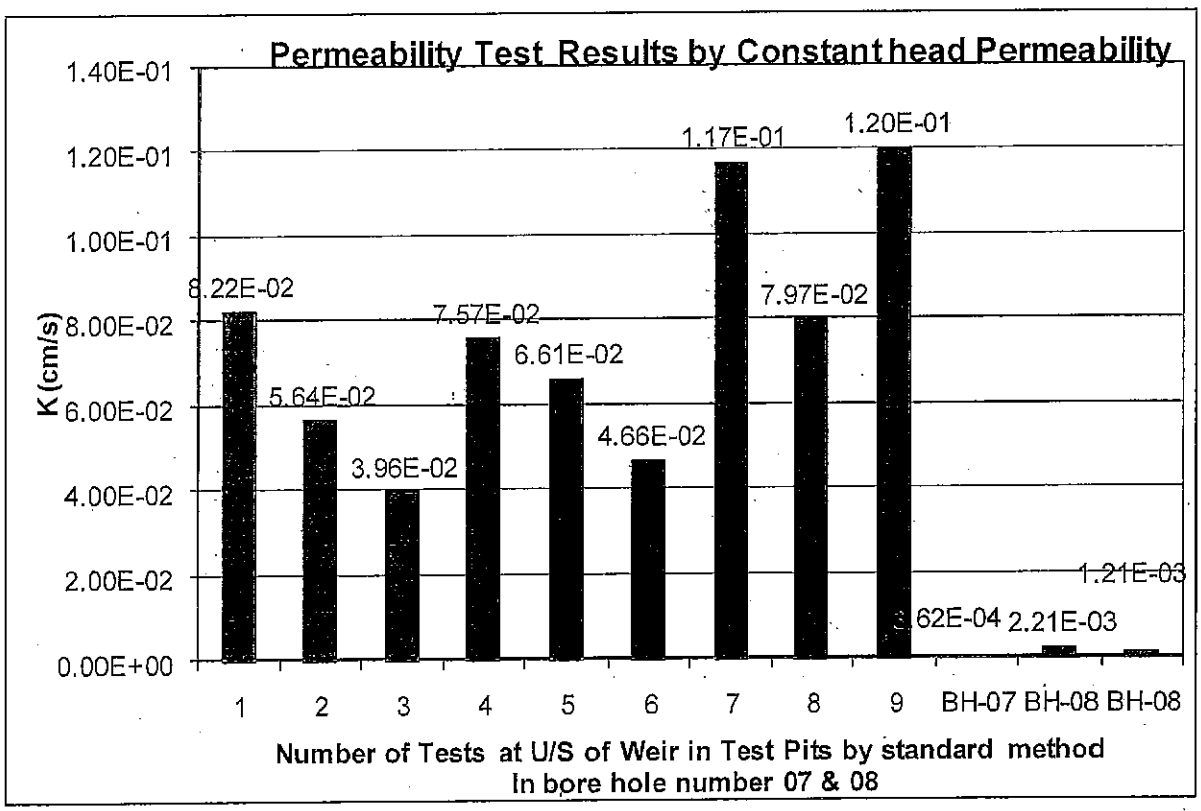


Figure 5.10: Permeability testing results at up stream of proposed Weir Axis and along bore holes

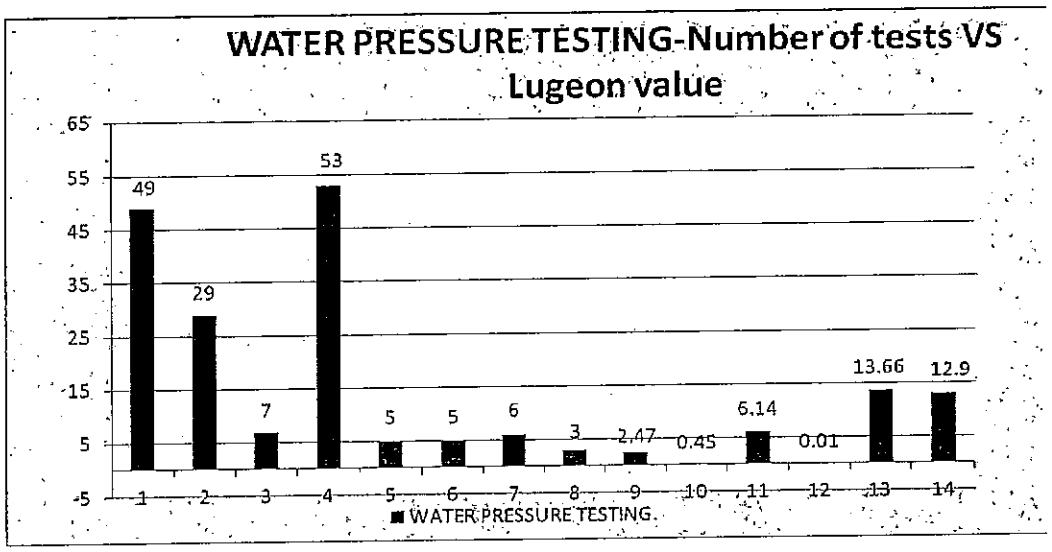


Figure 5.11: Water Pressure Testing

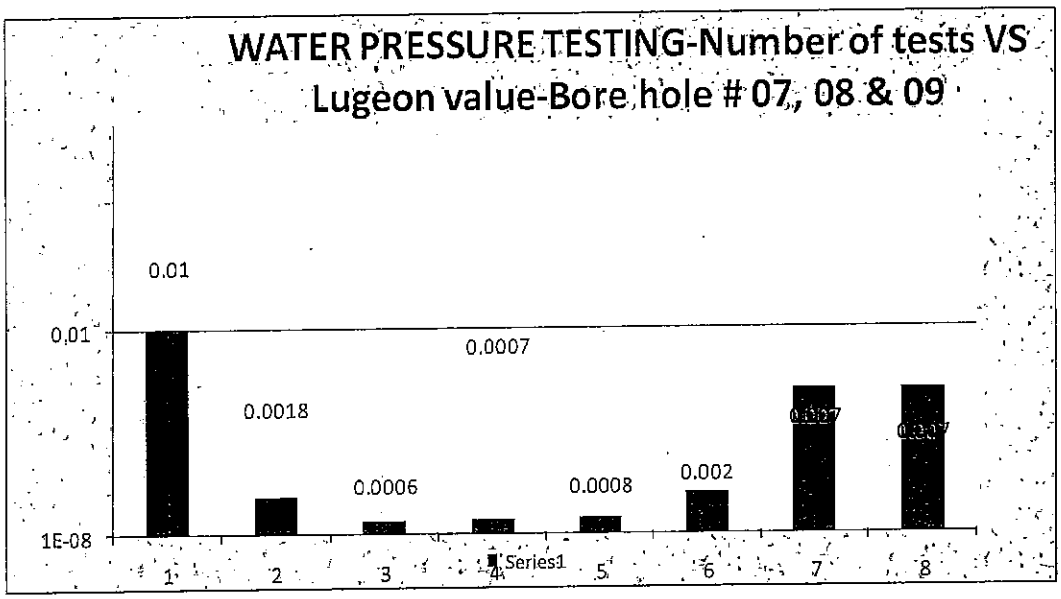


Figure 5.12: Water Pressure Testing

Water pressure testing statistical analysis is shown above and for reference **Annexure-A of Volume 3** i.e. of bore hole logs and **Annexure-C of Volume 3** i.e. field testing results are attached. Further analyses are arranged with the correlation of received RQD % and has discussed in section of geotechnical design studies.

Core recovery and RQD % analysis of all bore holes are concluded and are appended in final section of geotechnical design. Permeability and water pressure testing result values are also be discussed in detail in geotechnical design studies.

Ground water table observations were being monitored at site on regular intervals; statistical analysis of average levels have been discussed in relevant section and further details are incorporated in section of geotechnical design studies.

Further in depth statistical analysis are recommended for detailed design stage for comprehensive approach of geotechnical parameters.

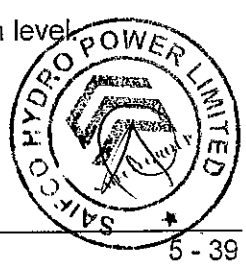
5.12.2 Headrace Power Tunnel

As described above metamorphic type of rock (Mica Schist, Quartz mica schist and Granitic Gneiss are well exposed along the entire power tunnel. Rocks are subdivided in to three to four types of rocks based upon rock mass characterization. Few Nallas are intersecting the power tunnel where measures are to be required regarding seepages along some anticipated open joints and fissures.

Scan line survey has been carried out along the power tunnel and all of the geological/geotechnical details have included in final geology/ geotechnical investigation report. Scan line Survey details were used for rock mass classification by using Q- method and it's all details are included in section of geotechnical design. Initial and permanent support systems in tunnel excavation have also been provided and included in the section of geotechnical design.

Three to four sets of joints have been identified and observed during surface geological mapping.

Surge tank area and penstock alignment/High pressure tunnel (Power house option-II) lies along the 40 to 50 degrees steep slope and up to 70 degrees maximum steep slope would create a number of imponderables and disadvantages: Overall working conditions along Surge shaft and along high pressure tunnel/Penstocks are quite favorable regarding topographic as well as good geological conditions except few perennial and non-perennial Nullahs. Sound metamorphic rock is well exposed along Surge shaft and penstock/High pressure tunnel where comprehensive plan of geotechnical investigations had been prepared and later executed as per requirement and scope of geotechnical investigations are attached with this report for ready reference. Surface geological mapping has been done and reference figures are attached with this report. Further improvements and analysis have done in geotechnical design section. At detailed design stage further investigations and in depth analysis are strongly recommended for more accurate assessment of safe cut slopes and support systems while analysis of present stage of studies in geotechnical design section are equally at detailed design level.



In the zone of power tunnel, Surge shaft/High pressure tunnel and along penstock area large amounts of cleaning measures are required, i.e. excavation of loose overburden, loose rock parts and intense safety measures (shortcreting, rock bolting, even anchoring).Final findings based upon this stage of feasibility studies and additional investigations with recommendations are included in this final report which are to be executed during detailed design stage.

Geotechnical parameters along Surge area as well as along high pressure tunnel/Penstocks are well described in chapter 6 covering safe cut slopes and any further support measures. These all analysis are based upon field and laboratory testing results as attached in **Annexure-D of Volume 3** for ready reference.

5.12.3 Power house and Allied structures

At power house and allied structures like tailrace, surface geological mapping has been done and further improvements were completed after getting drill hole data of BH-09.

All details of geotechnical measures are included in relevant section and for ready reference, bore hole data is attached as **Annexure-A of Volume 3** and field and laboratory testing results are attached in **Annexure-C & D of Volume 3** respectively.

Geotechnical investigations had been planned for power house area and table is attached as reference. Drill hole was drilled at location of Power house and same hole can give us picture for tailrace as well to explore the subsurface conditions of Power house area.

Three numbers of test pits were excavated around power house area to establish the design parameters keeping in view its nature of materials and major role of the test pits excavation is to evaluate the required construction materials of the hydro power scheme.

As per surface geological mapping of both options of Power house, Sound metamorphic rock is well spread under the foundation. Three to four sets of joints have been observed, picked and marked, joint spacing is 2 mm to 50 mm, opening of some joints are filled with clay and fine material and quartz and calcite filling has also been observed, some joints are open. Further analysis with model studies were carried out, the results of which has been appended in chapter 6 of feasibility report of geotechnical design.

The power house area option-II and surroundings consisting of Gneissic rocks, this belt tectonically assume as anticlinorium where strata dipping highly at eastern limb while west limb has comparatively gentle slopes. At power house Panjkora river flows in N-S direction and at power house rocks are dipping towards Panjkora river but slope angles are gentle to little steep, analysis have been carried out for different mode of failures and slope stability, with the help of

different model studies final safe cut slopes have been recommended and details with figures are included in section of geotechnical design. Some synclinorium structures have also been observed around power house.

Working for slope stability has been carried out and generally cut slope should be 1:1 (1 Horizontal: 1 Vertical) in loose Alluviums/Colluviums/Terrace deposits/Scree without any intercalation of rock while 1:3 (1 Horizontal: 3 Vertical), where metamorphic rock would be encountered and stand up time would be more than 24 hours even in saturated conditions.

Permanent slopes Stability analyses are included in section of geotechnical design (Chapter-6).

5.13 Evaluation of Construction Materials

The construction material has broadly considered two groups of materials; first the materials quarries and borrow areas considered during this stage of studies as these should comprise quality wise suitable sites and secondly potential new areas in the vicinity of the project area which should also be suitable and should have enough quantities for required construction materials. To fulfill the requirement for evaluation of the construction materials, seven numbers of test pits have excavated in available borrow areas upstream of weir and bulk samples had been taken and transported to testing laboratory CMTL for required tests. Three test pits were excavated in power house area for the same purpose and testing results are attached with this report as **Annexure-D of Volume 3** of laboratory testing results.

Detailed evaluation for all types of construction materials is included in this final volume after receiving all testing results and further remaining investigations.

For suitability of the construction materials, complete set of testing was being applied in the laboratory under the supervision of Consultant`s team.

Coarse aggregates are available in the vicinity of the project area along Panjkora River and second major source of the coarse and fine aggregates would be nearest quarries. Which materials quality would also be confirmed during detailed design stage while in present stage of feasibility studies, materials of the vicinity have been tested and confirmed regarding quality standards.

Fine and coarse aggregates should be suitable for construction and are to be available in ample quantity in the vicinity of project area. Results of grain size analysis are showing about 17 to 44 % sand with little silt and clay content which is the good indication for getting fine aggregates within the project vicinity.

In view of substantial quantity of rock excavation for different structures, samples from project area rock were also collected to check their suitability as concrete aggregate and random fill by Petrographic analysis and other laboratory tests. Results are showing that project area rock is alkali silica reactive and may not be used an aggregate with ordinary Portland cement/High Alkali cement while these can be used either with low alkali cements or with volcanic ash/pozzolanic materials.

Disposal areas for excavated materials and dumping zones have also been identified and are incorporated in the final volume of construction planning.

Slope protection and stone pitching materials are also available in abundance along Panjkora River as well as along Swat river beds.

Road materials are also available within the vicinity of the project area which can be prepared by installation of crusher plant during the construction period.

Cement and steel is also available in nearest main cities like Mardan but for project requirements, bulk quantities will be transported from Peshawar or Rawalpindi region with quality confirmation certificates of the manufacturer. Low alkali cement would also be transported from Rawalpindi region if required.

Water of the project area seems suitable for concrete and other construction works and as per few previous testing references of Panjkora river water is suitable for all construction purposes. Water quality and results are within permissible limits. Later at detailed design stage further in depth testing is recommended.

No harmful chemical contents like sulphate, chlorides, total dissolved salts and organic matter has been found and materials are suitable for construction. Testing results are attached as **Annexure-D of Volume 3.**

5.13.1 General

Abundant construction materials of almost all types are available in the Project area or its close vicinity. The coarse and fine aggregate for the concrete materials is available from the Panjkora river bed, which currently is meeting all local requirements. The Panjkora River presents vast alluvial terraces on both the banks of the meandering flows, which become inundated during high flow season and the river bed terraces are charged again with the aggregate material. Also similar material is available and being mined in abundant from the Kunai Khwar.

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Besides, some crushers have also been installed in Timergara and near Talash (some 4 km downstream, where the larger size cobbles and boulders from river and local nalas are being crushed to required sizes. The cohesive material shall also be abundantly available from the old river terraces with clay / silt cover existing on both the banks of the Panjkora and Kunai Khwar. Cement in the local market is being procured from the nearest cement factories situated in Cherat (140 km), Nizam abad (190 km) etc. Details of the findings of investigations are given below;

5.13.2 Concrete Materials

Large quantities of concrete shall be required for nearly all the project features – like weir structure, Intake structure, Sand trap structure, power channel, power tunnel of about 10 Km, Surge shaft and high pressure tunnel with the power facilities and the powerhouse building etc.

The Project area has been thoroughly investigated for the availability of such large quantities of materials. Surface plans have been prepared for the identified potential areas and test pits excavated for sampling purposes. Quality testing has been applied and as discussed above fine and coarse aggregates have been checked with different aspects and results are promising as suitable aggregates, for reference testing results are attached as **Annexure-D of Volume 3.**

5.13.3 Coarse Aggregate

- **Panjkora River bed Material**

As described above, the Panjkora river and its terraces will be the major source of nearly all types of materials, particularly the concrete aggregate materials consisting of both the coarse and fine aggregates. The Panjkora river valley generally is quite wide in the upstream reaches.

The river bed flat terraces comprise the sandy gravel material with cobbles and boulders of dominantly igneous origin. The rock types visually identified are the Granites, Garnet Mica Schist, Mylonised Granites and Amphibolite and Granitic Gneiss. Gabbro Norites, diorites ultramafics (pyroxenites etc), quarto feldspathic / quartz veis material and the amphibolite are present in upstream of weir as Kohistan Island arc rocks while Granites and Quartz or Garnet mica schist representing Indian plate rocks. All these rock types are considered as strong to very strong in nature and are considered suitable for the concrete aggregates. Currently, a crusher is operational on the terraces, which is processing the river bed material for both the coarse and fine aggregates for local use. Besides, at numerous locations the river bed material is being mined locally through digging shallow pits in the river bed material. It is therefore inferred that the Project requirements can be significantly met through this source alone.

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However, the processing and crushing of the coarser material shall have to be done before use into concrete plant.

- **Materials from the required excavation**

Large quantities of materials shall be available from the required excavations. This material shall originate from the underground excavations like tunnels, surge shaft and penstocks etc. The material dominantly available from required excavations will be the Granitic Gneiss, Quartz/Garnet Mica Schist with Mylonised granites and Amphibolite of igneous and metamorphic origin which is considered quite suitable for the aggregate with low alkali cements or Pozzolanic materials. These rocks as per testing results are showing Alkali silica reaction (ASR) potential to Ordinary Portland Cement (OPC). Therefore these bodies are not recommended for use as concrete aggregate with OPC or with high alkali cements. At detailed design stage further in depth investigations are required regarding further sub bodies of the rock within one unit.

- **Borrow Sources of coarse aggregate**

The borrow source of coarse aggregates has been noted outside the Project area which is described below;

- **Talash / Khazana Crushers**

Outside the Project area and nearly 20 km downstream of Timergara Town, some crushers have been installed in Talash / Khazana area. These crushers have been installed in a large left bank tributary of the Panjkora River. The Panjkora River in this reach passes through a narrow gorge and alluvial terraces are not available in this reach. These crushers are producing the coarse aggregate to meet the local requirements. The materials being crushed are the cobbles and boulders of large size belonging to igneous origin. This source can also be considered as alternate to the Timergara sources.

5.13.4 Fine Aggregate (Sand)

- **Panjkora River Sand Source**

The reliable and confirmed sand sources in the Project area are not available in large quantities. Currently, the local requirements are being met through mining the river bed materials from the shallow pits. The fine to medium grained sand with occasional pockets of medium to coarse sand are spread in the river terraces as 1 – 1.5 m thick layers in the sandy gravel layers. However, these pockets and layers are not continuous and provide only limited

quantities of sand. Generally the sandy gravel material also contains sand up to 20 – 25 %. At places the sand is being extracted through sieving in the sandy gravel material from the river bed. It is anticipated that for a project like this, the scattered, small extent sources may not be sufficient during the construction of the Project. Therefore to meet the requirements, borrow areas in the vicinity of the project have been identified and described below.

- **Kunai Khwar and Ruth Nala Sand**

Fine to medium, clean sand in the form of pockets and thin inter - layers is also present in the nala beds of Kunai Khwar which is major right bank tributary of the Panjkora river. Another source being locally exploited is from the Ruth nalla – another right bank tributary of Panjkora River. Appreciable quantities of sand can be obtained from these sources after screening of the nalla bed material.

- **Manufactured Sand**

The area in the vicinity of the Project has been explored for the identification and location of the reliable and permanent sand source. However, no such source could be found in the area. Therefore the only option left is that the sand be manufactured locally in the Project area through crushing the suitable rock materials obtained through required excavation or through crushing the river bed material like the gravel, cobbles and boulders. The river bed material seems quite suitable for this purpose and it is anticipated keeping in view the mineralogy of the material that this material can safely be used with OPC. But as per project borrow area materials testing results, sand is available within the Panjkora river bed from 17 to 44 % which is reflecting promising % of fines but further in depth studies are recommended during the detailed design stage for better optimization. In case of fines are reactive as project area rock dominantly reactive for Alkali Silica Reaction then low alkali cement or Pozzolanic materials are strongly recommended for all concrete works.

- **Borrow Sand Sources from Swat River Valley**

Sand sources available in the Project area and in vicinity may not meet the project requirements therefore the areas outside the Project area were also patrolled. The emphasis was given to Swat River valley at Chakdara nearly 40 km from Timergara.

The Swat river valley is wide open both in the upstream and downstream of the Chakdara bridge. Both these sites were visited for identifying some regular source of sand in this area. However, it was concluded that although sand is available in Swat valley, yet no regular source or terrace is present anywhere along the valley and locally sand is being mined from the

scattered thin layers and pockets inter bedded with sandy gravel material. However, the sand at places is commercially being mined for meeting the local market requirements.

Three note able sand sources in Swat River valley are worth mentioning as described below;

- **Shamozai Sand Area**

This sand source is situated 10 km upstream of Chakdara bridge along Mingora by–pass road. The sand is silty, coarse to medium grained in nature and is being mined from the river bed for commercial use. Large quantities of sand can be mined and screened in situ before transportation to the Project area.

- **Totakan Sand Area**

This source is located about 25 km downstream of the Chakdara bridge. The silty, fine to medium micaceous sand is being mined locally from the river bed for commercial use. The sand is being processed at both the banks of the river.

- **Tarai Sand Source**

This source is also present about 18 km downstream of the Chakdara bridge, from where the silty micaceous fine to medium sand like that of the Totakan source is being exploited locally for commercial use.

5.13.5 Cohesive material

Large extent old river terraces covered with silt and clay materials are present on both left and right banks of Panjkora River. These terraces possess about 1 to 2 m thick layer of cohesive soil on the old river sandy gravel material. Although almost all the terraces are thickly cultivated on both the banks, yet some barren patches of land can be found, from where the material can be procured for use in the Project. At left bank of Panjkora river just downstream of weir axis along the road, thick beds of cohesive materials are present with large quantities which can be further explored during detailed design stage.

5.13.6 Cement

Our background knowledge about the types of rocks and the mineralogy of the aggregate material present in the project area and in vicinity, indicates that the use of OPC shall not be quite safe for the concrete material and potential of the ASR exists. Therefore the OPC cannot safely be used in the Project construction.

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The local market in Temergara has been explored for obtaining firsthand information about the procurement of the cement (OPC) for local construction industry but low alkali cements are not available within the nearest project vicinity. It is also found that the cement in the market is being procured from the nearest cement factories mentioned below;

- Cherat Cement Factory – Naushehra, about 150 km from Temergara
- Nizam abad Cement Factory – Naushehra, about 180 Km from Temergara
- Bestway Cement Factory – Islamabad, about 250 km from Temergara
- Also there exist numerous other cement factories in Hasan abdal, Taxilla and Islamabad, within a range of 250 to 300 km from Temergara.

Accordingly as per investigation results, Ordinary Portland Cement (OPC) cannot be used and recommended for all concrete works keeping in view Alkali Silica Reactivity of available fine and coarse aggregates within the project vicinity. Low Alkali cements or volcanic ash/Pozzolanic materials are recommended for further blend distribution. Quality control certificates of the required cement will be the essential part of supply by the manufacturer.

5.13.7 Water

Water in general seems quite suitable for construction purposes; however with reference to some other close vicinity Panjkora water analysis, results meet the requirement of portable water and can be used for all construction works.

5.13.8 Steel

Steel, like cement, is not locally available and shall have to be procured from markets in Peshawar, Rawalpindi and Lahore.

5.14 Recommendations for Future Works

The geological and geotechnical investigations carried out and described in this chapter were aimed at generating data required for Feasibility level design of the Shigo Kas Hydropower Project. At detailed design stage additional investigations will be required which are briefly described below;

1. Detailed geological mapping along major structures like weir, intake, Sand trap, Surge shaft area, along Penstocks and more important along the tunnel for picking up more information on the lithological and structural features.

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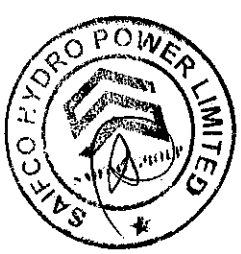
2. Drilling of boreholes in river bed alluvial terraces along the final layout of Weir Axis as well as at abutments, particularly at the present location of weir which is moved upstream about 200 meters from its previous location where three drill holes were drilled accordingly. As per surface geological mapping subsurface bed rock conditions at this final weir location will also be almost same as previous. For this purpose about 100 m drilling is envisaged. One more drilling is required in Tunnel outlet/Surge shaft area which can be extended into the depth of invert level of pressure tunnel and even 5 meters down to invert level. One drilling each is required along Penstock area and within Power house area for reconfirmation of subsurface conditions as encountered during present stage of feasibility studies. For this purpose total of 300 meters drilling is recommended for all structures during detailed design stage.

3. Keeping in view the large size diameter of the tunnel (about 08 m excavated), it is predicted that in-situ rock mechanic tests including the flat jack, plate load, over-coring and hydro fracturing shall be required for detailed design purposes. It is suggested that an exploratory Adit (which at later stage be converted into access tunnel) be excavated in the locations of adits as shown in surface geological mapping of the tunnel and used for rock mechanic testing.

4. A few test pits shall also be required in the foundation area for collection of bulk and block samples for laboratory testing for confirmatory purposes.

5. Laboratory testing shall be required on both soil and rock core samples including routine and specialized testing. Some laboratory testing shall also be required for construction material evaluation.

6. Confirmatory testing for Alkali Silica Reaction (ASR) potential shall be required through further laboratory testing including long-term mortar bar testing. Current studies have indication of such potential exists in the nearby materials and in depth analysis are further required at detailed design stage for confirmation and potential rate can be checked with different blend trials.



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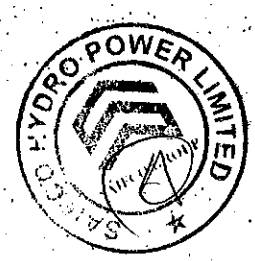
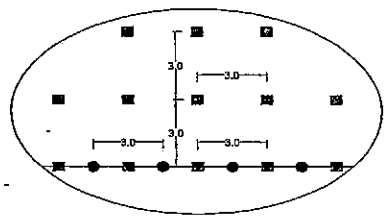
CHAPTER

5

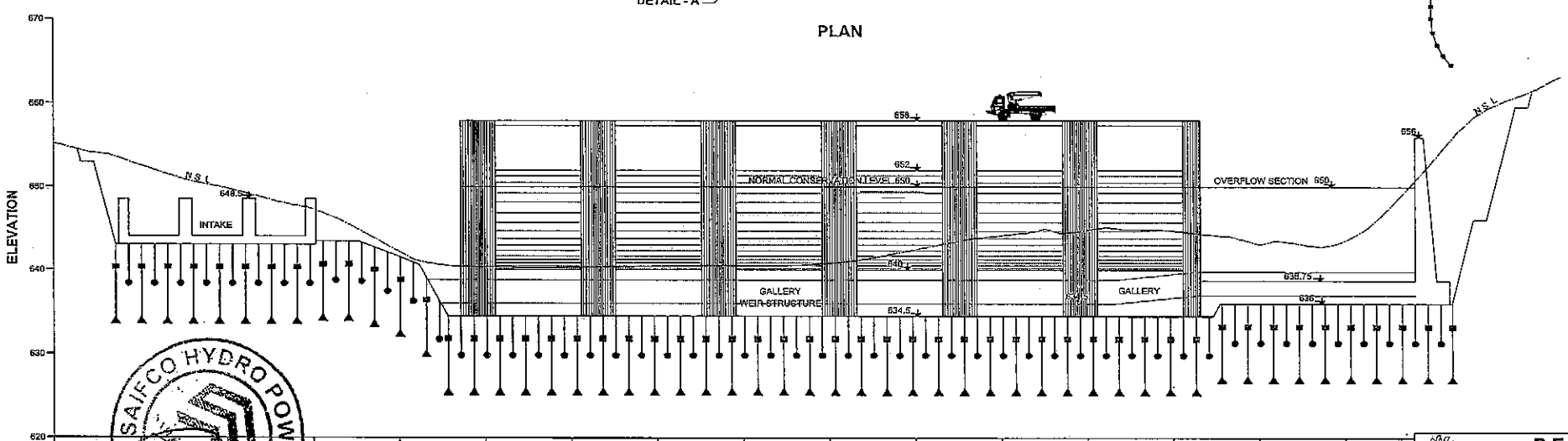
GEOLOGY & GEOTECHNICAL INVESTIGATIONS & CONSTRUCTION MATERIALS





DETAIL - A

PLAN



SECTION A - A

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LEGNED:

- ▲ = PRIMARY BOREHOLE
- ● = SECONDARY BOREHOLE
- ■ = CONSOLIDATION GROUTING

GROUTING DETAIL		
HOLE	DEPTH	SPACING C/C
PRIMARY	9.5 meters	3 meters
SECONDARY	5 meters	3 meters
CONSOLIDATION GROUTING	3 meters	3 meters

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Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

GROUTING PLAN AND PROFILE
(SHEET 1/1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
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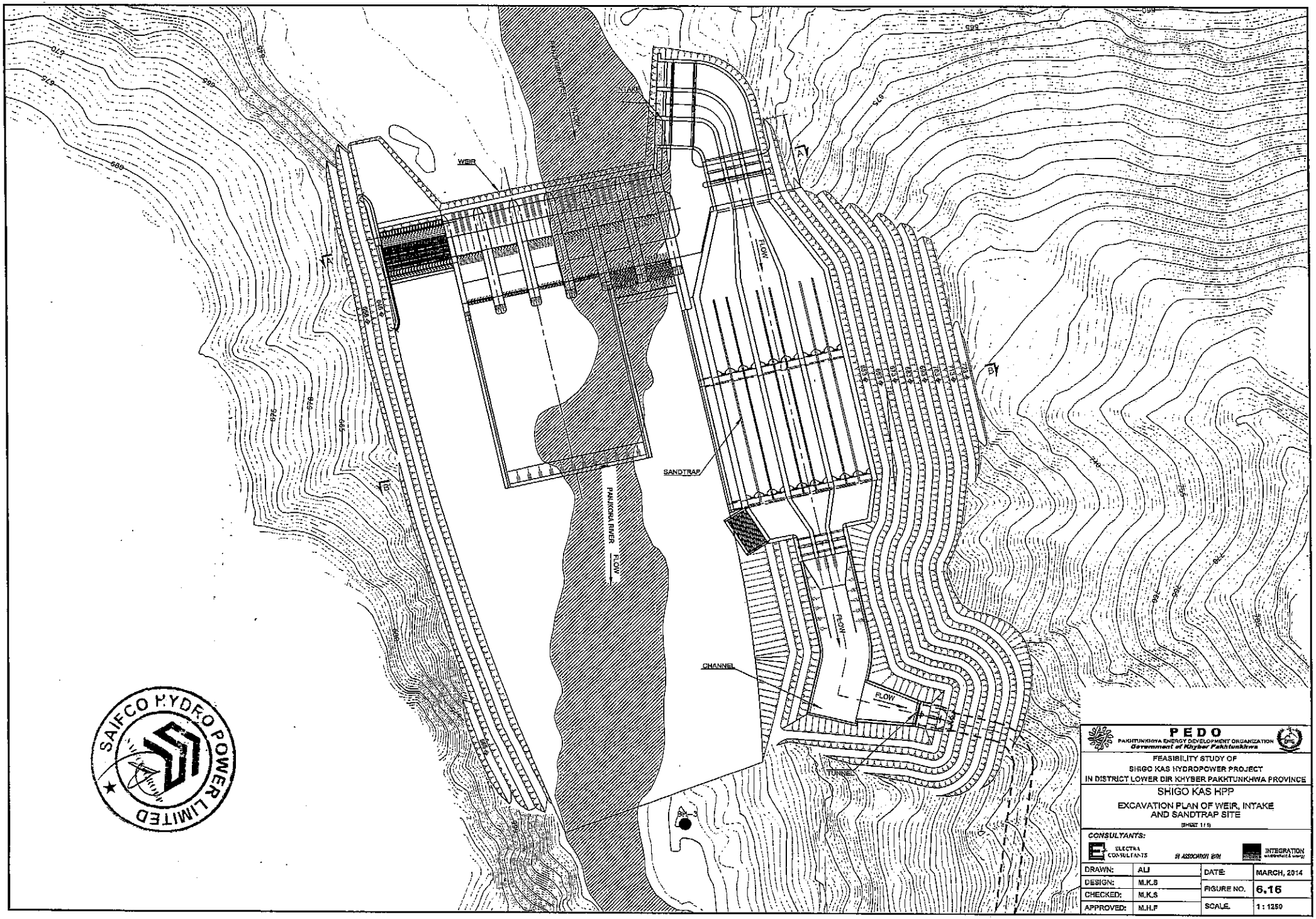
APPROVED:	M.H.F	SCALE.	1 : 550



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IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

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EXCAVATION PLAN OF WEIR, INTAKE AND SANDTRAP SITE

(SHEET 1 / 1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
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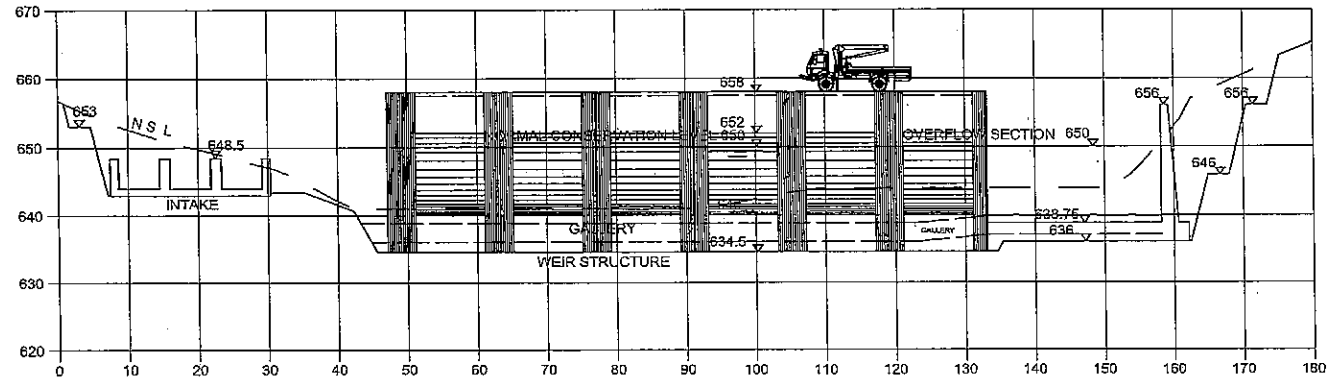
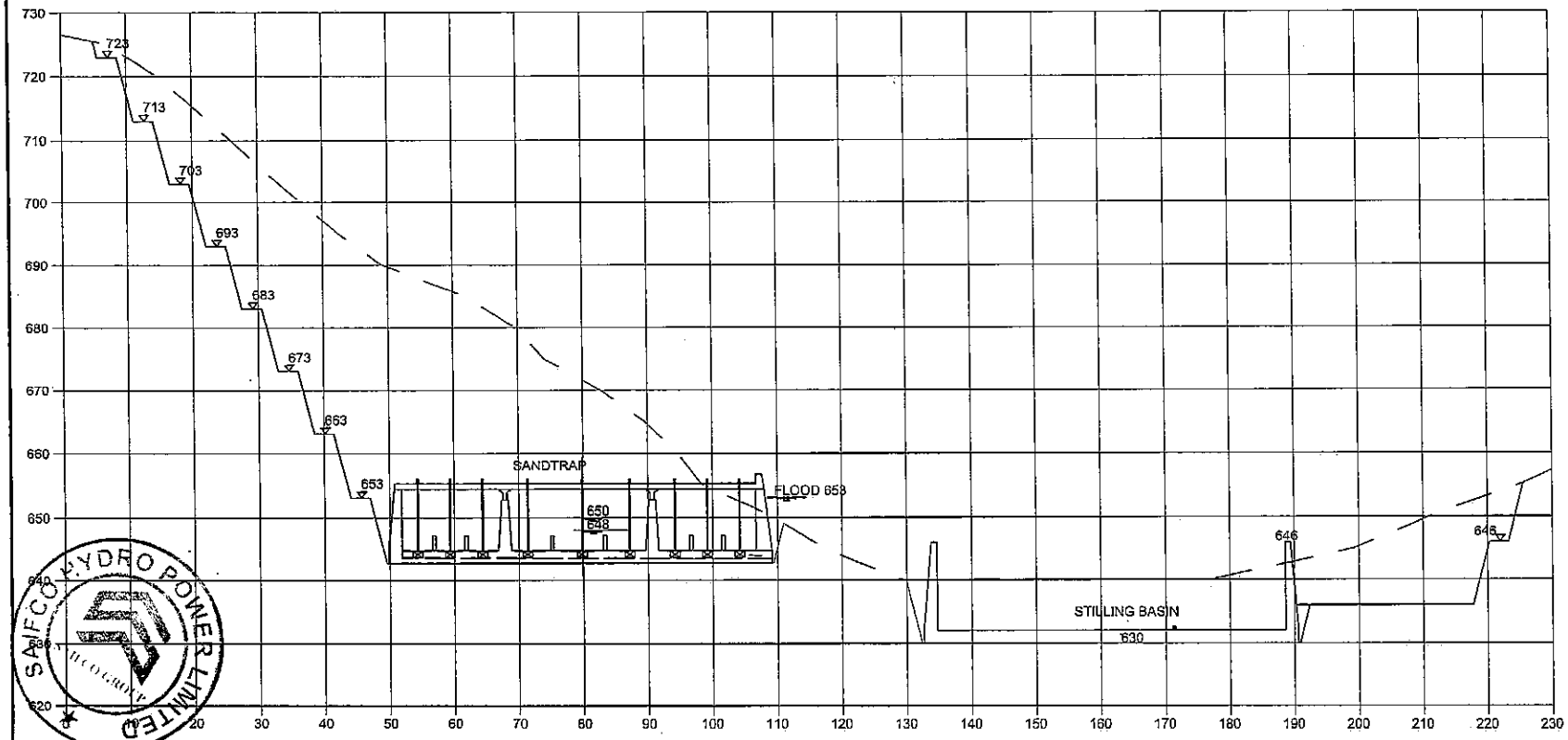
APPROVED:	M.H.F	SCALE.	1 : 1250



SECTION A - A'



SECTION B - B'

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FEASIBILITY STUDY OF SHIGO KAS HYDROPOWER PROJECT IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE			
SHIGO KAS HPP SECTIONS AT WEIR, INTAKE AND SANDTRAP SITE			
CONSULTANTS: ELECTRA CONSULTANTS in association with INTEGRATION			
DRAWN:	ALI	DATE:	MARCH, 2014
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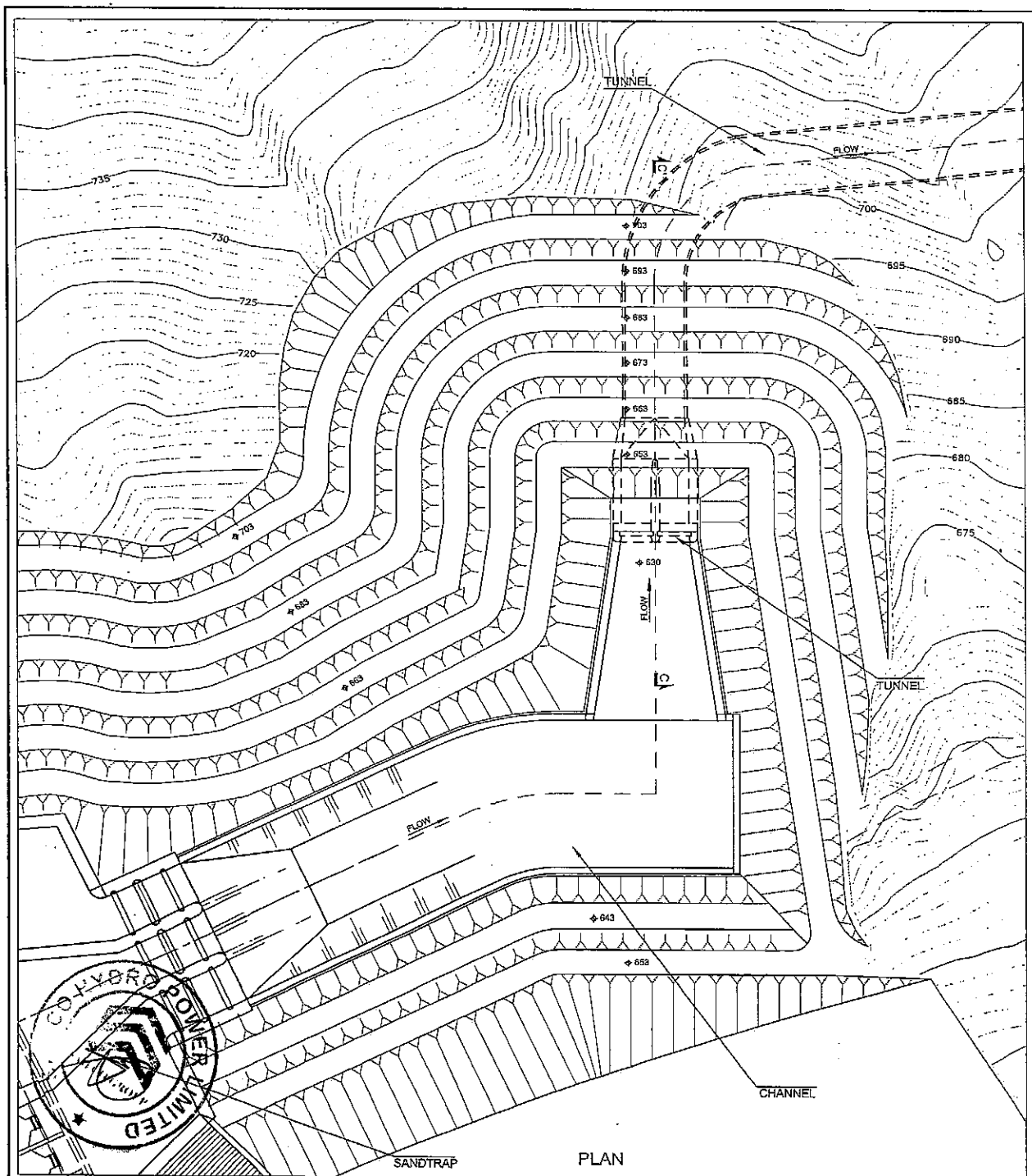
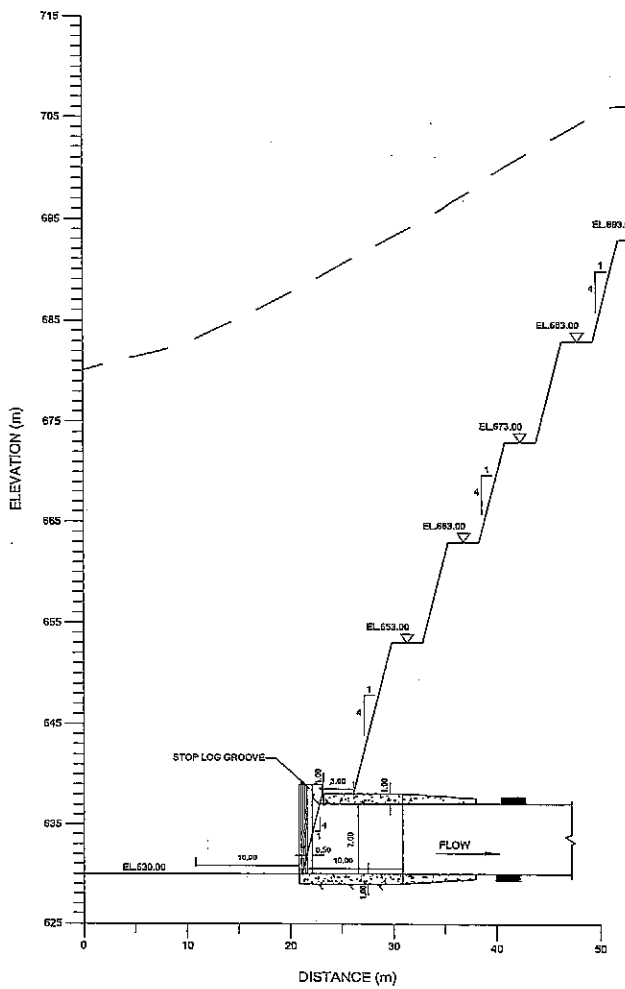
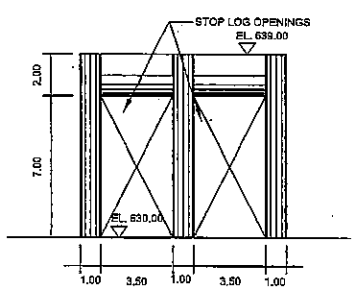


PLAN



TUNNEL PORTAL ELEVATION



SECTION C - C'

0 5 10 15 20 25 Meters

SCALE

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FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

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EXCAVATION PLAN & SECTION OF
TUNNEL INLET PORTAL
(SHEET 1/1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION engineering & energy

DRAWN:	ALI	DATE:	MARCH, 2014
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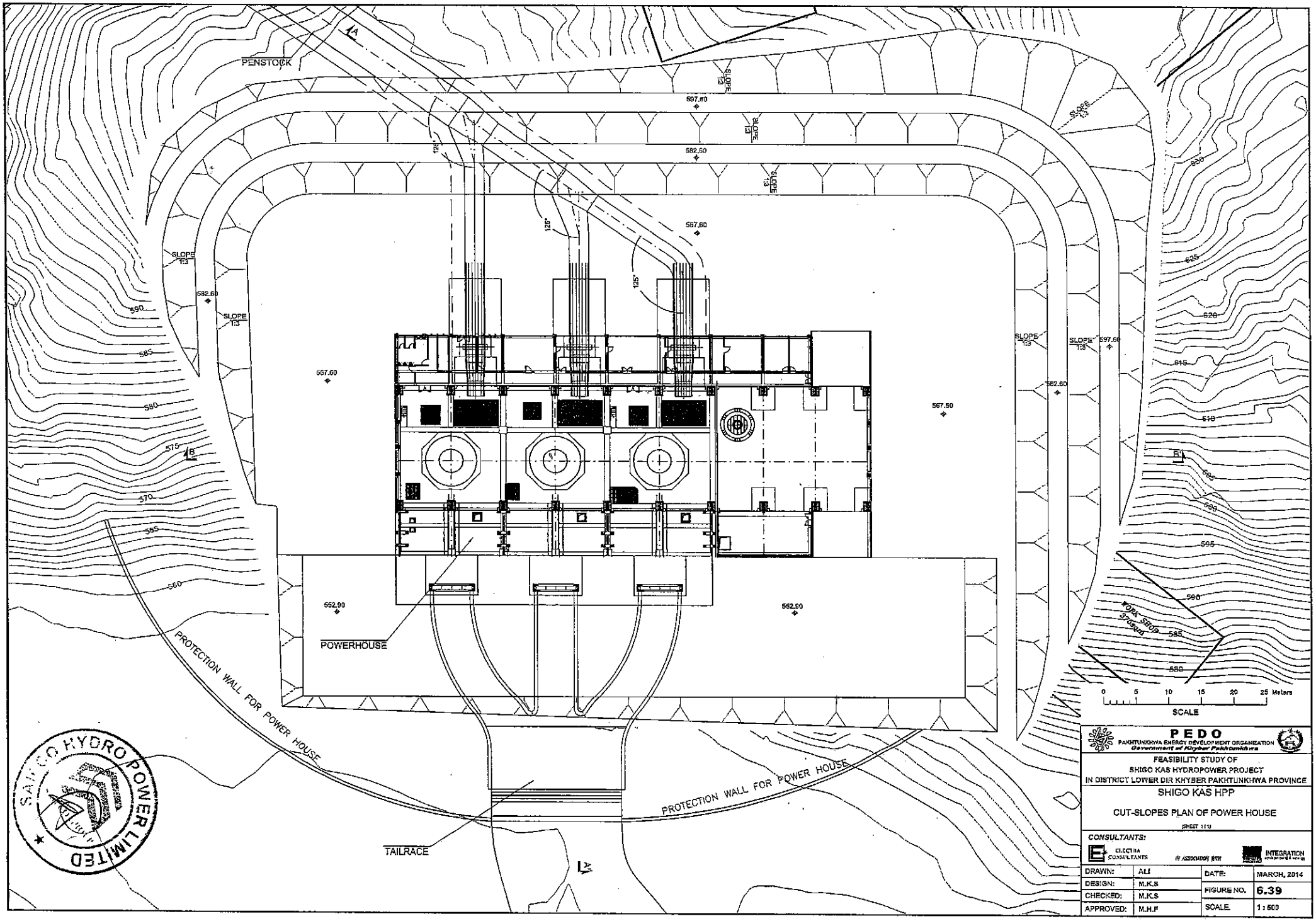

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FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

CUT-SLOPES PLAN OF POWER HOUSE

(SHEET 1 / 1)

CONSULTANTS:
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DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	M.K.S	FIGURE NO.	6.39
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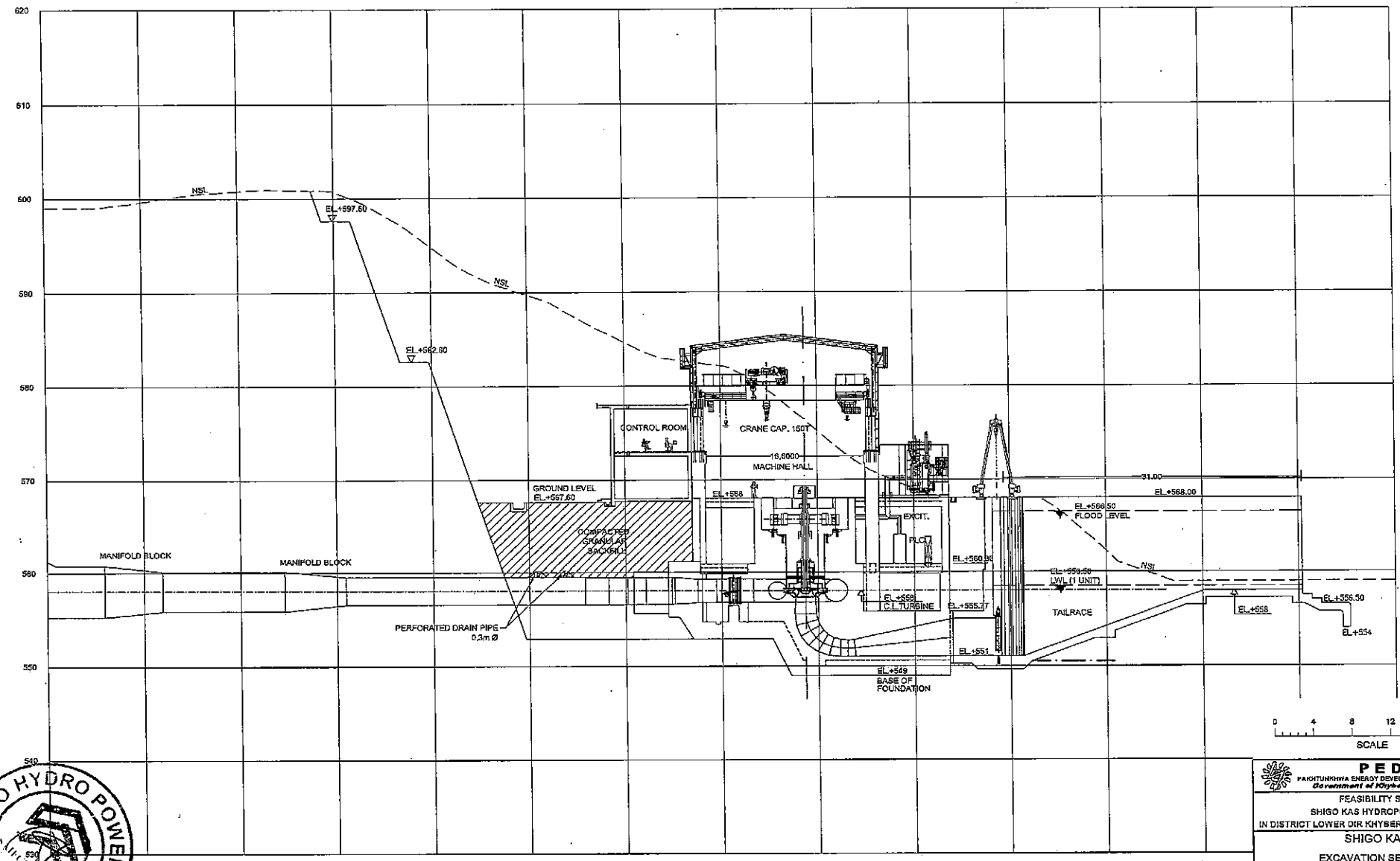
APPROVED:	M.H.F	SCALE	1:500



SECTION A - A'

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Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

EXCAVATION SECTION A - A'
OF POWER HOUSE

(SHEET 1 of 1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION environment & energy

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	M.K.S	FIGURE NO.	6.40
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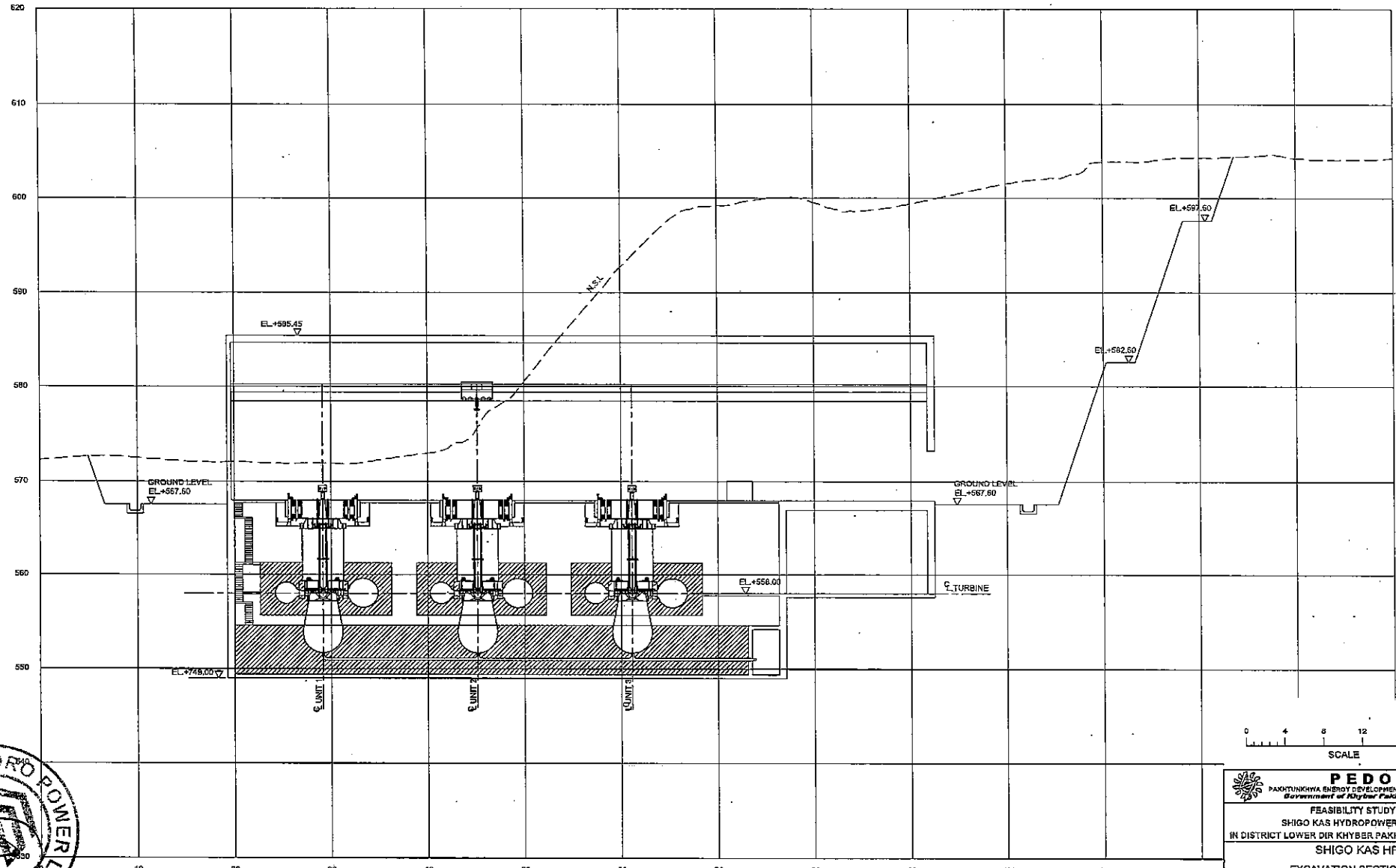
APPROVED:	M.H.F	SCALE.	1 : 400



SECTION B - B'

0 4 8 12 16 20 Meters

SCALE

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FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

EXCAVATION SECTION B - B'
OF POWER HOUSE

(SHEET 1/1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	M.K.S	FIGURE NO.	6.41
CHECKED:	M.K.S		
APPROVED:	M.H.F	SCALE.	1 : 400

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CHAPTER 6

GEOTECHNICAL DESIGN

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GEOTECHNICAL DESIGN

6.1 GEOTECHNICAL DESIGN OF WEIR STRUCTURE

6.1.1 GENERAL

The weir has been designed for a maximum flood discharge of 5,569 cumecs. The basic function of the weir is to divert the river flow in to intake structure at the left abutment. The reinforced concrete structure has been proposed which will be placed over the bed rock. According to the foundation condition and geology at site, safe and economical design has been carried out.

This chapter deals with the establishment of geotechnical design parameters on the basis of field and laboratory test results and geotechnical design studies for the ground and underground components of the Shigo Kas Hydropower Project. Following are the components of ground and underground works.

Ground Works:

- Design of Cut slopes for weir, intake, sand trap, tunnel and power house areas

Underground Works

- Foundation design of weir structure and Power house
- Tunnel design
- Foundation treatment works

6.1.2 GEOTECHNICAL INVESTIGATIONS

Investigations have been carried out during the feasibility stage. Three bore holes, one at right abutment, one in the river valley and one at the left abutment were drilled to provide information about the type and nature of the material in the river bed, the depth and extent of over burden in the foundations and elevation of bedrock. Investigation includes 85 linear meter drilling through 3 number boreholes. Field permeability in overburden and water pressure tests in rock have been carried at every 3-meter interval. Geotechnical investigations reveal that rock type at the weir site is Quartz-Mica Schist.

6.1.3 FOUNDATION CONDITIONS

River Valley

Depth from NSL to 2.9 m down

Overburden consists of Fine to coarse grained sand from NSL to 1.0 m and Medium to coarse gravels of igneous and metamorphic origin from 1.0 to 2.9 m. Average value of permeability in this range is 7.59 x 10^{-2} cm/sec, which means that strata is pervious and sufficient seepage will occur through this zone. Average material recovery in this zone is 30 %. It is estimated that strata is not dense which will cause settlement of weir structure. Therefore, in view of above, foundation of the weir structure has been placed over the bed rock.

Bed rock at depth 2.9 m

Rock type is Quartz-Mica Schist, which is moderate to highly weathered, highly foliated and jointed. Lugeon value varies from 32 to 84; this high value of Lugeon is the indication of open jointed rock.

Right Abutment

First 3-meter depth comprises of overburden, which is angular to sub angular gravels which shows that zone is pervious and seepage flows can occur through this. Following the overburden, rock type is Quartz-Mica Schist. RQD value ranges between 0 to 40% which shows that rock quality is very poor to poor shown in **Figure 6.1**.

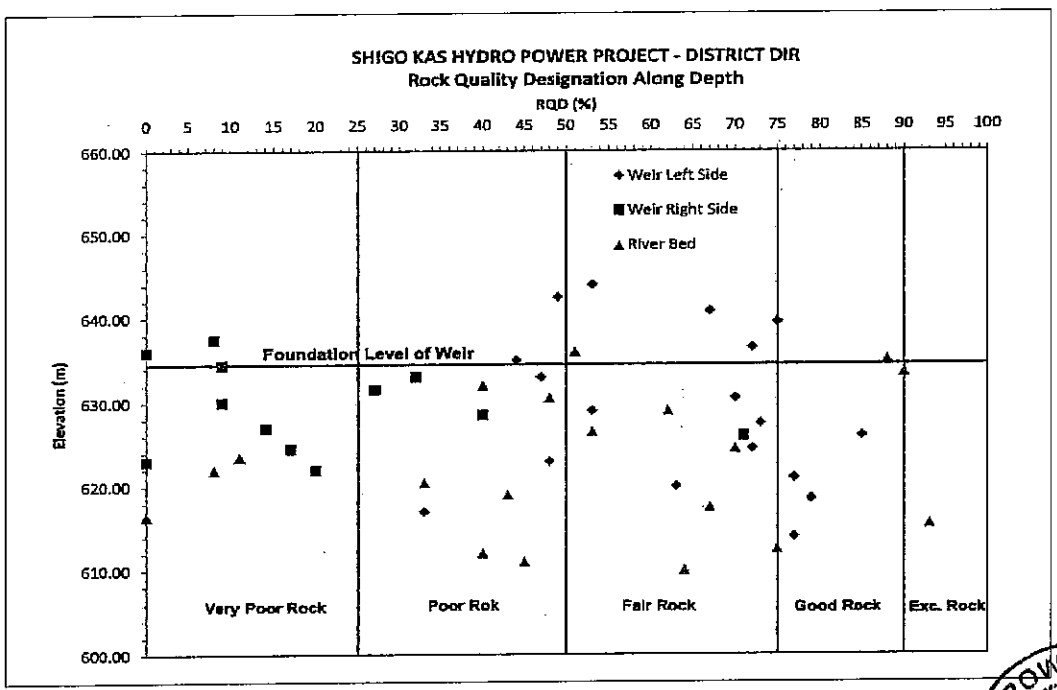

Figure 6.1: Rock Quality Designation along Depth

Left Abutment

First 1.5-meter depth comprises of overburden, which is angular to sub angular gravels which shows that zone is pervious and seepage flows can occur through this. Following the overburden, rock type is Quartz-Mica Schist. RQD value ranges between 30 to 70% which shows that rock quality is poor to fair.

Lugeon values at different depths and grouting requirement along the weir axis are shown in **Figure 6.2.**

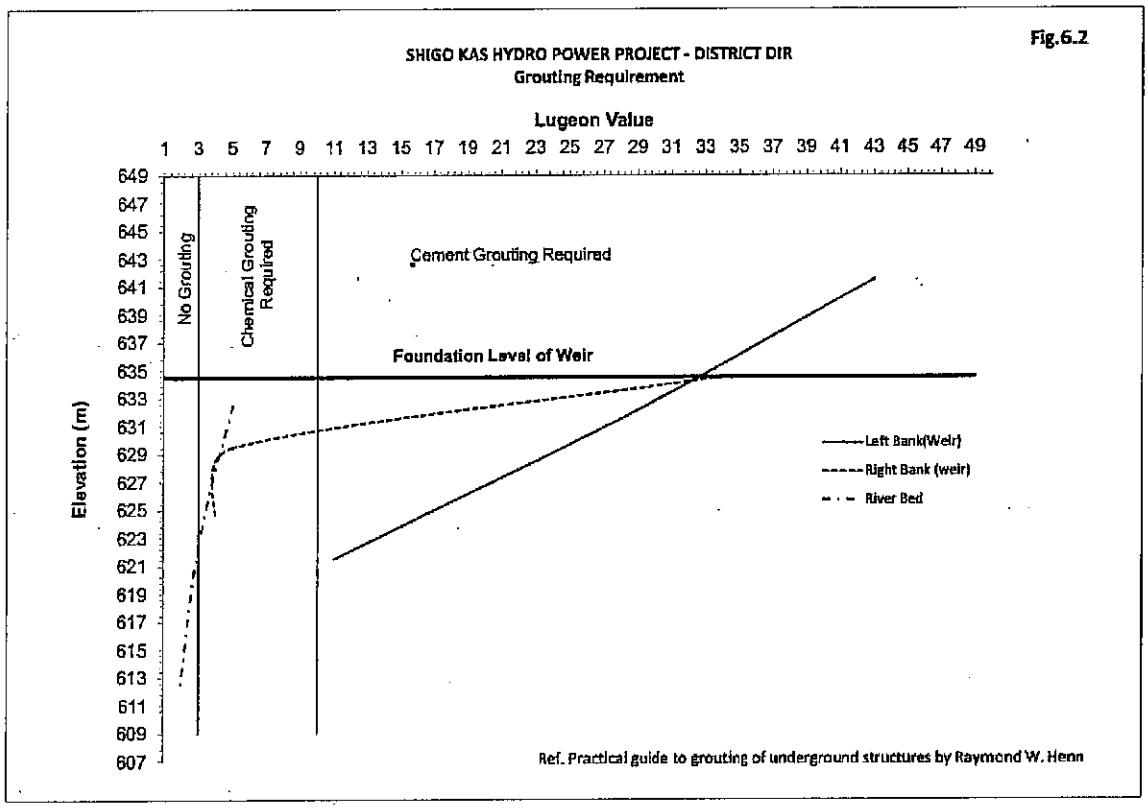

Figure 6.2 Lugeon Value & Grouting Requirement

6.1.4 DESIGN ASSUMPTIONS

Following design assumptions have been made:

- One longitudinal section in the river valley is assumed for the foundation design.
- Bed rock is assumed to be pervious due to low RQD;s values
- Highest lugeon value of 33 (3.3 10^{-4} cm/sec) has been selected for seepage analysis
- K-ratio is assumed to be 1.0
- Isotropic condition of foundation material is assumed for the analysis.
- Steady state condition is assumed for the analysis.

6.1.5 DESIGN CRITERIA

Following four main criteria have been adopted:

Flow paths of underground seepage flows have been increased by providing grouting curtain

- Depth of grout curtain has been established in order to achieve acceptable exit gradient and uplift pressures
- Exit gradient should be less than 0.3.
- Foundation (concrete thickness) has been designed against the uplift pressure.

6.1.6 STABILITY AND SEEPAGE ANALYSIS

Weir structure consists of over-flow (25m wide) and non overflow gated (84m wide) structures. Sliding and overturning stability of overflow concrete structure has been checked with computer software "CADAM", whereas concrete thickness for the chute and stilling basin area has been checked against uplift pressures using computer software "GeoStudio 2007". Details are given in the following sections:

6.1.6.1 NON-OVERFLOW STRUCTURE

Non-overflow structures consist of following two sections:

Section-I: With stilling basin (*for high floods*)

Section-II: Without stilling basin (frequently used)

Seepage analysis has been carried out for both sections of Non-overflow structure in accordance with the design criteria as stated above.

Section-I: With stilling basin (for high floods)

Seepage analysis model for section-I developed in Geostudio 2007. Seepage analysis has been carried out with and without grout curtain and drainage gallery. Uplift pressure distribution for different depths of grout curtain and drainage gallery has been checked to determine the most effective depth of grout curtain and drainage gallery. After various trials, it is found that grout curtain/drainage gallery depth of 9.5 m below the foundation level (El. 634.5 m) is optimum and cost effective to reduce the uplift pressures significantly. Result of seepage analysis (flow net diagram of section-I) is shown in **Fig.6.3 and Fig. 6.4**

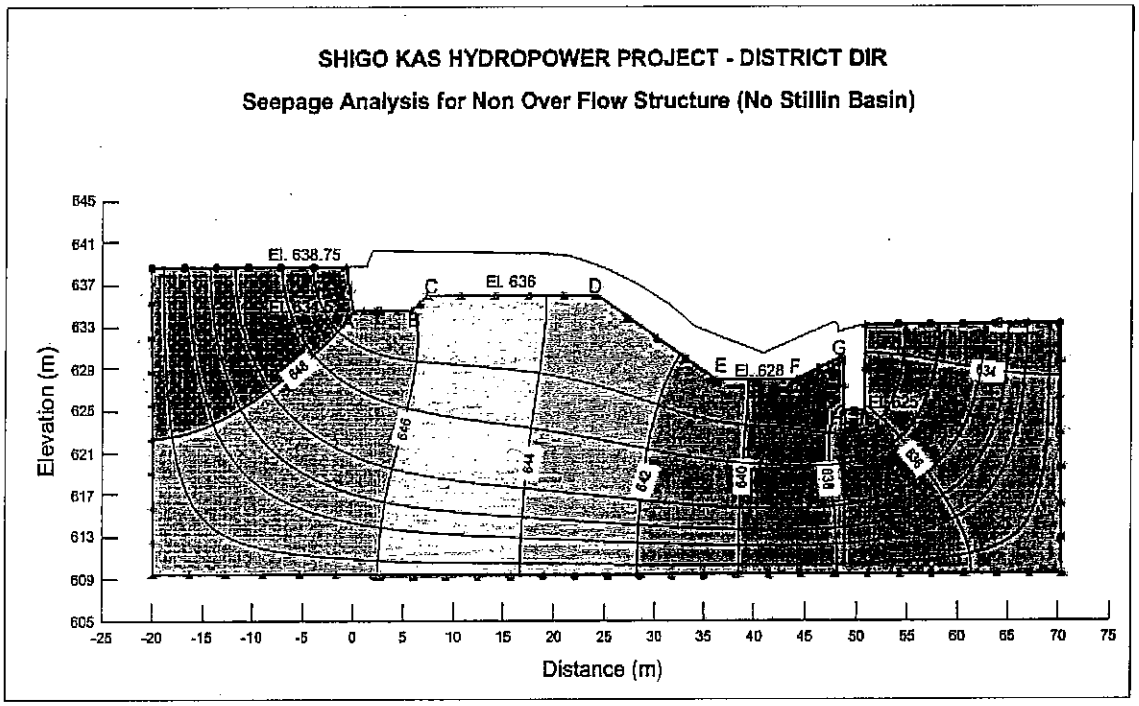

Figure 6.3: Seepage Analysis for Non Over Flow Structure (No Stilling Basin)

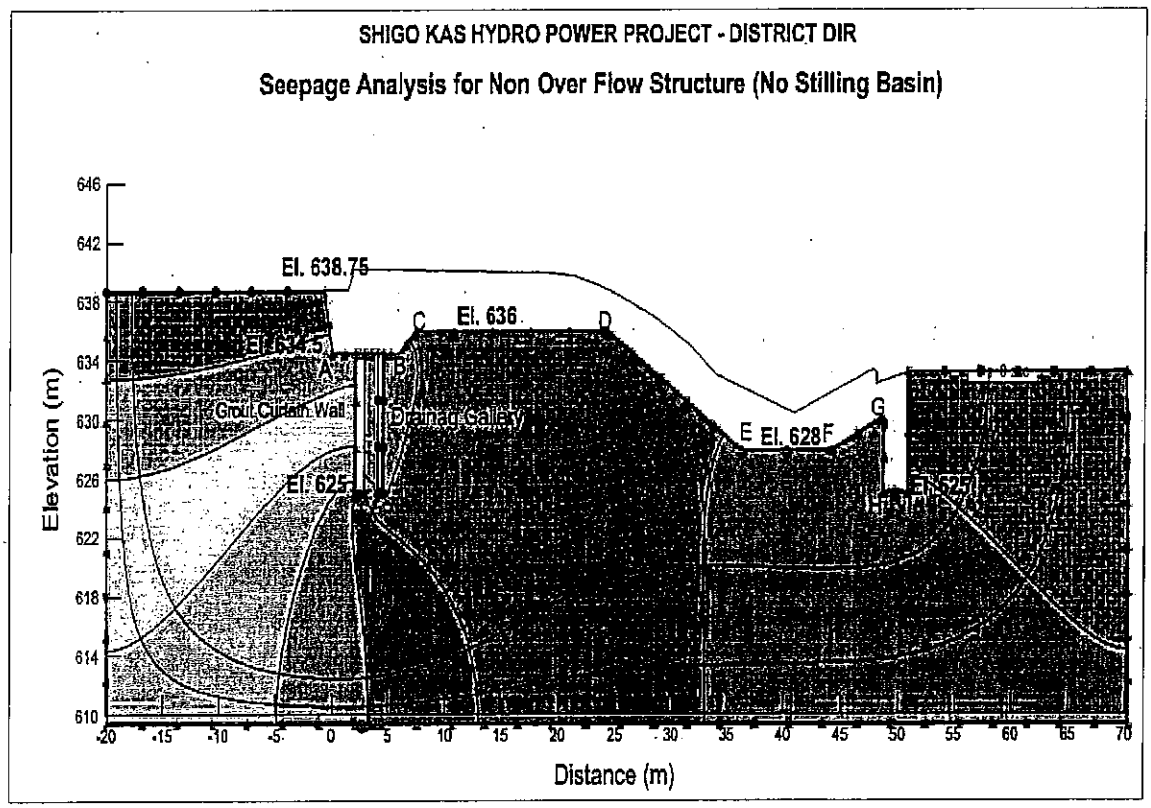

Figure 6.4: Seepage Analysis for Non Over Flow Structure (No Stilling Basin)

Uplift pressure distribution with and without grout curtain/drainage gallery has been plotted as shown in **Fig.6.5** which shows significant reductions of uplift pressure beneath the foundation. However, keeping in view the past experience of execution of grout curtain/drainage galley wells, 100% efficiency is not possible due to variations in rock foundations. Therefore, 50% efficiency of grout curtain is assumed and accordingly uplift pressures beneath the foundation have been increased 50% to determine the concrete thickness.

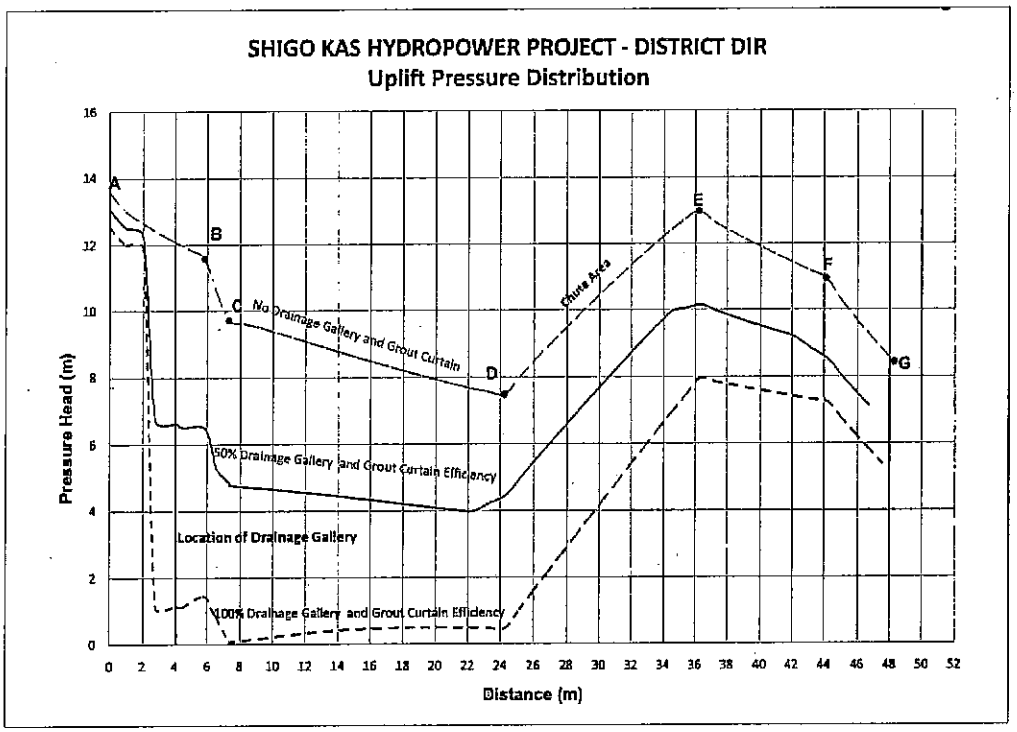

Figure 6.5: Uplift Pressure Distribution

Required and adopted concrete thickness in accordance with uplift pressures with 50% grout curtain efficiency is shown in **Fig.6.6** which shows that concrete thicknesses are inadequate before the grout curtain and in the chute area, whereas under the gated structures concrete thickness is adequate. Rock anchors will be required in the portions where concrete thickness is inadequate. Design of rock anchors are described in the subsequent following section.

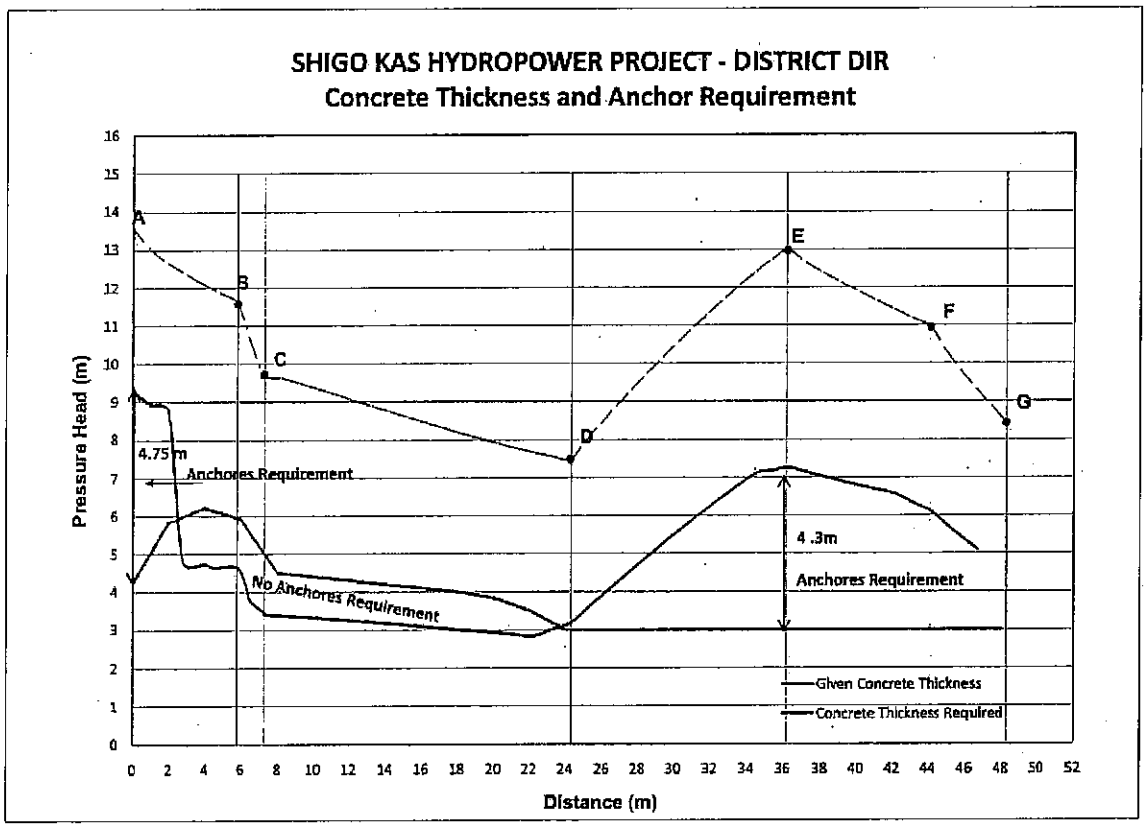

Figure 6.6: Concrete Thickness and Anchor Requirement

Section-II: With stilling basin (frequently used)

Seepage analysis model for section-II developed in Geostudio 2007. Seepage analysis has been carried out with and without grout curtain and drainage gallery. Uplift pressure distribution for different depths of grout curtain and drainage gallery has been checked to determine the most effective depth of grout curtain and drainage gallery. After various trials, it is found that grout curtain/drainage gallery depth of 13.75 m below the foundation level (El. 638.75m) is optimum and cost effective to reduce the uplift pressures significantly. Result of seepage analysis (flow net diagram of section-I) is shown in **Fig.6.7 and Fig. 6.8**.

Uplift pressure distribution with and without grout curtain/drainage gallery has been plotted as shown in **Fig.6.9,** which shows significant reductions of uplift pressure beneath the foundation. However, keeping in view the past experience of execution of grout curtain/drainage galley wells, 100% efficiency is not possible due to variations in rock foundations. Therefore, 50% efficiency of grout curtain is assumed and accordingly uplift pressures beneath the foundation have been increased 50% to determine the concrete thickness.

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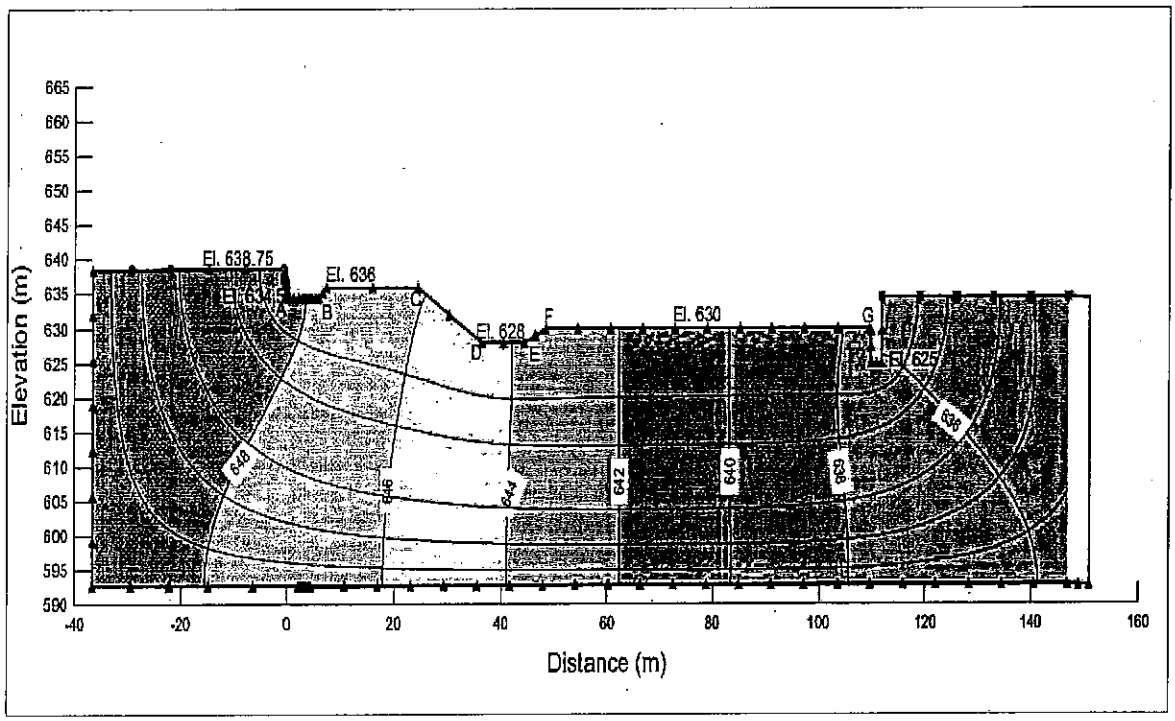


Figure 6.7: Seepage Analysis for Uplift Pressure (Non Over Flow Structure - With Stilling Basin)

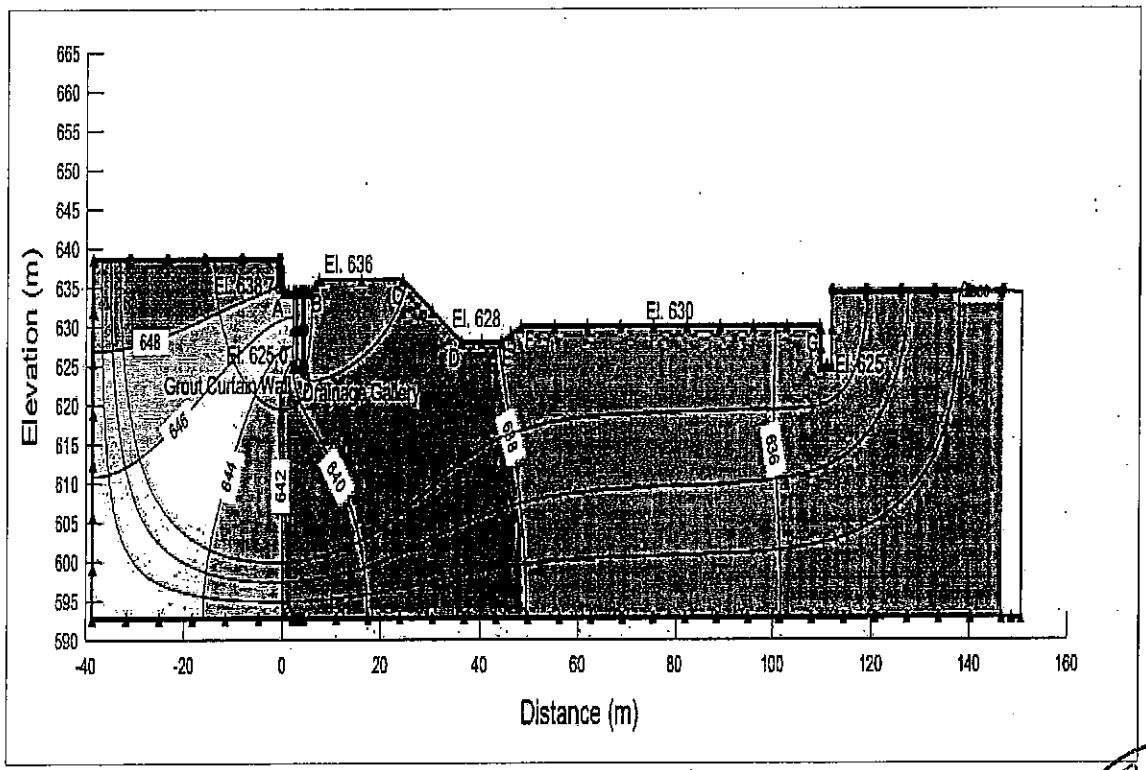


Figure 6.8: Seepage Analysis for Non-Overflow Structure (With Stilling Basin)

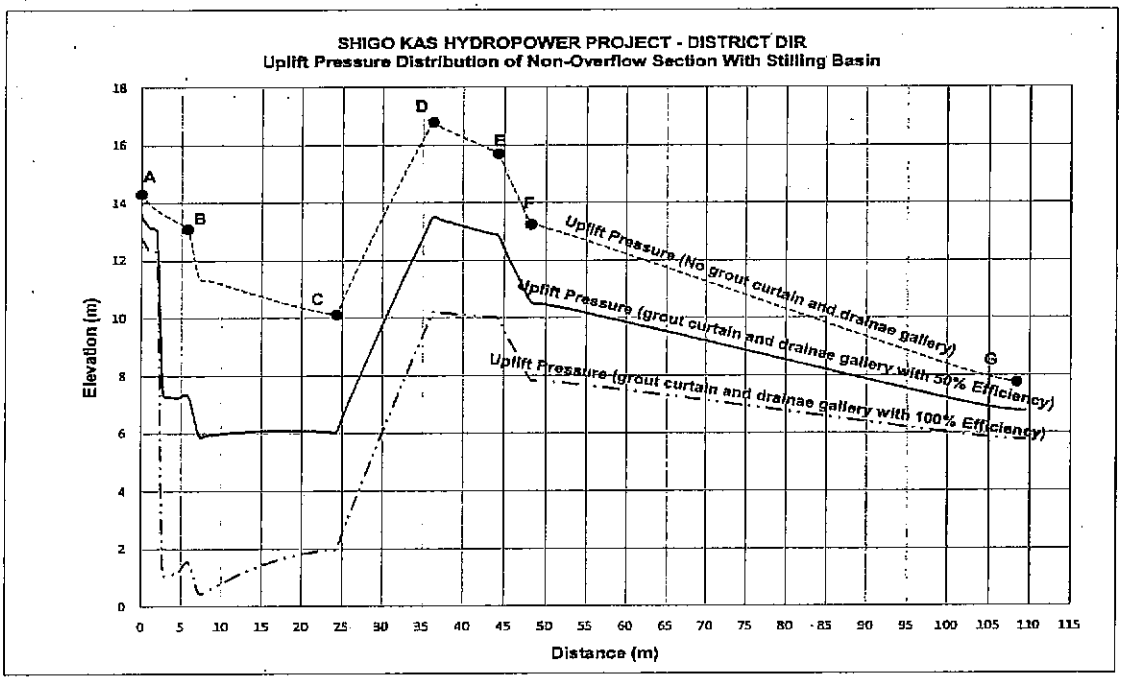


Figure 6.9: Uplift Pressure Distribution of Non-Overflow Section With Stilling Basin

Required and adopted concrete thickness in accordance with uplift pressures with 50% grout curtain efficiency is shown in **Fig.6.10** which shows that concrete thicknesses are inadequate before the grout curtain and in the chute area, whereas under the gated structures concrete thickness is adequate. Rock anchors will be required in the portions where concrete thickness is inadequate. Design of rock anchors are described in the subsequent following section.

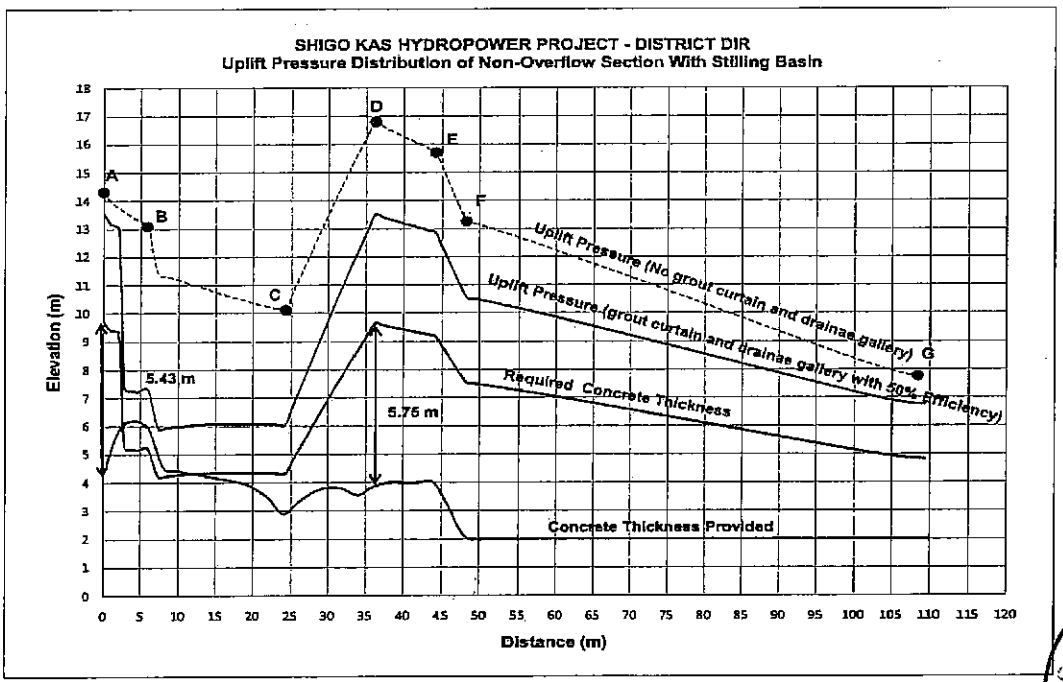


Figure 6.10: Uplift Pressure Distribution of Non-Overflow Section with Stilling Basin

6.1.6.2 OVERFLOW STRUCTURE

This overflow section will be used most of the time to spill excess flows up to 100 cumecs including environmental flows and to get rid of floating trash/debris.

Limit Equilibrium sliding analyses have been carried out to ensure that the weir foundation and foundation rock mass have adequate sliding stability. The analyses will be carried out with CADAM 2000 software. Sliding stability has been evaluated for the following features:

- Lift joints in the over flow structure
- Concrete/rock foundation interface
- Foundation rock mass.

It is necessary to evaluate sliding stability along lift joints and the concrete/rock surface for weir concrete structure. The evaluation of lift joint strength parameters will be based on the specified mix design and construction methodology.

Further details regarding load combinations, factor of safety requirements and various analysis to be carried out are covered in structural design criteria

6.1.6.3 CRITERIA ADOPTED

Factor of safety for stability of over flow weir structure against the sliding and overturning has been calculated for the following condition:

- Usual condition
- Flood Condition
- Usual condition with and without seismic acceleration (peak and sustained)

Stress analysis has also been carried out in order to ensure whether normal stresses do not exceed allowable stresses.

6.1.6.4 ADOPTED FACTOR OF SAFETY

For Stability analysis, following factors of safety have been adopted:

Loading Conditions	Sliding		Overturning		Uplift
	Peak	Residual	U/S	D/S	
Usual	3	1.5	1.2	1.2	1.2
Flood	2	1.2	1.1	1.1	1
Earthquake	1.3	1	1	1	1

6.1.6.5 GEOMETRY OF OVER FLOW STRUCTURE

Following geometry of the over flow structure has been adopted for the analysis:

- Crest Elevation = 650m
- Bed Rock Elevation (U/S and D/S) = 638.75 m and 638.1 m
- Upstream Reservoir Level under Operating Condition = 650 m
- Upstream Reservoir Level Flood Operating Condition = 654 m
- Downstream Water Level under Operating Condition = 638.1 m
- Downstream Water Level under Flood Condition = 640.5 m
- Foundation Level Below Bed Rock = 636.0 m

6.1.6.6 INPUT DATA

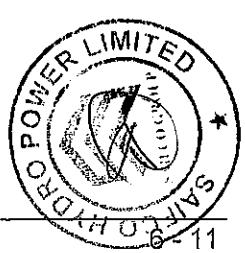
Following input data has been used for the analysis:

- Density of concrete = 2400 kg/m^3
- Effective unit weight of silt = 700 kg/m^3
- Angle of internal friction for silt = 20 degree
- Angle of internal friction for bed rock = 35 degree
- Cohesion = 0.0 lb/ft^2
- Compressive Strength of Rock = 300 Kpa
- Horizontal sustained ground acceleration = 0.15g
- Vertical sustained ground acceleration = 0.1g

6.1.6.7 ANALYSIS RESULTS

Model of the spillway is shown in **Fig.6.11. Table 6.1** shows the results for stability and stress analysis which shows that weir is safe against the sliding, overturning, uplift.

Similarly **Table 6.1** shows that maximum normal stress (229 Kpa) is less than the allowable compressible stress of 300 kpa.



CADAM - Model parameters

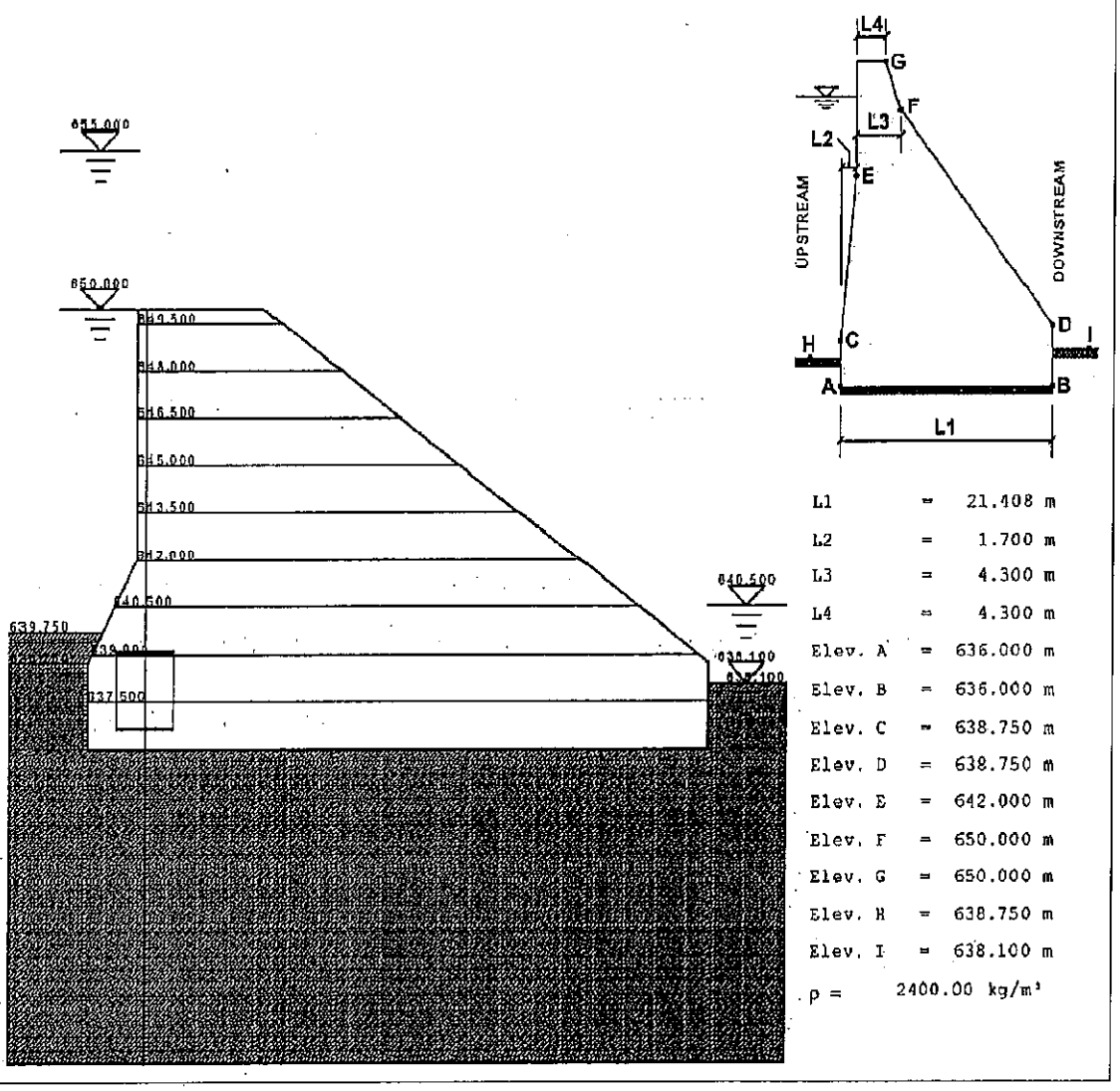
Page 1

by Martin Leclerc, M. Ing.
NSERC / Hydro-Quebec / Alcan Industrial Chair on Structural Safety of Concrete Dams
École Polytechnique de Montréal, Canada

General Information:

Project:
Dam:
Owner:
Dam location:
Project engineer:
Analysis performed by:
Date: 2/9/2014

Geometrical Dimensions & Concrete Volumetric Mass(ρ):



L1	=	21.408 m
L2	=	1.700 m
L3	=	4.300 m
L4	=	4.300 m
Elev. A	=	636.000 m
Elev. B	=	636.000 m
Elev. C	=	638.750 m
Elev. D	=	638.750 m
Elev. E	=	642.000 m
Elev. F	=	650.000 m
Elev. G	=	650.000 m
Elev. H	=	638.750 m
Elev. I	=	638.100 m
ρ =		2400.00 kg/m³

Figure 6.11: Model of the spillway

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Table 6.1: Results for Stability and Stress Analysis- Sheet 1

Table 6.1
Sheet 1 of 3

CADAM 2000 - Result report

Project: Shigo Kas HPP	Project engineer:
Dam:	Analysis performed by: Moin
Owner:	Date: 09 February 14
Dam location:	Units: Metric

LOAD COMBINATION FACTORS

	Usual	Flood	Seismic #1	Seismic #2	Post-seismic
Self-weight	1.000	1.000	1.000		
Hydrostatic (upstream)	1.000	1.000	1.000		
Hydrostatic (downstream)	1.000	1.000	1.000		
Uplift pressures	1.000	1.000	1.000		
Silts	1.000	1.000	1.000		
Ice					
Post-tensioning					
Applied forces					
Seismic (horizontal)					
Seismic (vertical)					

USUAL COMBINATION (STRESS ANALYSIS)

Joint ID	Joint Upstream elevation (m)	Cracking: Upstream Crack length (%)	Cracking: Upstream Crack length (m)	Cracking: Downstream Crack length (%)	Cracking: Downstream Crack length (m)	Stresses: Normal stresses Upstream (kPa)	Normal stresses Downstream (kPa)	allowable stresses tension (kPa)	allowable stresses Compression (kPa)	Shear Upstream (kPa)	Shear Maximum (kPa)	Shear Maximum at -axis (% of joint)	Shear Downstream (kPa)
1	649.500					-11.101	-8.994	0.000	-7992.000	0.000	-3.780	32.640	12.318
2	648.000					-49.086	-19.689	0.000	-7992.000	0.000	-5.393	28.990	26.966
3	646.500					-84.928	-24.242	0.000	-7992.000	0.000	-2.985	22.313	33.202
4	645.000					-117.659	-28.238	0.000	-7992.000	0.000	-0.644	11.345	38.674
5	643.500					-149.934	-31.690	0.000	-7992.000	0.000	43.403	100.000	43.403
6	642.000					-178.738	-36.540	0.000	-7992.000	0.000	50.045	100.000	50.045
7	640.500					-184.697	-56.608	0.000	-7992.000	96.611	-7.083	52.540	77.530
8	639.000					-196.354	-73.383	0.000	-7992.000	102.708	-8.188	50.251	100.505
9	637.500					-207.927	-111.259	0.000	-7992.000	0.000	53.738	50.000	0.000
10	Base					-211.748	-148.640	0.000	-6993.000	0.000	66.007	50.000	0.000

USUAL COMBINATION (SLABLIFT ANALYSIS)

Joint ID	Joint Upstream elevation (m)	Safety factors: Sliding Peak	Sliding Residual	Overturning Toward US	Overturning Toward DS	Uplifting	Resultants: Normal (kN)	Shear (kN)	Moment (kN-m)	Position (% of joint)	Uplift Final Force (kN)	Rock Passive wedge resistance (kN)
1	649.500	40.844	34.272	18.664	9.003	11.970	-50.1	1.2	-4.4	48.253	4.8	0.000
2	648.000	12.334	10.349	14.475	8.223	10.687	-242.0	19.6	-121.3	42.879	25.0	0.000
3	646.500	8.261	6.932	12.631	7.423	9.948	-496.4	60.1	-418.2	40.735	55.5	0.000
4	645.000	6.632	5.565	11.635	6.833	9.468	-813.2	122.6	-926.1	39.785	98.0	0.000
5	643.500	5.785	4.855	11.036	6.720	9.545	-1198.9	207.2	-1717.5	39.149	140.3	0.000
6	642.000	5.231	4.390	10.626	6.332	9.229	-1642.2	313.9	-2758.3	38.991	199.6	0.000
7	640.500	4.932	4.138	10.522	5.313	7.936	-2183.3	442.7	-3495.3	41.153	314.8	0.000
8	639.000	4.747	3.983	10.389	4.870	7.363	-2823.4	594.8	-4491.2	42.402	443.7	0.000
9	637.500	4.464	3.748	8.518	4.326	6.507	-3416.6	766.9	-3692.0	44.952	620.4	7.416
10	Base	5.806	2.964	6.010	3.605	5.124	-3857.6	942.1	-2410.2	47.081	935.4	90.850
	Required:	3.000	1.500	1.200	1.200	1.200						

FLOOD COMBINATION (STRESS ANALYSIS)

Joint ID	Joint Upstream elevation (m)	Cracking: Upstream Crack length (%)	Cracking: Upstream Crack length (m)	Cracking: Downstream Crack length (%)	Cracking: Downstream Crack length (m)	Stresses: Normal stresses Upstream (kPa)	Normal stresses Downstream (kPa)	allowable stresses tension (kPa)	allowable stresses Compression (kPa)	Shear Upstream (kPa)	Shear Maximum (kPa)	Shear Maximum at -axis (% of joint)	Shear Downstream (kPa)
1	649.500					-43.390	-21.865	1200.000	-12000.000	0.000	-3.543	24.548	29.932
2	648.000					-75.211	-22.696	1200.000	-12000.000	0.000	31.085	100.000	31.085
3	646.500					-95.911	-32.464	1200.000	-12000.000	0.000	44.449	100.000	44.449
4	645.000					-115.608	-43.198	1200.000	-12000.000	0.000	59.164	100.000	59.164
5	643.500					-135.436	-53.802	1200.000	-12000.000	0.000	73.687	100.000	73.687
6	642.000					-155.609	-64.055	1200.000	-12000.000	0.000	87.729	100.000	87.729
7	640.500					-159.373	-85.359	1200.000	-12000.000	63.364	24.313	41.907	116.906
8	639.000					-161.003	-89.725	1200.000	-12000.000	84.217	27.462	43.941	122.687
9	637.500					-168.281	-128.216	1200.000	-12000.000	0.000	93.728	50.000	0.000
10	Base					-150.518	-177.182	0.000	-10500.000	0.000	108.678	50.000	0.000

SAICO HYDRO LIMITED

Table 6.1: Results for Stability and Stress Analysis- Sheet 2

Table 6.1
Sheet 2 of 3

CADAM 2000 - Result report

Project: Shigo Kas HPP	Project engineer:
Dam:	Analysis performed by: Moin
Owner:	Date: 09 February 14
Dam location:	Units: Metric

FLOOD COMBINATION STABILITY ANALYSIS

Joint ID	Upstream elevation (m)	Safety factors: Sliding: Peak	Sliding: Residual	Overturning: Toward U/S	Overturning: Toward D/S	Uplifting	Resultants: Normal (kN)	Shear (kN)	Moment (kN-m)	Position (% of joint)	Uplift: Final Force (kN)	Rock Passive wedge resistance (kN)
1	649.500	6.315	5.299	5.808	3.477	4.238	-162.6	25.8	-44.6	44.499	50.2	0.000
2	648.000	2.927	2.456	6.269	3.922	5.277	-344.6	117.7	-218.8	41.060	80.6	0.000
3	646.500	2.518	2.113	6.786	3.719	5.618	-583.7	231.8	-437.3	41.761	126.4	0.000
4	645.000	2.406	2.019	7.178	3.617	5.656	-885.2	367.9	-749.9	42.401	182.3	0.000
5	643.500	2.375	1.993	7.463	3.570	6.032	-1249.2	526.1	-1185.8	42.810	248.2	0.000
6	642.000	2.372	1.991	7.674	3.552	6.167	-1675.7	706.3	-1775.9	43.053	324.3	0.000
7	640.500	2.437	2.045	7.912	3.273	5.609	-2214.3	908.7	-2019.7	44.960	480.4	0.000
8	639.000	2.336	1.960	4.685	2.759	3.939	-2624.5	1123.3	-2603.3	45.262	893.0	0.000
9	637.500	2.298	1.929	4.025	2.478	3.488	-3066.7	1337.7	-1148.2	48.251	1232.4	7.416
10	Base	3.336	1.642	3.765	2.276	3.267	-3507.7	1551.1	1018.3	51.356	1547.4	90.850
	Required:	2.000	1.300	1.100	1.100	1.100						

SEISMIC #1 COMBINATION - PEAK ACCELERATIONS (STRESS ANALYSIS)

Joint ID	Upstream elevation (m)	Cracking: Upstream Crack length (%)	Upstream Crack length (m)	Downstream Crack length (%)	Downstream Crack length (m)	Stresses: Normal stresses: Upstream (kPa)	Normal stresses: Downstream (kPa)	allowable stresses: tension (kPa)	allowable stresses: Compression (kPa)	Shear: Upstream (kPa)	Shear: Maximum (kPa)	Shear: Maximum at I-axis (% of joint)	Shear: Downstream (kPa)
1	649.500					-11.101	-8.994	2181.600	-21816.000	0.000	-3.780	32.640	12.318
2	648.000					-49.066	-19.689	2181.600	-21816.000	0.000	-5.393	28.990	26.966
3	646.500					-84.928	-24.242	2181.600	-21816.000	0.000	-2.985	22.313	33.202
4	645.000					-117.659	-28.238	2181.600	-21816.000	0.000	-0.644	11.345	38.674
5	643.500					-149.934	-31.690	2181.600	-21816.000	0.000	43.403	100.000	43.403
6	642.000					-178.738	-36.540	2181.600	-21816.000	0.000	50.045	100.000	50.046
7	640.500					-184.697	-56.608	2181.600	-21816.000	96.611	-7.083	52.540	77.530
8	639.000					-196.354	-73.383	2181.600	-21816.000	102.708	-8.188	50.251	100.505
9	637.500					-207.927	-111.259	2181.600	-21816.000	0.000	53.738	50.000	0.000
10	Base					-211.748	-148.640	0.000	-19089.000	0.000	66.007	50.000	0.000

SEISMIC #1 COMBINATION - PEAK ACCELERATIONS (STABILITY ANALYSIS)

Joint ID	Upstream elevation (m)	Safety factors: Sliding: Peak	Sliding: Residual	Overturning: Toward U/S	Overturning: Toward D/S	Uplifting	Resultants: Normal (kN)	Shear (kN)	Moment (kN-m)	Position (% of joint)	Uplift: Final Force (kN)	Rock Passive wedge resistance (kN)
1	649.500	40.844	34.272	18.664	9.003	11.970	-50.1	1.2	-4.4	48.253	4.6	0.000
2	648.000	12.334	10.349	14.475	8.223	10.687	-242.0	19.6	-121.3	42.879	25.0	0.000
3	646.500	8.261	6.932	12.631	7.423	9.948	-496.4	60.1	-418.2	40.735	55.5	0.000
4	645.000	6.632	5.565	11.635	6.833	9.468	-813.2	122.6	-926.1	39.785	96.0	0.000
5	643.500	5.785	4.855	11.036	6.720	9.545	-1198.9	207.2	-1717.5	39.149	140.3	0.000
6	642.000	5.231	4.390	10.626	6.332	9.229	-1642.2	313.9	-2758.3	38.991	199.6	0.000
7	640.500	4.932	4.138	10.522	5.313	7.936	-2183.3	442.7	-3495.3	41.153	314.8	0.000
8	639.000	4.747	3.983	10.399	4.870	7.363	-2823.4	594.8	-4491.2	42.402	443.7	0.000
9	637.500	4.464	3.748	8.518	4.326	6.507	-3416.6	766.9	-3692.0	44.952	620.4	7.416
10	Base	5.805	2.964	6.010	3.605	5.124	-3857.6	942.1	-2410.2	47.081	935.4	90.850
	Required:	1.300	1.000	1.100	1.100	1.100						

SEISMIC #1 COMBINATION - SUSTAINED ACCELERATIONS (STRESS ANALYSIS)

Joint ID	Upstream elevation (m)	Cracking: Upstream Crack length (%)	Upstream Crack length (m)	Downstream Crack length (%)	Downstream Crack length (m)	Stresses: Normal stresses: Upstream (kPa)	Normal stresses: Downstream (kPa)	allowable stresses: tension (kPa)	allowable stresses: Compression (kPa)	Shear: Upstream (kPa)	Shear: Maximum (kPa)	Shear: Maximum at I-axis (% of joint)	Shear: Downstream (kPa)
1	649.500					-11.101	-8.994	2181.600	-21816.000	0.000	-3.780	32.640	12.318
2	648.000					-49.066	-19.689	2181.600	-21816.000	0.000	-5.393	28.990	26.966
3	646.500					-84.928	-24.242	2181.600	-21816.000	0.000	-2.985	22.313	33.202
4	645.000					-117.659	-28.238	2181.600	-21816.000	0.000	-0.644	11.345	38.674
5	643.500					-149.934	-31.690	2181.600	-21816.000	0.000	43.403	100.000	43.403
6	642.000					-178.738	-36.540	2181.600	-21816.000	0.000	50.045	100.000	50.046
7	640.500					-184.697	-56.608	2181.600	-21816.000	96.611	-7.083	52.540	77.530
8	639.000					-196.354	-73.383	2181.600	-21816.000	102.708	-8.188	50.251	100.505
9	637.500					-207.927	-111.259	2181.600	-21816.000	0.000	53.738	50.000	0.000
10	Base					-211.748	-148.640	0.000	-19089.000	0.000	66.007	50.000	0.000

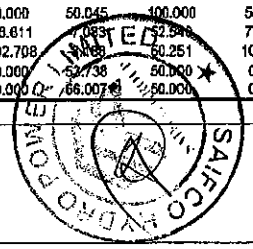

Table 6.1: Results for Stability and Stress Analysis- Sheet 3

Table 6.1
Sheet 3 of 3

CADAM 2000 - Result report

Project: Shigo Kas HPP	Project engineer:
Dam:	Analysis performed by: Moin
Owner:	Date: 09 February 14
Dam location:	Units: Metric

SEISMIC #1 COMBINATION - SUSTAINED ACCELERATIONS STABILITY ANALYSIS

Joint ID	Upstream elevation (m)	Safety factors: Sliding Peak	Sliding Residual	Overturning Toward U/S	Overturning Toward D/S	Uplifting	Resultants: Normal (kN)	Shear (kN)	Moment (kN-m)	Position (% of joint)	Uplift Final Force (kN)	Rock Passive wedge resistance (kN)
1	649.500	40.844	34.272	18.664	9.003	11.970	-50.1	1.2	-4.4	48.253	4.6	0.000
2	648.000	12.334	10.349	14.475	8.223	10.687	-242.0	19.6	-121.3	42.879	25.0	0.000
3	646.500	8.261	6.932	12.631	7.423	9.948	-496.4	60.1	-418.2	40.735	55.5	0.000
4	645.000	6.632	5.565	11.635	6.833	9.468	-813.2	122.6	-926.1	39.785	96.0	0.000
5	643.500	5.785	4.855	11.036	6.720	9.545	-1198.9	207.2	-1717.5	39.149	140.3	0.000
6	642.000	5.231	4.390	10.626	6.332	9.229	-1642.2	313.9	-2758.3	38.991	199.6	0.000
7	640.500	4.932	4.138	10.522	5.313	7.936	-2183.3	442.7	-3495.3	41.153	314.8	0.000
8	639.000	4.747	3.983	10.389	4.870	7.363	-2823.4	594.8	-4491.2	42.402	443.7	0.000
9	637.500	4.464	3.748	8.518	4.326	6.507	-3416.6	766.9	-3692.0	44.952	620.4	7.416
10	Base	5.805	2.964	6.010	3.605	5.124	-3857.6	942.1	-2410.2	47.081	935.4	90.850
	Required:	1.300	1.000	1.100	1.100	1.100						

6.1.7 FOUNDATION TREATMENT WORKS

In view of the above results for seepage, stability, RQD's and Lugeon values analyses, following foundation treatment works have been suggested to increase the bearing capacity of foundation rock and reduce the uplift pressures:

- Consolidation grouting of entire foundation area (**Fig. 6.12** in Annexure-6A)
- Primary and secondary curtain grouting (**Fig. 6.12** in Annexure-6A)



6.1.8 DESIGN OF FOUNDATION ANCHORAGE SYSTEMS

Rock Anchorage for Gated Portion of Weir Structure

Foundation of non-over flow portions of weir structure has been placed over the sound rock. Uplift pressure beneath the foundation as given in **section 6.1.6.1** should be resisted by the foundation concrete weight. For this structure, weight of concrete thickness is not sufficient to resist the uplift pressures. Therefore, remaining hydraulic uplift pressures has been proposed to be resisted by the rock anchorage. Detailing of rock anchorage (Type-A) design is given in **Table 6.2**, which resulted the following recommended rock anchorage design:

Anchor Length = 2.0 m
Dia of Anchor = 0.075 m
Grid Spacing = 1 m x 1 m

Table 6.2: Detailing of rock anchorage (Type-A) design

SHIGO KAS HYDROPOWER PROJECT - UPPER DIR
GROUND ANCHOR CAPACITY DESIGN AGAINST THE UPLIFT PRESSURES
(Non Over Flow Portion of Weir)

Assumption: 1. Factor Safety adopted is 3.0 due to permannet amchor
2. Unconfined compressive strength (UCS) of rock mass is 10% of UCS of Intact roc
3. Rock/gout compressive strength is taken as 10% of UCS of rock mass (Ref. British Standard Code Practices for Ground Anchorages BS 8081-1989)

X (m)	Pressure Head (m) from Seepage Analysis	Pressure in KN/m2	Pull Out Capacity (Kn)of one Anchor with FOS=3.0	Ultimate Bond or skin fricton at rock/grout interface (Kn/m2)	Dia of Anchor (m)	Length of Anchor (m)	Recommended
0.99	8.9	88	263	500	0.075	2.2	
2.00	8.8	86	258	500	0.075	2.2	
2.77	4.8	47	142	500	0.075	1.2	
25.15	3.5	35	104	500	0.075	0.9	
26.01	3.9	38	115	500	0.075	1.0	
26.87	4.3	42	125	500	0.075	1.1	
27.73	4.6	45	135	500	0.075	1.1	
28.58	4.9	48	145	500	0.075	1.2	
29.44	5.3	52	155	500	0.075	1.3	
30.30	5.6	55	165	500	0.075	1.4	
31.16	5.9	58	175	500	0.075	1.5	
32.02	6.3	61	184	500	0.075	1.6	2.0m Anchor Length at grid spacing of 1m x 1m. Bar # 11 Shear Strength of Steel (0.6Fy) =248211.3 Kpa (3600 psi)
32.88	6.6	64	193	500	0.075	1.6	
33.73	6.9	67	202	500	0.075	1.7	
34.59	7.1	70	210	500	0.075	1.8	
35.45	7.2	70	211	500	0.075	1.8	
36.31	7.3	71	214	500	0.075	1.8	
37.30	7.1	70	210	500	0.075	1.8	
38.28	7.0	69	206	500	0.075	1.7	
39.27	6.9	68	203	500	0.075	1.7	
40.26	6.8	66	199	500	0.075	1.7	
41.24	6.7	65	196	500	0.075	1.7	
42.23	6.6	64	193	500	0.075	1.6	
43.22	6.3	62	186	500	0.075	1.6	
44.20	6.1	60	179	500	0.075	1.5	
45.03	5.7	56	169	500	0.075	1.4	
45.86	5.4	53	159	500	0.075	1.3	
46.68	5.1	50	150	500	0.075	1.2	

6.2 GEOTECHNICAL DESIGN OF CUT SLOPES – WEIR AREA

6.2.1 General

Weir is located at 634.5 m above m.a.s.l. Left abutment rises to about El. 687 m with an average inclination of 20 degree, whereas right abutment rises to about El. 683.0 with an average inclination of 23.5 degree. Geotechnical investigations show that average overburden thickness at left abutment is 1.5 m and 3.0 m at right abutment. Overburden at both the slopes comprises gravel intermixed with fine medium grained soils and heavily reinforced with vegetation and trees. Therefore, chances of mass sliding due to rain water are not there.

Bothe slopes are mild and stable in the existing condition. However RQD's values from drilling of one bore hole at both the abutments as shown in **Fig.6.1** shows that right abutment is very poor, whereas left abutment is poor to fair. Since foundation of weir at right abutment is placed at about 16m below the NSL, therefore due to very low RQD's values, it is required to design the cut slopes at safe slope face and by providing berms at minimum 10 m vertical height.

However left abutment of weir is resting with rock and overburden with mild slopes of low height therefore there is no need to provide any slope protection measures. In this section rock slope at right abutment has been analyzed and designed

6.2.2 Geotechnical Investigations

Investigations have been carried out during the feasibility stage. Two bore holes, were planned to provide information about the type and nature of the material, the depth and extent of overburden in the foundations and elevation of bedrock. The Investigation includes 55 meter drilling of 2 number boreholes (BH-1 and BH-2). Field permeability tests in overburden and water pressure tests in rock have also been carried out at every 3-meter interval. The rock has been identified as Quartz-Mica Schist.

6.2.3 Rock Conditions

Geotechnical investigations reveal that rock type at the right abutment is Quartz-Mica Schist., which is weathered and highly fractured. Low value of RQD indicates that rock is of very poor quality. Laboratory tests have been carried out in order to know the engineering properties of rock. For the design of cut slopes following engineering properties have been used:

- Cohesion: 100 kpa,
- Angle of Internal friction: 35°
- Unit weight of rock: 25 Kn/m^3

6.2.4 Design Assumptions

Following design assumptions have been made:

- Cut slopes have been designed under drained conditions.
- Plane wedge failure has been assumed.
- Critical failure plane has been assumed 0.5 times the sum of slope face angle and angle of internal friction.
- Seismic coefficient of 0.1g has been assumed.
- No tension crack has been assumed.

6.2.5 Design Criteria

Following two main criteria has been adopted:

- Cut slopes have stabilized at a factor of safety of 1.3 without considering seismic effect
- Cut slopes have stabilized at a factor of safety of 1.0 with considering seismic effect

6.2.6 Analysis of Slopes

Plane failure analysis of cut slopes in rock has been carried out by following two methods:

- Analysis of Discontinuity data
- Stability analysis using computer software SWEDGE by using results of discontinuity data and rock mass properties

6.2.7 Analysis of Discontinuity data

Discontinuities mean all discontinuities present in the rock mass that may be technically joints, bedding planes, minor faults and other surfaces of weaknesses. Computer software DIP has been used for stereo plotting of joint data and determination of joint sets. All the joint sets data for weir, intake, sand trap areas collected during geological mapping of the project has been used in DIP software, which resulted three major joints sets as shown in **Fig.5.13**.

Joint Set No	Dip/ Direction	Trend/Plunge
J1	55/197	17/35
J2	72/334	154/18
J3	60/29	208/30

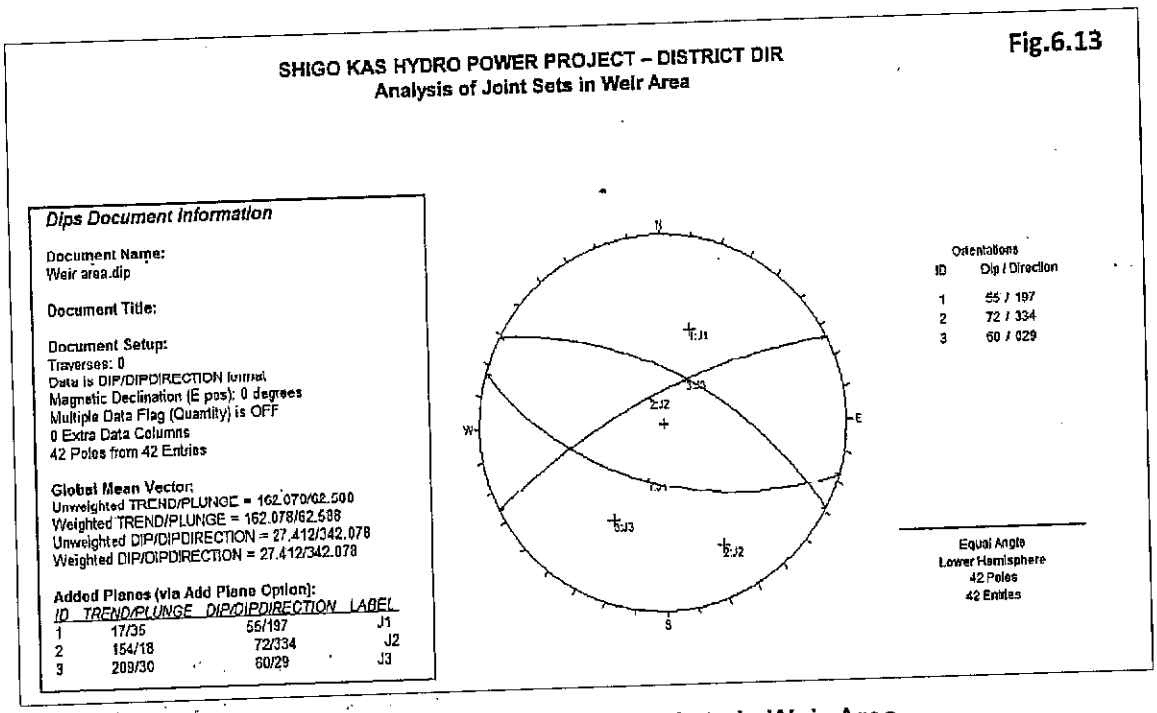

Figure 6.13: Analysis of Joint Sets in Weir Area

Three major joint sets shows that rock is jointed where wedge failure is a common type. Markland (1972) proposed that wedge failures occur along the lines of intersection of joints and hence, these intersections must 'daylight' in the slope faces. In order for the line of intersection to 'daylight', the plunge of the intersection should be less than the dip angle of the slope face measured along the trend of the intersection. In addition, the plunge of the intersection must exceed the friction angle of the joint planes. For cut slope face angle of 4V:1H and plunge value of 18° to 35° of all the three major joint sets, it is estimated that line of intersection of wedge will be daylighted and may cause stability problem depending upon the angle of internal friction of joint planes.

Further stability analysis has been carried out using computer software UNWEDGE, for which following parameters have been adopted:

Strength Parameters

Cohesion = 0 Kpa
Angle of Internal Friction of Joint Planes = 25°
Seismic coefficient = 0.1g
Required FOS =1.5

Geometry of Cut Slope

Cut Slope Angle = 4V:1H
Max. Vertical Cut Height = 10m
Berm Width = 3 m

Results of stability analyses for joints sets J1 and J2 are shown in **Fig. 6.14 and 6.15.** Which reveals the following results.

Conditions	Required FOS	FOS Obtained
Without seismic effect	1.5	4.14
With seismic effect	1.0	2.14

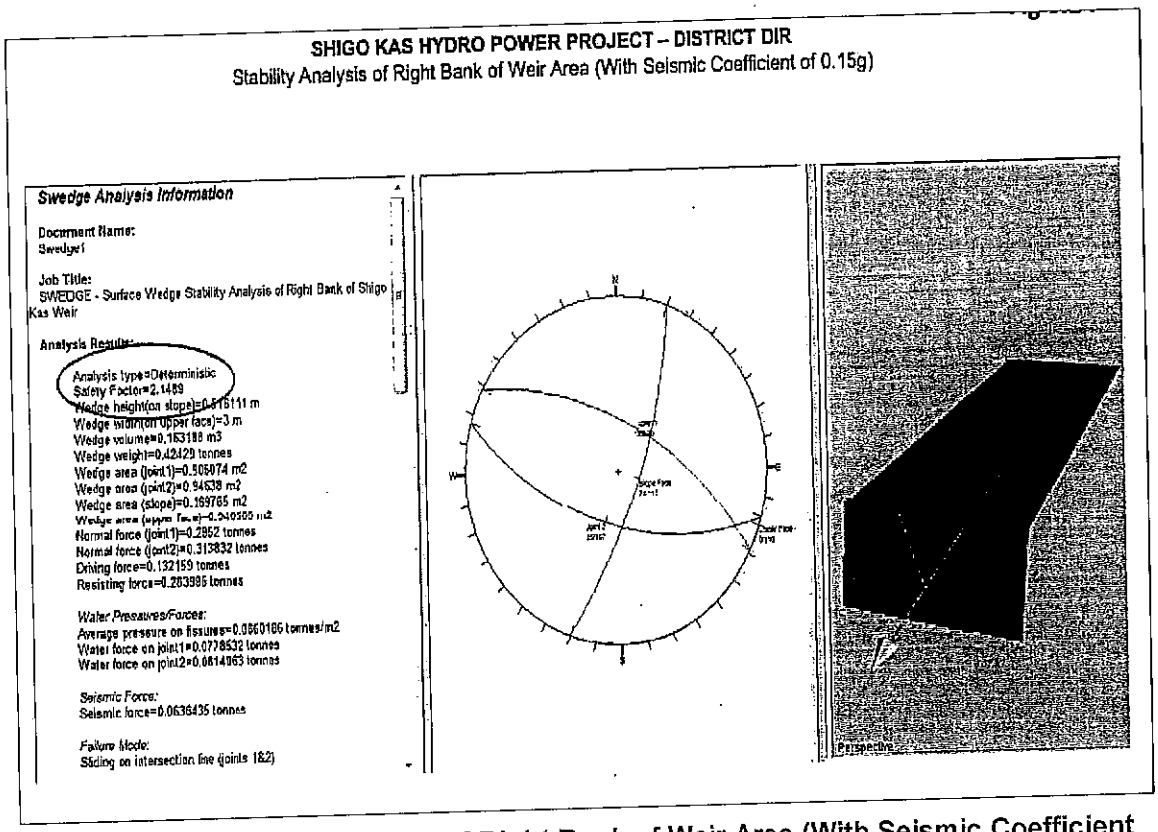

Figure 6.14: Stability Analysis of Right Bank of Weir Area (With Seismic Coefficient Of 0.15g)

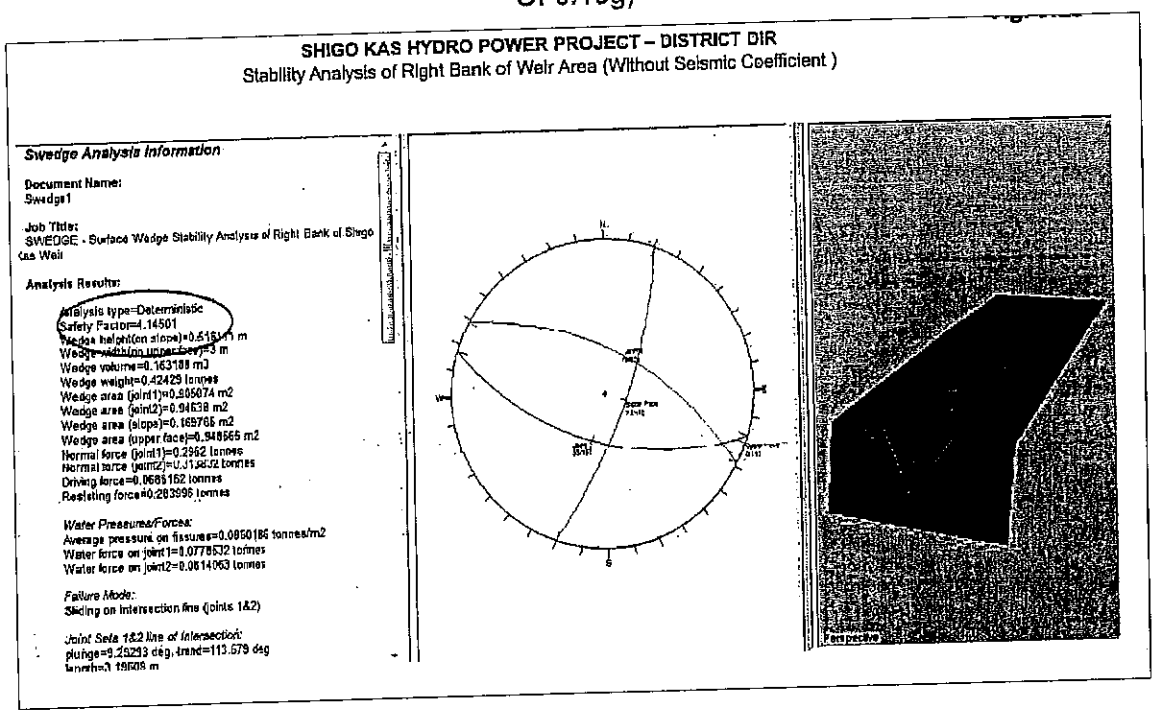

Figure 6.15: Stability Analysis of Right Bank of Weir Area (Without Seismic Coefficient)

Stability analyses results show that without provision any protection measures Factor of Safety (FOS) is greater than 1.5 for both seismic and without seismic conditions. Therefore, using these results cut slopes layout plan and cross sections for the weir, intake and sand trap are given in **Fig. 6.16 and 6.17.**

6.3 GEOTECHNICAL DESIGN OF HEADRACE TUNNEL

6.3.1 Introduction

The Shigo Kas weir structure site is located 10 km downstream from Timergara Town, where Panjkora River becomes narrow again and passes a bottleneck. This bottleneck is located 13 km upstream the Junction of Panjkora River with Swat River. Surface power house is located near village Mitta which has been connected through 10.20 km long headrace tunnel. The alignment of the head race tunnel and power house location has been proposed based on the geology and topography of the area.

The Project layout includes an arrangement of power generation facility consisting of intake structure, sand trap, headrace tunnel, forebay, penstock, surface powerhouse and tailrace channel.

This chapter includes the interpreted ground conditions, initial stability proof and preliminary support requirements for headrace tunnel and access/construction adits.

6.3.2 Design Guidelines and References

The experiences with underground openings and general design guidelines consulted for the current feasibility study includes:

- Practical Engineering by Evert Hoek
- Tunnels and Shaft in Rock; U.S Army Corps of Engineers; 1997

Further references are made to the existing and on-going hydropower projects in Pakistan, wherein past experiences have been taken in account to establish the sound feasibility of the current project.

6.3.3 Geological Conditions

The detailed project area geology pertinent to various underground structures is presented in the Chapter-5 of this report.

To confirm the geological condition along the headrace tunnel, geological mapping and NGI Q value estimates of surface exposures has been conducted. Due to accessibility and high snow covered altitude, it was physically impossible to make a traverse along the tunnel alignment. The only possible corridor of the geological mapping and Q estimates of bedrock was the left bank road along the river and few Nallas along the right bank. The only borehole data available for the tunnel are the boreholes drilled at weir site, sand trap, tunnel intake and power house area.

According to the results of geological mapping, the tunnel driving face is expected to pass through various types of lithologies including thick faulted blocks and shear zones. The basic lithologies to be encountered will be as follows:

- Granite Gneiss/Schistose Gneiss/Quartz mica Schist (Rock)
- Overburden /Few Moraines Evidences/Colluviums/Scree
- Terraces / River Deposits/Cultivated land terraces
- Shear and Faulted zones
- Sliding Zones

It is probable that tunnel construction will encounter almost same tunneling conditions due to same geological units. **Table 6.3** represents description of rock units expected to be encountered during tunneling.

Table 6.3: Description of Project Rock for Tunneling

Granite Gneiss :	• Mostly alignment tunnel is passing through the gneiss and power house and tailrace structure will be built on the gneiss rock. The rock is exposed at anticline axis and a flank. • Rock is very strong to strong in strength. Joint spacing is 60 mm to 200 mm i.e. very small to small. Mostly joints are open and somewhere filled with silty clays / clayey silt • Major joint sets orientates N53°W and dip 45°NE

	• Three sets of joints have been observed in the exposed rock along Tunnel alignment. Mean resultant direction is North-West dipping towards North-East. All the joints along tunnel have favorable dips for excavation of the tunnel and tunnel drive is almost along the foliation plains which is also another favorable factor for tunnel drive, at inlet area excavation drive will across the strike while about after mid of the tunnel area tunnel drive will be along the strike

6.3.4 Mechanical Parameters of Rocks

During the current feasibility study, no field geotechnical investigation i.e. drilling of boreholes has been carried out along the tunnel route due to difficult access except one borehole (BH-5) at tunnel intake. Therefore, following the same geological unit of the project area, strength and deformation parameters of rock mass have been established by using the laboratory test results of cores samples collected from the boreholes (BH-1 to BH-6).

Following strength and deformation parameters shown in **Table 6.4** have been established keeping in view the laboratory test results and engineering judgment:

Table 6.4: Strength and Deformation Parameters

Rock Unit Weight (Y)	2.7 Kn/m^3	(Average values of laboratory test results, refer **Annexure A of volume 3**)
Angle of Internal Friction (ϕ)	30 Degree	(Average values of laboratory test results, refer **Annexure A of volume 3**). It seems to be correct due to low RQD.
Cohesion (c)	0 Kpa	In case of contact with water, it can be reduced to zero.
Unconfined Compressive Strength (UCS)	83 Mpa	(Average values of laboratory test results, refer **Annexure D of volume 3)**
Point Load Index (I)	6.5 Mpa	(Average values of laboratory test results, refer **Annexure D of volume 3)**

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Elastic Modulus of Intact Rock	3.38×10^4 Mpa	Only one test performed (BH-1), Refer **Annexure D of volume 3**)
Elastic Modulus of Rock Mass	10,296.0 Mpa	Using Hoek-Brown Classification by computer Software Rock Data1, Result is attached as **Fig. 6.18**
Poisson's Ratio	0.025	Only one test performed (BH-1), Refer **Annexure D of volume 3**)

6.3.5 In Situ Stress Conditions

Because the maximum ground cover of the headrace tunnel is 1,300 m, thus the in-situ stress determination will be the one of the key issues of the project. There is no available data of the magnitude and orientation of the in-situ stress around the project.

For the preliminary design, the maximum stress is assumed to be vertical stress, which is estimated by the following simple equation (**Fig.6.19**):

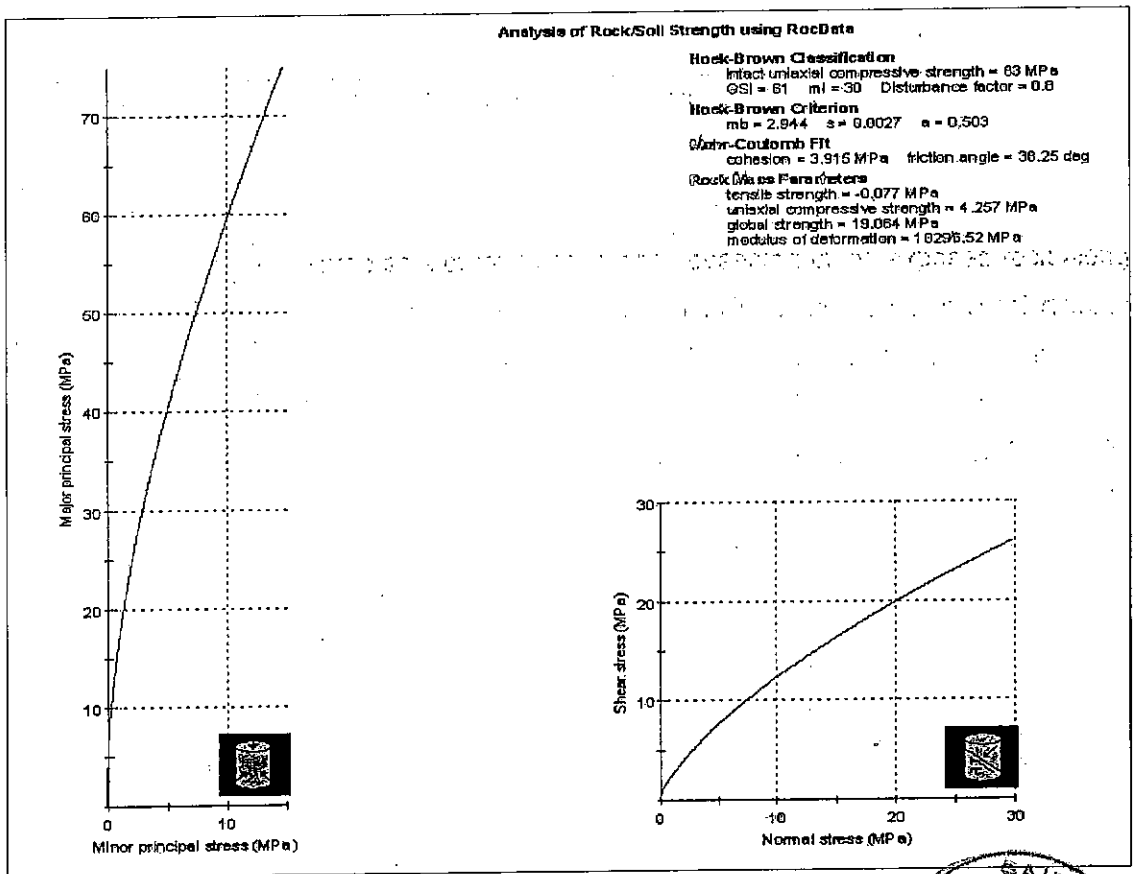

Figure 6.18: Estimation of Rock Deformation Parameters Using Hoek-Brown Criteria

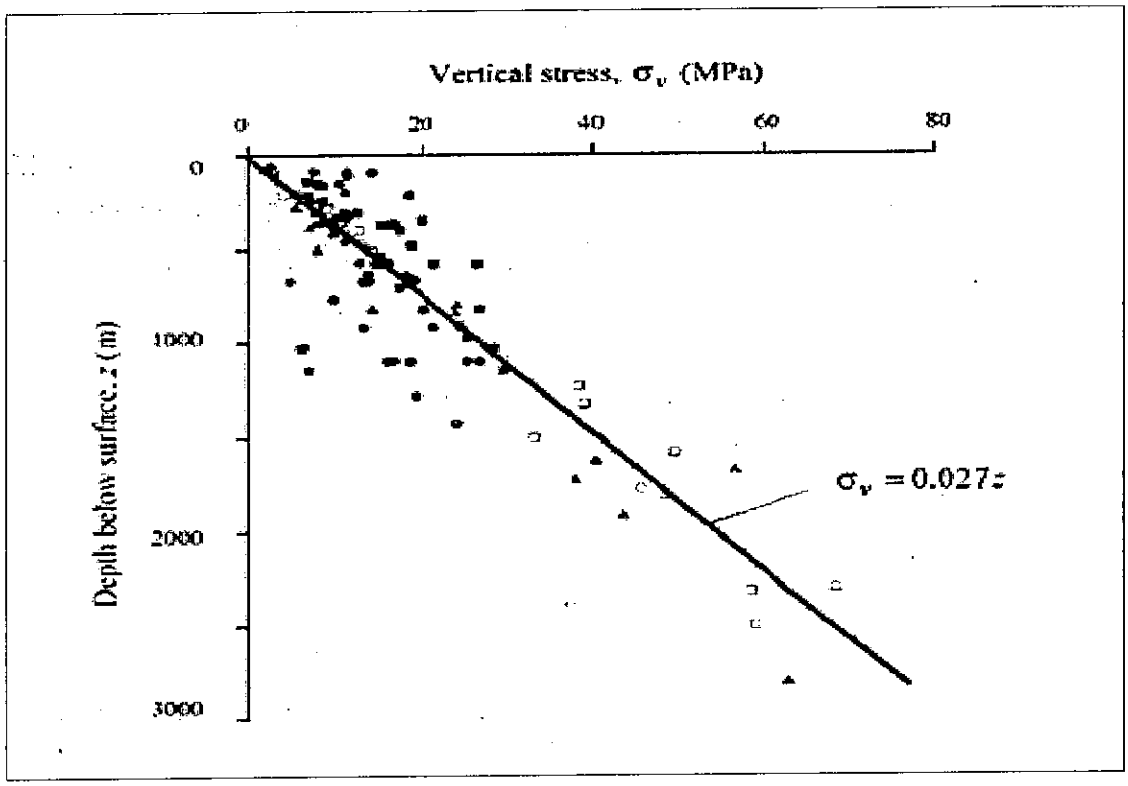

Figure 6.19: Vertical Stress Measurements from Projects around the World

$$\sigma_v = \gamma \cdot z$$

Where:

σv : vertical stress (MPa)

γ: unit weight of rock mass (=0.027MN/m³)

z : depth of ground cover (m)

As shown, measurements of vertical stress at various sites around the world confirm that the above relationship is valid for the estimation of the vertical stress.

The horizontal stress acting on an element of rock at a depth z below surface is normally estimated by using the ratio of the average horizontal stress to the vertical stress as follows:

$$\sigma_h = K \times \sigma_v = K\,Y\,Z$$

Where:

σh: horizontal stress (MPa)

k: ratio of horizontal stress to vertical stress

The initial state of stress will also be influenced by the non-horizontal ground surface (topographic slope) in the present case. During present study, in situ stress measurement by hydraulic fracturing has not been carried out therefore till the stress measurements are made, which is only possible at the construction stage, the current FEM trial will be done at K = 1.5

6.3.6 Design Methods In Rock Engineering In Practice For Tunnels

6.3.6.1 Design Methods

Three main approaches for the design of rock tunnels are commonly being used;

- Analytical
- Empirical and
- Observational

In view of the complex nature of rock masses and difficulties encountered with their characterization, the analytical approach is the least used approach in current rock engineering practice.

The empirical approach relates to the experiences gained on previous projects to the conditions anticipated at a proposed site. The Rock Mass Classification Approach which forms the backbone of the Empirical Design is widely used in rock tunneling at present.

The observational approach used now days is based on observations and monitoring of tunnel behavior during construction and selecting or modifying the designed support as the project proceeds and rock conditions warrants so. This represents essentially a "build as you go" philosophy since support is adjusted during construction to meet the change in rock condition. In fact this is the final and permanent support which may vary grossly at places from the designed support. This final support is the support agreed in the field in the light of the designed support by the consultants and the contractor.

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The observational method of design and construction has been named as NEW AUSTRIAN TUNNELING METHOM (NATM) and has been used in the construction of Turbela Dam Tunnels (15m Dia 1.5 km long - 5 Nos) Malakand Auxilliary Tunnel (5 m Dia 4.0 km long), Gandaf Tunnel (3.75 m Dia 2.81 km long) and Baja Tunnel (3.75 m Dia 1.0 km long),Lakh Pass tunnel 10 m Dia, 200m long near Quetta, [investigation and detail design completed, now under construction] and all (16 Nos) Traffic Tunnels in Makkah Mukarama (16 m Dia - various lengths) in ring roads, all Tunnels in Saudi Arabia outside Makkah, Beris Dam Tunnel (5m dia-400 m long) [Malaysia].

The support system designed for all these tunnels were based on Empirical method. However NATM (observational) methods have been used to modify it during construction as the excavation proceeded as per actual rock condition exposed.

6.3.6.2 Empirical Methods of Design

Rock mass classification, which is the backbone of the empirical design approach, an widely employed tool in rock tunneling, is being practiced at present in USA, France, Western Europe, South Africa, Australia, New Zealand, Spain and some East European countries.

In rock engineering more than a dozen empirical rock mass classifications have been developed. There are only few methods which are used in the engineering practice nowa-days.

6.3.7 Main Rock Classification Methods

To date, the rock mass classification systems which generally have been proposed are as follows:

- Terzaghi Rock Load Classification:1947
- Lauffers Classification.1958
- Deers Rock Quality Designation Classification (RQD).1964
- Rock Structures Rating Concept (RSR).1972
- The Geomechanical Classification (Rock Mass Rating) RMR.1973
- The Rock Mass Quality (Q system).1974
- CRIEPT method of Rock Classification (Japanese Method).

All these design procedures are guide lines but decisions for parameters of rocks anticipated keeping the available data in mind are made on experiences gained on constructed projects for similar rock conditions.

6.3.8 Methodology used for Shigo Kas HPP Headrace Tunnel

Due to limited geological information along the route of tunnel and limited boreholes data, quantitative rock classification system i.e. The Q System has been used to estimate the tunnel supports based on the a numerical assessment of the rock mass quality using the following six parameters:

- Rock quality designation (RQD)
- Number of joint sets (Jn)
- Roughness of most unfavorable joint or discontinuity (Jr)
- Degree of alteration or filling along the weakest joint (Ja)
- Water inflow (Jw)
- Stress condition given as the stress reduction factor (SRF)

The above six parameters are grouped into three quotients to give the overall rock mass quality:

$$Q = \frac{RQD}{J_n} \times \frac{J_r}{J_a} \times \frac{J_w}{SRF}$$

6.3.9 Analysis of Discontinuity data

Discontinuities mean all discontinuities present in the rock mass that may be technically joints, bedding planes, minor faults and other surfaces of weaknesses. Computer software DIP has been used for stereo plotting of joint data and determination of joint sets. All the joint sets data for headrace tunnel areas collected during geological mapping of the project has been used in DIP software, which resulted three major joints sets as shown in **Fig.6.20** and given in **Table 6.5** below:



Table 6.5:Major Joint Sets

Joint Set No	Dip/ Direction	Trend/Plunge
J1	61/209	29/29
J2	45/55	235/45
J3	56/325	145/34

Three major joint sets shows that rock is jointed where wedge failure is a common type.

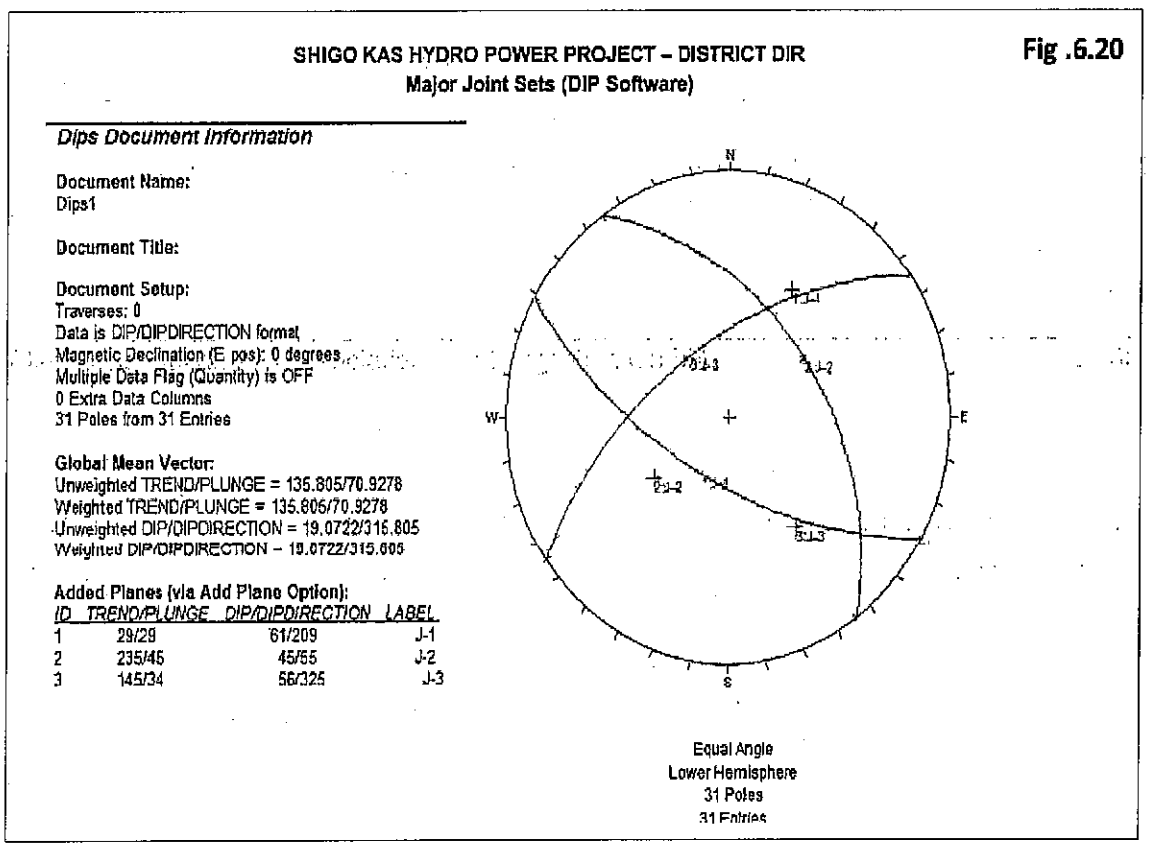


Figure 6.20: Vertical Stress Measurements from Projects around the World

6.3.10 Zones along the Tunnel Route

Keeping in view same rock type (Qartize) and similar geological conditions i.e discontinuities, number of joint sets, joint spacing etc. whole the headrace tunnel stretch is considered as one geological zone except the tunnel orientation. Therefore headrace tunnel is divided into three sections depending upon the tunnel alignment orientation:

Section –I : RD 0+00 to 1+200 (Tunnel Alignment Orientation: N08°E)

Section –II: RD 1+200 to 4+000 (Tunnel Alignment Orientation: N48°E)

Section –III: RD 4+00 to 9+500 (Tunnel Alignment Orientation: N04°E)

Section –IV: RD 9+500 to 10+200 (Tunnel Alignment Orientation: N28°E)

6.3.11 Tunnel Rock Support Design

As mentioned above in section 6.3.8, tunnel rock support has been designed using the Q-system rock mass classification. On the basis of field reconnaissance visit and field geological mapping, following rock description **(Table 6.6)** has been selected to establish the Q-vale:

Table 6.6: Estimated Ratings of Q-System

Sr. No.	Rock Description	Q-Rating		Remarks
1.	ROCK QUALITY DESIGNATION	RQD	20	
2.	JOINT SET NUMBER Three joint sets + Random	Jn	12	Block size =RQD/Jn= 1.67
3.	JOINT ROUGHNESS NUMBER Rock wall contact before 10 cm shear B. Rough, irregular, undualting	Jr	3	Inter Block Shear Strength = Jr/Ja = 1.0
4.	JOINT ALTERATION NUMBER D. Silty-, or sandy-clay coatings, small clay- fraction (non-softening)	Ja	3.0	σc = 83 Mpa (**Table-6.3**) σ1 = 1200* 27=32.4 Mpa σc/ σ1 = 2.56

5.	JOINT WATER REDUCTION B. Medium inflow or pressure, occasional outwash of joint fillings	Jw	0.66	Active Stress = Jw/SRF= 0.0825
6.	STRESS REDUCTION FACTOR L. Mild rockburst (massive rock)	SRF	8.0	**Note:** σc= Compressive Strength of rock mass σ1= Principal Stress=yxh
Q= 1.67x1x0.0825 = 0.14				

In relating the value of the index Q to the stability and support requirements of underground excavations, Barton et al (1974) defined an additional parameter which they called the Equivalent Dimension, De, of the excavation. This dimension is obtained by dividing the span, diameter or wall height of the excavation by a quantity called the Excavation Support Ratio, ESR. Hence:

$De = ESR = \frac{\text{Excavation span, diameter or height (m)}}{\text{Excavation Support Ratio}}$

The value of *ESR* is related to the intended use of the excavation and to the degree of security which is demanded of the support system installed to maintain the stability of the excavation. Barton et al (1974) suggest the following values:

Excavation category *ESR*

A	Temporary mine openings	3-5
B	Permanent mine openings, water tunnels for hydro power (excluding high pressure penstocks), pilot tunnels, drifts and headings for large excavations.	1.6

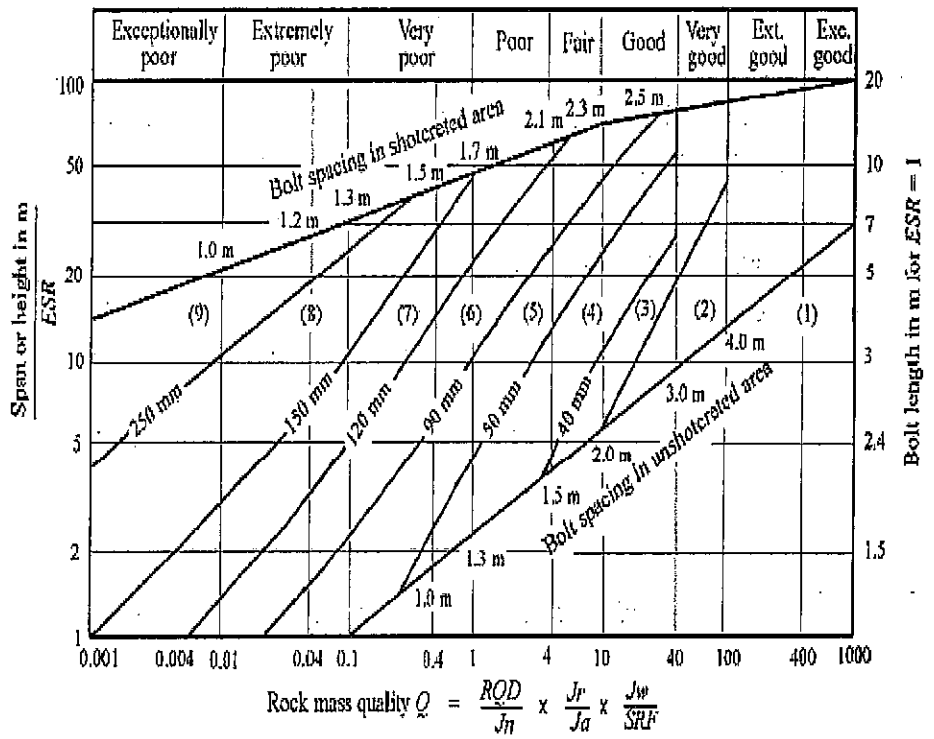
C	Storage rooms, water treatment plants, minor road and railway tunnels, surge chambers, access tunnels.	1.3
D	Power stations, major road and railway tunnels, civil defence chambers, portal intersections.	1.0
E	Underground nuclear power stations, railway stations, sports and public facilities, factories.	0.8

The headrace tunnel falls into the category of Class-B, Permanent mine openings, water tunnel etc. and is assigned an excavation support ratio *ESR* = 1.6. Hence, for an excavation span of 7 m, the equivalent dimension, ***De* = 7/1.6 = 4.375**.

The equivalent dimension, *De*, plotted against the value of Q, is used to define a number of support categories in a chart published in the original paper by Barton et al (1974). This chart has recently been updated by Grimstad and Barton (1993) to reflect the increasing use of steel fiber reinforced shotcrete in underground excavation support. **Fig. 6.21** is reproduced from this updated chart.

SHIGO KAS HYDRO POWER PROJECT – DISTRICT DIR **Fig. 6.21**

Estimated Rock Support Category Based on Tunneling quality Index (Q-System)
(After Grimstad and Barton 1993)



REINFORCEMENT CATEGORIES

1) Unsupported
2) Spot bolting
3) Systematic bolting
4) Systematic bolting with 40-100 mm unreinforced shotcrete
5) Fibre reinforced shotcrete, 50 - 90 mm, and bolting
6) Fibre reinforced shotcrete, 90 - 120 mm, and bolting
7) Fibre reinforced shotcrete, 120 - 150 mm, and bolting
8) Fibre reinforced shotcrete, > 150 mm, with reinforced ribs of shotcrete and bolting
9) Cast concrete lining

Figure 6.21: Estimated Rock Support Category Based on Tunneling quality Index (Q-System) (After Grimstad and Barton 1993)

From **Fig. 6.21**; a value of *De* of 4.375 and a value of Q of 0.14 places this tunnel excavation in category (6) which requires a pattern of rockbolts (spaced at 1.5 to 3 m) and 75-100 mm of fiber reinforced shotcrete.

Barton et al (1980) provide additional information on rock bolt length, maximum unsupported spans and roof support pressures to supplement the support recommendations published in the original 1974 paper.

The length L of rock bolts can be estimated from the excavation width *B(7m)* and the Excavation Support Ratio *ESR* of 1.6

$$L = (2+0.15B)/ESR = (2+0.15x7)/1.6 = 1.9 \text{ say } 2m$$

Maximum unsupported span = 2 *ESR* $Q^{0.4}$ = 2x 1.6x $0.14^{0.4}$ = 1.5 m

Tunnel support system as suggested above by Q-System has now been verified and optimized through computer software UNWEDEG in respect of support requirement and PHASE in respect of strength factor in the following sections.

6.3.12 Results of Numerical Analysis of Tunnel Section

During the current feasibility study a limited numerical check for wedge stability, deformation stability and strength factor of the headrace tunnel has been carried out using conservative input parameters (Table-3) for the Granite Gneiss/Schistose Gneiss/Quartz mica Schist (Rock)belonging to class B 5 support classes of Q-System.

Results of Wedge Stability Analysis (UNWEDGE)

Without any rock support, Factor of Safety (FOS) for all the four section of headrace tunnel is less than required FOS of 1.5 as shown in **Fig. 6.22 to 6.25** with the seismic coefficient of 0.15g (OBE). This means that adequate rock support system is required to stabilize the wedges formed around the tunnel section.



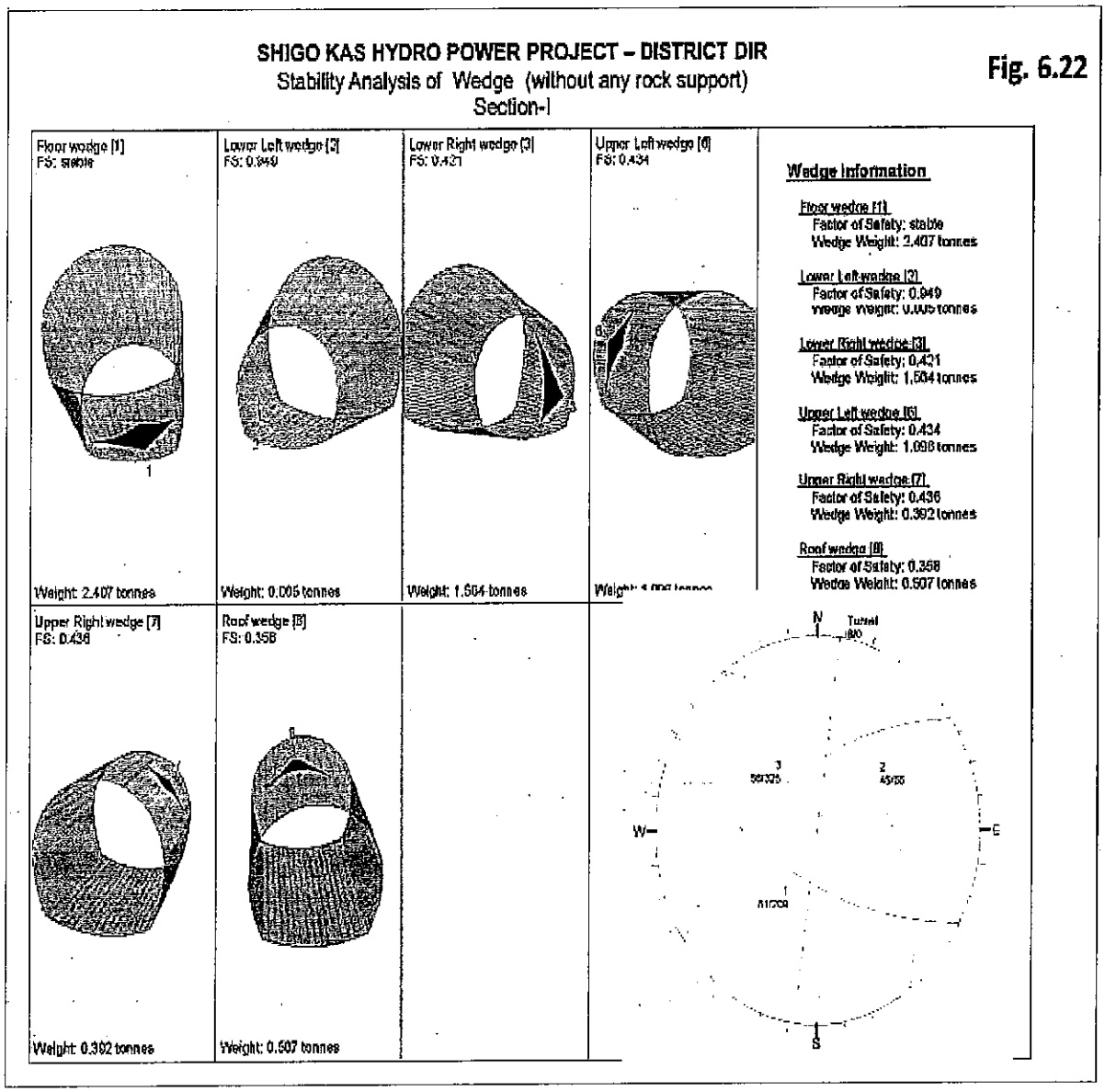


Figure 6.22: Stability Analysis of Wedge (without any rock support) Section-I

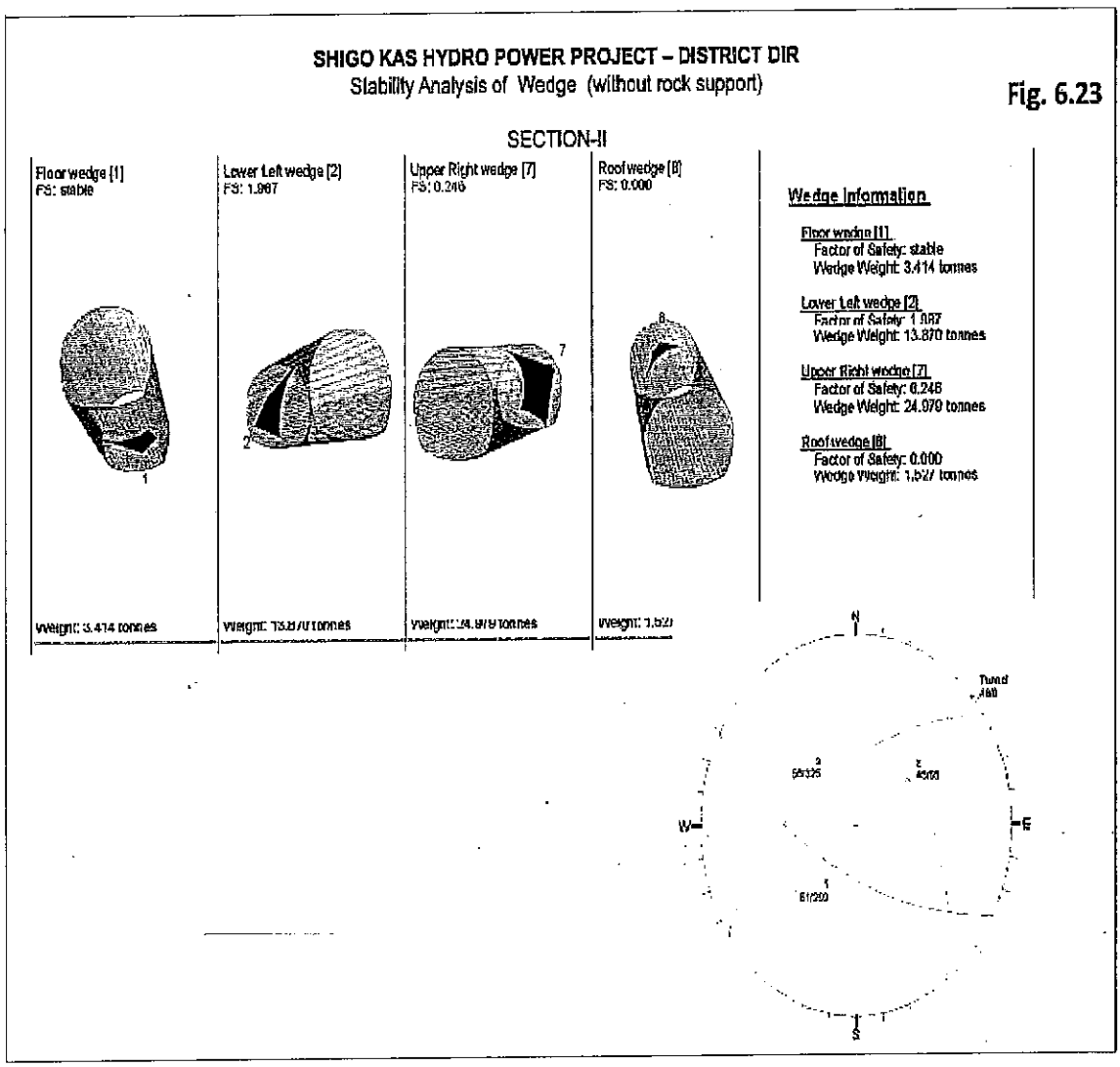


Figure 6.23: Stability Analysis of Wedge (without rock support) SECTION-II



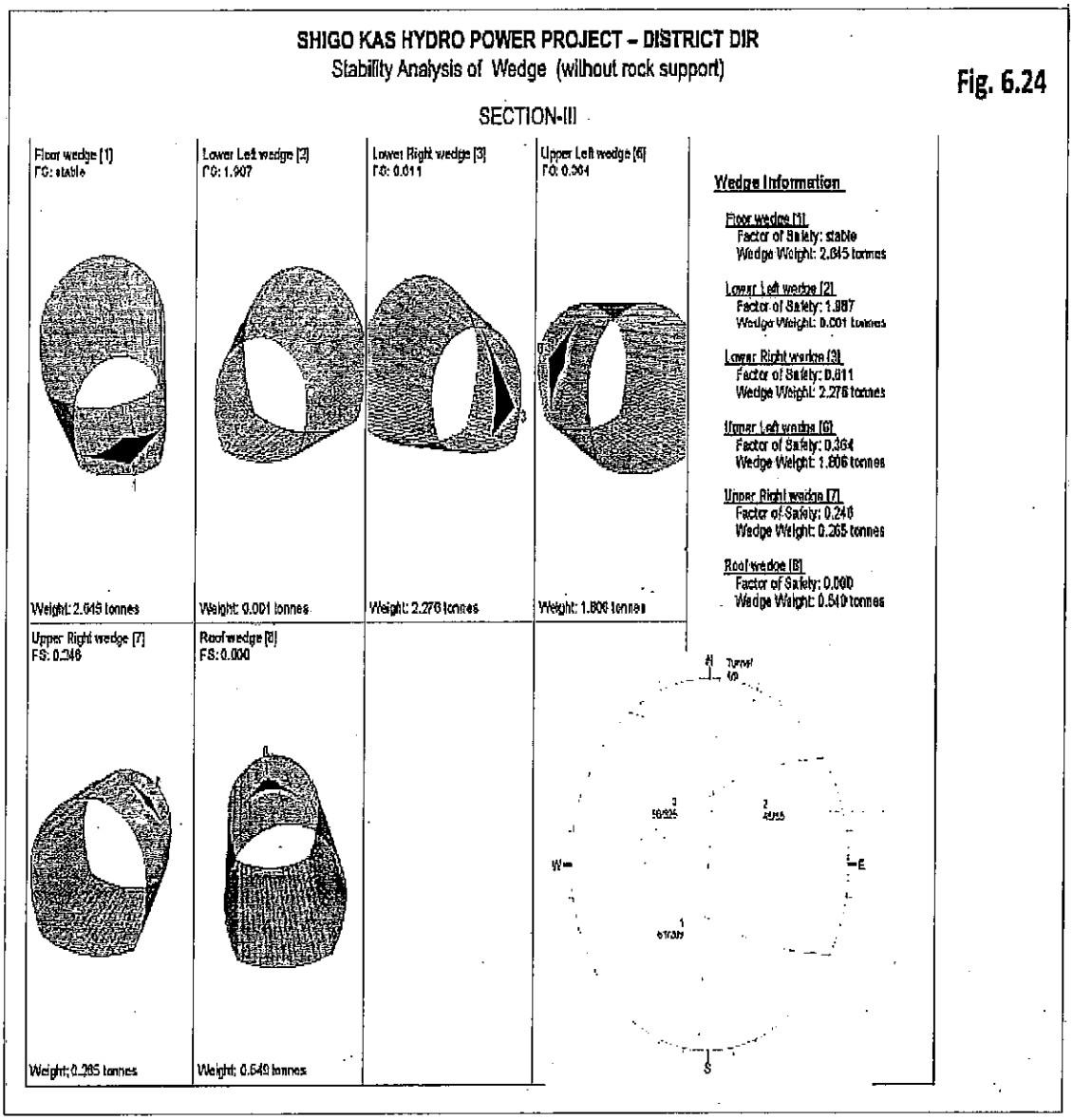


Figure 6.24: Stability Analysis of Wedge (without rock support) SECTION-III

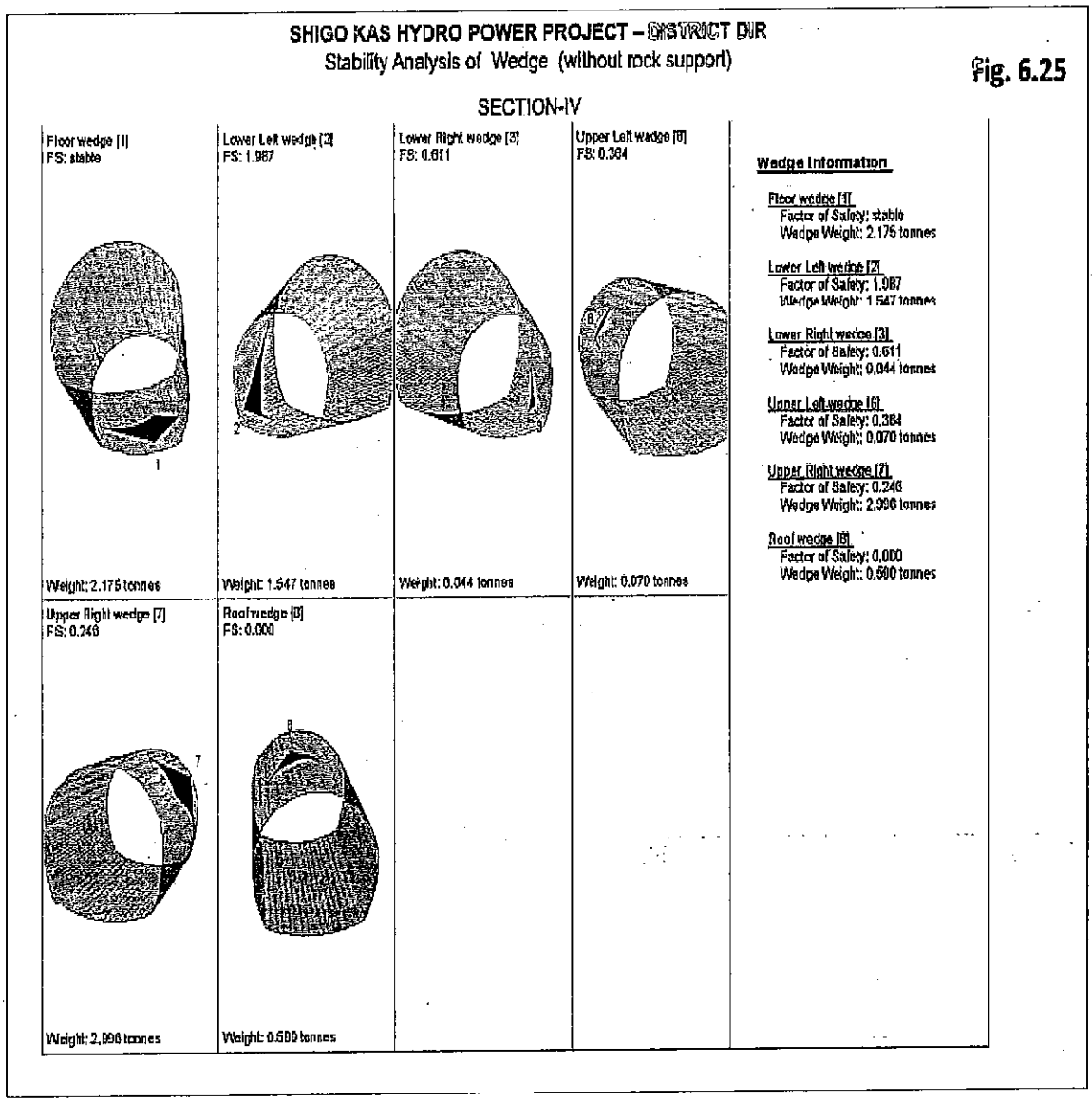
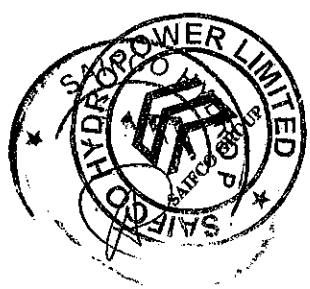


Figure 6.25: Stability Analysis of Wedge (without rock support) SECTION-IV

By applying the anchored bolt (mechanical bolt) around the tunnel section at wedge locations with different length and spacing for all the four sections of headrace tunnel, achieved FOS is greater than the 1.5 as shown in **Fig. 6.26 to 6.29.** There is no need to provide shotcrete as suggested by Q-System (**section 6.3.13**).



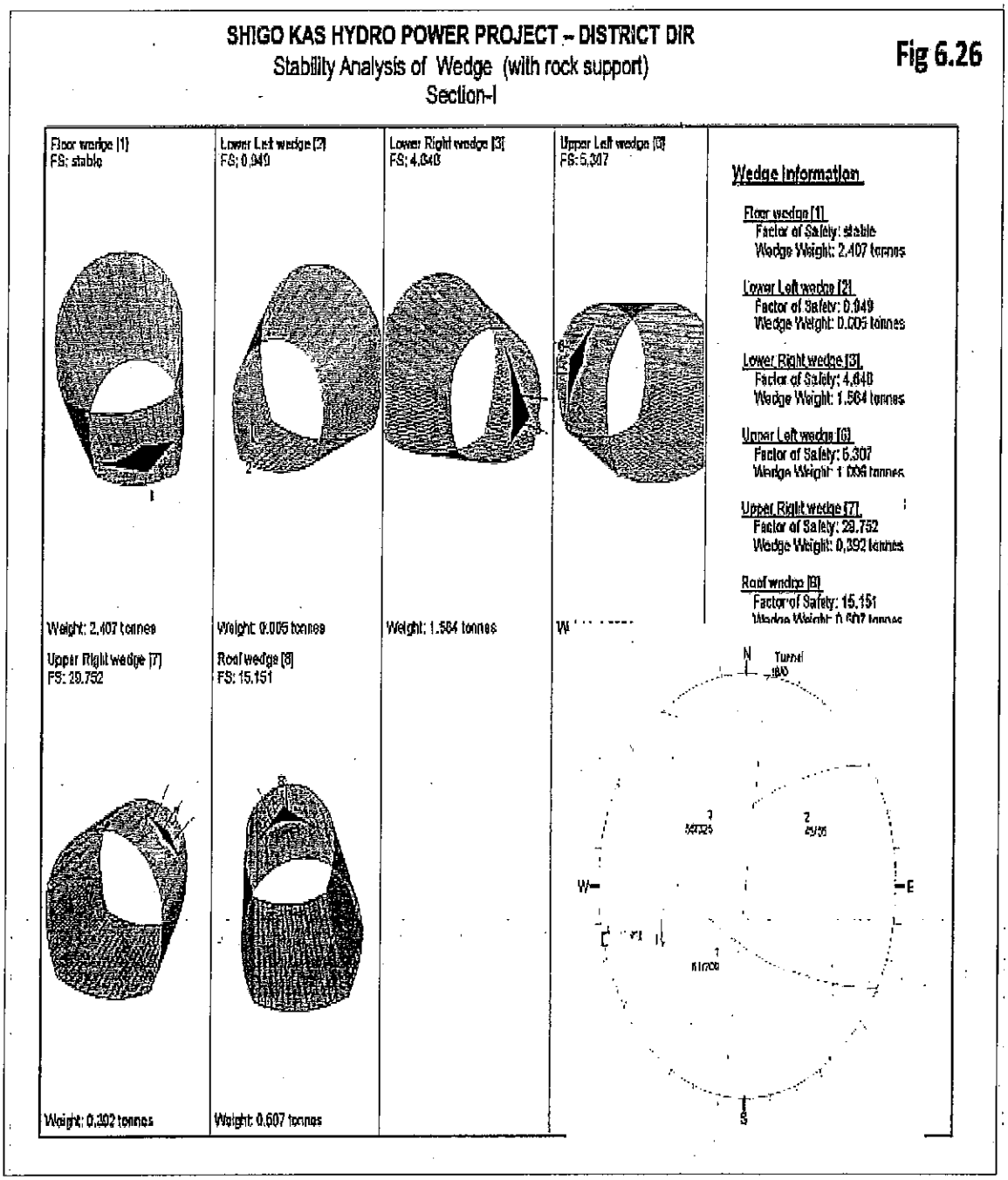


Figure 6.26: Stability Analysis of Wedge (With Rock Support) Section-I

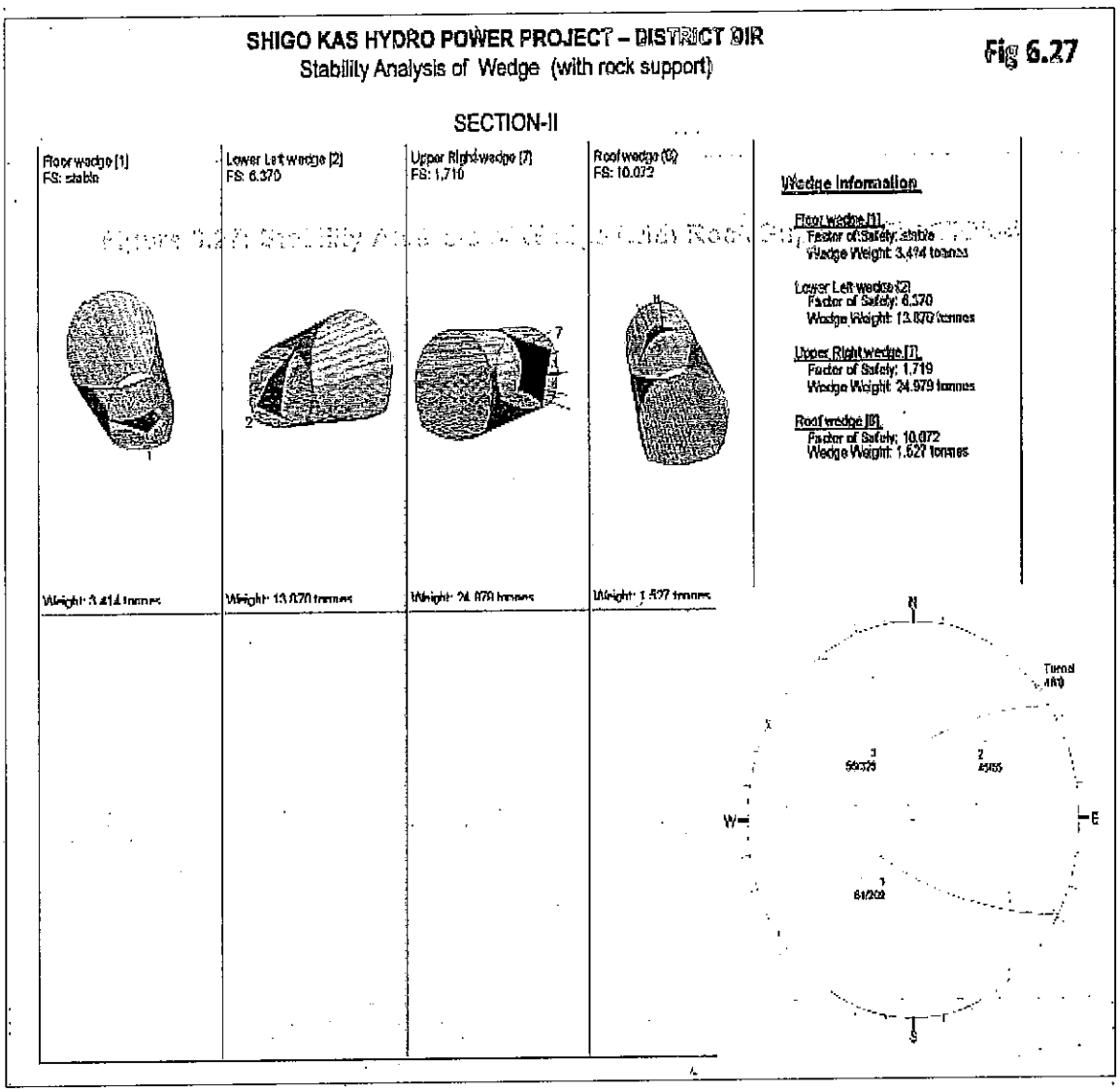


Figure 6.27: Stability Analysis of Wedge (with Rock Support) SECTION-II

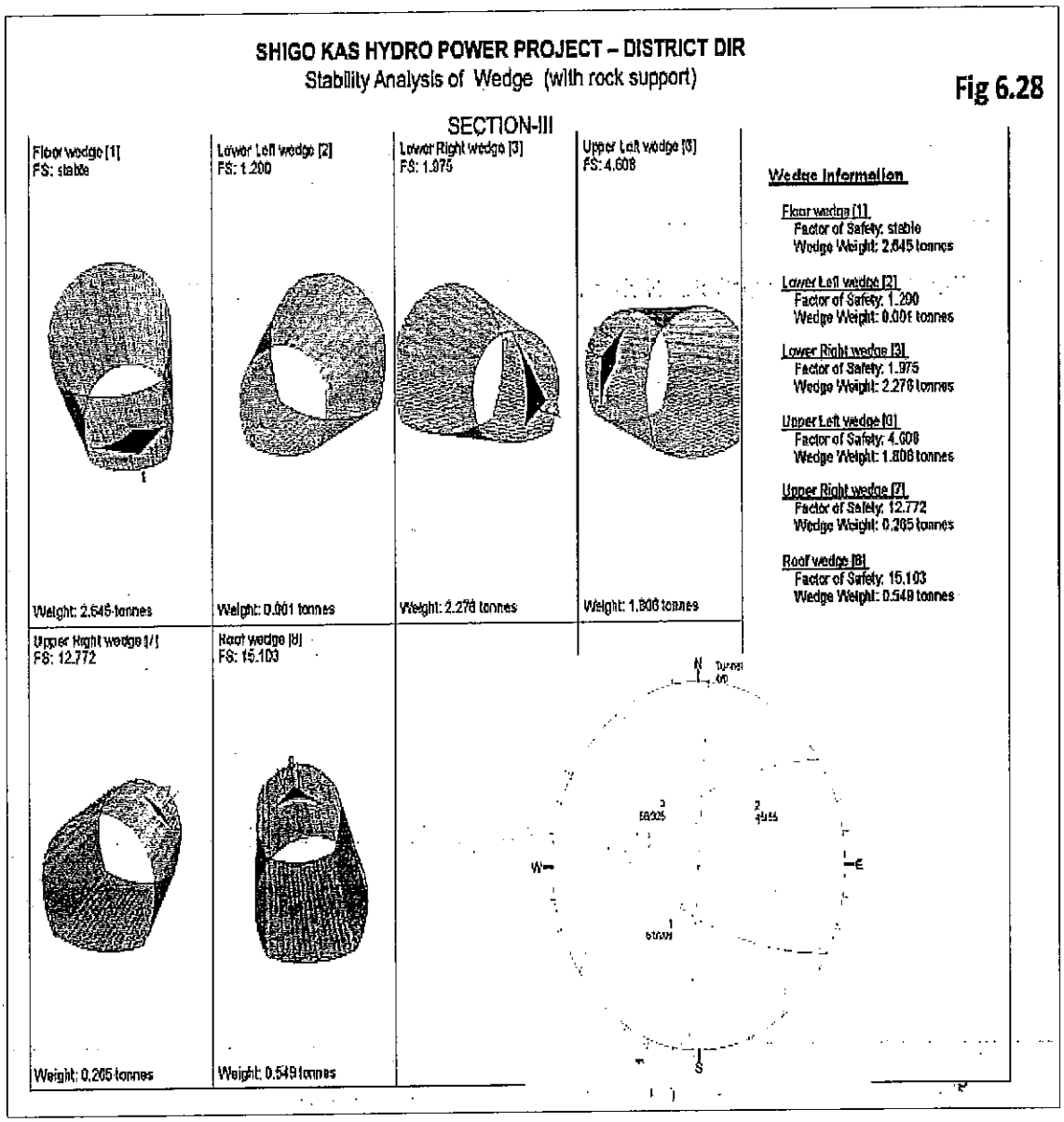


Figure 6.28: Stability Analysis of Wedge (with Rock Support) SECTION-III

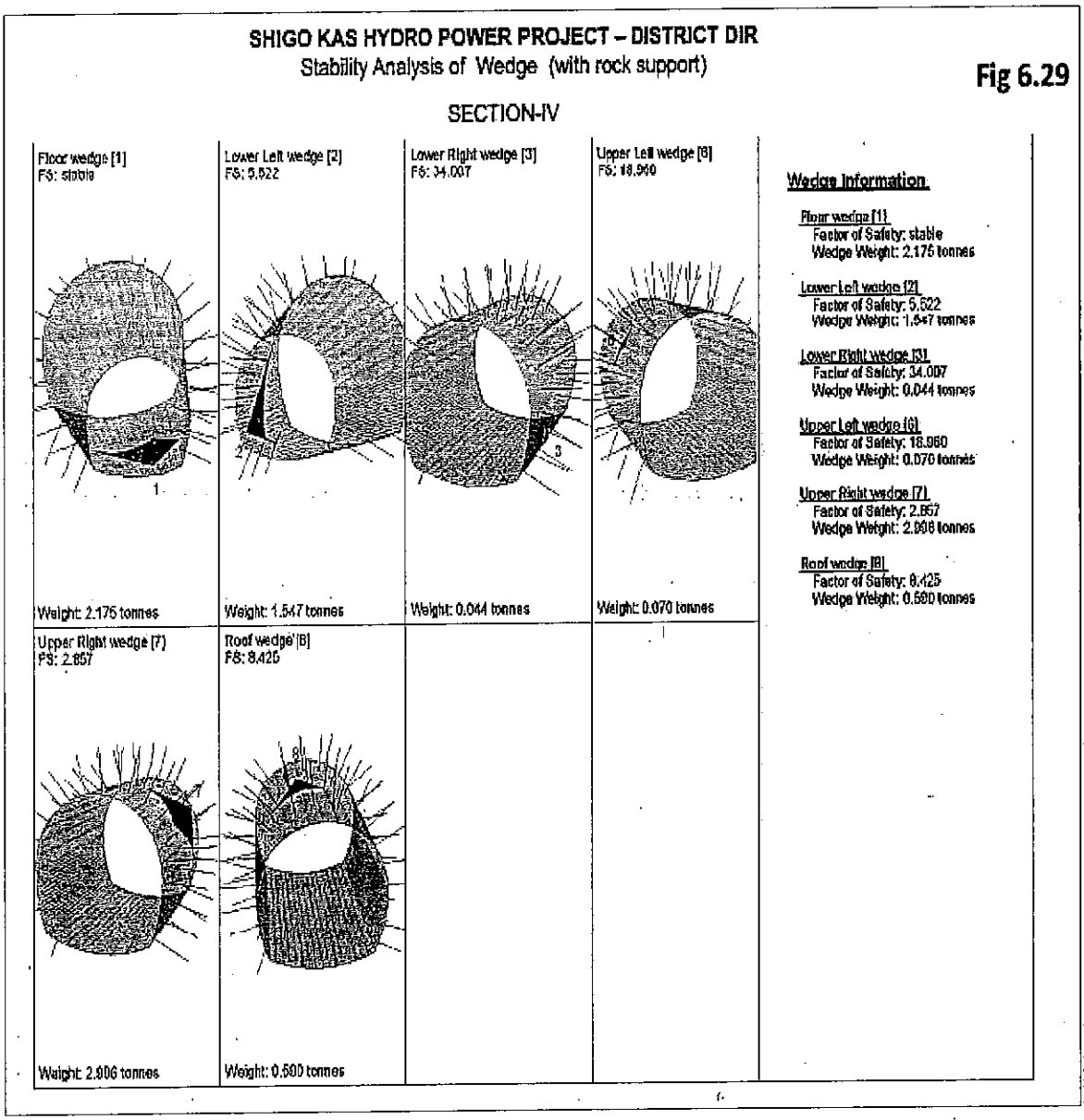


Figure 6.29: Stability Analysis of Wedge (with Rock Support) SECTION-IV

Results of Stress Analysis (Phase)

Rock support for the headrace tunnel has now been finalized with stress analysis using the computer software PHASE-2, wherein following criteria has been adopted:

- Strength factor should be greater than 1.0 along the excavation boundary
- Total displacement of tunnel section should be minimum.

Stress analysis is mainly dependent on the depth of rock overburden above the tunnel and ratio of horizontal to vertical stress ratio (K-ratio =1.5). For the headrace tunnel, tunnel alignment has been divided into three sections keeping in view the rock overburden depth. Results of stress analyses for all the three sections for deformation and strength factor are shown in **Fig. 6.30 to 6.32** and **Fig. 6.33 to 6.35** respectively,

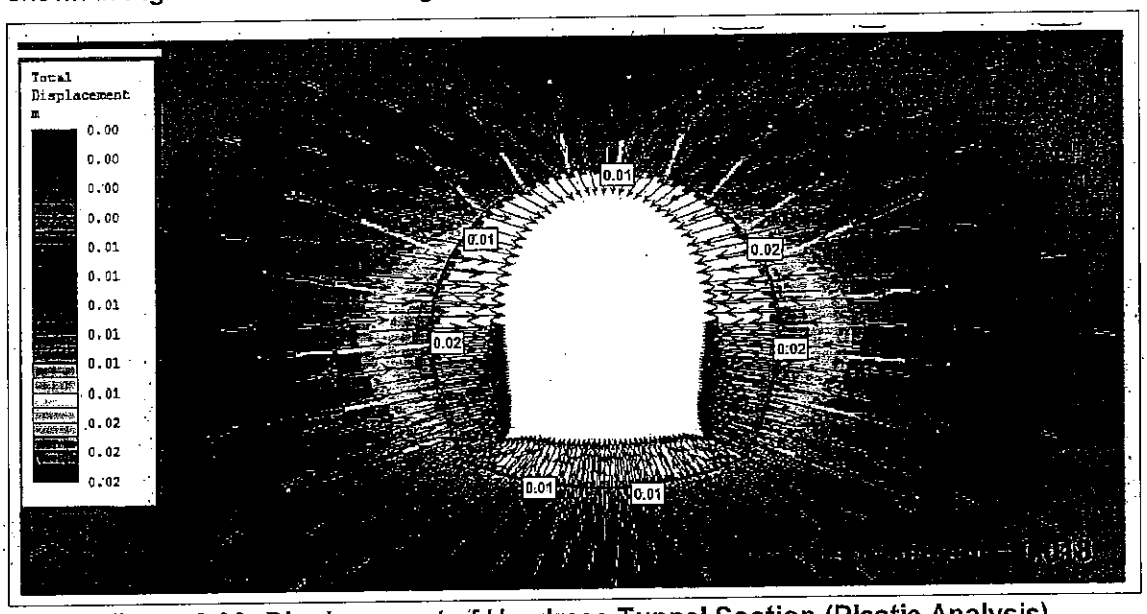


Figure 6.30: Displacement of Headrace Tunnel Section (Plastic Analysis)

Section-I (Rock Overburden Depth = 425 m)

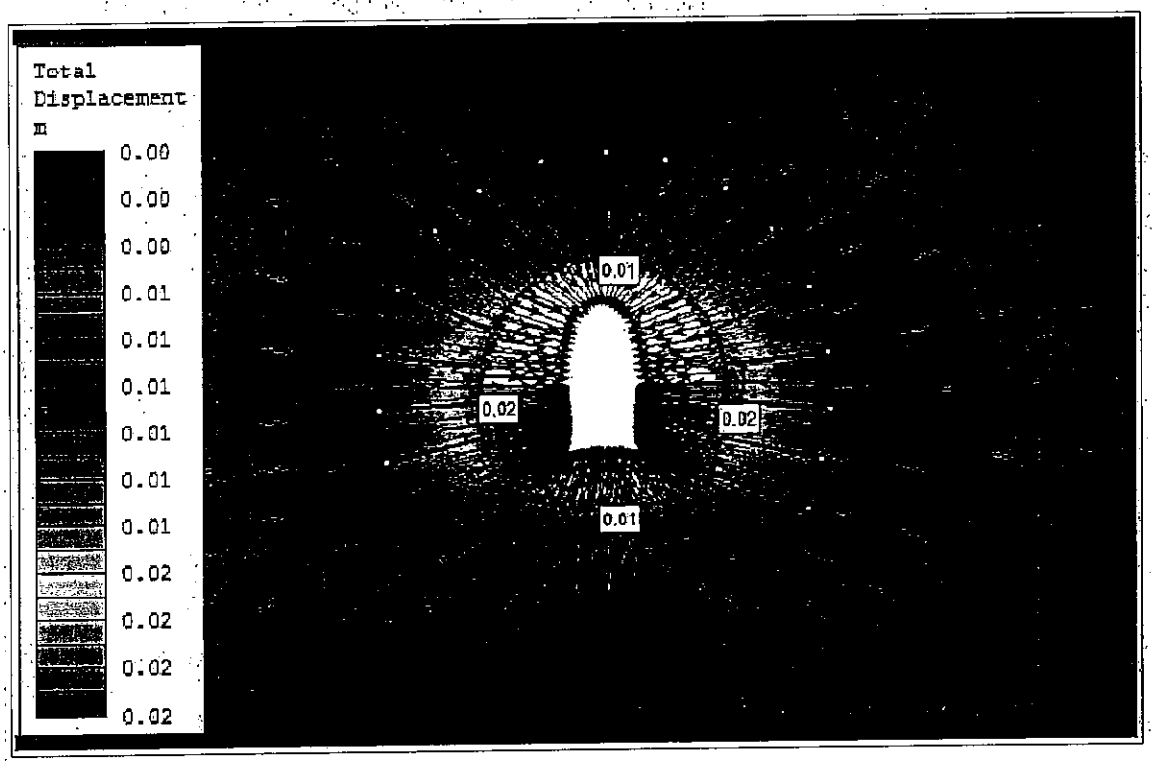


Figure 6.31: Displacement of Headrace Tunnel Section (Plastic Analysis)

Section-II (Rock Overburden Depth = 1300 m

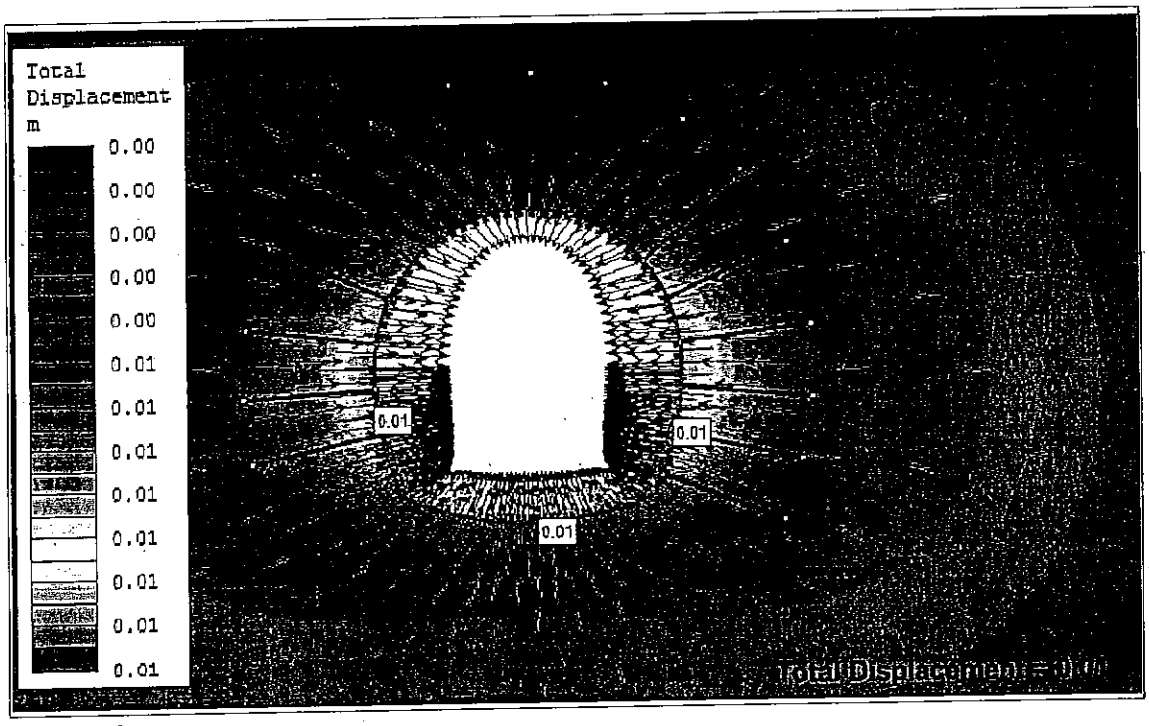


Figure 6.32: Displacement of Headrace Tunnel Section (Plastic Analysis)

Section-III (Rock Overburden Depth = 730 m)

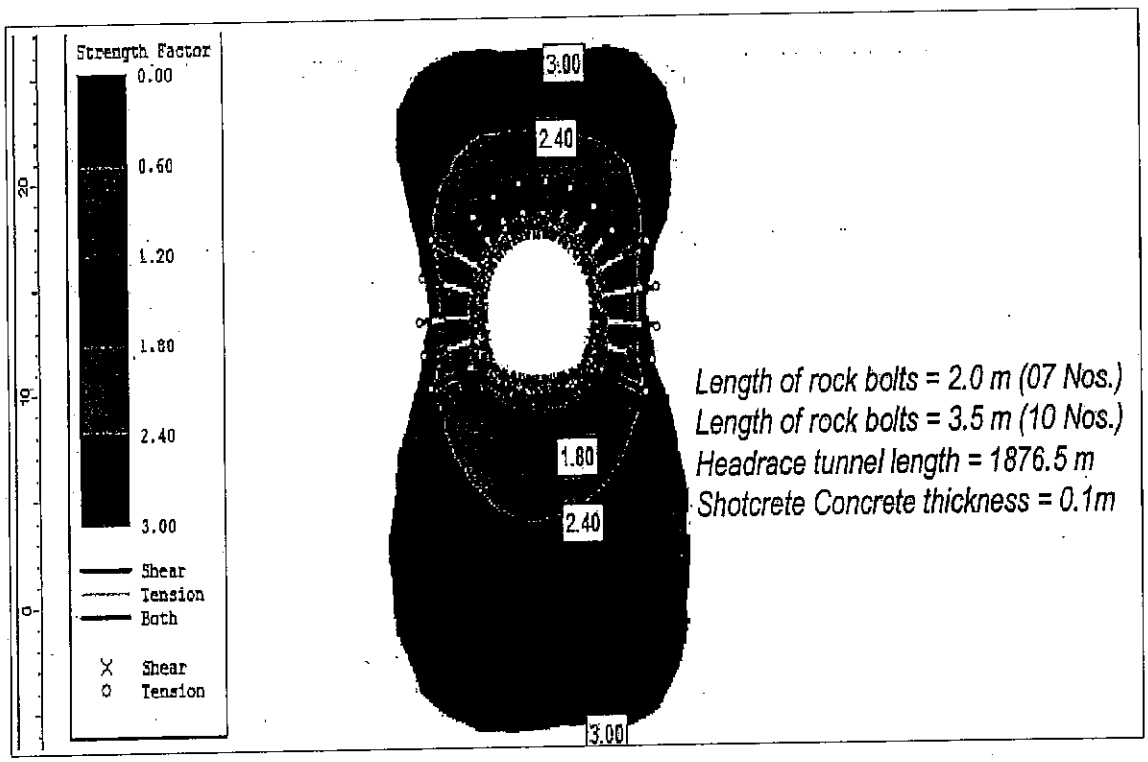


Figure 6.33: Strength Factor of Headrace Tunnel Section (Plastic Analysis)

Section-I (Rock Overburden Depth = 425 m)

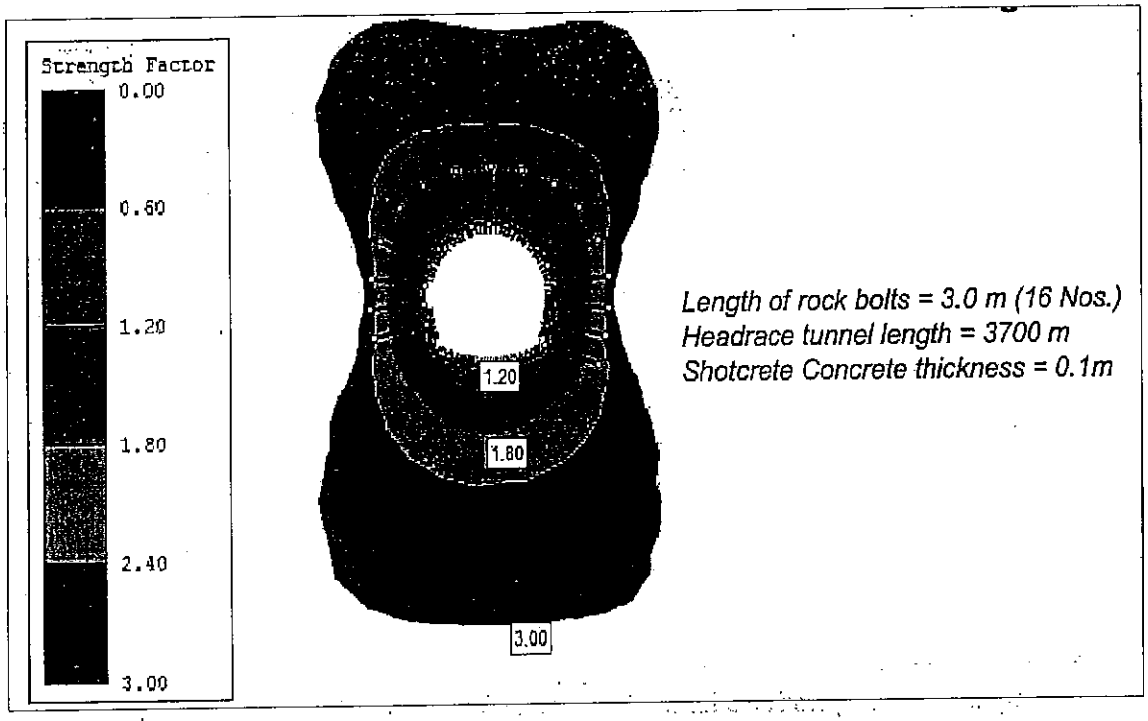


Figure 6.34: Strength Factor of Headrace Tunnel Section (Plastic Analysis)

Section-II (Rock Overburden Depth = 1300m)

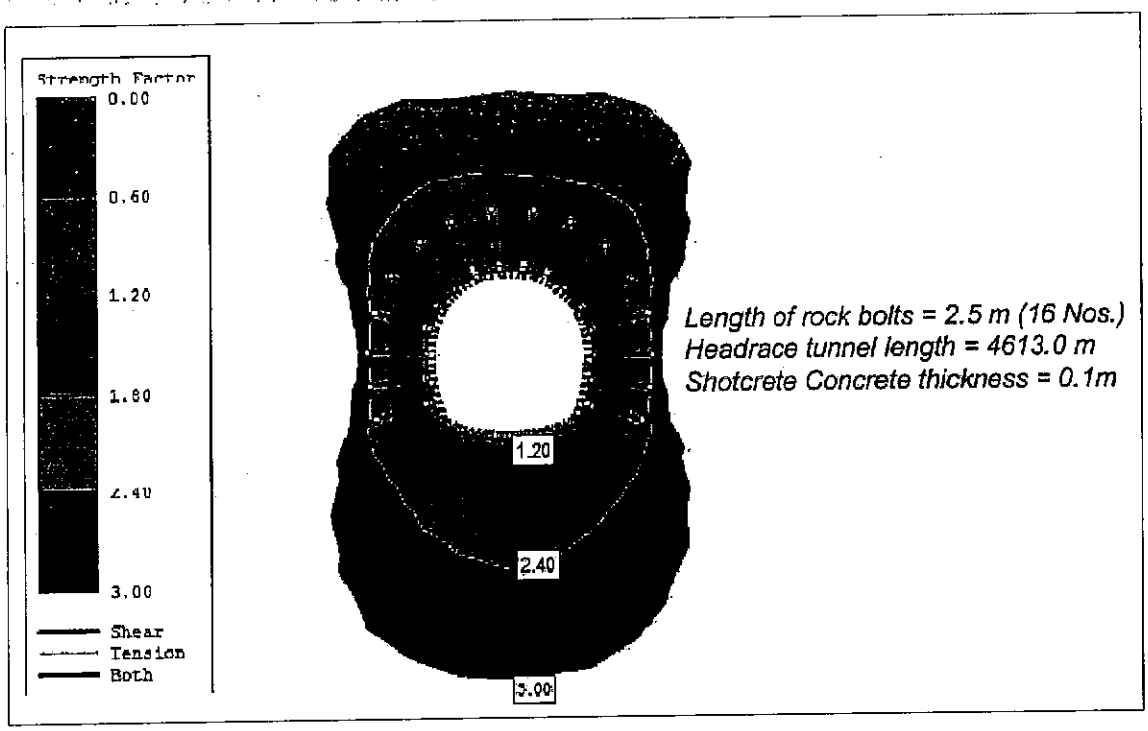


Figure 6.35: Strength Factor of Headrace Tunnel Section (Plastic Analysis)

Section-III (Rock Overburden Depth = 730 m)

6.3.13 Conclusions and Recommendations for Tunnel Design

Proposed horseshoe shape of headrace tunnel has been designed with best engineering judgment and available laboratory and field test results. It is recommended that during the detail design stage, when more reliable rock mass parameters will be available the numerical rock support optimization should be carried out. However, the best solution of any support application is achieved through numerical and empirical methods.

On the basis of same geological features, empirical method (Q-system), Results of Wedge stability analyses and Stress analyses, following rock support system has been recommended for the whole stretch of tunnel alignment

- Length of rock bolt = 3.0 m
- Spacing in-plane and our of plane = 1.3 m
- Bolt Diameter = 25mm
- Fiber Reinforced Shotcrete thickness = 60mm

6.3.14 Tunneling Through the Shear Zones

Keeping in view the geological mapping of the tunnel route, headrace tunnel is passing through the 7 number of nullah, where shear zones may intersect the headrace tunnel. Therefore, using the conservative approach about 800 m length of headrace tunnel is assumed to pass through the shear zone. For successful tunneling through the shear zones or fault, an observational type of excavation and support strategy would be implemented at the time of construction which include tunnel heading mapping, probe drilling etc.

It is an anticipated that poor rock conditions will be encountered though much of this zone. This may necessitate a substantial number of shotcrete encased steel sets or equivalent heavy support, in addition to the conventional support.

The proposed headrace tunnel has finished vertical and horizontal dimensions of 7.0 m. The concrete lining is added at a later stage to reduce the roughness of the tunnel surface and thereby improve the flow of water through the tunnel.

6.3.15 Surge Tank

The surge tank has been provided at the end of the headrace tunnel. It consists of a tank of 20 m diameter with an opening to the surface.

Access roads will be required to both the 20m diameter surge tank and to the valve chamber. Most of the construction will be done using raise bore technology. The 20 m diameter surge tank will require an initial excavation into the slope to provide a platform for construction of the shaft. It is anticipated that the slopes to form the platform will be benched and supported using a combination of rock anchoring and sprayed concrete.

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Stress analysis has been carried out to determine the factor of safety against the strength factor along the excavation boundary of surge shaft. Result is shown as **Fig. 6.36** which shows that strength factor is less than 1.5 without any rock support. Therefore, rock bolts of 12 m length @ 3m spacing in plain have been provided and checked for stress reduction factor as shown in **Fig 6.37** which shows that strength reduction factor is greater than 1.5.However, to stop the water inflows into the surrounding the rock mass, concrete lining will be required. Due to fractured rock as evident from low RQD's values, wedge failure may be occurred which will rock support through bolting

6.4 DESIGN OF CUT SLOPES FOR SURFACE POWER HOUSE

6.4.1 General

Power house is located at 549 m above MSL. Ground level in the area is about 550 m, which rises to about 600 m which require 51 m of cutting in rock. On the basis of probabilistic hazard analysis, the PGA of 0.38g associated with Operating Basis Earthquake (OBE) is recommended for the power house design.

6.4.2 Geotechnical Investigation

Investigations have been carried out during current feasibility stage. One bore hole, was planned to provide information about the type and nature of the material, the depth and extent of overburden in the foundations and elevation of bedrock. The Investigation includes 50 meter drilling of BH-09. Field permeability in overburden and water pressure tests in rock have also been carried out at every 3-meter interval. The rock has been identified as quartz-mica-schist.

6.4.3 Foundation Condition

Bedrock level in BH-9 was found at depth of 9.5 m from natural ground surface, Ground water was found in borehole-1 15.5m respectively which needs to be dewatered during construction stage. Water pressure test shows that Lugeon values are less than 1.0, which means that foundation rock is highly impervious and tight. Laboratory tests have been carried out in order to know the engineering properties of rock. For the design of cut slopes following engineering properties have been used:

- Cohesion: 100 kpa.
- Angle of Internal friction: 35°
- Unit weight of rock: 25 Kn/m^3

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6.4.4 Design Assumptions

Following design assumptions have been made:

- Cut slopes have been designed under drained conditions.
- Plane failure has been assumed.
- Critical failure plane has been assumed 0.5 times the sum of slope face angle and angle of internal friction.
- Seismic coefficient of 0.38g has been assumed.
- No tension crack has been assumed.

6.4.5 Design Criteria

Following two main criteria has been adopted:

- Cut slopes have stabilized at a factor of safety of 1.3 without considering seismic effect
- Cut slopes have stabilized at a factor of safety of 1.0 with considering seismic effect

6.4.6 Analysis of Cut Slopes

Plane failure analysis of cut slopes in rock have been carried out by developing a graphical relationship between slope heights and slope face angles for a given engineering properties of rock mentioned above. Maximum contour height in power house area is 600 m and foundation of power house elevation is 549.0 m. For a slope height of 51m, results shows that slope face angle with a factor of safety of 1.3 is 2.4 V: 1H **(Fig. 6.36).** In other word, slope is stable but rock has to be cut to accommodate the power house entirely on rock foundation for the power house elevation mentioned above. For further safety berms of 3 m width have been provided at every 15m height

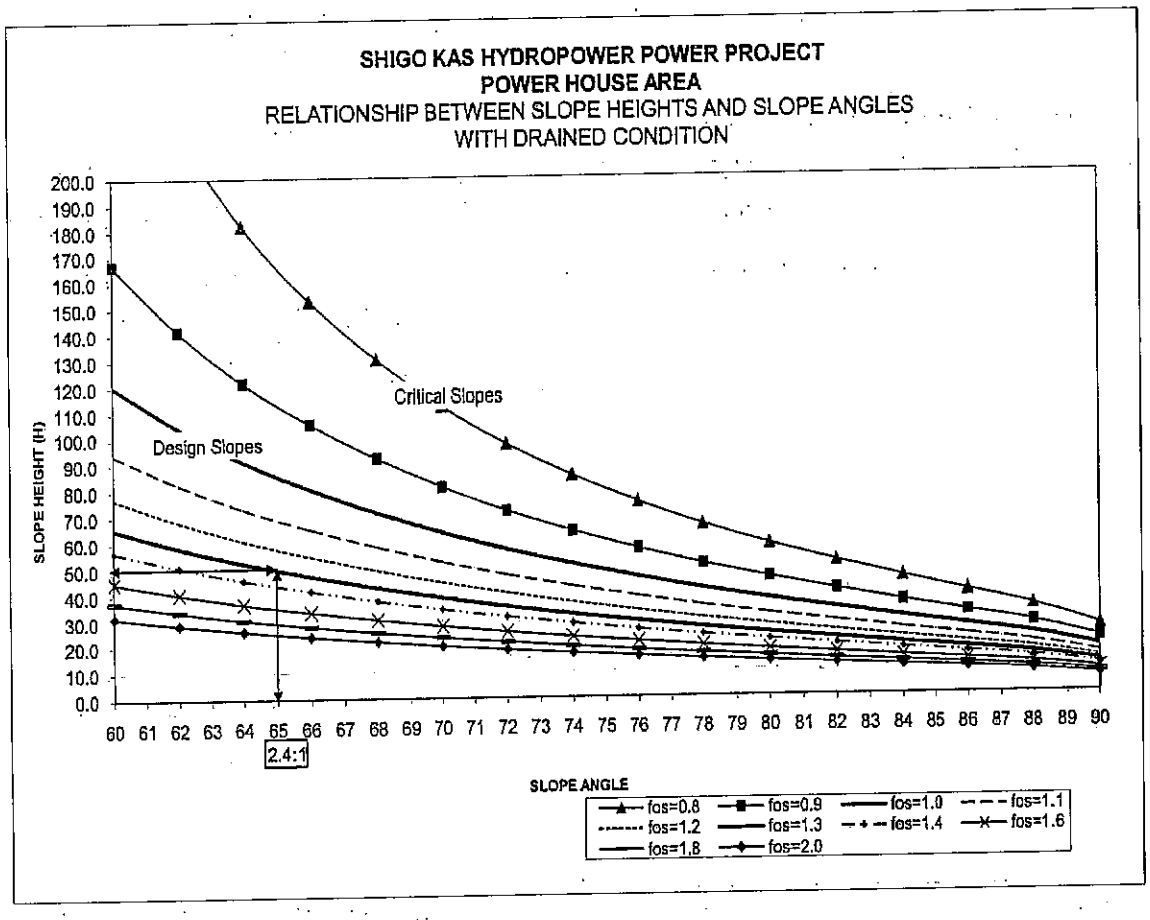

Figure 6.36: Relationship between Slope Heights and Slope Face Angles

In order to counter check the manual calculations analysis has also been carried with and without considering seismic effect by using computer software Rock Pack-III which shows that cut-slopes design as per above mentioned slope height and berms are stable. Results are shown in **Fig. 6.37 and 6.38.** Layout Plan and cross section of cut-slopes are shown as **Fig. 6.39 and 6.40 and 6.41 in** Annexure-6A.

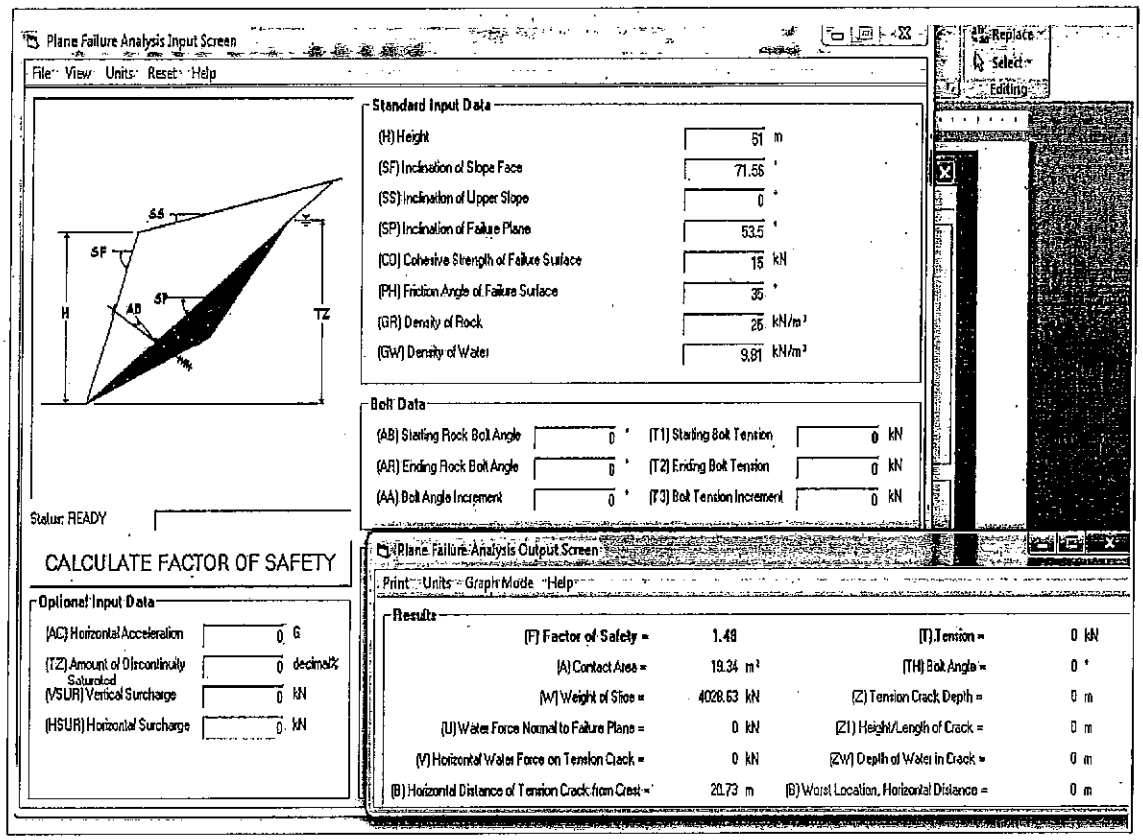

Figure 6.37: Stability Analysis of Cut-Slopes of Power House Area – Without Seismic Effect

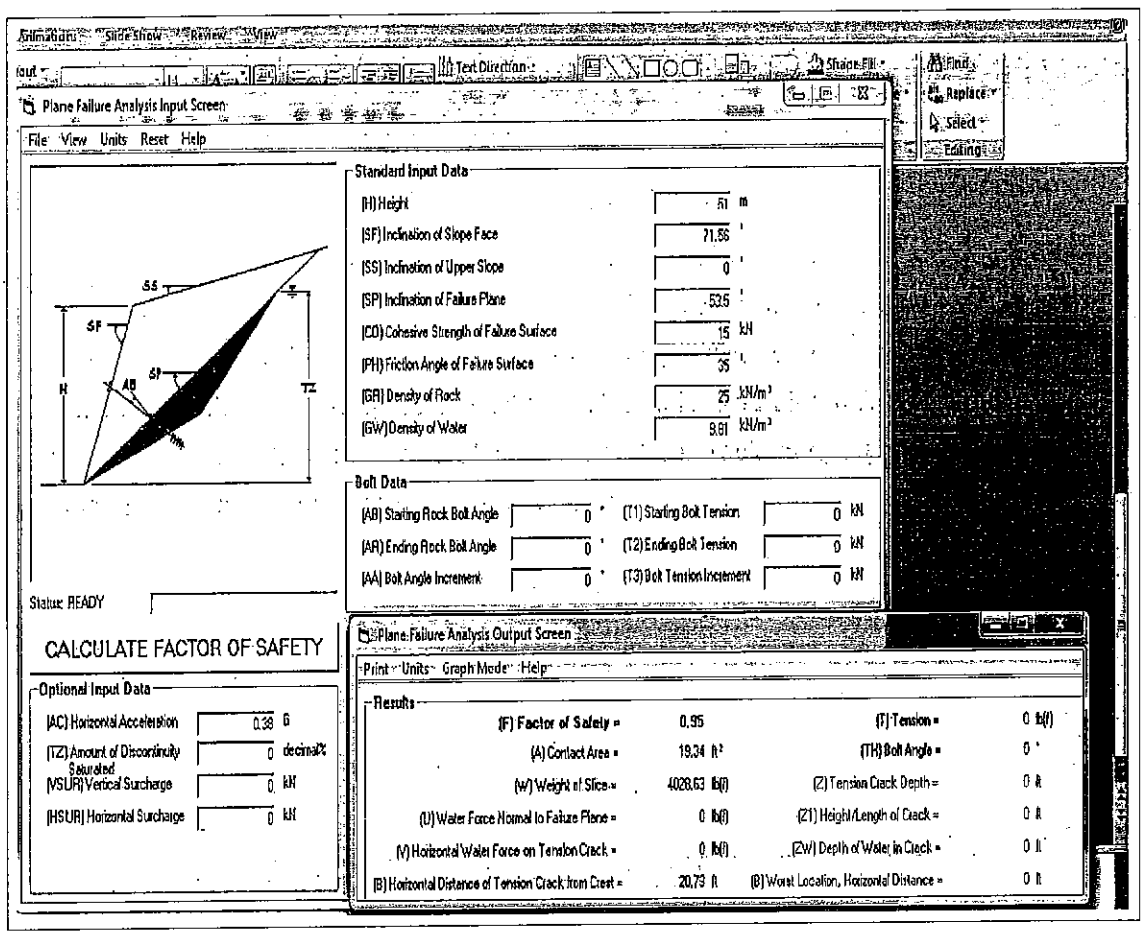

Figure 6.38: Stability Analysis of Cut-Slopes of Power House Area – With Seismic Effect

6.5 ACCESSES FOR UNDERGROUND WORKS (ADITS)

Two Adits A1 and A2 at appropriate mid location of headrace tunnel in accordance with ease of construction planning has to be given access for excavation. It can be in the form of a horse shoe tunnel of 4 meters dia in which dumping trucks can pass and should have a gradient on which they can operate easily. Rock in this area also falls into the category of Class-B as for the headrace tunnel area, therefore, rock support system and design parameters will be the same as of headrace tunnel.

Annexure-7B

Chronological catalogue of non-instrumental (historic) seismic Data of Northern Pakistan

S #	Year	Date	Detail	Estimated MM
1	4.B.C		Aristobulous of Cassandra, who accompanied Alexander on his expedition to India, points out that the country above the river Hydaspaes (Jhellum) was subjected to earthquake which caused the ground to open so that even the bed of river were changed.	IX-X
2	25 AD		A destructive earthquake in Northwestern Pakistan which laid Taxila in ruins and caused widespread havoc throughout the countryside. The effects of this earthquake can still be seen among the excavated remains. As a result of the earthquake new methods of building construction were introduced as it was reduced from four to two storey with special precautions to make the foundation secure.	IX
3	1505	Jul,6	Region north of Kabul totally destroyed. In Kabul, many houses collapsed and fortress damaged. Felt upto Agra.	VIII-IX VII-VIII (Kabul)
4	1552		Damaging in Kashmir.	V
5	1669	Jun, 4	A very violent earthquake felt all over Kashmir	VI-VIII
6	1669	Jun, 23	The earthquake felt at Attock caused a fissure of 50 yard long in the ground.	VIII-IX
7	1780		Severe shock in Kashmir.	V-VII
8	1827	Sep, 24	Destructive in Lahore region. Fort Kolitaran near city destroyed, about 1000 perished in ruins. A hill shaken down, which fell into river Rowee (Ravi) produced and inundation of 100 acres of land.	VIII-IX
9	1828	Jun, 6	Destructive in Srinagar and shook down many houses and killed many people (perhaps 1000 people and 1200 houses). Earth opened at many places about the city and foetid water.	IX-X
10	1831		Severe in Peshawar & valley of Indus, extended from Peshawar to Dera Ghazi Khan, felt severely at Dera Band (Daraban), rocks fell at many places, water forced from crevasses.	VIII-IX (Daraban) & IV-VI (Peshawar & D.G.Khan)
11	1832	Jan, 22	Near Lahore violent, people rushed out of houses.	VI
12	1832	Feb, 21	Lahore, valley of Badakhshan, N.W India.	

S #	Year	Date	Detail	Estimated MM
			Huge masses of rocks were thrown from the cliffs at many places choking of valleys. Great part of population destroyed.	
13	1842	Feb, 19	Felt at Peshawar and Kabul. At Kabul said to have lasted for 03 minutes, several shocks, rocked the fourth in frightful manner. At Peshawar very destructive, "earth trembled like aspen leaf", several killed. At Ferozpur, severe. At Ludhiana north south, the hot springs of Souah (temp 140^0-110^0) became as cold as the ordinary wells, water diminished greatly and at times the springs were completely dry. These appearances continued for 25 days.	VI-VII (Kabul) VII (Peshawar) VI (Ferozepur)
14	1847	Mar, 30	Punjab. A shock causing more fright than injury.	VI
15	1851	Jan, 17	Strongly felt at Multan and in the Punjab, originating from Fort Munro, shocks continued for almost a month, some of them felt in Lahore. Damaging earthquake in the Sulaiman Range. Slight damage at Ferozepur and Wazirabad.	VI-VII (Wazirabad) & V-Vi (Fort Munro)
16	1851	Jan, 21	Lahore and all Punjab. Similar to Jan 17th event but stronger.	VI
17	1851	Feb, 4	Lahore appears to have extended all over Punjab.	V-VI
18	1851	Feb, 6	As above.	V-VI
19	1851	Feb, 17	Lahore, Multan, not severe.	V
20	1853	Nov.	Strongly felt at Attock.	VI
21	1858	Aug, 11	Damaging Shocks at Simla felt throughout the Punjab, Calcutta and Madras.	V-VI
22	1858	Aug, 23	Lahore slight at 6:30 P.M. Jacobabad at 2:P.M about imperceptible.	III-V
23	1858	Aug, 29	Lahore, Sharp shocks.	IV
24	1865	Jan, 22	Slight damage and great panic in Peshawar; long duration.	V-VII
25	1865	Dec, 4	Lahore, two small shocks.	III-V
26	1867	Nov, 10	Damaging in Bannu.	VII-VIII
27	1868	Aug, 11	Damaging in Peshawar; a portion of the fort was shaken down (official record)	VII-VIII
28	1868	Nov, 12	Violent shocks were felt in Lahore, Dera Ismail Khan and Attock, followed by many after-shocks, which were felt throughout Punjab.	IV-VI (Attock)
29	1869	Mar, 24	Severe shock in the Upper reaches of Jhellum.	V-VII
30	1869	Mar, 25	A large earthquake in the Hindukush, strongly felt at Kohat, Lahore, Peshawar,	V (Kohat, Lahore &

S #	Year	Date	Detail	Estimated MM
			and at Khojend and Tashkant; shocking lasting 20 seconds.	Peshawar)
31	1869	April	Peshawar, part of fort shaken down (official record)	VII-VIII
32	1869	Dec, 20	Rawalpindi shock said to have lasted for 1/2 minute; cracked walls and caused all people to rush out of houses. Attock- A series of shocks at intervals of about 20 sec. Lawrencepur- 1st shock lasted for 20 sec and other lasted for 5 seconds. Campbell pur- for half an hour, building much damaged.	VII-VIII
33	1869	Dec, 24	Rawalpindi- Murree some very heavy claps of thunder preceded	VII-VIII
34	1871	April	Severe at Rawalpindi and Murree; originating from Kashmir.	VI (Rawalpindi &Murree)
35	1871	May, 22	Damaging shock at Gilgit. Felt at Meerat, Agra, Landur; Many after-shocks.	VII-VIII (Gilgit)
36	1875	Dec, 12	Damaging in villages between Lahore and Peshawar where a number of people were killed.	VII-VIII
37	1878	Mar, 2	Damaging earthquakes in the Punjab. At Kohat several houses and public buildings and portion of the wall of fort fell. At Peshawar, it caused damage to houses and city walls. Damaging at Attock, Abbotabad, Rawalpindi, Jhellum, and Murree. Strongly felt at Bannu, Nowshera, Mardan, Lahore and Simla. Many after-shocks.	VII-VIII (Peshawar & Kohat) VI-VII (Rawalpindi & Attock)
38	1883	April	Damaging shock at Peshawar.	VI-VII
39	1885	May, 30	Destructive shocks in Kashmir (Sopor, Gulmarg, Srinagar about totally ruined and 3000 people killed.) Heavy damage at Gurais and Punch; Muzaffarabad heavily damaged. Felt at Peshawar, Lahore, Simla, Leh, Kapalu and Gilgit in a radius of 650 km. Many after-shocks.	VII (Muzaffarabad) IV (Peshawar)
40	1893	Nov, 3	Slight damage at Peshawar, Nowshera, and throughout Punjab.	VI-VII
41	1902	Jan, 20	Large earthquake, damaging in Chitral area, also felt widely in Punjab and Simla.	IV (Punjab)
42	1905	Apr, 4	Kangra Earthquake. In Rawalpindi, few lofty buildings were cracked.	V-VI (Rawalpindi)
43	1919	Sep, 5	Strongly felt in Lahore.	V
44	1929	Feb, 1	Destructive earthquake, perhaps shallower than calculated, ruined Skorzor and Drosh. Damage was equally heavy in USSR at Kulyab. It caused substantial damage in	VI-VII (Abbotabad & Peshawar)

S #	Year	Date	Detail	Estimated MM
			Abbotabad, Peshawar, Cherat, and Dushambe. It was felt in a radius of 1000 km.	
45	1939	Nov, 21	Destructive in Badakhshan area, the damage extended to Srinagar, Rawalpindi and Kargal. At Drosh, seriously damaged. Felt within a radius of 600 km/	V-VI (Rawalpindi)
46	1940	May, 27	Felt in Peshawar.	IV
47	1945	Jun, 22	Destructive at Chamber and parts of Kashmir. Strongly felt at Rawalpindi, Peshawar, Lahore and Simla.	V (Rawalpindi)
48	1947	Jul, 10	Damaging in Bahaderwal; strongly felt at Gulmerg, Srinagar, Dalhousie, and Simla and in Kumaon hills. Felt at all over Kashmir, in parts of Punjab and N.W.F.P. Followed by after-shocks.	IV (Punjab & N.W.F.P)
49	1952	May, 11	Felt in Punjab.	V-VI
50	1953	Mar, 1	Slight damage in Campbellpur.	V-VI
51	1956	Sep, 16	Destructive in Ghazni district of Afghanistan where many villages were destroyed, animals lost. The damage was equally serious at Said Karem. Caused panic at Kohat. Strongly felt at Parachinar, Parwan, Loger, Ghazni, Nazerejat, Bahsud, Makur, Rawalpindi and Srinagar. Radius of perceptibility about 450 km.	V (Rawalpindi)
52	1962	Aug, 2	Felt at Rawalpindi.	IV
53	1966	Jan, 11	Felt at Risalpur.	IV
54	1966	Feb, 2	Strongly felt around Abbotabad where it caused minor damage at Havelian. Felt at Rawalpindi, Islamabad, Abbotabad, and Taxila. The shocks were felt at Muzaffarabd and Gujjar Khan.	V (Islamabad)
55	1977	Feb, 14	Caused damage 7 km northeast of Rawalpindi in 20 villages (Kuri, Malot and Pindi Baghwal around Nilor, most of Katcha houses either collapsed or damaged while cracks developed in few houses built with dressed blocks of Sandstone and sand-cement mortar.	VII

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CHAPTER 7

SEISMIC HAZARD ASSESSMENT

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SEISMIC HAZARD ASSESSMENT

7.1 Executive Summery

Geotectonic of the Northern Pakistan is related to the collision of the two plates namely Indian Plate with Eurasian plate, and subsequent formation process of the Himalayan ranges. The intercontinental collision has resulted in intense deformation with complex folding involving strike-slip and thrust faulting. This tectonic process is the origin of the seismicity along the Himalayas and in particular where Northern Pakistan is located. The major regional faults related to the intercontinental collision and considered to be active and capable of generating earthquakes, include Main Karakorum Fault (MKF), Main Mantle Thrust (MMT), Panjal Thrust, Main Boundary Thrust (MBT), Main Frontal Thrust (MFT) and Salt Range Thrust.

Shigo kas Hydropower project is located near the vicinity of Main Mantle Thrust (MMT) on Panjkora River in Lower Dir, in a zone which is seismically active due to the Continuing northward drifting of the Indian plate and its subduction under the Eurasian plate. This tectonic activity has resulted in the production of a crustal accretion wedge; The Himalayan range. Seismic Hazard Evaluation, based on available data / literature regarding regional geology, tectonics, non-instrumental and instrumental seismicity, has been carried out for Shigo kas Hydro Power Project by including some 618 events in the present study (since 1927).

The Deterministic Seismic Hazard Analysis (DSHA) has revealed that for Shigo kas Hydropower Project, Main Mantle Thrust could be the critical fault, capable of generating a magnitude 7.6 Mw Earthquake (equivalent October 8, 2005 Kashmir Earthquake). Maximum Credible Earthquake due to active faults in the region is calculated to be of the order of 0.46g due to an earthquake 7.6 magnitude, having a hypocenter at 30 kms from the site.

Operating Basis Earthquake (OBE) acceleration can be assumed to be half of MCE value, but keeping the fact in mind that the seismic gap perpetually floats on the fault and wherever the situation is seismically suitable, a quake is triggered. Once an area experiences a quake, its epicentral volume is crushed and it becomes unable to accept any further geo-technical stress. This means that once an area has experienced an earthquake, it will not experience another earthquake of a similar magnitude for a long time. The time gap is usually about three to five times the return period of the earthquake. The available seismic data has been analyzed to evaluate Peak Ground acceleration (PGA) at the site. The calculated value of maximum Peak Ground acceleration by earthquake history for Shigo kas Hydropower project site is 0.05g. After

applying the necessary safety factor (MCE) to the observed PGA, The OBE is calculated to be of the order of 0.31g.

Peak Ground Acceleration at Shigo kas Hydropower Project Site from Earthquake records since 1927.	0.05g
Design Spectral Acceleration Value	0.11g to 0.5g (mean 0.31g)
Half of MCE value	0.31g
Operational Basis Earthquake value at Shigo kas Hydropower Project site	**0.31g**

Shigo kas site is just on the major tectonic features called Main Mantle Thrust (MMT) and that appears to be a seismically quite tectonic zone since long. This is a dangerous sign. Data of 618 earthquake events within 110 kilometers (1 degree) quadrangle distance, around Shigo kas has been collected from International and National agencies. The density of earthquakes is quite scattered, and apparently no structural/tectonic features can be interpreted from that data. Design Spectral Acceleration response supports the OBE value calculated for this site.

7.2 SEISMIC HAZARDS

A hydropower project is planned to be build at Shigo kas area (34.72^0, 71.81^0), which is located 10 km downstream from Timergara Town, Lower Dir, where Panjkora River becomes narrow again and passes a bottleneck. This bottleneck is located 13 km upstream the Junction of Panjkora River with Swat River. Location map of Project site and tectonic elements are shown in **Figure 7.1.**

Earthquakes are generally caused by the release of accumulated stresses in the earth's crust. These stresses build up due to crustal deformation resulting from the movement of continental plates, and are released along faults causing rupture of the crust. Therefore, the occurrence of earthquakes is not merely a random phenomenon but is governed mainly by elastic and tectonic processes.

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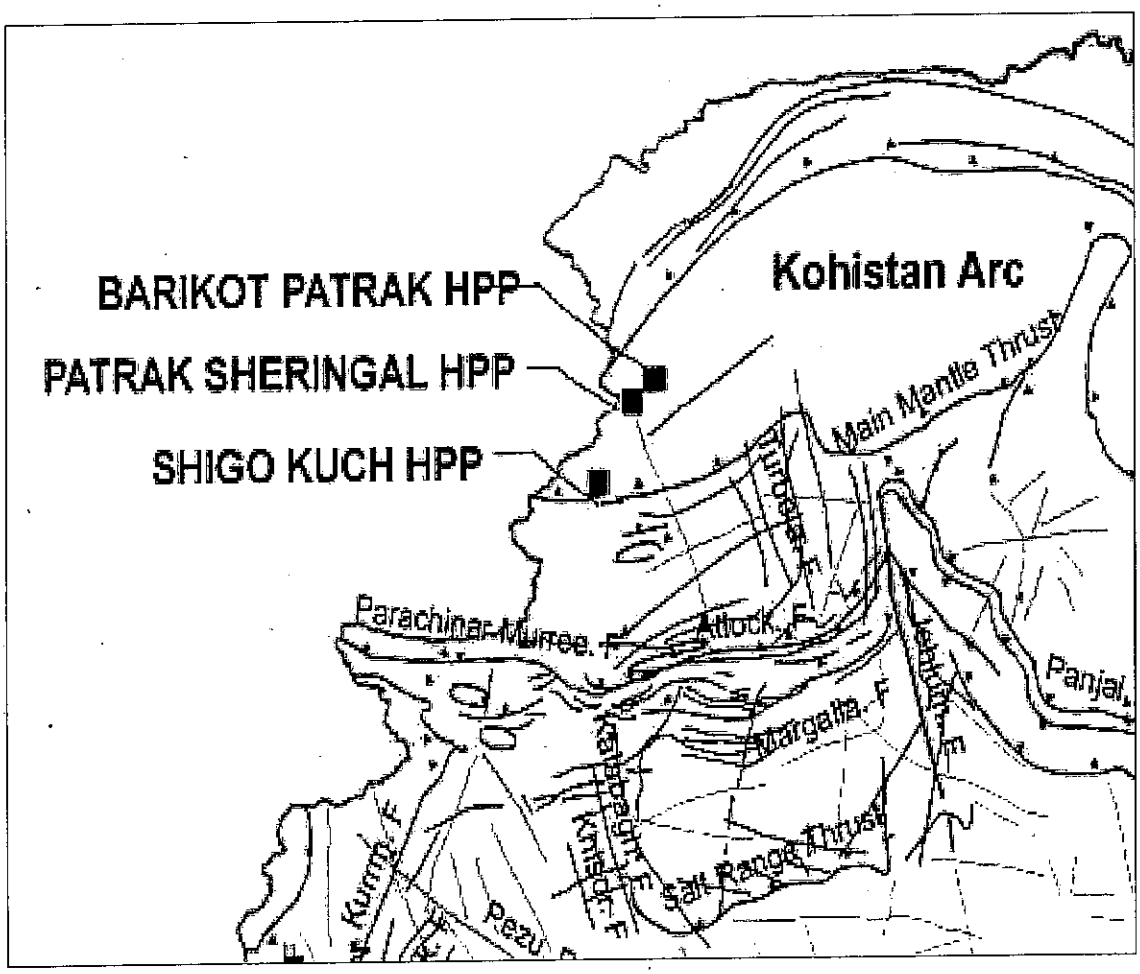

Fig 7.1: Location Map and Tectonic Elements of Shigo kas, HPP site, KP. Pakistan.

According to Tectonic Map of Pakistan **Figure 7.2**, the site is located in a highly seismically active area affected by the continuing northward drifting of the Indian plate and its subduction below the southern flank of Eurasian plate. The collision of the two plates began about 50 million years ago and the full contact between them was completed about 40 million years ago. Yet the Indian plate keeps on slowly drifting northward. As the Indian plate subducts below the Eurasian plate, its top surface layers get "peeled off" and folded back. This has resulted in the production of a crustal accretion wedge, the Himalayan Range, and this deformation is continuing at the rate of about 2-4 cm per year. The accreted wedge is made up of Continental crust and is separated by a general plane of decollement or separation along weak strata. The geology in this corner of the Indian plate is very complex and a biaxial state of stresses in the crust has created sharp bends and closed arches of faults called syntaxes.

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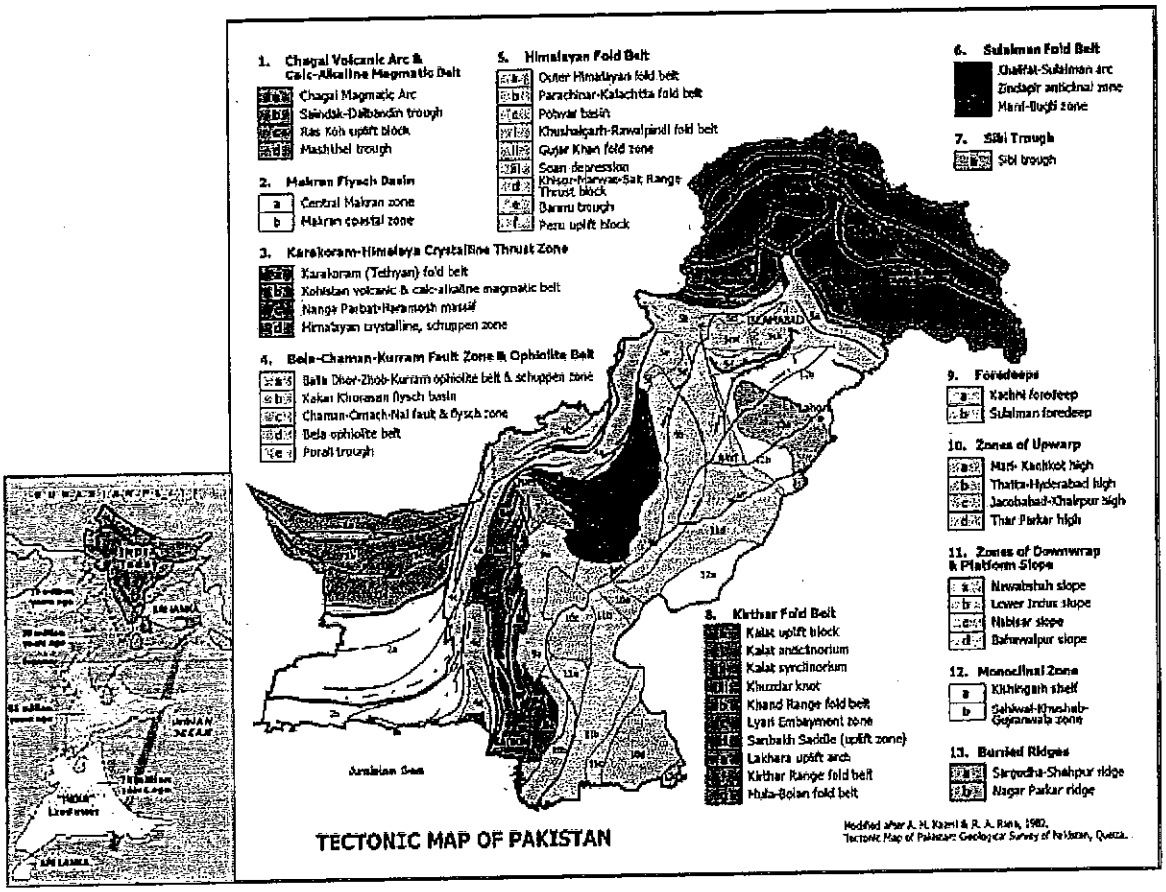

Fig 7.2: The Indian Plate colliding with Eurasian Plate and Tectonic Map of Pakistan (After Geological Survey of Pakistan)

The geotectonic of the whole region is therefore related to the collision of the Indian tectonic plate with the Eurasian Plate and subsequent formation process of the Himalayan ranges. This intercontinental collision 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. This tectonic process is the origin of the seismicity along the Himalayas and in particular where Northern Pakistan and Kashmir are located. The major regional faults, related to the intercontinental collision, include Main Karakorum Fault (MKF), Reshun Thrust, Main Mantle Thrust (MMT), Punjal Thrust (PT), Main Boundary Thrust (MBT), Main Frontal Thrust (MFT) and Salt Range Thrust. The Shigo kas hydropower project site is located in the sub-Himalayas very close to the Main Mantle Thrust.

The above discussion indicates that the project site is located in an area where crustal deformation is an active process due to presence of some major active faults in the region and it is, therefore, imperative to carry out seismic hazard evaluation for safe design of the various project structures and equipment.

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This report covers Seismic Hazard Evaluation for Shigo kas hydropower project (34.72^0, 71.81^0). The analysis is based on available seismic data and literature regarding regional geology and tectonics. All important faults within a radius of 111 Km (1^0) of the Project areas have to be taken into consideration. The Maximum Credible Earthquake (MCE) is that earthquake which is based on an evaluation of the maximum earthquake potential considering the regional and local geology and seismology of the area, and is an event which might occur once in about 10,000 years. It is that earthquake which produces the maximum vibratory ground motion against which the water retaining structures and certain other vital components have to be designed that they may undergo some displacements, but should continue and to retain water, while several structural components may suffer damages and be rendered non-operational. Maximum Credible Earthquake (MCE) for each causative fault has to be determined by applying Deterministic Seismic Hazard Analysis (DSHA) approach.

The operating Basis Earthquake (OBE) on the other hand, is an earthquake event which could reasonably be expected to affect the dam site during the life of the structures. These are the range of earthquake events which produce the vibratory ground motions for which those features of the project that are necessary for its safety and continued operation are designed to remain functional with some repairable damage. The selection of the appropriate vibratory ground motions for such structure will be chosen based on judgment of the acceptable risk for that structure. A value for the Operating Basis Earthquake (OBE) for serviceability level safety has also been recommended. Tectonic and geological information already available in scattered technical literature was gathered for the purposes of this feasibility study.

In the present study, assessment has been made for the Maximum Credible Earthquake (MCE) as safety level and the Operating Basis Design Earthquake (OBE) as serviceability level for the Shigo kas Hydropower Project in the Khyber Pakhtunkhawa Province of Pakistan. The MCE and OBE together with the corresponding engineering parameters (i.e. peak ground acceleration and design response spectra) needed for the design of the dam and related structures, have been derived based on the recommendations of the ICOLD Bulletin 72 (1989) *"Selecting Seismic Parameters for Large Dams"*. Under the MCE load some damage to the dam is allowed, but an uncontrolled outflow of the reservoir must be avoided and all safety related equipments have to remain functional. Under the OBE, no structural damage such as tension cracks in concrete dams are allowed and all equipment has to remain functional. In the hazard analysis, a number of parameters play an important role, so that reasonable assumptions on the uncertainties have to be made. Therefore, all assumptions are clearly presented in this feasibility report, and their consequences will be discussed. For evaluating the

Operating Basis Earthquakes the geological evidence, historical seismicity and instrumental seismicity are discussed below:

7.3 Regional Tectonics and Seismicity

As also stated earlier, the tectonic setting of northern Pakistan is characterized by the collision of Eurasian and Indian continental plates. The orogeny process started in the late Eocene to Early Oligocene with the formation of the Himalayan Range. It is also understood that a second collision immediately north of Pakistan took place in Paleozoic era. A regional tectonic map of Pakistan as well as Northern areas is given in **Figures 7.1, 7.2, and 7.3.**

Relative to Eurasia, the Indian plate is still moving northwards. The latest GPS measurements indicate the North-Western Part of Sub-Continent i.e. mostly Pakistan is moving 10 mm per year in north direction and 11 mm in westward direction. Indus suture line that coincides with upper Tsengo river valley represents the original site of the continental collision along which linear and well-developed ophiolites suites are found. These ophiolites are interpreted as the remnants of the oceanic crust of the Tethys Ocean trapped during the collision between the Indian and the Eurasian continental blocks. Major portion of this convergence boundary involved folding and thrusting of the upper crustal layers in the shape of MKF (Main Karakorum Fault), MMT (Main Mantle Thrust), MBT (Main Boundary Thrust), MFT (Main Frontal Thrust) and SRT (Salt Range Thrust). A number of associated thrusts and strike-slip faults were also developed in the collision zone between MKF and SRT.

The MKF, now interpreted largely, as a strike-slip fault as opposed to a thrust fault (based on latest plate movement data) separates rocks of Eurasian landmass from Kohistan island arc complex. The Kohistan Island Arc is separated from the Indian plate by MMT. The MBT separates pre-collision Paleozoic and Mesozoic sedimentary rocks of the Indian plate from the younger post-collision Himalayan molasses sediments. A single detachment surface, called the Main Himalayan Thrust (MHT), is believed to exist beneath the entire rocks south of MMT into which all Main Faults bottom out and merge. This surface extends southwards till it emerges out in the shape of Salt Range Thrust.

In addition, the western Himalayas exhibit a peculiar structural pattern consisting of two northward projecting loops or re-entrants, the Nanga Parbat-Harmosh Massif syntaxis and the Hazara-Kashmir syntaxis. Around these syntaxes, the entire regional geological trends take a sharp turn to make curved loops.

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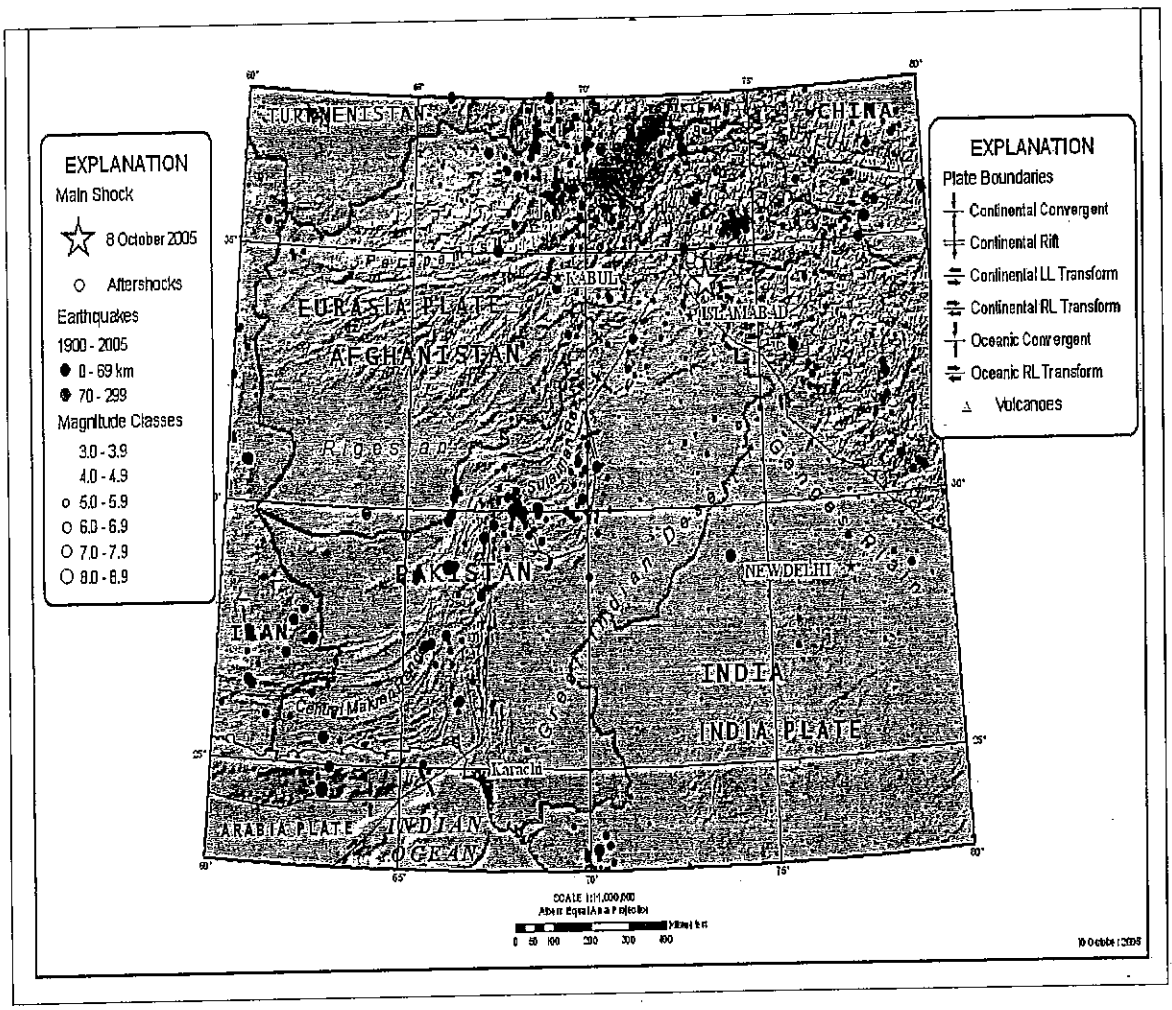


Fig 7.3: Northern Pakistan Earthquake of 2005 with Regional Seismicity and Tectonic Elements of Pakistan (after USGS)

Northern parts of Pakistan and adjoining areas have their peculiar geological and seismic conditions causing frequent occurrence of severe earthquakes. These areas have remained under detailed study by several seismologists / geoscientists for delineating earthquake – generating fault system. Most of these areas are occupied by Himalayan Range, in which the Kashmir and Northern Pakistan area lies. The earthquake activity as shown in an overview map in **Figure 7.3**, clearly demonstrates how the earthquakes concentrate along the plate margins. Even when the details about the map (time period, sources, magnitude, type etc.) are not available it shows clearly the regional earthquake distribution. Even though the Himalayan region is huge and contains large parts that are remote and sparsely populated, the professionals have some overview of the seismicity there for the last 500 years, even with indications of an earthquake deficit at present. As a result of the continent-to-continent collision in the Himalayas, the highest mountains in the world have been created, still being uplifted

more rapidly than any other mountain chain. The seismicity in northern Pakistan occurs over a large crustal depth range. The maximum depth of the seismicity increases gradually from 35 km deep in the area where the Precambrian rocks of the Indian shield outcrop in the Punjab plains, to 70 km deep under the higher Himalayas. Available information about the depth of the Moho in this area (Farah and others, 1977) indicates that the maximum hypocentral depths roughly correspond to the lower boundary of the crust

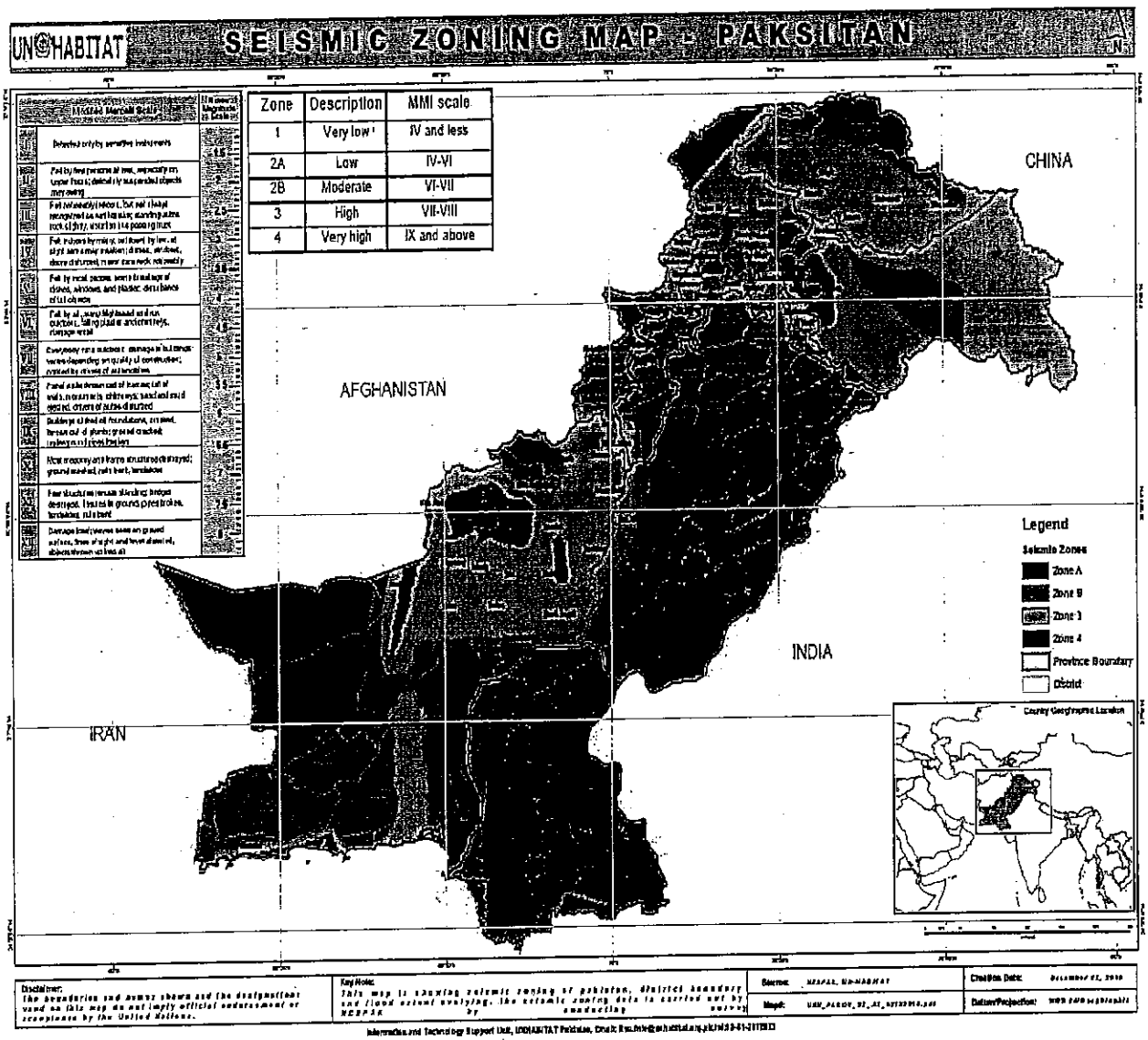


Fig 7.4: Seismic Zoning Map of Pakistan

(Seeber and Jacob, 1977). Major tectonic features relevant to producing an earthquake of high magnitude, are described in the ensuing section. The seismic zoning map of Pakistan is shown in Fig 7.4. The project area falls in Zone 3 showing that the area may experience an earthquake with MM Intensity of VII to VIII.

7.4 Active Faults in the Region

7.4.1 Hazara Thrust Fault System:

Seeber and Jacob 1977 suggest that the two major northwest-trending fault zones, the Indus-Kohistan Seismic Zone (IKSZ) and the Hazara Lower Seismic Zone (HLSZ), well defined by the deeper crustal seismicity, are discordant with the overlying arcuate structural trends of the Hazara. These fault zones are interpreted as buried extensions of the north westerly Himalayan frontal faults beyond their surface termination at the Western Himalayan Syntaxis. Topographic steps aligned with the fault zones are prominent surface expressions of these buried structures. Hazara fault is directly connected to the Hazara Lower Seismic Zone (HLSZ), forming a northward – dipping reverse fault continuous from the surface to the lower crust. The Hazara Lower Seismic Zone is well defined below 20 Km, but it is sparse above this depth and the suggested relationship between seismicity and surface geology is entirely speculative

7.4.2 Main Boundary Thrust (MBT)

In one of the interpretations, the MBT is considered as the sole thrust below the thick sequence of inner-shelf sediments, originally resulting on the northern margin of India. It is also one of the imbricate thrusts that contribute to the current shortening of the sedimentary wedge.

Slip on the MBT may occur by earthquake ruptures. In analogy to the slip behavior of imbricate thrusts within the accretionary wedges of oceanic subduction zones, the repeat time for earthquake on the MBT is expected to be considerably longer than the repeat time of great earthquakes on the underlying detachment.

7.4.3 Main Frontal Thrust (MFT) / Riasi Fault

Two independent pieces of evidence suggest that the 1905 Kangra rupture extends under two distinct high intensity zones. Before the 1905 main shock, at least seven separate foreshocks were felt (Middlemiss, 1910) within 24 hours. Five of these were felt only locally so that the location assigned according to the felt reports are probably not that inaccurate. Thus, the 1905 foreshocks are distributed along a portion of the Himalayan Front, which may have intensity >8 on Rossi-Forel (RF) scale of intensities. The 1905 event is generally believed to have ruptured the detachment along some 300 Km of the Himalayan front. This event is characterized by low intensities (RF VII to VIII) above most of the rupture. These low intensities may be due to low liquefaction potential in the plains and to low landslides potential in the mountains.

7.4.4 Kashmir Thrust (KT)

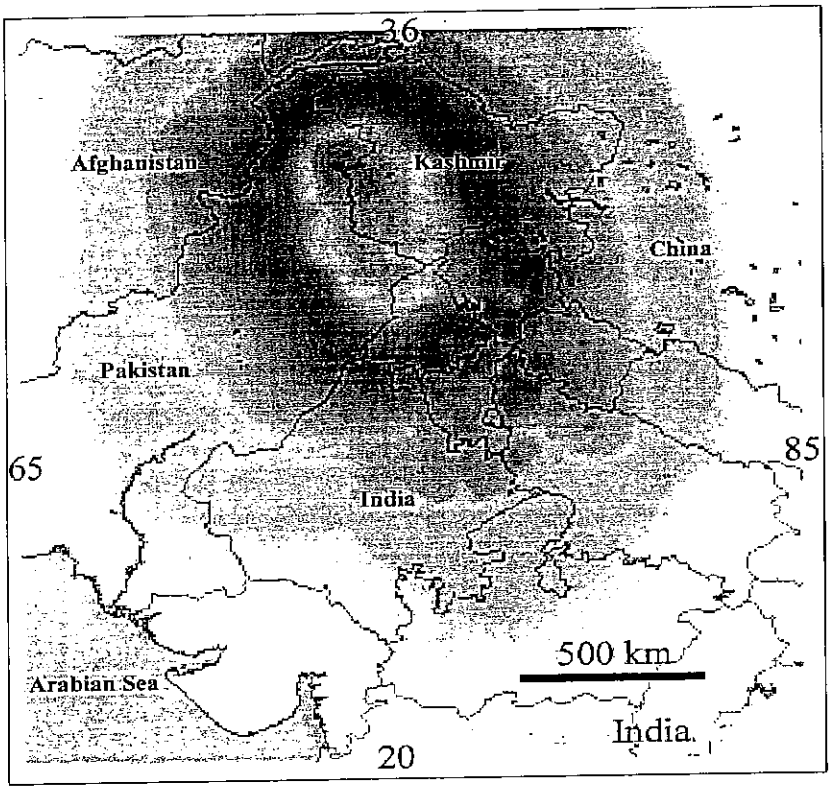
Kashmir Thrust (KT) has been assigned to the active fault connecting Muzaffarabad with Balakot. Reference is made of a Report on Seismic Microzonation of Balakot and surrounding Areas, published in March 2006 by the Center of Excellence in Geology, University of

Peshawar in collaboration with ICIMOD (Nepal), ITC (Netherlands), ADPC (Thailand) and Associated Institute of United Nation University (Japan). Recent studies have proved that Kashmir Fault is traceable up to 4 Km north of Balakot city and it has its extension up to Banna Allai area. It may also be considered an extension of the Main Frontal Thrust (MFT).

The most recent major earthquake in the area occurred on 08 October, 2005, whose epicenter was near Ghori (34°29'35" N and 73°37'44") about 19 Km NE of Muzaffarabad. The minimum moment magnitude (Mw) of the earthquake measured by the United States Geological Survey (USGS) was 7.6 and the hypocenter was located at a depth of 26 Km below the ground surface.

The earthquake caused severe destruction in large area of northern Pakistan **Figure 7.5** and to a lesser degree in northern Afghanistan and northern India. The area that suffered most serious damage was Azad Kashmir, Khyber Pakhtoonkhawa Province (KP) of Pakistan, and south-west part of the Kashmir valley in the Indian controlled Kashmir. The province of Punjab of Pakistan was also affected by the earthquake to some extent. As many as 73,000 people lost their lives besides colossal damage to buildings and infrastructure (**Figure 7.5**).

The available evidence of ground rupture suggests that earthquake was caused most probably by movement along the Kashmir Thrust. The surface rupture is continuous over a distance of 75 km and cuts across the Hazara syntaxis reactivating the Tanda and the Muzaffarabad faults. North of Muzaffarabad the surface rupture coincides approximately with the MBT, on the southwestern flank of the syntaxis, although the two faults have opposite dip angles. The rupture terminates abruptly at the hairpin turn of the MBT showing a strong structural control. The fault offset is 4 m on average and peaks to 7 m northwest of Muzaffarabad. The rupture lasted about 25 s and propagated updip and bi-laterally by $\sim$ 2 km/s, with a rise time of 2–5 s. The shallowness and compactness of the rupture, both in time and space, provide an explanation for the intensity of destructions. The study sheds some light on seismic hazard in the Himalaya, and raises concern regarding the possibility of a repetition of the 1555 AD event which presumably ruptured the Himalayan front south of the Kashmir basin and may have reached a magnitude M_w > 8.(Jean-Philippe Avouac, et al, 2006).



PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Moderate/Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<.17	.17-1.4	1.4-3.9	3.9-9.2	9.2-18	18-34	34-65	65-124	>124
PEAK VEL (cm/s)	<0.1	0.1 1 1	1.1 3.4	3.4 8.1	8.1 16	16-31	31-60	60-116	>116
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII		

Fig 7.5: Intensity Map of Kashmir Earthquake 2005

7.4.5 The Main Mantle Thrust (MMT)

According to interpretation of the structure of the Kohistan Himalaya the "Kohistan sequence" (30,000 km^2 of amphibolites, metagabbros and associated volcanic) may be the crust of an ancient calc-alkaline island arc. During the suturing of India and Asia, this oceanic rock sequence was obducted onto the Paleozoic cover of the Indian shield over a large over thrust (Main Mantle Thrust or MMT). The deformation during this event was chiefly crustal simple shear as attested by the flatly dipping foliation and the north-south elongation lineation in the rocks. High pressure metamorphism also affected the deformed rocks at places along the MMT. Late folds, such as the large Nanga-Parbat anticline, make the present geometry more complex. The "Kohistan sequence" is overthrust to the south onto a folded and metamorphosed series (presumably of Paleozoic age), which belong to the northern margin of the Indian shield

("Lower Swat" or Buner schistose group). The contact between the two units is clearly tectonic everywhere, and not intrusive. The contact can be clearly seen south of Patan, in the Indus Valley, where it is marked by mylonites (pyroxene fragments in serpentinite matrix). The overthrust can be traced westward through Shangla Pass, across the Swat Valley near Khwazakhela (20 km NNE of Saidu) and the Dir Valley of Zullam. It is also the basal contact of the Dargai Preidotite Klippe (Malakand).This major contact, which over a vast area separates lower crustal or upper mantle (mafic and ultramafic) rocks from the sialic crust of the Indian Shield, can be referred to as the "Main Mantle Thrust" or MMT, a term which emphasizes both its characteristics and its similarity to the other two major overthrusts of the Himalayan belt further east – the Main Central Thrust (MCT) and the Main Boundary Thrust (MBT). Rocks typical of high pressure metamorphism are locally associated with MMT. At Shangla Pass, a large outcrop of glaucophane blueschists marks the contact between the basic complex and the Buner schistose group. To the North, another major contact separates the Kohistan sequence from the sialic metamorphic rocks of the Hindu-Kush and Karakoram ranges. At Shigo kas the rocks exposed includes Amphibolite Belt, quartz mica, schists and quartzites sequences. Shigo kas site is just on the main Mantle Thrust, which is seismically quite since long.

7.5 Geology of the Area

As already discussed the geology in this corner of the Indian plate is very complex and a biaxial state of stresses in the crust has created sharp bends and closed arches of faults called syntaxes. In this particular area the crust of an ancient calc-alkaline island arc is present. At Kalkot Barikot Patrak HPP site the Geology is in a series of quartiztic sandstones, quartzites and green-grey schists of little metamorphic influence; even some claystone layers can be observed. At Patrak Shiringal, area is covered with a series of quartzitic sandstones, siltstones and claystones with little schistrose character. The Geology of the Shigo kas site includes Amphibolite Belt, quartz mica, schists and quartzites sequences. The detailed geological map is shown in **Figure 7.6**.

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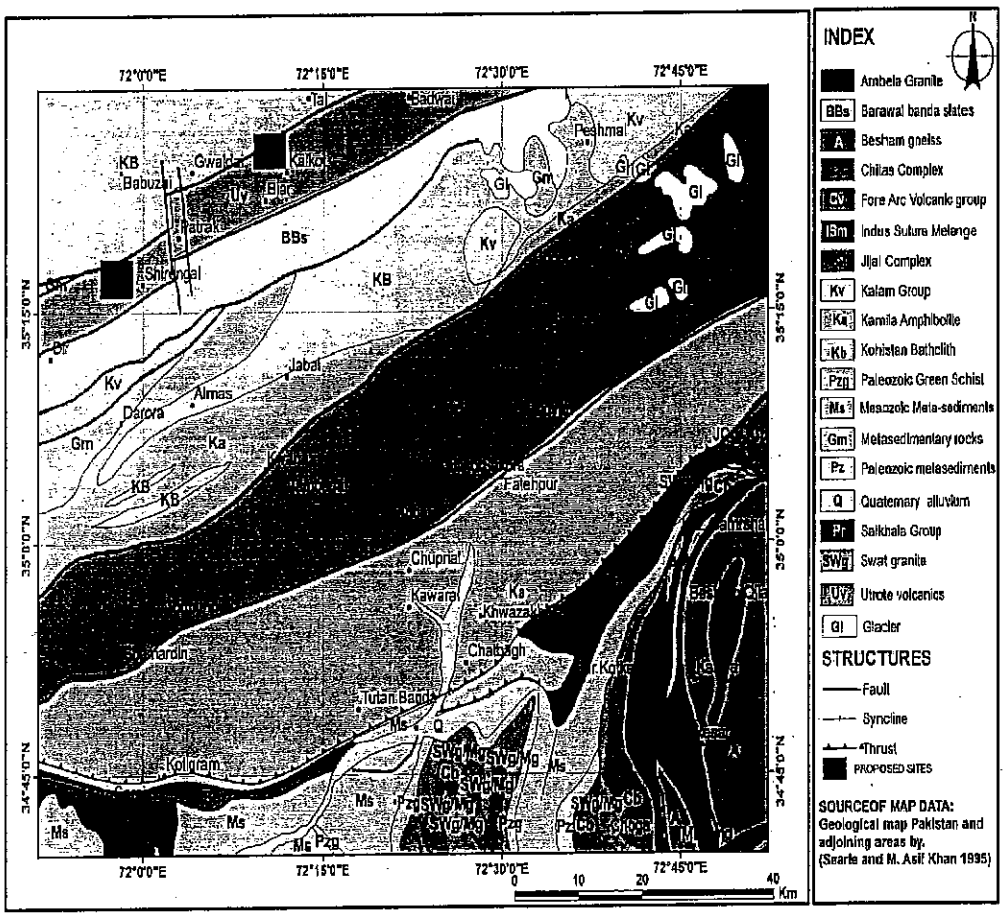

Fig 7.6: Detailed Geological Map of the region, showing the three HPP sites.

7.6 Seismic Hazard Evaluation

All evaluations are based on the historical and instrumental recorded seismicity in the area, documented in various catalogues. The time span that is reliably covered by these catalogues is from 1927 to May 2013 **(Annexure-7A)**. Before 1927, there are no earthquake records in the database used for this project. To assess the seismicity of the area, the following catalogues have been evaluated:

- PMD, Pakistan Meteorological Department, historical database.
- PDE, United State Geological Survey, database.
- WAPDA Turbela Mangla seismic network
- ISC, International Seismological Centre England, database.
- Harvard database.
- GFZ Germany database

7.6.1 Non-Instrumental (Historical) Data & Computation

Non-Instrumental/ historical data is based solely on human observations and is referred to as intensity or felt data. Such information is invaluable for assigning seismic risk to a zone. Intensity data becomes particularly valuable when it can be related to instrumental data. The correlation of "cause and effect" possibly provides a very reasonable interpretation of a seismic event. **Annexure-7B** gives the chronological record of historical damaging earthquakes and their estimated Intensities in Northern Pakistan.

Even though damage to structures is a function of ground acceleration, the amplitude of the ground motion and the length of time that the ground vibration lasts, yet attempts have been made to convert qualitative non-instrumental intensity data into quantitative acceleration terms. From the descriptive records of historical earthquake data, the damages recorded at different areas have been assigned intensity values on Modified Mercalli Scale (MMS) ranging from I to XII corresponding to accelerations rising from 0.005g to 2.0g.

It is estimated that occurrence of intensity VIII to IX has a high probability of at least once in the lifetime of any hydropower structure situated in Northern areas of Pakistan. There are different empirical relationships correlating "I" with "a". The acceleration value can be obtained corresponding to different intensities by the Empirical relationships developed by Neumann, Gutenberg & Richter, Hershberger etc. These relationships are given below:

- Log a = 0.308 (I-1) + 0.267 (Neumann)
- Log a = I/3-1/2 (Gutenberger & Richter)
- Log a = 3/7 (I) -9/10 (Hershberger)

Where Log = Log to the base 10

a = Acceleration in cm/sec^2 (1.0g = 980 cm/sec^2)

I = M. M. Intensity.

For various intensity values, the acceleration relationships are shown in **Table 7.1**.

Table 7.1: Intensity values and acceleration relationship

M.M. Intensity	NEUMANN	GUTENBERGER & RICHTER	HERSHBERGER	Average
V	0.032	0.015	0.018	0.22
VI	0.065	0.032	0.048	0.048
VII	**0.133**	**0.07**	**0.128**	**0.11**
VIII	**0.27**	**0.15**	**0.345**	**0.255**
IX	0.549	0.32	0.925	0.598

For the purpose of analysis, an average of the three acceleration values for each of the estimated intensities VII & VIII for Shigo kas Hydropower Project in Khyber Pakhtunkhwa of Pakistan as shown in **Table 7.1**.

The average value of accelerations as computed above thus ranges from 0.11 to 0.26 for intensity VII & VIII respectively.

7.6.2 Instrumental Data & Computations

As stated earlier that data from international as well as national institutes was obtained and sorted out to eliminate the multiple entries of events. The data has been evaluated with respect to reliability and completeness. For the period after 1964, it can be assumed that the ISC catalogue is complete at least in respect of large events, and that the epicenter locations are reliable, since the ISC data are based on the processing and analyzing of a maximum of station data. In contrast, it was seen that in other catalogues, large events could fall into the investigated region because of uncertain epicenter location. After 2004, only EPIC (USGS) and PMD data are available, so that these databases were selected as representative for the most recent years. There are two international accepted approaches for events having missing data in terms of magnitude and depth. Some researchers substitute a standard Mw value of 2.8, and depth of 8 km for such events. Whereas some use the relationship:

$$Ms = 7.15 - 0.0446 \times (year - 1900) \quad year < 1963$$

The homogenization of magnitudes was made and converted all the body wave magnitudes (Mb) to Surface wave magnitudes (Ms) using the following relationship:

If Ms (USGS) definition is given, adopted it as Magnitude Ms
Else if an alternate Ms Value is available, accepted it as Ms
If only Mb value is given, converted them using:

Adopted Ms = 1.8 X Mb -5.2 (if the year is <1963)

Else Adopted Ms = 1.8 Mb X -4.3

$0.8\ M_L - 0.6Ms = 1.04$

In this region, the instrument recording is available from 1927 **(Annexure-7A)**, and available information as to the time, location and the magnitude of all recorded earthquakes around this project area, is collected. **Figure 7.7** shows the spatial distribution of the epicenters of all earthquakes occurring within 111 km (1^0) in the area. Shigo kas HPP site is kept at the centre, whereas for comparison sake other two sites namely Patrak Shringal and Kalkot barikot-Patrak have also been marked.

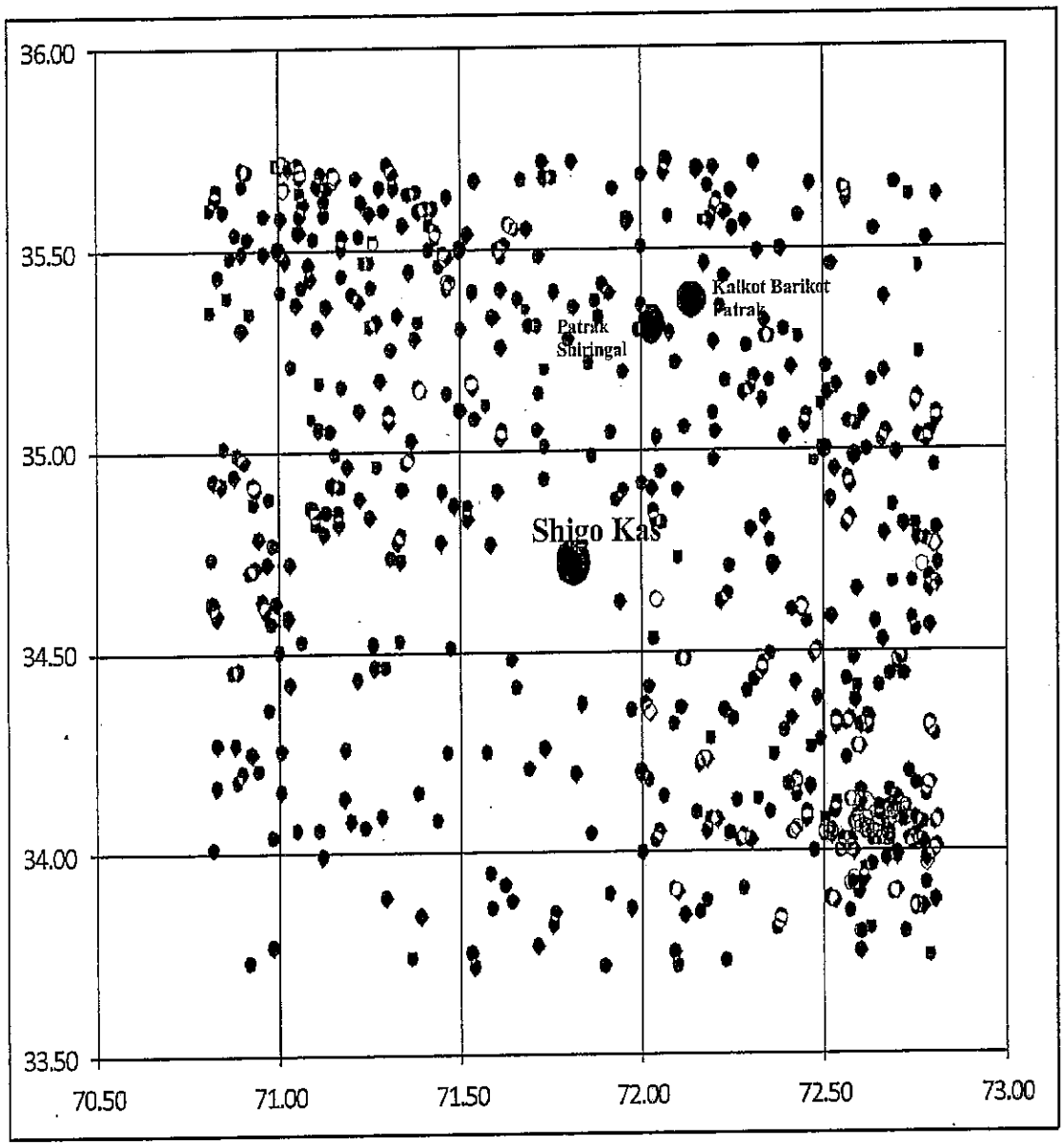

Fig 7.7: Spatial distribution of the epicenters of earthquakes around Shigo kas Hydropower Project, KP, Pakistan.

Figure 7.8 shows the frequency of all earthquakes occurring within 111 km with respect to distance from Shigo kas site. The linear relation between numbers of earthquakes and distance shows that up to 12 km distance there is less likelihood of earthquake event. Whereas the logarithmic relation shows that there is likelihood of earthquake occurrence within 6 km of the Shigo kas site.

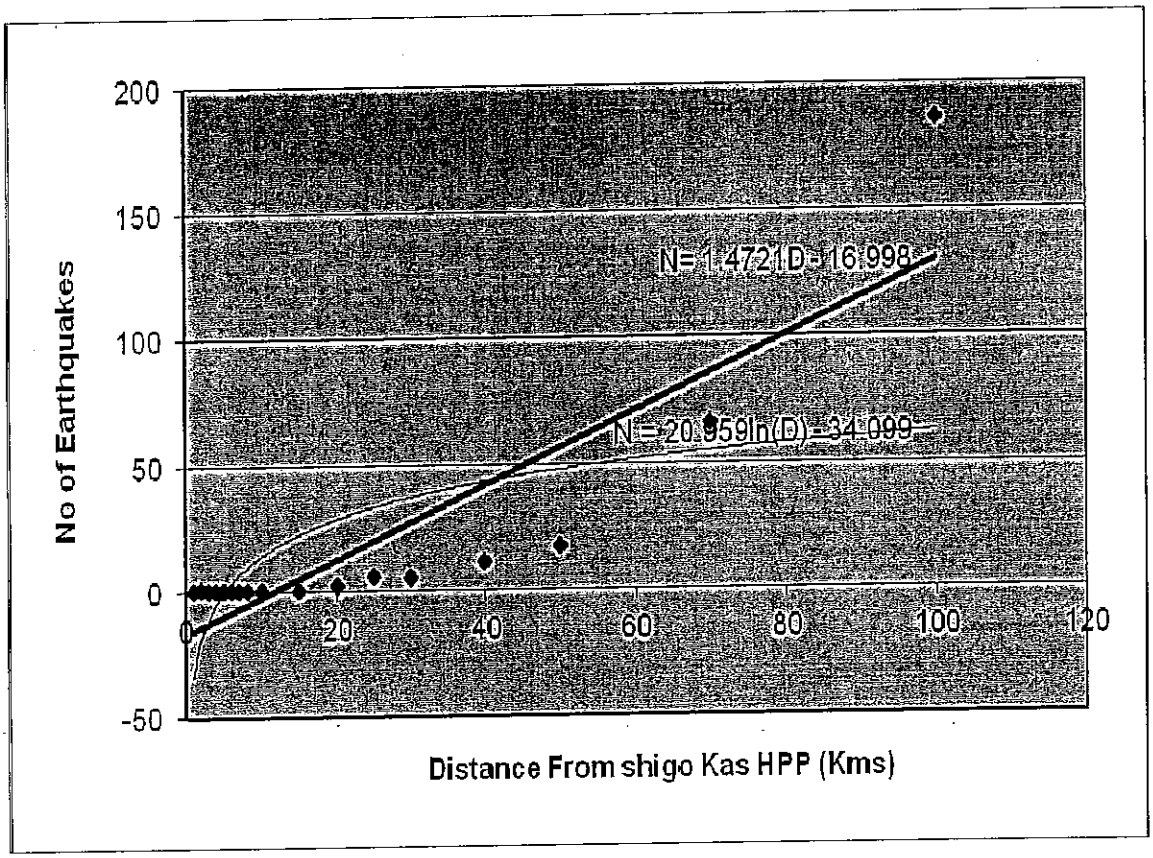

Fig 7.8: Number of earthquakes vs Distance from Shigo Kas, and plot of linear and logarithmic relationship between the two parameters.

7.6.3 Attenuation Relationship

Ground motion at the epicenter has been calculated using the following empirical formulae developed by different scientists:

- $a = 6.6 \times 10^{-2} \times 10^{0.4M} \times R^{-1.39} g$ — ORPHAL AND LAHOUD
- $a = 0.279 \times e^{0.8M} \times R^{-1.64} g$ — DEVENPORT
- $a = 5.7 \times e^{0.8M} \times (R + 40)^{-2} g$ — ESTEVA
- $a = 1080 \times e^{0.5M} \times (R + 25)^{-1.32}$ cm/s^2 — DENOVAN

Where a = acceleration
M = Magnitude
R = depth to hypocenter

The values calculated for M = 6, 7, 7.6 and 8 with hypocenter depth as 15 to 25 are calculated as shown in **Table 7.2.**

Table 7.2: PGA values for Magnitude 6, 7, 7.6 & 8 Earthquake with hypocenter depth as 15 & 20 kilometers

Earthquake Magnitude (M)	Hypo - central Depth (Km)	Acceleration "a"				
		ORPHAL	DEVEN PORT	ESTEVA	DENO-VAN	Average
6	15	0.376	0.391	0.224	.163	0.289
7	15	0.946	0.871	0.499	.269	0.646
7.6	20	1.125	0.896	0.692	0.317	0.757
8	20	1.626	1.234	0.953	0.388	1.050

The values of computed acceleration for 6, 7, 7.6 and 8 magnitudes range between 0.289g to 1.05g. Value for Magnitude 7.6 with focal depth of 20 Km has significance, as 2005 Kashmir Earthquake can be correlated with this value. The focal depth of this earthquake is 20 Km as per Indian Geological Survey records, as per USGS records, it is 26 Km, as per Global CMT records, it is calculated to be 12 Km and as per Japan (IISEE), its focal depth is 30 km. In this report a value of 20 Km is adopted.

Strong motion records of the Kashmir earthquake of October 8, 2005 from the different Pakistani stations were obtained and presented in **Table 7.3.**

Table 7.3: Evaluation of PGA in Pakistan using different Formulae

Station	Mag Mw	Dist. Kms	ORPHAL	DEVENPORT	ESTEVA	DENOVAN	Observed PGA
Abbottabad	7.6	37	0.4783	0.3268	0.4201	0.2079	0.087
Murree	7.6	53	0.2903	0.1813	0.288	0.1535	0.069
Nilor	7.6	82	0.1583	0.0886	0.1674	0.1011	0.023
Tarbela	7.6	80	0.1638	0.0923	0.173	0.1037	0.1
Brotha	7.6	125	0.0881	0.0444	0.0915	0.0648	0.04

Turbella and Brotha records are from WAPDA Microseismic Network. Correlations with the available attenuation relationship with the observed values have been attempted. It was found that the relationship developed by Denovin fits well with the WAPDA records. Devenport formula also shows a good correlation, but for shorter epicentral distances, very high PGA resulted by using this formula. Anyhow for other stations, there is a wide discrepancy. Another way is to take a mean of all the calculated PGA values of different authors, and utilize it for appropriate interpretation. The first approach is used for evaluation of PGA for Shigo kas HPP

site by applying Denovan formula for all the events occurring within 110 Km (1 degree) from the site.

7.6.4 Maximum Credible Earthquake

The Magnitude 'M' of the Maximum Credible Earthquake (MCE) that can be associated with the aforementioned tectonic features, has been worked out by using Tocher formula (M = Log L + 5.77/1.02). Using this relationship, the credible magnitude earthquake of different faults for full and half rupture lengths have been calculated and are shown in Table 7.4. By assuming the level of shaking to be adequately characterized by the Peak horizontal acceleration, an attenuation relationship developed by Cornell et al, has been used to select the causative source of earthquake.

$$\ln PHA\ (gals) = 6.74 + 0.859\ M - 1.80\ \ln (R + 25)$$

The Peak Horizontal Acceleration (PHA) values thus obtained for Full length rupture of Main Mantle thrust is 0.795g and for half length rupture of MMT is 0.624g **Table 7.4.**

Table 7.4: Maximum Credible Earthquake due to MMT in the region

Fault	Fault Rupture Length (km)	Magnitude		Source to site distance	Peak Horizontal Acceleration	Peak Horizontal Acceleration
		Full length (M)	Half length (M)	Km	Full Length PHA	Half Length PHA
Main Mantle Thrust	100	7.66	7.36	20	0.795	0.624

The peak horizontal acceleration (PHA) is the most commonly used type of ground acceleration in engineering applications, and is used to set building codes and design hazard risks. Peak ground acceleration (PGA) is a measure of earthquake acceleration on the ground and an important input parameter for earthquake engineering, also known as the design basis earthquake ground motion (DBEGM). It is a vector sum of H1, H2 and V (Both of horizontal and vertical components).

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7.6.5 Safety Evaluation Earthquake (SEE)

As per ICOLD guidelines (Revised 2010) the Safety Evaluation Earthquake (SEE) will produce the maximum level of ground motion for which the dam should be designed or analyzed. For dams whose failure would present a great social hazard, the SEE will normally be characterized by a level of motion equal to that expected at the dam site from the occurrence of deterministically evaluated MCE or of the earthquake determined by using probabilistic procedures, such as specifying 50% or higher probability of not being exceeded in a large number of years. It will be required at least that the impounding capacity of the dam be maintained when subjected to that seismic load.

Should failure of the dam present no hazard to life, a level of motion less than that associated with the Maximum Credible Earthquake may be acceptable to represent the Safety Evaluation Earthquake, based on alternative considerations such as the cost of the designed dam resulting from a specified level of motion and the cost of failure of the completed structure. This should be considered a special case and should be based on a socially accepted agreement.

7.6.6 Operational Basis Earthquake

Shigo kas HPP site is located site on Panjkora River in Lower Dir. It is located just on Main Mantle Thrust (MMT) a major tectonic feature of this region. Data of 618 earthquake events within 111 kilometers (1 degree) quadrangle distance around Shigo Kas, has been collected from International and National agencies (**Annexure-7A**). USGS catalogue from 1973 to March 2013 has been explored. Map indicating the seismic events around Shigo kas area has been prepared and presented in (Figure 7.7).The presence of Main Mantle Thrust at Shigo kas appears to be a seismically quite tectonic zone. It is a dangerous sign, as stress is accumulating at this site. Evaluation of seismic events with respect to reliability and completeness has been accomplished.

The epicentral as well as hypocentral distance of each Seismic event from Shigo kas has been calculated, and after applying suitable PGA relationship, PGA value has been determined. The maximum PGA value at this site comes out as 0.05g from the observed earthquakes presented in **Annexure-7A.** It is a normal procedure to take 100 years maximum Earthquake as one of the OBE (Ellis L. K, 1993), which is 0.05g by the observed data for the last 86 years. There are six events in the list which produced PGA more than 0.045g. The events happened on 30-09-1927 (PGA 0.054), 08-07-2005 (PGA 0.05g), 10-03-1977 (PGA 0.05g), 12-05-2004 (PGA

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Shigo kas HPP site is located site on Panjkora River in Lower Dir. It is located just on Main Mantle Thrust (MMT) a major tectonic feature of this region. Data of 618 earthquake events within 111 kilometers (1 degree) quadrangle distance around Shigo Kas, has been collected from International and National agencies (**Annexure-7A**). USGS catalogue from 1973 to March 2013 has been explored. Map indicating the seismic events around Shigo kas area has been prepared and presented in (Figure 7.7).The presence of Main Mantle Thrust at Shigo kas appears to be a seismically quite tectonic zone. It is a dangerous sign, as stress is accumulating at this site. Evaluation of seismic events with respect to reliability and completeness has been accomplished.

The epicentral as well as hypocentral distance of each Seismic event from Shigo kas has been calculated, and after applying suitable PGA relationship, PGA value has been determined. The maximum PGA value at this site comes out as 0.05g from the observed earthquakes presented in **Annexure-7A**. It is a normal procedure to take 100 years maximum Earthquake as one of the OBE (Ellis L. K, 1993), which is 0.05g by the observed data for the last 86 years. There are six events in the list which produced PGA more than 0.045g. The events happened on 30-09-1927 (PGA 0.054), 08-07-2005 (PGA 0.05g), 10-03-1977 (PGA 0.05g), 12-05-2004 (PGA

0.047g), 12-06-1988 (PGA 0.046g) and 26-02-2005 (PGA 0.43g). Alternatively half of MCE value is taken as OBE, which is 0.31g for this area. This high value has a return period of 10000 years; hence it is feasible to adopt a medium approach: Table **7.5.**

Table 7.5: OBE at Shigo kas site, KP, Pakistan

Peak Ground Acceleration at Shigo kas Hydropower Project Site from Earthquake records since 1927.	0.05g
Design Spectral Acceleration Value	0.11g to 0.5g (mean 0.31g)
Half of MCE value	0.31 g
Operational Basis Earthquake value at Shigo kas Hydropower Project site.	**0.31 g**

The Hypocentre distribution in a 111 kilometers quadrangle **Figure 7.9**, shows that the area has a cluster of shallow earthquakes (focal depth 33 Km), but some medium depth earthquake (70-210 Km depth) are also visible in the area. In the database few earthquakes depth of focus is not given, and plot has taken them as an event with 0 Km depth. Since the Shigo kas lies on the Island Arc, a remnant of old oceanic crust, hence majority of earthquakes are at shallow depth.

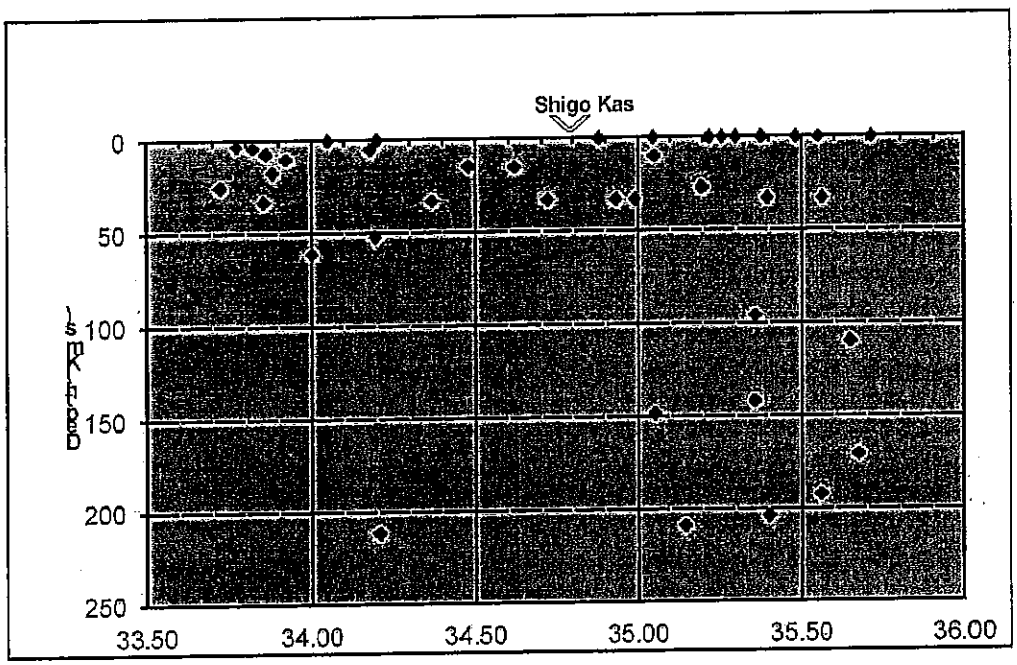

Fig 7.9: Hypocenters Depth on N-S Section through Shigo kas HPP site with a distance of 111 Km on either side from the site

Standard Design response spectra are based on a general characteristic shape that is defined in terms of estimates of selected ground motion parameters, which can be effective peak ground accelerations or spectral accelerations. The approach is to develop design response spectra using peak ground motion parameters (peak ground acceleration, velocity and displacement), multiplied by a series of appropriate spectral amplification factors that depend on the damping level. Spectral acceleration is given as a function of moment magnitude, distance to the rupture plane, fault type, soil conditions, and whether the site is on the hanging wall:

$$\ln PHA = f_1(M, r_{rup}) + Ff_3(M) + HWf_4(M, r_{rup}) + Sf_5(PGA_{rock})$$

where $f_1(M, r_{rup})$ is the basic attenuation form for rock sites, and the other three terms are modifications for fault type, hanging wall effects, and soil conditions, respectively. Abrahamson & Silva (1997) equation has been utilized for the calculation of design spectral acceleration along with standard deviation, and is presented in **Figure 7.10**, for OBE. As is evident, maximum vertical spectral acceleration is expected for waves having 0.1 second period.

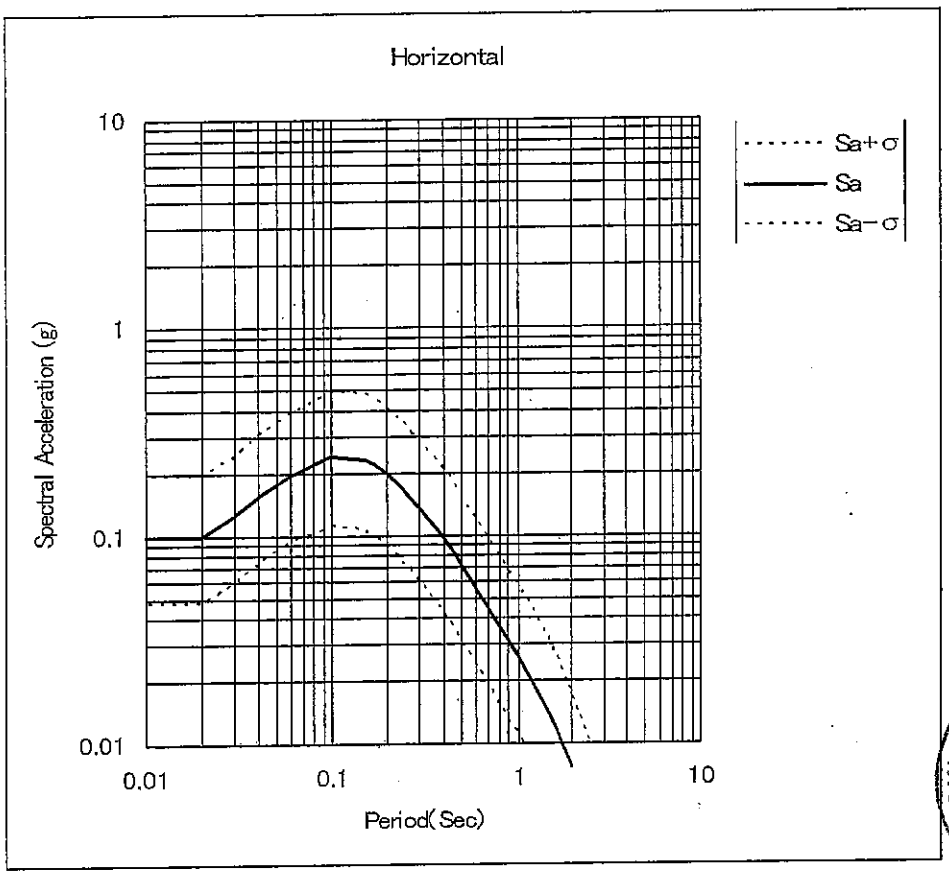

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Fig 7.10: Design Spectral Acceleration Due to Operational Basis Earthquake for Shigo kas HPP after Abrahamson, N. A. and W. Silva.

7.6.7 Return Period

A return period also known as a recurrence interval is an estimate of the interval of time between an earthquake of a certain intensity or size. It is a statistical measurement denoting the average recurrence interval over an extended period of time, and is usually required for risk analysis (i.e. whether a project should be allowed to go forward in a zone of a certain risk) and also to dimension structures so that they are capable of withstanding an event of a certain return period (with its associated intensity). When dealing with a structure design expectations the return period is useful in calculating the risk of the structure with respect to a given earthquake return period when given the design life expectation.

There is the likelihood of at least one event that exceeds design limits during the expected life of the structure: it is the complement of the likelihood that *no* events exceed design limits. To get an approximate value of the return period, RP, given the exposure time, T, and exceedance probability, r = 1 - non-exceedance probability, NEP, (expressed as a decimal, rather than a percent).

RP = T / r* Where r* = r(1 + 0.5r).
r* is an approximation to the value -loge (NEP).
In the above case, where r = 0.10, r* =0.105 which is approximately = -loge (0.90)= 0.10536
Thus, approximately, when r = 0.10, RP = T / 0.105

In **Table 7.6**, the exceedance probability is constant for different exposure times. ICOLD recommendation is shown in bold letters and is approximately 475 years.

Table 7.6 ICOLD recommendations on return period

				Rule of Thumb		Exact
NEP	T	r	r*	Calculation	RP	RP
0.9	**50**	**0**	**0.11**	**50/0.105**	**476**	**474.6**
0.9	100	0	0.11	100/0.105	952	949.1
0.9	250	0	0.11	250/0.105	2381	2373

Figure 7.11 shows the frequency of earthquakes versus magnitude of earthquakes around Shigo kas HPP site utilizing the seismic events data presented in **Annexure-7A**, and expressed as per Gutenberg-Richter law.

$$\text{Log } N = 6.3 - 1.16\ M$$

The b-value comes out to be of the order of 1.16. It is little bit lower than 1 due to the fact that it is very close to Main Mantle Thrust, and hence may have higher seismicity. Similarly 6.30 value of 'a' is determined **Figure 7.11**. This is the place where the frequency line intercepts with the magnitude axis. The Return Period using the above Gutenberg-Richter Law for a Magnitude 7 earthquake in this area is 70 years, whereas for a 7.6 magnitude earthquake it comes out to be of the order of 340 years.

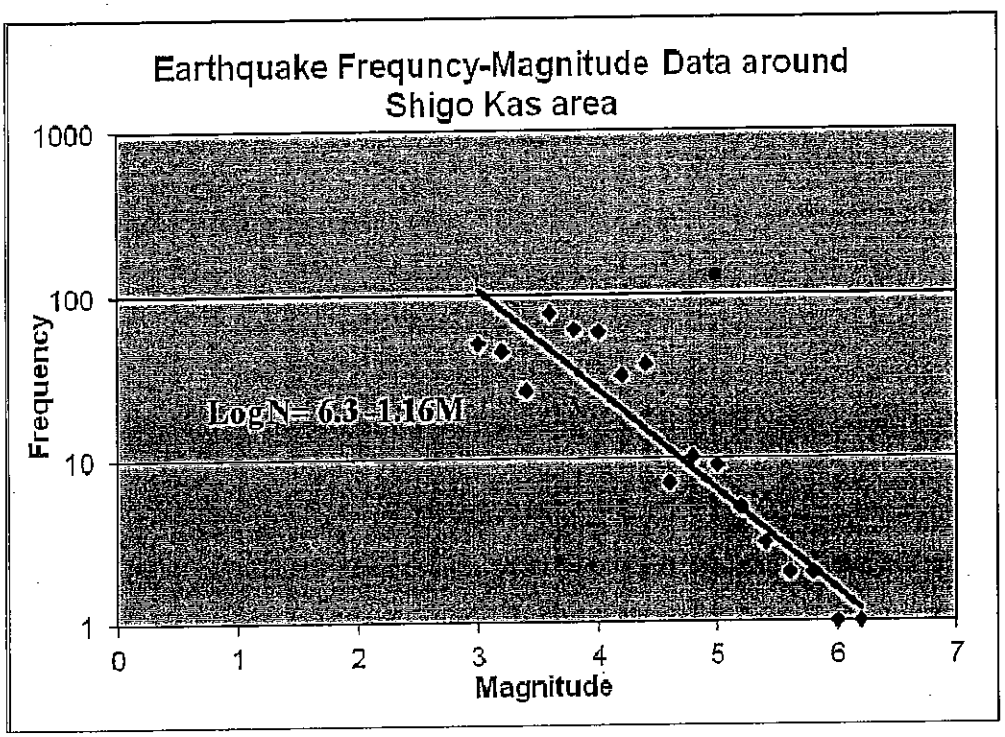

Fig 7.11: Gutenberg Richter equation for Shigo kas area

A fact should also be kept in mind that earthquakes have a certain frequency and a return period. If the return period is, say Y years, and then an earthquake of similar magnitude is likely to occur after Y years anywhere along a fault line. The seismic gap perpetually floats on the fault and wherever the situation is seismically suitable, a quake is triggered. Once an area experiences a quake, its epicentral volume is crushed and it becomes unable to accept any further geo-technical stress. This means that once an area has experienced an earthquake, it will not experience another earthquake of a similar magnitude for a long time. The time gap is usually about three to five times the return period of the earthquake. Usually the return period of medium-sized earthquakes (of magnitude ranging from 6.0 to 7.0) is of the order of a few decades. For powerful earthquakes (with magnitude higher than 7.0), the return period

usually 100 years or more. Hence the possibility of occurrence of one earthquake immediately after another at the same location or in its vicinity is almost nil.

7.6.8 Conclusions

- The Shigo kas HPP site lies in a high seismically active zone due to its proximity to MMT which might experience seismic hazard of significantly high magnitude.

- The latest event of October 08, 2005 earthquake of Muzaffarabad-Balakot produced an Intensity of around IX with a Magnitude of 7.6. Therefore, on the basis of felt intensity data of recurring events, an intensity range of VII to VIII would be reasonable for the region under study.

- On the basis of felt intensity data and the instrumental record of macro and micro seismicity, the faults of Main Boundary Thrust (MBT), Kashmir Thrust (KT), Main Mantle Thrust (MMT) and Indus Kohistan Seismic Zone (IKSZ) are considered to be active in the Northern Pakistan area.

- With Deterministic Seismic Hazard Analysis (DSHA), value of 0.62g for Maximum Credible Earthquake (MCE) has been calculated. The available 618 seismic events around this site indicate OBE values of the range of 0.31 for Shigo kas HPP, the value is also within the range calculated by the Design Response Spectrum.

- The return period as per Gutenberg-Richter Law for a 7.6 magnitude earthquake is calculated to be of the order of 340 years, and for a Magnitude 7 earthquake is 70 years for Shigo kas HPP site.

- The values calculated in the previous paras are considered adequate for structures of the relatively small Hydropower Projects involving diversion weirs and small structures.

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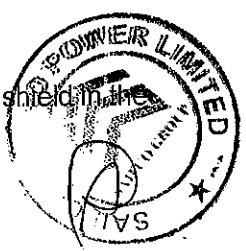

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Annex

6A

DRAWINGS

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CHAPTER

6

GEOTECHNICAL DESIGN

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ANNEXURE-7A

EARTHQUAKE CATALOGUE FOR SHIGO KAS AREA

Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
1927	9	5	2010	34.20	72.00	0	5.6
1927	9	30	1840	34.20	72.00	0	5.9
1928	5	2	1403	34.20	72.00	0	5.4
1928	11	14	04:33:09	35.00	72.50	110.0	6.1
1963	03	06		33.80	72.60	36.0	4.3
1964	02	13	05:10:47	34.99	72.70	68.0	4.9
1964	06	06		33.80	72.60	33.0	4.5
1966	01	11	09:13:00	34.00	72.00	61.0	5.0
1966	02	19		35.30	70.90	59.0	5.1
1966	6	11	06:08:48	35.72	72.07	92.0	5.2
1966	10	01	07:38:30	34.72	70.97	39.0	5.1
1967	7	17	09:57:25	35.30	71.50	249.0	4.6
1968	03	03	09:31:21	34.71	72.36	43.0	5.3
1968	06	28	19:39:50	34.59	70.83	28.0	4.9
1969	05	15	20:39:49	34.62	70.82	49.0	5.6
1969	08	27	22:35:55	35.36	71.13	76.0	5.5
1970	1	1	08:17:42	35.60	71.40	223.0	4.5
1970	7	26	20:30:40	35.09	72.61	46.0	4.9
1971	5	9	19:26:34.20	35.54	71.06	81.7	5.7
1971	07	22		34.80	72.30	160.0	4.8
1972	03	10	14:36:16	33.90	72.70	39.0	5.4
1972	04	17	02:24:50	34.00	72.80	44.0	5.2
1972	08	27		33.90	71.50	58.0	
1972	09	27	02:03:39	33.99	72.70	39.0	5.1
1972	10	01		34.10	72.80	42.0	
1973	2	9	14:57:52.36	35.58	71.01	83.1	4.9
1973	10	23	192630.9	34.16	72.78	12.5	4.2
1973	11	8	51451.5	34.08	72.71	13	3.9
1973	11	28	230221	33.92	72.58	10	3.5
1973	12	2	81647.7	34.08	72.75	5	3.8
1973	12	30	151600.6	34.1	72.45	12	4.5
1973	12	31	173015.8	34.04	72.5	10	3.6
1973	12	31	74614.7	34.05	72.5	1.3	4.5
1973	12	31	24310.4	34.08	72.5	1.2	3.5
1973	12	31	25940.6	34.04	72.52	1.25	4.1
1973	12	31	181719.5	34.05	72.52	10	4.2
1974	1	2	211524.1	34.08	72.21	20	3.9

Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
1974	1	17	07:46:40.31	35.54	71.43	105.8	4.9
1974	1	23	110413.9	34.07	72.8	15	3.7
1974	03	26	04:45:54	34.05	72.62	15.0	4.5
1974	4	8	195326.6	33.85	72.57	20	3.6
1974	5	11	23:47:46.94	35.70	72.16	43.9	4.9
1974	05	14		35.70	72.20	44.0	4.5
1974	6	16	105805.7	34.17	72.79	25	3.9
1974	6	19	183540.4	33.83	72.38	0	3.8
1974	7	3	135512.2	34.31	72.62	45	3.6
1974	7	18	110935.1	33.75	72.6	0	4.5
1974	7	30	11:41:30.22	35.48	71.46	97.2	5.3
1974	8	7	90754.7	34.17	72.4	15	4.2
1974	10	22	50303.48	34	72.54	12.5	3.6
1974	11	15	100248.3	33.88	72.53	10	4.4
1974	11	24	201946.7	34.17	72.75	40	3.9
1975	2	5	181313.1	33.8	72.72	10	3.5
1975	3	12	63812.6	34.43	72.56	45	3.5
1975	12	22	194704.7	34.4	72.29	15	3.5
1976	1	12	75834.1	33.92	72.57	8	4.1
1976	2	29	153108.4	34.28	72.49	10	3.6
1976	3	9	60133	33.97	72.78	32.5	3.9
1976	3	15	93246.78	34.05	72.64	15	3.9
1976	3	17	215630.5	34.03	72.63	15	3.7
1976	3	18	1648.3	34.06	72.62	15	4.1
1976	4	11	224315.5	33.97	72.63	7.5	3.6
1976	8	19	1512.85	34.11	72.72	13.9	3.7
1976	10	6	12857.4	34.81	72.56	52.0	4.9
1976	10	12	205325.2	34.03	72.27	20	3.5
1976	10	12	205350.6	34.04	72.28	20	3.9
1976	10	13	4735.45	34.05	72.24	20	3.9
1976	12	15	54612.3	35.37	71.22	222.0	4.5
1977	01	07	06:31:13	34.62	70.95	47.8	5.4
1977	3	17	04:34:22.58	35.68	71.15	97.7	5.0
1977	6	18	90326.15	34.12	72.62	27.5	5.1
1977	7	11	110818	34.01	72.57	17.5	3.7
1977	7	16	72223.06	34.15	72.6	20	3.8
1977	10	5	92930.11	34.44	72.68	12.5	4.4
1977	10	5	103519.2	34.44	72.72	12.5	4.5
1978	1	5	143231.2	34.03	72.57	17.5	4.6
1978	2	1	160540.7	34.12	72.6	22.5	3.9
1978	2	11	75456	34.12	72.53	45	3.5
1978	3	6	205337.4	33.92	72.78	5	3.6

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Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
1978	3	11	90038.1	34.99	70.89	147.0	4.7
1978	3	24	02:49:49.39	35.10	71.22	175.4	4.3
1978	6	5	121507.9	34.2	72.73	40	3.5
1979	1	2	00:44:29.34	35.71	71.01	177.4	4.4
1979	1	4	133737.8	34.1	72.35	15	4.5
1979	3	13	04:10:24.85	35.65	71.01	73.6	4.8
1979	4	27	3517.05	33.87	72.75	17.5	4.1
1979	4	27	44817.9	33.86	72.77	15	4.3
1979	4	29	08:24:09.39	35.46	71.08	85.8	4.9
1979	7	26	64510.87	34.17	72.42	27.5	3.5
1979	8	18	11423.7	34.03	72.67	12.5	4.1
1979	9	4	00:28:16.54	35.15	71.38	-	4.8
1979	9	4	204139.6	34.47	72.7	20	3.5
1979	12	23	3449	34.05	72.18	14.3	4.1
1980	01	17	04:16:19	34.91	71.14	24.7	5.0
1980	2	18	143612.5	34.18	72.42	30	3.8
1980	6	29	17:26:23.32	35.19	72.67	44.6	4.8
1980	7	10	19:32:32.00	35.69	72.06	3.6	4.9
1980	07	27	11:24:00	34.62	72.04	52.5	4.4
1980	08	27		34.90	72.10	33.0	4.1
1980	9	28	104355.1	34.13	72.58	5	3.7
1981	02	06	09:54:01	34.35	72.03	262.9	4.3
1981	2	18	11:35:09.95	35.20	72.41	4.0	5.0
1981	10	02	23:51:36	34.08	71.20	71.7	4.5
1981	11	9	33225.78	34.43	72.31	45	3.7
1981	12	27	72357.34	34.71	72.77	10.0	4.1
1982	3	13	191343	33.91	72.09	20	3.9
1982	3	13	192911.9	34.13	72.26	5	3.9
1982	4	14	83117.59	33.98	72.67	15	4.5
1982	9	2	94324.81	33.93	72.58	11.2	4.2
1983	1	1	04:39:48.32	35.68	71.21	203.9	4.3
1983	1	24	20:28:28.52	35.65	71.31	196.0	4.0
1983	5	12	03:47:55.24	35.34	71.32	33.0	4.6
1983	8	19	21241.53	33.75	72.09	6.8	4.1
1983	8	30	3147.27	34.36	70.97	10.0	4.0
1983	10	20	06:16:08	34.26	71.01	243.3	4.3
1983	10	20	10:09:06	34.73	71.33	33.0	4.0
1983	12	31	07:27:56.98	35.47	72.17	228.0	4.7
1984	1	4	135311.6	34.33	72.25	10	4.2
1984	1	4	135622	33.97	72.78	5	4.3
1984	1	4	135913	33.98	72.78	10	4.6
1984	2	1	17:25:13.02	35.54	71.52	-	4.6

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Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
1984	02	03	21:11:01	34.98	70.91	33.0	4.5
1984	02	12	13:40:36	34.90	70.94	22.0	4.8
1984	02	18	07:04:59	34.20	71.82	51.8	4.9
1984	02	18	07:08:56	34.35	72.02	33.0	4.5
1984	2	22	12:44:06.28	35.36	71.81	142.0	4.1
1984	3	25	163218.7	34.23	72.56	5	3.6
1984	7	14	112.24	34.14	72.06	10	3.7
1984	08	13	11:25:57	33.72	71.90	25.0	4.3
1984	8	19	21:15:46.64	35.05	71.11	33.0	4.2
1984	9	14	11:33:27.71	35.25	71.30	33.0	4.3
1984	9	20	161430.48	33.86	71.97	7.2	4.4
1985	02	18		35.70	70.90	110.0	4.4
1985	2	25	193032.5	34.31	72.53	34.9	4.1
1985	2	25	192723	34.26	72.59	31.3	3.5
1985	3	1	171717.1	34.11	72.65	25.3	3.9
1985	3	19	43710.64	34.03	72.04	42.6	4.3
1985	5	6	10:58:11.75	35.47	71.02	164.9	4.3
1985	06	13		33.90	72.10	33.0	4.2
1985	6	30	25608.67	34.07	72.77	5	3.6
1985	7	29	13:08:27.73	35.17	71.28	124.2	4.4
1985	10	4	83133.67	34.14	72.78	16.3	3.5
1985	10	22	07:43:52.50	35.60	71.42	179.2	4.2
1985	12	7	80802.24	34.07	72.58	5	3.6
1986	1	27	12275.6	33.88	71.64	17.0	4.2
1986	2	1	230307.2	34.47	72.33	10	3.8
1986	2	21	23922.47	33.95	71.58	10.0	4.3
1986	2	22	4053.76	33.92	71.62	10.0	4.0
1986	4	2	00:58:07.90	35.66	71.11	179.2	4.8
1986	05	16	05:16:13	34.00	72.58	15.0	4.0
1986	5	19	72834.26	34.03	72.73	15	3.5
1986	07	10	07:56:12	34.10	72.68	2.0	4.5
1986	12	30	130525.3	33.81	72.37	15	3.5
1987	3	1	05:58:33.01	35.62	71.12	213.9	4.0
1987	03	16	06:09:36	34.83	72.34	212.1	4.2
1987	12	8	10:39:16.50	35.02	72.78	68.0	4.7
1988	3	22	134001.9	34.38	72.48	5	4.0
1988	4	11	21543.14	34.45	72.33	10	4.2
1988	4	13	205752.6	34.48	72.58	5	4.0
1988	5	15	19:40:14.37	35.66	71.14	191.0	4.5
1988	6	12	44438.22	34.62	71.94	15.2	4.2
1988	07	08		34.50	71.00	210.0	4.5
1988	7	20	195954.95	35.05	71.71	10.0	4.1

Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
1988	10	24	82148.57	34.86	71.09	33.0	4.8
1988	12	15	09:47:29	33.99	71.12	79.3	4.3
1989	1	12	05:34:22.04	35.65	71.28	110.9	4.3
1989	1	18	01814.57	35.09	72.81	7.0	4.0
1989	2	2	82958.29	34.58	72.52	22.9	4.1
1989	02	20	01:08:51.	33.77	70.98	87.8	4.4
1989	12	5	24637.28	34.08	72.72	10	3.5
1990	1	3	20:51:48.63	35.40	71.00	315.7	4.0
1990	2	23	142926.2	33.85	72.16	7.6	3.5
1990	4	1	70755.54	33.92	72.57	17.5	3.9
1990	4	4	18:46:49.28	35.09	72.45	222.0	3.8
1990	4	20	41857.25	35.14	72.51	6.9	4.0
1990	4	29	24542.08	35.28	72.35	10.0	4.0
1990	6	8	93326.19	33.74	72.79	10	3.5
1990	08	21	18:27:00	33.72	71.54	33.0	4.5
1990	8	21	93937.3	34.83	72.57	3.9	4.4
1990	8	23	13110.31	34.57	72.64	13.4	4.4
1990	09	04	10:59:18	34.94	70.88	33.0	4.9
1990	10	2	09:38:04.45	35.71	71.30	168.6	4.3
1990	10	9	180858.5	34.08	72.69	11.4	3.5
1990	10	10	215622.6	34.04	72.75	7.4	4.1
1990	11	4	114843.3	34.49	72.35	12.8	3.7
1990	11	10	09:46:02.58	35.09	71.30	33.0	4.3
1990	11	10	94603.25	35.33	71.59	33.0	5.5
1990	12	24	23:57:22	34.86	71.48	171.8	3.8
1990	12	31	175846.2	34.23	72.72	29.3	
1991	1	8	230211	34.06	72.64	14.4	4.3
1991	1	28	18:01:40.87	35.07	71.30	33.0	4.3
1991	2	3	225626.99	34.48	71.64	14.5	4.4
1991	2	24	13371.15	35.07	72.81	3.4	4.5
1991	03	16	03:57:42	34.52	72.66	33.0	4.9
1991	05	24	15:38:03	34.98	72.20	210.0	3.9
1991	5	24	194436.3	34.11	72.71	14.5	3.5
1991	8	12	201748.5	34.5	72.48	25.3	3.8
1992	1	3	63830.63	34.11	72.68	14.5	3.8
1992	1	16	202539.98	34.37	72.01	33.0	3.9
1992	02	06	18:47:03	34.78	72.75	33.0	4.4
1992	2	8	44736	34.49	72.47	50	4.1
1992	2	14	135052	34.1	72.15	50	4.0
1992	2	20	08:29:07.22	35.56	71.64	192.6	3.8
1992	3	29	17:09:02.99	35.70	71.06	262.1	3.9
1992	04	09	22:21:54	34.79	71.33	225.3	

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Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
1992	4	16	11:42:10.57	35.57	72.29	33.0	4.5
1992	4	17	124321.2	34.03	72.55	13.6	4.6
1992	04	17	12:42:58	34.13	72.70	12.9	4.6
1992	5	31	111321.7	33.72	72.1	13.9	3.5
1992	7	7	15:41:15.08	35.16	71.54	10.0	4.5
1992	7	8	612	34.25	71.57	10.0	4.0
1992	12	9	06:49:35.41	35.58	72.07	33.0	4.2
1992	12	11	145821	33.75	71.53	1.0	4.1
1993	1	10	174641.4	34.08	72.72	13.7	3.8
1993	4	2	115121	34.60	72.41	14.0	4.0
1993	05	15	08:14:04	34.90	72.03	33.0	4.3
1993	05	15	07:27:12	34.83	72.04	33.0	4.3
1993	6	26	103546.3	34.01	72.81	10	4.0
1994	1	3	195316.11	34.83	71.52	33.0	4.4
1994	01	07	09:25:48	34.82	71.16	48.9	4.8
1994	1	15	170840.3	33.8	72.6	6.3	3.6
1994	5	12	115614	34.46	71.26	21.0	4.1
1994	5	25	111515.88	35.56	71.34	33.0	4.8
1994	7	7	151158	34.01	72.55	15	3.8
1994	7	25	93357	34.15	71.38	0.0	4.0
1994	08	04	22:43:10	33.84	72.12	28.0	4.3
1994	9	12	22:05:49.06	35.40	71.61	203.9	4.4
1994	10	19	9329	34.22	72.16	10.0	4.4
1994	11	29	02:56:45.94	35.71	71.03	167.3	4.3
1994	12	9	17:39:55.96	35.39	71.20	171.7	4.1
1994	12	19	32221	33.77	71.71	3.0	4.7
1994	12	19	03:22:18	34.05	72.05	33.0	4.3
1995	01	17	22:15:55	34.62	70.99	92.0	4.6
1995	2	3	00:22:13.90	35.36	71.05	145.5	4.5
1995	3	7	55523.75	34.09	72.59	11.1	3.7
1995	5	7	105554	34.03	72.65	10	3.8
1995	5	7	111549.6	34.02	72.74	12.5	3.8
1995	6	1	11:25:16.40	35.03	71.36	40.0	4.5
1995	9	3	04:49:56.13	35.56	71.63	33.0	4.2
1995	10	22	11:01:56.34	35.42	71.46	72.4	4.6
1995	11	13	163552	34.05	72.42	15	4.4
1995	11	13	163420.07	33.93	72.61	35	4.0
1995	11	28	05:51:04.20	35.06	72.12	69.6	4.3
1995	12	11	18:11:39	34.88	70.97	33.0	4.2
1995	12	30	23:40:16	34.85	72.03	33.0	4.3
1996	1	12	14:35:02.08	35.14	71.46	145.3	4.0
1996	1	14	63848	34.80	72.81	33.0	

Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
1996	1	19	122739	35.57	72.19	110.0	5.1
1996	2	13	13:23:05.47	35.69	71.31	154.6	4.2
1996	02	19	11:21:53	34.90	71.45	102.7	4.4
1996	2	20	25019.1	34.05	72.67	5	5.2
1996	02	20	02:55:52	34.04	72.67	45.7	4.9
1996	2	20	25543.13	34.1	72.69	56.3	4.9
1996	03	08	01:26:31	34.88	71.22	-	4.2
1996	3	21	132211	35.49	72.32	110.0	4.8
1996	4	17	214831	35.50	72.38	230.0	4.6
1996	5	8	123154	34.81	72.72	0.0	4.6
1996	5	24	162344	34.35	72.23	5.0	4.6
1996	5	24	162528.2	33.84	72.38	0.4	3.5
1996	05	24	16:23:44	34.42	72.42	54.6	4.5
1996	5	31	01:22:25.80	35.67	71.54	-	4.2
1996	6	1	5835.6	34.33	72.57	12.2	3.5
1996	7	24	172436	34.27	70.83	33.0	5.0
1996	7	31	16711	35.58	72.43	110.0	4.2
1996	08	03	19:56:36	34.84	71.25	54.9	4.3
1996	8	3	195632	35.42	71.46	110.0	4.0
1996	9	2	45720	35.46	72.52	33.0	4.4
1996	09	08	10:47:15	34.03	72.30	12.3	4.8
1996	9	8	104859.3	34.06	72.6	13.39	4.5
1996	10	9	22:40:40.70	35.08	71.54	-	4.4
1996	11	8	231537	35.65	71.92	110.0	4.3
1996	12	29	10:57:20	34.53	71.06	86.1	4.3
1997	1	12	2031	35.65	72.55	33.0	4.2
1997	1	18	7391	34.23	72.18	26.0	4.6
1997	2	7	03:32:56.03	35.41	71.25	33.0	4.2
1997	2	7	223526	35.62	72.56	33.0	4.4
1997	03	07	18:33:01	34.72	71.80	33.0	4.2
1997	03	10		34.90	71.60	-	4.5
1997	03	19	19:57:13	34.77	71.58	64.2	5.0
1997	4	3	19:24:26.20	35.55	71.68	-	4.1
1997	4	10	13804.41	33.93	72.58	13.76	4.2
1997	5	10	09:05:36.28	35.59	71.06	33.0	4.3
1997	5	16	65823.05	34.31	72.6	7.15	3.8
1997	05	19	22:21:49	34.61	72.44	16.3	4.3
1997	5	27	201642.9	34.23	72.17	4.89	3.5
1997	5	27	172219.3	34.06	72.42	5	3.5
1997	5	28	92201.83	33.9	72.69	33.53	3.7
1997	6	7	23422	34.36	72.11	10.0	4.1
1997	6	13	213424.3	34.14	72.42	15.69	3.6

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Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
1997	6	19	154741	35.04	72.79	33.0	4.0
1997	06	21	13:10:12	34.93	71.73	33.0	4.3
1997	7	29	184629	34.06	72.42	37.88	3.9
1997	9	11	101736	35.63	71.46	33.0	4.2
1997	9	19	16189	35.64	72.25	33.0	4.7
1997	9	23	05:02:30.40	35.21	71.03	-	4.4
1997	11	09	17:17:35	33.85	71.76	33.0	4.4
1997	11	21	2019	35.66	72.46	110.0	4.1
1997	12	11	04:21:53.40	35.64	71.35	193.7	3.8
1997	12	20	55339	34.85	71.13	0.0	4.0
1997	12	21	15:56:43.42	35.05	71.61	148.6	4.3
1998	1	20	18410	35.52	72.78	110.0	4.7
1998	2	21	190851.18	34.48	72.71	14.79	3.8
1998	03	06		35.10	71.50	128.0	5.4
1998	03	07	15:41:06	34.18	70.89	117.5	4.0
1998	3	7	154108.17	35.17	71.53	92.0	3.9
1998	4	23	205953.6	34.48	72.7	23.68	3.6
1998	5	9	10:00:59.40	35.72	71.81	-	4.3
1998	05	10	09:42:23	34.37	72.59	-	4.3
1998	7	12	54457.5	34.08	72.68	7.5	4.8
1998	07	12	05:45:02	34.02	72.77	66.0	4.9
1998	8	28	12458	35.63	72.81	110.0	4.1
1998	8	30	144430.4	34.05	72.61	8.47	3.7
1998	9	5	213834.1	34.05	72.41	12.67	3.5
1998	11	09	17:52:55	34.95	72.05	122.1	4.1
1998	12	20	04421	34.20	70.90	33.0	4.0
1998	12	20	00:44:20	34.24	70.93	89.3	4.5
1999	1	23	213135.12	35.46	71.44	33.0	4.3
1999	02	22	17:06:57	34.57	70.98	51.2	4.1
1999	3	19	150047.65	34.29	72.8	24.09	3.7
1999	4	1	74235	34.41	72.02	10.0	4.1
1999	4	16	15:09:11.50	35.32	71.27	33.0	4.1
1999	04	20	19:29:04	34.96	71.19	230.8	4.3
1999	4	28	20:56:26.41	35.43	72.23	33.0	4.2
1999	5	12	22:02:35.35	35.72	71.01	167.5	4.2
1999	5	16	00:20:31.03	35.62	71.23	180.7	4.1
1999	5	26	45113.31	33.91	72.28	5.95	3.9
1999	6	9	94510.23	34.32	72.79	36.99	4.1
1999	6	20	221621.24	34.13	72.57	29.59	3.5
1999	7	10	07:11:24.00	35.63	72.73	15.0	2.9
1999	07	24	19:36:45	34.85	71.16	148.3	4.2
1999	8	4	12:48:19.80	35.28	72.34	33.0	4.0

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Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
1999	8	4	124614.11	34.33	72.41	5	4.0
1999	8	4	124830	34.66	72.81	10.0	4.3
1999	8	8	1312 3.53	34.05	72.68	32.7	3.6
1999	8	9	05:06:57.50	35.36	72.00	96.0	4.0
1999	08	19	19:11:04	34.21	71.69	211.7	4.0
1999	08	23	20:18:34	34.43	71.21	120.2	4.3
1999	8	23	201840	35.00	72.62	110.0	4.1
1999	08	26	09:59:26	34.71	70.94	47.0	5.0
1999	08	30	11:24:51	34.77	70.98	-	3.8
1999	9	12	2927.65	34.05	72.51	5	3.6
1999	09	26	09:07:41	34.07	71.24	33.0	4.5
1999	10	26	07:28:45.97	35.06	72.45	86.5	4.3
1999	10	30	09:13:02	34.53	71.33	33.0	3.1
1999	12	20	21935.36	33.73	72.23	5	3.6
2000	02	26	14:51:35	34.60	70.96	-	4.1
2000	2	29	07:40:12.49	35.38	72.67	33.0	4.4
2000	5	13	42157	35.71	72.31	33.0	4.3
2000	5	22	234743.28	34.08	72.61	10.08	3.7
2000	6	22	03:48:58.30	35.72	71.05	158.5	4.1
2000	7	3	215854.11	34.12	72.62	19.53	4.1
2000	7	20	64912	34.67	72.74	1.0	4.5
2000	08	09	05:06:55	34.78	70.94	42.1	4.9
2000	08	09	05:03:56	34.58	71.02	48.6	4.9
2000	8	9	571	34.26	71.18	1.0	4.5
2000	8	10	223253.1	34.05	72.41	5	3.8
2000	08	21	06:13:12	34.80	71.12	-	4.2
2000	9	3	112946.8	34.32	72.56	6.97	3.9
2000	9	4	112948.8	34.15	72.68	10.85	3.9
2000	9	4	104123.4	34.58	72.74	34.4	4.0
2000	9	30	22:10:56.07	35.68	71.06	173.2	4.1
2000	10	1	163047.2	34.71	72.24	15	3.5
2000	10	2	3734.19	34	72.47	5	3.7
2000	10	3	162836.1	34.05	72.41	5.74	3.7
2000	10	30	150735.3	34.08	72.81	18.96	3.7
2000	11	11	122819.3	34.16	72.46	13.97	4.0
2000	12	22	160918.6	34.08	72.45	8.79	3.7
2000	12	23	225815.3	34.08	72.65	12.14	3.7
2001	1	16	55058.02	34.07	72.6	12.78	3.8
2001	2	3	04:51:14.62	35.68	71.73	170.9	4.3
2001	02	17	22:46:21	34.46	70.89	56.3	4.1
2001	2	24	201510.4	34.3	72.39	15	3.5
2001	03	09		35.50	71.00		

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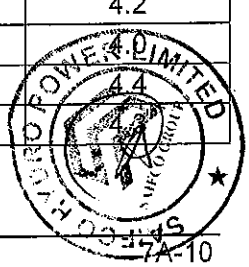
Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
2001	3	23	222146.2	34.65	72.79	5	4.0
2001	4	1	13:56:28.30	35.30	71.99	-	4.3
2001	4	22	704.58	34.48	72.12	5	3.5
2001	4	27	12:41:27.37	35.53	71.43	-	4.1
2001	5	7	171151	34.03	72.68	3	3.5
2001	10	2	00:39:21.56	35.43	71.09	90.3	4.9
2001	11	06	20:29:03	34.99	71.86	33.0	3.9
2001	11	10	15:21:15	34.93	70.82	110.6	4.4
2001	12	20	20:07:37.82	35.38	71.66	-	4.3
2001	12	29	15:03:54	34.70	70.92	-	4.3
2002	04	01	07:00:51	34.08	71.43	33.0	4.3
2002	4	7	20:53:35.63	35.60	72.21	33.0	4.5
2002	04	13	08:17:12	34.21	70.94	-	3.2
2002	4	18	12:53:07.28	35.07	72.57	74.6	4.0
2002	5	13	110043.2	35.09	72.2	34	3.5
2002	05	27	00:05:09	33.84	71.39	10.0	4.6
2002	7	4	20:37:28.18	35.45	71.36	-	4.2
2002	9	13	04:28:09.59	35.15	71.71	209.2	3.8
2002	10	22	213025	33.82	71.75	4.0	4.2
2002	11	2	00:18:23.69	35.20	71.95	27.0	3.7
2002	11	8	04:06:53.28	35.36	72.22	-	3.8
2002	12	3	6374.5	34.1	72.7	15	4.0
2002	12	3	8121	34.1	72.72	15	3.5
2002	12	11	6374.5	34.1	72.7	15	4.0
2002	12	11	8121	34.1	72.72	15	3.5
2003	06	06	23:34:55	33.96	72.61	33.0	3.2
2003	07	30	04:42:45	34.32	72.09	33.0	3.2
2004	01	04	23:37:04	34.17	70.83	51.8	4.5
2004	03	30	18:48:25	34.27	70.88	-	4.3
2004	3	30	10:05:25.90	35.22	71.85	-	4.2
2004	05	12	16:14:21	34.90	71.95		4.4
2004	6	21	03:50:21.40	35.26	71.61	-	4.3
2004	7	4	17:10:34.75	35.22	72.10	-	4.0
2004	7	19	22:27:47.69	35.64	71.38	-	4.3
2004	8	10	14:03:52.31	35.66	72.70	-	4.2
2004	8	27	15:24:10.68	35.28	71.37	-	5.1
2004	09	10	05:33:57	34.30	72.79	-	4.1
2004	10	06	05:24:13	34.98	72.58	200.0	5.3
2004	10	7	19:23:23.20	35.60	71.29	-	4.2
2004	10	11	16:14:24.24	35.42	71.47	-	4.0
2004	10	30	04:58:09	34.05	71.86	-	4.4
2004	12	3	03:22:13.63	35.31	71.11	-	



Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
2005	01	01	10:23:50	34.79	72.67	10.0	4.4
2005	02	16	22:32:13	34.48	72.11	10.0	4.0
2005	02	26		35.50	71.50		6.2
2005	4	29	18:45:57.67	35.05	71.91	-	3.6
2005	05	15	14:01:02	34.92	70.84	-	3.8
2005	6	16	03:39:12.09	35.48	71.72	-	3.9
2005	07	01	09:50:46	34.95	72.53	33.0	4.7
2005	7	5	42506.59	34.18	71.69	5.0	
2005	07	08	08:14:07	34.88	71.93	-	4.3
2005	7	16	00:02:06.60	35.40	71.76	33.0	4.1
2005	8	3	09:19:32.85	35.26	72.29	-	3.8
2005	8	29	01:31:35.91	35.21	72.51	-	4.2
2005	10	8	233414.37	35.18	72.31	10.0	4.3
2005	10	08	09:51:10	34.56	72.79	16.0	4.6
2005	10	08	11:49:07	34.76	72.80	10.0	4.7
2005	10	09	07:59:00	34.33	72.62	13.0	5.0
2005	10	23	213216.62	34.76	72.81	10.0	4.1
2005	10	28	215329.1	34.25	72.74	10.0	
2005	10	31	123258.54	35.61	71.07	35.0	4.7
2005	11	4	20:54:49.90	35.12	72.33	10.0	4.3
2005	11	09	11:11:27	34.91	71.34	15.0	5.0
2005	11	20	150042.91	34.71	72.77	10.0	3.6
2006	1	13	53635	35.03	71.61	-	4.0
2006	1	28	212213	35.03	72.39	-	3.9
2006	1	28	203947	35.06	72.59	-	3.8
2006	1	29	211323	35.17	72.35	-	3.8
2006	1	29	161225	34.41	72.65	10.0	4.2
2006	3	7	193121	35.05	71.14	35.0	4.2
2006	4	26	151527	34.65	72.59	10.0	4.1
2006	5	4	12223	34.62	72.22	0.0	4.2
2006	5	4	22132	35.30	72.39	0.0	3.8
2006	5	15	3210	35.50	71.60	139.0	4.5
2006	5	28	135943	34.55	72.75	15.0	3.3
2006	7	6	192727	34.53	72.03	38.3	3.3
2006	7	30	11:33:52	34.08	72.19	23.3	4.4
2006	8	4	14:49:47	34.97	71.35	10	4.2
2006	9	10	5:28:15	35.49	70.90	102.3	4.3
2006	10	16	21:27:55	35.54	70.88	0	4.1
2006	10	20	18:45:05	34.84	71.10	33	3.0
2006	10	24	4:27:53	34.86	71.52	33	3.[illegible]
2006	11	8	13:55:53	35.11	72.75	33.5	4.[illegible]
2007	1	22	8:19:22	34.25	71.46	33	3.[illegible]

SAIFCO HYDRO POWER LIMITED

Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
2007	2	11	16:03:13	35.39	71.91	64.1	4.3
2007	5	20	11:36:47	34.10	72.53	59.7	4.4
2007	7	22	18:27:15	34.68	72.79	26.5	4.1
2007	9	4	1:50:34	35.13	71.53	86	
2008	1	5	17:02:27	34.81	72.75	10	3.0
2008	2	5	21:18:31	35.29	72.08	205.5	3.8
2008	2	20	13:17:15	34.07	72.59	477	5.3
2008	3	7	21:52:11	34.91	72.57	47.7	4.3
2008	3	26	15:14:44	34.42	71.03	0	4.4
2008	4	11	3:58:52	34.18	72.02	10	3.3
2008	4	21	10:38:20	34.33	72.53	10	3.2
2008	4	23	16:02:38	33.73	70.92	10	3.3
2008	5	6	23:38:02	35.59	72.23	33	5.5
2008	5	11	20:56:59	35.57	71.96	217.2	5.8
2008	7	5	13:57:33	35.55	72.25	190.9	4.2
2008	7	12	2:20:39	34.63	72.04	0	4.3
2008	7	24	19:23:18	33.88	72.18	10	3.1
2008	8	28	6:33:43	34.09	71.28	0	4.4
2008	9	7	15:48:41	34.92	72.00	0	3.9
2008	11	30	1:05:22	34.06	71.11	0	4.2
2009	1	9	12:40:26	33.89	71.29	0	4.6
2009	1	12	23:30:10	35.15	71.39	0	3.9
2009	2	9	0:31:05	33.86	72.75	0	3.8
2009	3	3	9:51:32	35.59	71.25	0	4.0
2009	3	8	14:26:46	34.45	70.87	0	4.1
2009	3	12	5:13:02	34.72	71.03	0	4.2
2009	3	20	4:35:20	35.14	72.28	0	4.6
2009	3	23	18:55:49	34.26	71.73	0	4.5
2009	5	28	14:59:47	35.41	71.89	73.8	4.3
2009	6	26	3:20:33	35.68	71.75	78.5	4.0
2009	9	6	1:53:55	34.28	72.19	10	3.0
2009	9	9	19:41:18	35.16	71.17	10	3.6
2009	9	12	15:04:40.5	34.71	72.81	21	4.3
2009	10	6	07:56:32.2	34.52	71.26	35	4.3
2009	10	30	6:49:20	34.87	70.93	90	2.8
2009	11	4	13:18:19	35.31	71.25	10	3.1
2009	11	5	1:01:55	35.11	71.57	10	2.5
2009	11	6	9:50:09	35.65	70.83	24	3.6
2009	11	7	9:57:43	35.64	71.06	10	2.3
2009	11	10	0:32:01	35.17	71.11	10	2.9
2009	11	10	13:31:46	35.52	71.26	10	3.5
2009	11	11	6:23:23	35.40	71.46	10	

Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
2009	11	15	23:45:38	35.35	71.68	20	2.2
2009	11	15	0:08:30	35.45	72.76	10	2.3
2009	11	17	19:07:00	34.08	72.62	10	3.1
2009	11	19	2:30:14	34.82	71.10	10	2.7
2009	11	24	8:40:33	35.56	71.41	10	2.6
2009	11	25	9:08:20	35.34	70.92	10	2.5
2009	11	27	8:33:14	35.32	71.38	10	2.9
2009	11	30	1:54:07	33.81	72.63	10	2.5
2009	12	1	22:17:44	35.38	70.86	40	2.5
2009	12	6	21:21:41	35.20	71.73	10	2.2
2009	12	8	12:17:11	35.37	71.87	56	3.0
2009	12	17	22:57:53	35.51	71.26	10	2.1
2009	12	24	01:09:59.8	35.53	71.17	90	4.3
2009	12	27	11:49:20	34.41	72.59	110	2.9
2009	12	31	3:13:24	35.31	71.71	10	3.3
2010	1	1	1:51:18	34.51	71.47	10	3.8
2010	1	2	4:24:31	35.08	71.09	10	2.5
2010	1	3	10:21:28	35.55	71.65	80	2.4
2010	1	4	18:44:23	34.06	71.05	10	2.9
2010	1	5	00:52:32.3	34.01	70.82	10	3.7
2010	1	8	22:59:36	34.24	72.36	10	2.7
2010	1	8	20:43:19	35.64	72.56	10	2.6
2010	1	9	9:14:16	35.49	71.45	20	2.6
2010	1	9	0:12:05	35.01	71.73	10	2.9
2010	1	10	0:00:00	35.65	71.01	90	2.7
2010	1	10	14:02:38	33.90	71.91	10	3.3
2010	1	16	7:14:05	35.17	72.63	10	3.3
2010	1	19	13:52:31	34.46	71.29	10	3.0
2010	1	22	4:35:37	35.47	71.25	10	2.7
2010	1	26	21:20:50.1	33.87	71.58	15	3.9
2010	1	29	8:00:10	34.13	72.32	10	2.8
2010	2	6	6:40:06	35.15	72.30	16	2.8
2010	2	10	00:21:36.4	35.58	71.12	0	3.8
2010	2	28	11:45:38.3	35.60	71.38	54.3	4.2
2010	3	1	15:30:24	34.04	70.98	25	3.6
2010	3	1	23:23:49	34.26	72.46	10	2.7
2010	3	2	13:39:07	34.26	72.46	10	2.7
2010	3	21	22:41:00	35.48	71.61	10	2.4
2010	3	28	7:00:08	34.86	72.69	38	3.4
2010	4	3	17:49:24	35.62	72.21	10	3.2
2010	4	3	16:05:19.1	34.77	72.78	0	4.1
2010	4	5	1:31:56	35.41	71.06	78	3.3

Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
2010	4	9	17:55:48.1	35.04	72.67	113.8	4.9
2010	4	10	8:20:38	35.50	71.41	10	3.2
2010	4	10	22:58:42.1	34.96	72.80	0	3.8
2010	4	22	13:31:28	34.57	72.45	10	3.2
2010	4	25	12:33:06	34.73	72.10	10	2.9
2010	4	27	14:56:20.2	35.03	72.04	0	4.3
2010	4	27	0:34:59	35.28	72.43	10	2.4
2010	5	6	0:23:55	34.96	71.27	10	2.8
2010	5	6	1:07:05	33.74	71.36	10	3.2
2010	5	11	21:57:36.5	35.44	72.14	0	
2010	5	12	18:18:58	34.97	72.47	10	2.6
2010	5	20	23:40:00	35.66	70.90	10	3.1
2010	5	21	1:22:49	35.71	70.99	180	2.4
2010	5	22	1:51:31	35.11	72.49	32	2.7
2010	5	26	03:51:04.2	35.48	70.87	0	3.8
2010	5	31	2:14:32	35.17	72.23	10	3.3
2010	6	3	01:50:31.1	35.55	72.64	0	4.3
2010	6	15	19:15:36.8	35.32	72.34	0	4.2
2010	7	2	13:35:08.8	34.15	71.01	0	4.1
2010	7	26	06:17:48.0	35.63	70.83	0	4.3
2010	8	24	07:52:42.1	35.67	71.66	0	3.9
2010	8	26	21:13:21.9	35.02	72.66	0	4.0
2010	8	30	15:22:59.7	35.51	72.00	0	3.8
2010	9	4	08:49:19.8	34.82	72.06	0	4.2
2010	9	20	15:37:36.5	35.04	72.76	0	3.8
2010	9	26	10:53:33.8	35.27	72.20	0	4.1
2010	10	9	04:13:56.2	34.41	71.65	0	4.3
2010	10	12	08:28:37.6	35.59	70.96	0	3.9
2010	10	14	16:21:23.3	34.35	71.97	0	3.6
2010	11	18	17:58:25.4	34.99	71.15	0	3.9
2010	12	7	06:17:59.2	35.50	71.17	0	3.9
2010	12	8	04:57:59.8	34.87	72.52	0	4.0
2011	1	10	04:29:32.5	35.69	71.11	56.8	3.8
2011	2	5	12:21:31.0	34.92	70.93	0	3.8
2011	2	9	15:10:17.8	35.53	71.10	49.7	3.8
2011	2	17	01:56:08.3	35.31	71.69	0	4.1
2011	2	23	13:20:24.3	35.72	71.72	52.2	3.8
2011	2	28	20:01:39.5	35.43	71.17	0	3.7
2011	3	26	02:33:14.6	35.43	70.83	0	3.9
2011	4	2	14:39:22.4	33.89	72.51	0	4.2
2011	4	13	03:58:26.8	34.77	72.35	0	4.1
2011	4	15	07:41:40.2	34.67	72.69	161.1	3.8

HYDRO POWER LIMITED
7-A-14

Date			Time	Latitude	Longitude	Depth	Magnitude
Year	Month	Date					
2011	4	19	04:22:09.1	34.74	71.30	0	3.8
2011	5	1	09:02:58.9	34.77	71.32	0	4.3
2011	5	10	19:19:57.5	35.60	70.85	78.2	3.9
2011	5	15	22:39:12.5	35.33	71.88	0	3.9
2011	5	15	06:48:37.9	35.16	72.53	69.3	4.2
2011	6	4	11:30:11	35.49	70.96	234	4.3
2011	6	5	12:48:25.2	35.28	71.80	62.6	3.9
2011	6	5	01:31:22.3	35.13	72.76	0	4.5
2011	6	6	17:28:46.6	34.91	71.17	79.9	3.7
2011	7	2	00:12:31.4	35.53	70.92	73.2	4.0
2011	8	9	04:28:58.3	35.69	71.15	74.8	3.9
2011	8	13	02:17:59.0	34.64	72.23	0	3.9
2011	8	30	08:29:01.8	35.65	72.18	0	3.9
2011	8	31	22:46:01.0	35.53	71.22	0	4.0
2011	10	4	20:46:13	35.35	70.81	10	2.8
2011	10	13	18:57:28.7	34.14	71.18	0	4.4
2011	10	30	18:55:16	34.98	71.36	10	2.9
2011	11	7	01:25:12	35.57	72.17	10	1.6
2011	11	12	02:01:29	35.6	70.81	10	2.6
2011	11	22	00:19:35.7	34.93	72.56	0	3.8
2011	11	22	05:19:48	35.24	72.76	45	2.9
2012	1	4	15:18:45	35.39	71.53	0	4.1
2012	1	26	20:36:54	35.51	71.62	0	4.3
2012	2	11	9:51:58	35.70	70.91	0	4.0
2012	2	25	20:58:43	34.37	71.83	0	4.3
2012	3	12	14:01:35	34.26	72.60	18	4.8
2012	3	24	19:08:07	34.60	72.43	0	3.9
2012	3	27	4:46:57	35.05	72.20	0	4.1
2012	4	12	2:38:08	34.77	71.44	0	4.7
2012	4	17	06:36:46	35.01	70.85	13	2.9
2012	4	18	22:32:56	34.73	70.81	79.1	3.3
2012	5	22	2:55:18	33.90	72.60	16.4	4.6
2012	5	27	9:29:58	33.88	72.80	48.4	4.9
2012	5	31	16:17:54	35.47	71.23	10	2.3
2012	6	22	17:27:01	35.68	72.00	0	4.3

SAIF-CO HYDRO POWER LIMITED

PEDO

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
GOVERNMENT OF KHYBER PAKHTUNKHWA







SHIGO KAS HYDROPOWER PROJECT DISTRICT LOWER DIR

FEASIBILITY REPORT

October 2014

VOL 2 OF 3

ELECTRA CONSULTANTS
in association with
INTEGRATION environment & energy GmbH

Project Office:
71, Street 4, Sector N-3, Phase IV, Hayatabad, Peshawar, KPK
Tel: +92 91-5812934, Fax: +92 91-5837842, Email: dir3projects@yahoo.com

SAIF CO HYDRO POWER LIMITED

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
DISTRICT LOWER DIR

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FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
DISTRICT LOWER DIR

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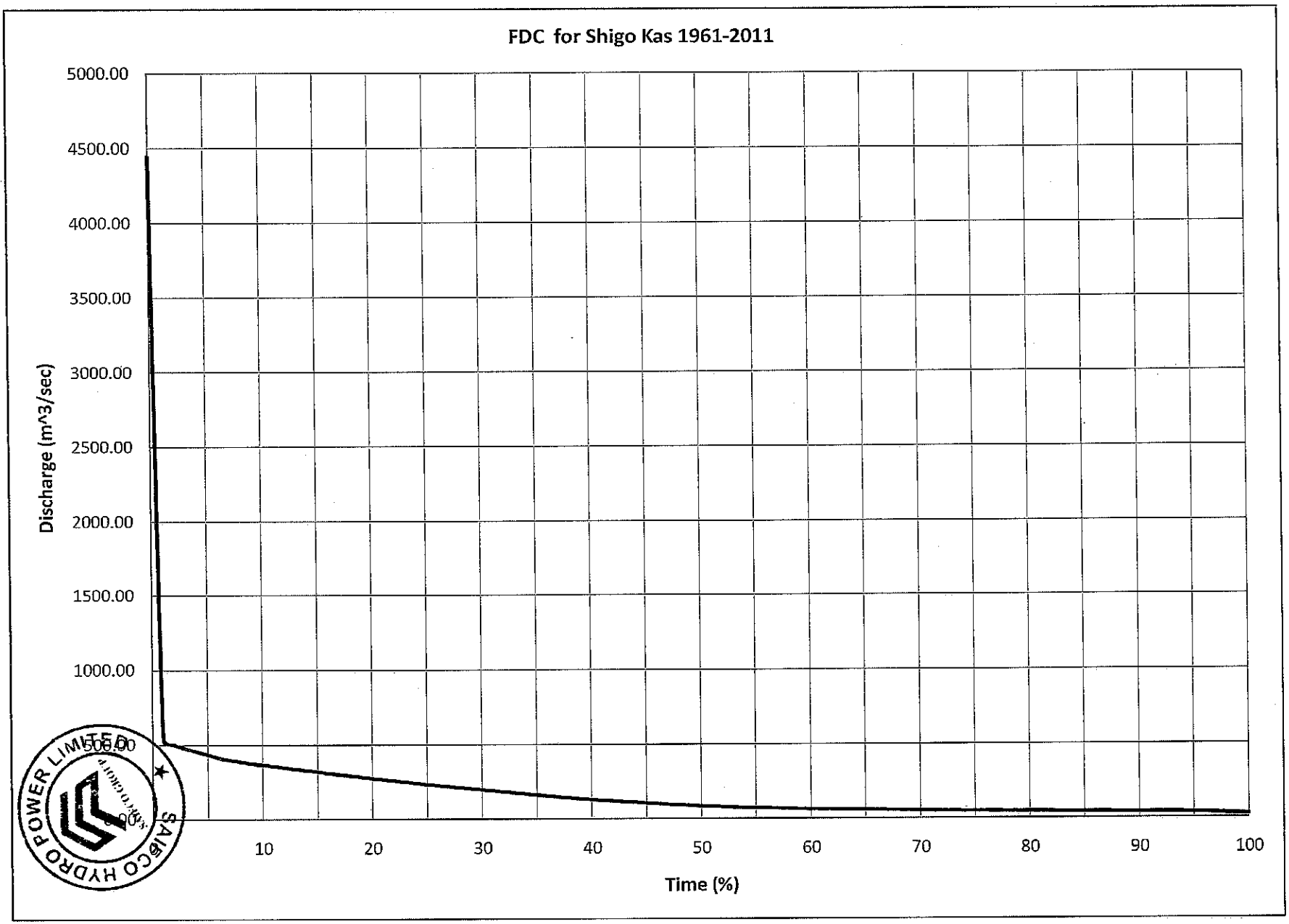

FDC for Shigo Kas 1961-2011
5000.00
4500.00
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
Discharge (m^3/sec)
10
20
30
40
50
60
70
80
90
100
Time (%)

SHEIGO - KASS HPP ANNUAL ENERGY CALCULATION
(FLOW DURATION CURVE METHOD)

Design Discharge	Q_D	150.0	m^3/sec	150.0	
Environmental Flows	Q_E	5.00	m^3/sec		
No. & Type of Units		3	FRANCIS		
Rated Discharge (Single unit)	Q_R	50.0	m^3/sec		
Rated Net Head	H_n	78.5	m	Variable TWL	
Turbine Efficiency at Q_R	h_T	93%			
Generator Efficiency	h_G	97%			
Transformer Efficiency	h_{Tr}	98.0%			
Scheduled Outage	T_S	6	days		
Forced Outage	T_F	6	days		

GROSS POWER	102.0	MW
ANNUAL ENERGY	520	GWh
PLANT FACTOR	58.2	%

Unit-1	350 days	Unit-3	190 days
Unit-2	235 days	Unit-4	0 days

TIME INCR.		PERIOD	FLOW DURATION	HWL	TWL	Losses	NETHEAD	TURBINE-1			TURBINE-2			TURBINE-3			TURBINE-4			ANNUAL ENERGY
								Q_1	η_{T1}	$Energy_1$	Q_2	η_{T2}	$Energy_2$	Q_3	η_{T3}	$Energy_3$	Q_4	η_{T4}	$Energy_4$	
(days)	(%)	(days)	(m^3/s)	(m asl)	(m asl)	(m)	(m)	(m^3/s)	(%)	(GWh)	(m^3/s)	(%)	(GWh)	(m^3/s)	(%)	(GWh)	(m^3/s)	(%)	(GWh)	(GWh)
0	0.0%	0	1355.5	650.000	562.688	13.50	73.8	50.000	93.0%	0.000	50.000	93.0%	0.000	50.000	93.0%	0.000	0.000	0%	0.000	0.000
5	1.4%	5	1101.4	650.000	561.973	13.500	74.5	50.000	93.0%	3.874	50.000	93.0%	3.874	50.000	93.0%	3.874	0.000	0%	0.000	11.622
10	2.7%	5	847.3	650.000	561.184	13.500	75.3	50.000	93.0%	3.915	50.000	93.0%	3.915	50.000	93.0%	3.915	0.000	0%	0.000	11.745
15	4.1%	5	593.2	650.00	560.28	13.50	76.2	50.000	93.0%	3.962	50.000	93.0%	3.962	50.000	93.0%	3.962	0.000	0%	0.000	11.887
20	5.5%	5	421.4	650.000	559.536	13.500	77.0	50.000	93.0%	4.001	50.000	93.0%	4.001	50.000	93.0%	4.001	0.000	0%	0.000	12.002
25	6.8%	5	402.5	650.000	559.455	13.500	77.0	50.000	93.0%	4.005	50.000	93.0%	4.005	50.000	93.0%	4.005	0.000	0%	0.000	12.015
30	8.2%	5	383.5	650.000	559.373	13.500	77.1	50.000	93.0%	4.009	50.000	93.0%	4.009	50.000	93.0%	4.009	0.000	0%	0.000	12.028
35	9.6%	5	364.6	650.000	559.290	13.500	77.2	50.000	93.0%	4.014	50.000	93.0%	4.014	50.000	93.0%	4.014	0.000	0%	0.000	12.041
40	11.0%	5	350.1	650.000	559.210	13.500	77.3	50.000	93.0%	4.018	50.000	93.0%	4.018	50.000	93.0%	4.018	0.000	0%	0.000	12.053
45	12.3%	5	337.6	650.000	559.141	13.500	77.4	50.000	93.0%	4.021	50.000	93.0%	4.021	50.000	93.0%	4.021	0.000	0%	0.000	12.064
50	13.7%	5	325.1	650.000	559.072	13.500	77.4	50.000	93.0%	4.025	50.000	93.0%	4.025	50.000	93.0%	4.025	0.000	0%	0.000	12.075
55	15.1%	5	312.5	650.000	559.003	13.500	77.5	50.000	93.0%	4.028	50.000	93.0%	4.028	50.000	93.0%	4.028	0.000	0%	0.000	12.085
60	16.4%	5	300.0	650.000	558.934	13.500	77.6	50.000	93.0%	4.032	50.000	93.0%	4.032	50.000	93.0%	4.032	0.000	0%	0.000	12.096
65	17.8%	5	287.4	650.000	558.865	13.500	77.6	50.000	93.0%	4.036	50.000	93.0%	4.036	50.000	93.0%	4.036	0.000	0%	0.000	12.107
70	19.2%	5	274.9	650.000	558.796	13.500	77.7	50.000	93.0%	4.039	50.000	93.0%	4.039	50.000	93.0%	4.039	0.000	0%	0.000	12.118
75	20.5%	5	263.3	650.000	558.732	13.500	77.8	50.000	93.0%	4.043	50.000	93.0%	4.043	50.000	93.0%	4.043	0.000	0%	0.000	12.128
80	21.9%	5	252.9	650.000	558.676	13.500	77.8	50.000	93.0%	4.046	50.000	93.0%	4.046	50.000	93.0%	4.046	0.000	0%	0.000	12.137
85	23.3%	5	242.6	650.000	558.619	13.500	77.9	50.000	93.0%	4.048	50.000	93.0%	4.048	50.000	93.0%	4.048	0.000	0%	0.000	12.145
90	24.7%	5	232.3	650.000	558.562	13.500	77.9	50.000	93.0%	4.051	50.000	93.0%	4.051	50.000	93.0%	4.051	0.000	0%	0.000	12.154
95	26.0%	5	222.0	650.000	558.508	13.500	78.0	50.000	93.0%	4.054	50.000	93.0%	4.054	50.000	93.0%	4.054	0.000	0%	0.000	12.163
100	27.4%	5	211.7	650.000	558.449	13.500	78.1	50.000	93.0%	4.057	50.000	93.0%	4.057	50.000	93.0%	4.057	0.000	0%	0.000	12.172

SHEIGO HYDRO POWER LIMITED

TIME INCR.		PERIOD	FLOW DURATION	HWL	TWL	Losses	NETHEAD	TURBINE- 1			TURBINE- 2			TURBINE- 3			TURBINE- 4			ANNUAL ENERGY
								Q_1	η_{T1}	$Energy_1$	Q_2	η_{T2}	$Energy_2$	Q_3	η_{T3}	$Energy_3$	Q_4	η_{T4}	$Energy_4$	
(days)	(%)	(days)	(m^3/s)	(masl)	(masl)	(m)	(m)	(m^3/s)	(%)	(GWh)	(m^3/s)	(%)	(GWh)	(m^3/s)	(%)	(GWh)	(m^3/s)	(%)	(GWh)	(GWh)
105	28.8%	5	201.4	650.000	558.392	13.500	78.1	50.000	93.0%	4.060	50.000	93.0%	4.060	50.000	93.0%	4.060				12.181
110	30.1%	5	191.2	650.000	558.336	13.500	78.2	50.000	93.0%	4.063	50.000	93.0%	4.063	50.000	93.0%	4.063				12.189
115	31.5%	5	182.0	650.000	558.280	13.500	78.2	50.000	93.0%	4.066	50.000	93.0%	4.066	50.000	93.0%	4.066				12.198
120	32.9%	5	172.9	650.000	558.207	13.500	78.3	50.000	93.0%	4.070	50.000	93.0%	4.070	50.000	93.0%	4.070				12.210
125	34.2%	5	163.7	650.000	558.135	13.500	78.4	50.000	93.0%	4.074	50.000	93.0%	4.074	50.000	93.0%	4.074				12.221
130	35.6%	5	154.5	650.000	558.063	13.500	78.4	50.000	93.0%	4.077	50.000	93.0%	4.077	50.000	93.0%	4.077				12.232
135	37.0%	5	145.4	650.000	557.991	11.468	80.5	48.459	93.3%	4.069	48.459	93.3%	4.069	48.459	93.3%	4.069				12.208
140	38.4%	5	136.2	650.000	557.919	11.401	80.7	45.405	93.8%	3.842	45.405	93.8%	3.842	45.405	93.8%	3.842				11.525
145	39.7%	5	127.1	650.000	557.846	11.327	80.8	42.351	94.1%	3.601	42.351	94.1%	3.601	42.351	94.1%	3.601				10.803
150	41.1%	5	120.3	650.000	557.793	11.266	80.9	40.091	93.8%	3.402	40.091	93.8%	3.402	40.091	93.8%	3.402				10.206
155	42.5%	5	114.1	650.000	557.744	11.207	81.0	38.030	93.5%	3.221	38.030	93.5%	3.221	38.030	93.5%	3.221				9.663
160	43.8%	5	107.9	650.000	557.696	11.142	81.2	35.969	92.4%	3.016	35.969	92.4%	3.016	35.969	92.4%	3.016				9.047
165	45.2%	5	101.7	650.000	557.647	11.071	81.3	33.907	91.1%	2.805	33.907	91.1%	2.805	33.907	91.1%	2.805				8.416
170	46.6%	5	95.5	650.000	557.598	10.994	81.4	31.846	89.7%	2.600	31.846	89.7%	2.600	31.846	89.7%	2.600				7.800
175	47.9%	5	89.4	650.000	557.549	10.909	81.5	29.785	88.4%	2.399	29.785	88.4%	2.399	29.785	88.4%	2.399				7.197
180	49.3%	5	83.2	650.000	557.501	10.814	81.7	27.724	87.0%	2.203	27.724	87.0%	2.203	27.724	87.0%	2.203				6.609
185	50.7%	5	78.4	650.000	557.463	10.734	81.8	26.150	86.0%	2.056	26.150	86.0%	2.056	26.150	86.0%	2.056				6.169
190	52.1%	5	75.2	650.000	557.438	10.675	81.9	25.063	85.3%	1.956	25.063	85.3%	1.956	25.063	85.3%	1.956				5.869
195	53.4%	5	71.9	650.000	557.412	10.612	82.0	35.965	92.4%	3.045	35.965	92.4%	3.045							6.091
200	54.8%	5	68.7	650.000	557.386	10.544	82.1	34.335	91.3%	2.877	34.335	91.3%	2.877							5.754
205	56.2%	5	65.4	650.000	557.361	10.471	82.2	32.704	90.3%	2.712	32.704	90.3%	2.712							5.424
210	57.5%	5	62.1	650.000	557.335	10.393	82.3	31.074	89.2%	2.549	31.074	89.2%	2.549							5.099
215	58.9%	5	58.9	650.000	557.309	10.308	82.4	29.444	88.1%	2.390	29.444	88.1%	2.390							4.780
220	60.3%	5	55.9	650.000	557.259	10.225	82.5	27.971	87.2%	2.249	27.971	87.2%	2.249							4.498
225	61.6%	5	54.2	650.000	557.240	10.174	82.6	27.125	86.6%	2.169	27.125	86.6%	2.169							4.338
230	63.0%	5	52.6	650.000	557.211	10.121	82.7	26.279	86.1%	2.090	26.279	86.1%	2.090							4.181
235	64.4%	5	50.9	650.000	557.181	10.066	82.8	25.433	85.5%	2.012	25.433	85.5%	2.012							4.024
240	65.8%	5	49.2	650.000	557.152	10.007	82.8	49.175	93.1%	4.242										4.242
[illegible]	67.1%	5	47.5	650.000	557.123	9.945	82.9	47.483	93.4%	4.113										4.113
[illegible]	[illegible]	5	45.8	650.000	557.093	9.880	83.0	45.791	93.7%	3.984										3.984
[illegible]	[illegible]	5	44.1	650.000	557.064	9.811	83.1	44.099	94.0%	3.853										3.853
[illegible]	[illegible]	5	43.1	650.000	557.046	9.767	83.2	43.066	94.2%	3.773										3.773
[illegible]	[illegible]	5	42.1	650.000	557.030	9.725	83.2	42.105	94.1%	3.686										3.686
[illegible]	74.0%	5	41.1	650.000	557.013	9.681	83.3	41.145	93.9%	3.599										3.599

SAIFCO HYDRO POWER LIMITED
SAIFCO GROUP

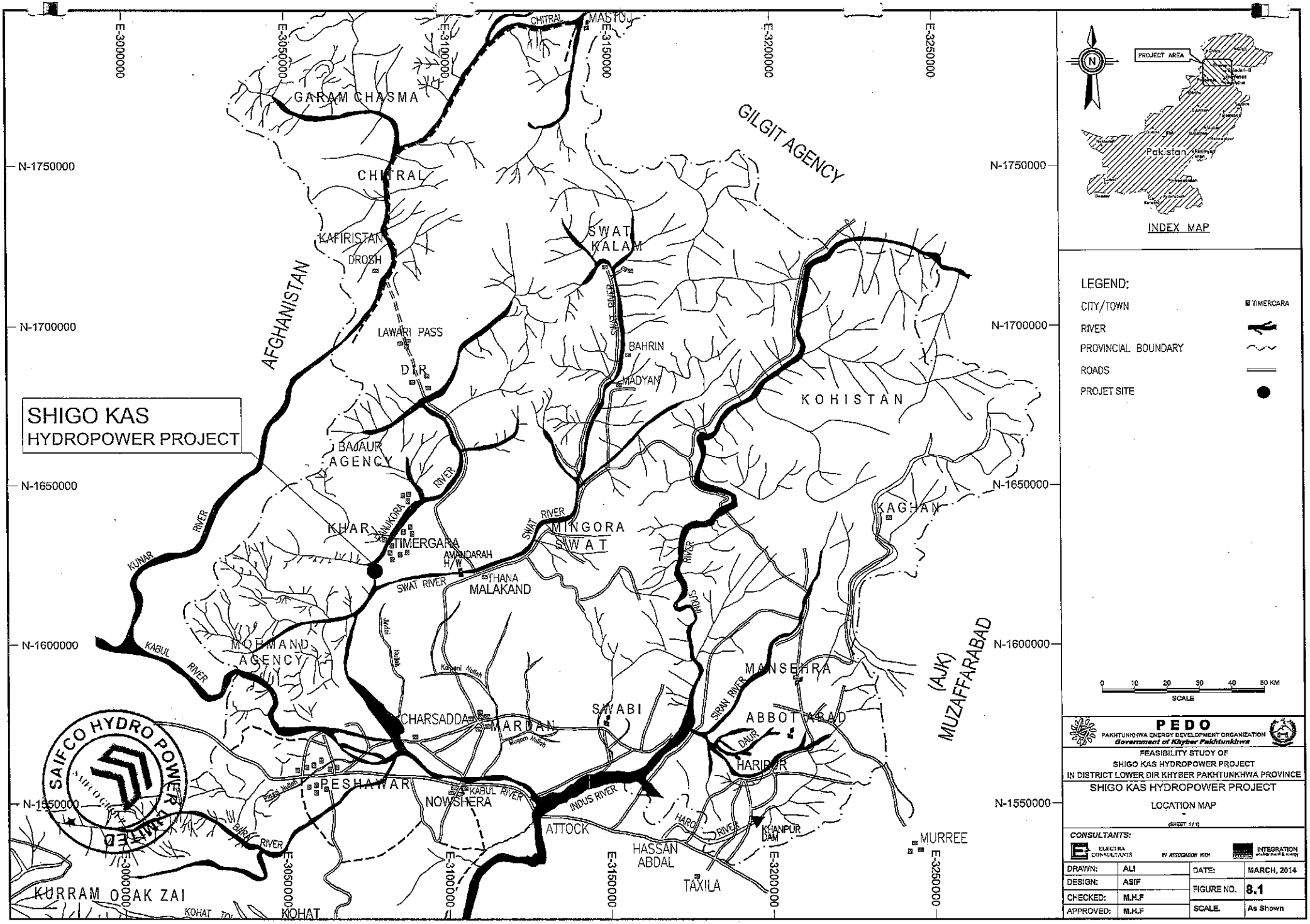
TIME INCR.		PERIOD	FLOW DURATION	HWL	TWL	Losses	NETHEAD	TURBINE - 1			TURBINE - 2			TURBINE - 3			TURBINE - 4			ANNUAL ENERGY
								Q_1	η_{T1}	$Energy_1$	Q_2	η_{T2}	$Energy_2$	Q_3	η_{T3}	$Energy_3$	Q_4	η_{T4}	$Energy_4$	
(days)	(%)	(days)	(m^3/s)	(masl)	(masl)	(m)	(m)	(m^3/s)	(%)	(GWh)	(m^3/s)	(%)	(GWh)	(m^3/s)	(%)	(GWh)	(m^3/s)	(%)	(GWh)	(GWh)
275	75.3%	5	40.2	650.000	556.996	9.636	83.4	40.185	93.8%	3.513										3.513
280	76.7%	5	39.2	650.000	556.980	9.589	83.4	39.225	93.7%	3.426										3.426
285	78.1%	5	38.3	650.000	556.963	9.540	83.5	38.264	93.5%	3.340										3.340
290	79.5%	5	37.3	650.000	556.946	9.490	83.6	37.304	93.3%	3.250										3.250
295	80.8%	5	36.5	650.000	556.932	9.445	83.6	36.493	92.7%	3.164										3.164
300	82.2%	5	35.8	650.000	556.920	9.405	83.7	35.782	92.3%	3.089										3.089
305	83.6%	5	35.1	650.000	556.908	9.364	83.7	35.072	91.8%	3.014										3.014
310	84.9%	5	34.4	650.000	556.895	9.321	83.8	34.361	91.4%	2.940										2.940
315	86.3%	5	33.6	650.000	556.883	9.277	83.8	33.650	90.9%	2.866										2.866
320	87.7%	5	32.9	650.000	556.871	9.232	83.9	32.939	90.4%	2.793										2.793
325	89.0%	5	32.2	650.000	556.858	9.185	84.0	32.228	90.0%	2.721										2.721
330	90.4%	5	31.6	650.000	556.847	9.139	84.0	31.550	89.5%	2.652										2.652
335	91.8%	5	31.0	650.000	556.836	9.097	84.1	30.950	89.1%	2.592										2.592
340	93.2%	5	30.4	650.000	556.826	9.054	84.1	30.350	88.7%	2.532										2.532
345	94.5%	5	29.8	650.000	556.816	9.009	84.2	29.750	88.3%	2.473										2.473
350	95.9%	5	27.3	650.000	556.773	8.809	84.4	27.269	86.7%	2.232										2.232
355	97.3%	5	23.8	650.000	556.712	8.477	84.6													0.000
360	98.6%	5	20.3	650.000	556.651	8.061	85.3													0.000
365	100.0%	5	16.8	650.000	556.591	7.522	85.9													0.000
		365	MEAN ANNUAL ENERGY (GWh)							=										537.62

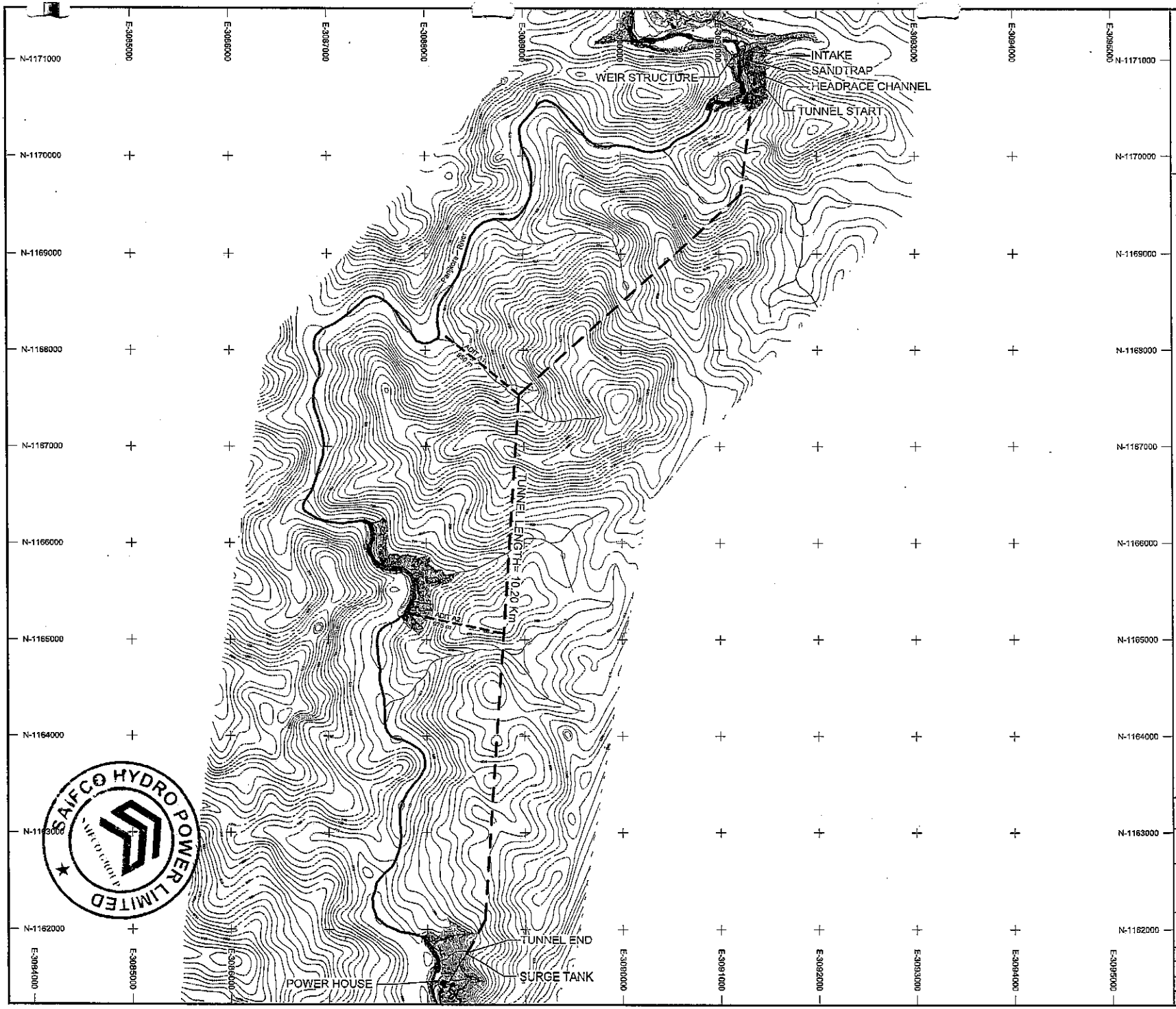
Annual Outages (12 days closure) = 3.3%

Mean Annual Energy (GWh) = 520

Plant Factor = 58.2%

SAIFCO HYDRO POWER LIMITED
SAIFCO GROUP


SHIGO KAS
HYDROPOWER PROJECT
GILGIT AGENCY
AFGHANISTAN
GARAM CHASMA
CHITRAL
MASTUJ
KAFIRISTAN
DROSH
LAWARI PASS
DIR
SWAT KALAM
BAHRIN
MADYAN
KOHISTAN
BAJAUR AGENCY
KHAR
TIMERGARA
AMANDARAH H/W
THANA
MALAKAND
MINGORA
SWAT
KAGHAN
MOHMAND AGENCY
CHARSADDA
MARDAN
SWABI
MANSEHRA
ABBOTABAD
HARIPUR
PESHAWAR
NOWSHERA
ATTOCK
HASSAN ABDAL
TAXILA
KHANPUR DAM
MURREE
KURRAM OAK ZAI
KOHAT
KUNAR RIVER
KABUL RIVER
SWAT RIVER
INDUS RIVER
SIRAN RIVER
HARO RIVER
BARA RIVER
DAUR
(AJK) MUZAFFARABAD
SAIFCO HYDRO POWER LIMITED
E-3000000
E-3050000
E-3100000
E-3150000
E-3200000
E-3250000
N-1750000
N-1700000
N-1650000
N-1600000
N-1550000
PROJECT AREA
Pakistan
INDEX MAP
LEGEND:
CITY/TOWN
TIMERGARA
RIVER
PROVINCIAL BOUNDARY
ROADS
PROJET SITE
0 10 20 30 40 50 KM
SCALE
PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa
FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE
SHIGO KAS HYDROPOWER PROJECT
LOCATION MAP
(SHEET 1/1)
CONSULTANTS:
ELECTRA CONSULTANTS
IN ASSOCIATION WITH
INTEGRATION
DRAWN: ALI
DESIGN: ASIF
CHECKED: M.H.F
APPROVED: M.H.F
DATE: MARCH, 2014
FIGURE NO. 8.1
SCALE. As Shown



N

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.

LEGEND:

- RIVER
- NULLAH
- HOUSES/SHOPS
- MOSQUE/SCHOOL
- ROAD
- TRACK

SAIFCO HYDRO POWER LIMITED

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PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HYDROPOWER PROJECT

PROJECT LAYOUT PLAN

(SHEET 1 / 1)

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.2
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE.	1 : 35,000



N

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.

LEGEND

- RIVER
- NULLAH
- HOUSES/SHOPS
- MOSQUE/SCHOOL
- ROAD
- TRACK

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PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

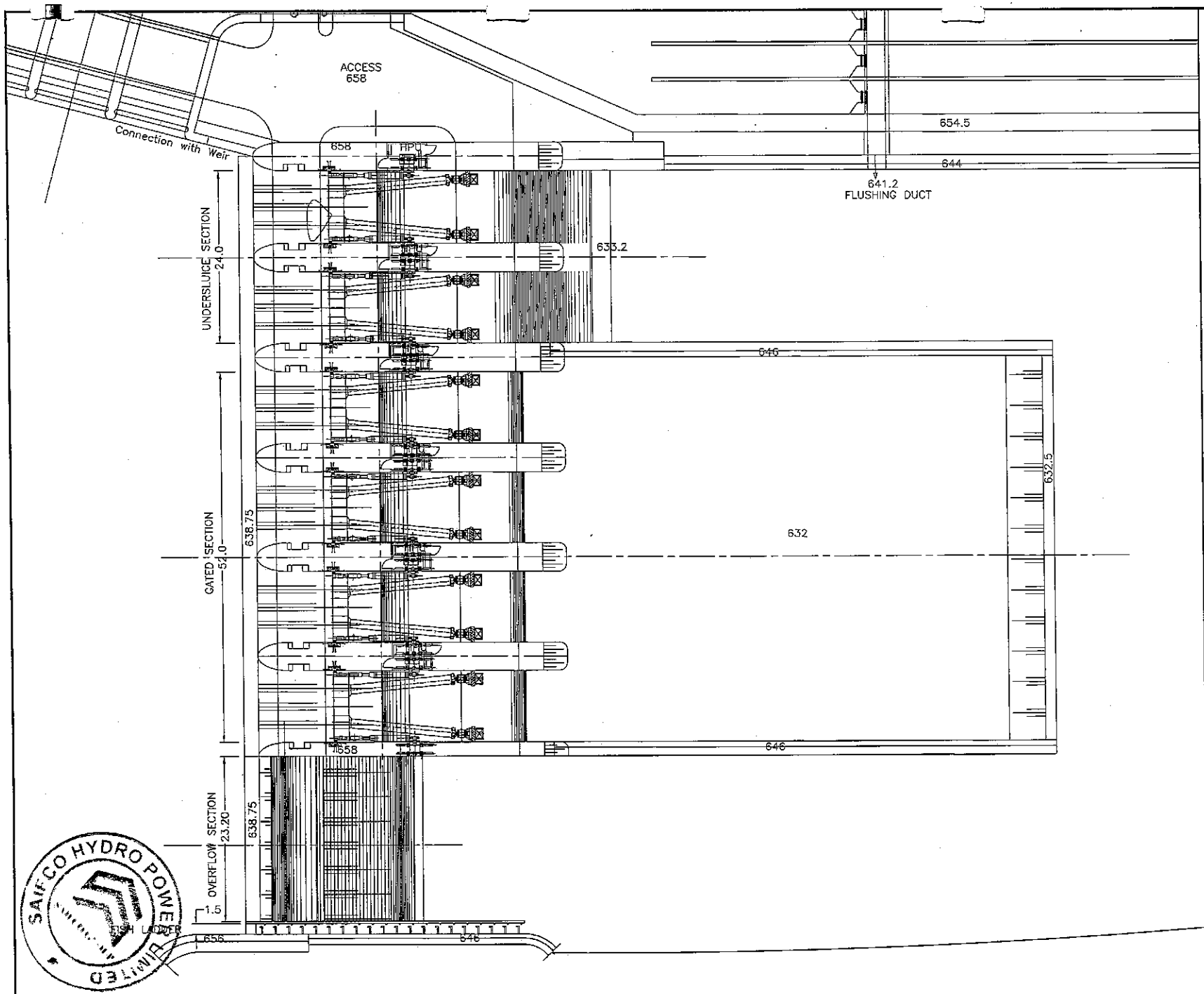
FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HYDROPOWER PROJECT

WEIR STRUCTURE-INTAKE AND SANDTRAP
LAYOUT PLAN
(SHEET 1/1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.3
CHECKED:	M.H.F	SCALE.	1 : 1200
APPROVED:	M.H.F		



NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.

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PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HYDROPOWER PROJECT

WEIR STRUCTURE
PLAN

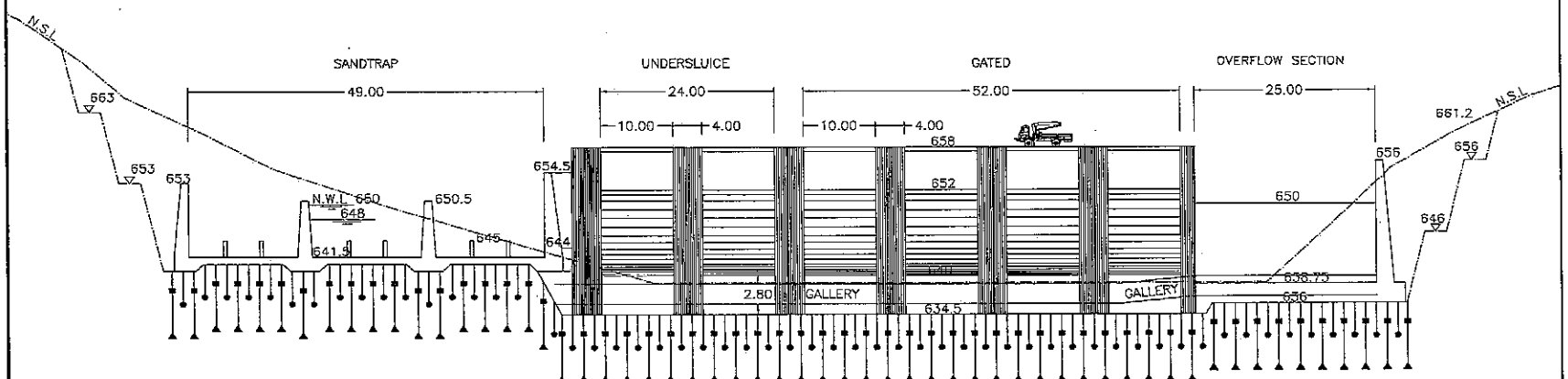
CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.4
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE.	1 : 500

SAIFCO HYDRO POWER LIMITED

LEFT BANK

RIGHT BANK



WEIR AND SANDTRAP SECTION

GROUTING DETAIL		
HOLE	DEPTH	SPACING C/C
PRIMARY	9.5 meters	3 meters
SECONDARY	5 meters	3 meters
CONSOLIDATION GROUTING	3 meters	3 meters

LEGNED:

▲ = PRIMARY BOREHOLE
● = SECONDARY BOREHOLE
■ = CONSOLIDATION GROUTING

SAIFCO HYDRO POWER LIMITED

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

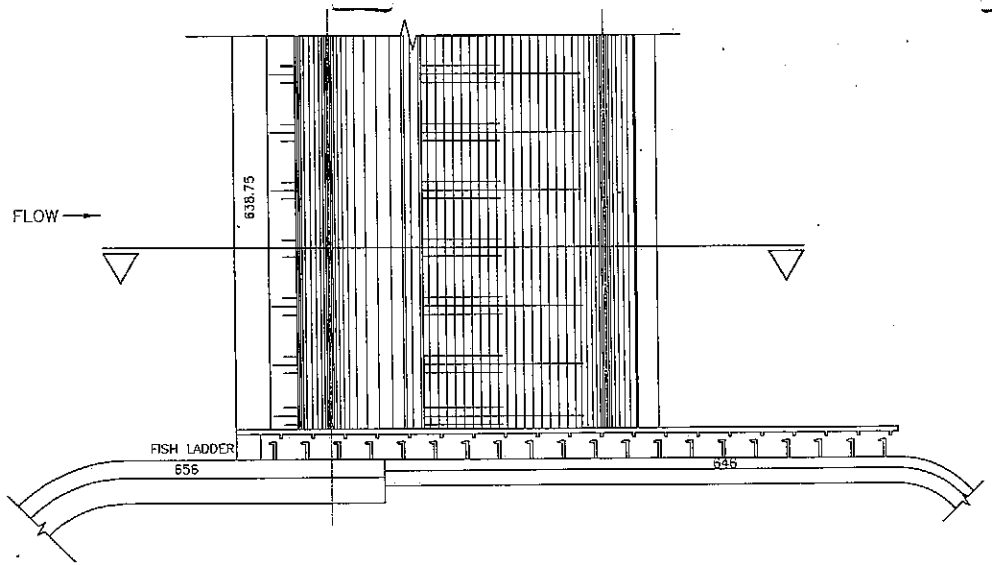
SHIGO KAS HYDROPOWER PROJECT

WEIR AND SANDTRAP SECTION

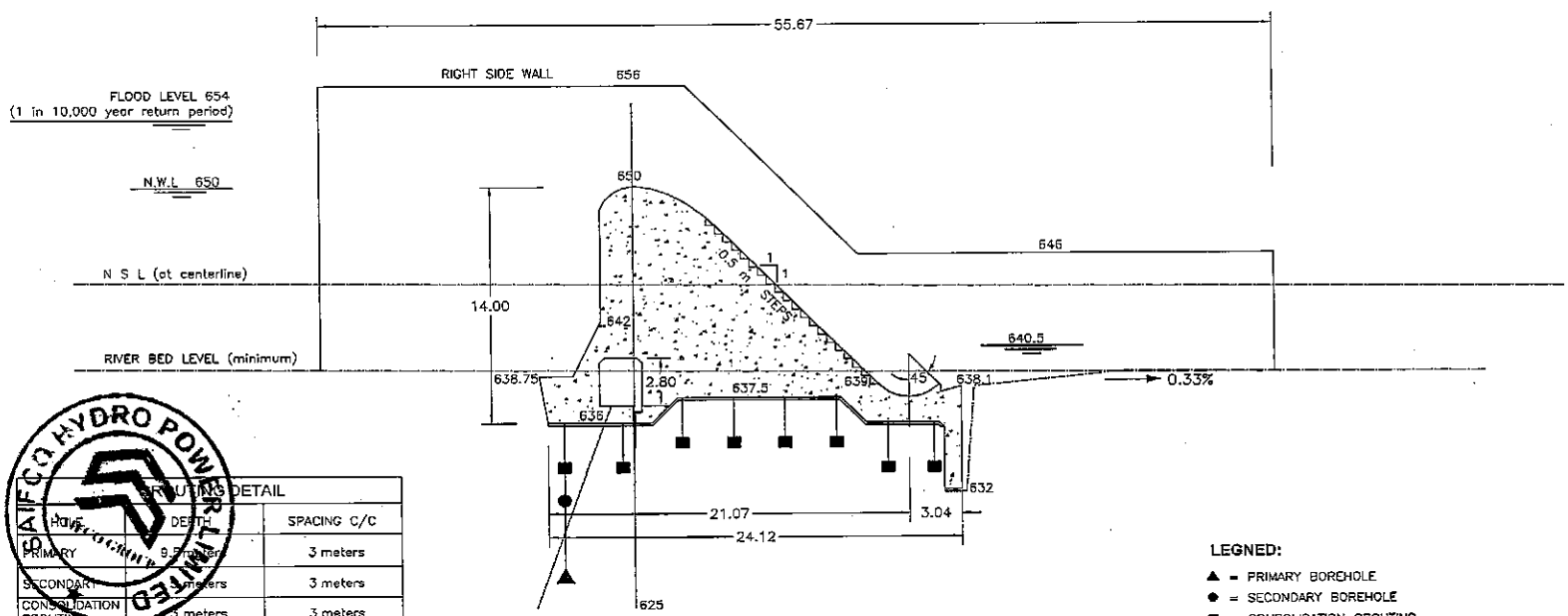
(SHEET 1/1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8,5
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE:	1 : 650



OVERFLOW - PLAN



OVERFLOW - SECTION

GROUTING DETAIL		
	DEPTH	SPACING C/C
PRIMARY	9.5 meters	3 meters
SECONDARY	3 meters	3 meters
CONSOLIDATION GROUTING	3 meters	3 meters

LEGNED:

- ▲ = PRIMARY BOREHOLE
- ● = SECONDARY BOREHOLE
- ■ = CONSOLIDATION GROUTING

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

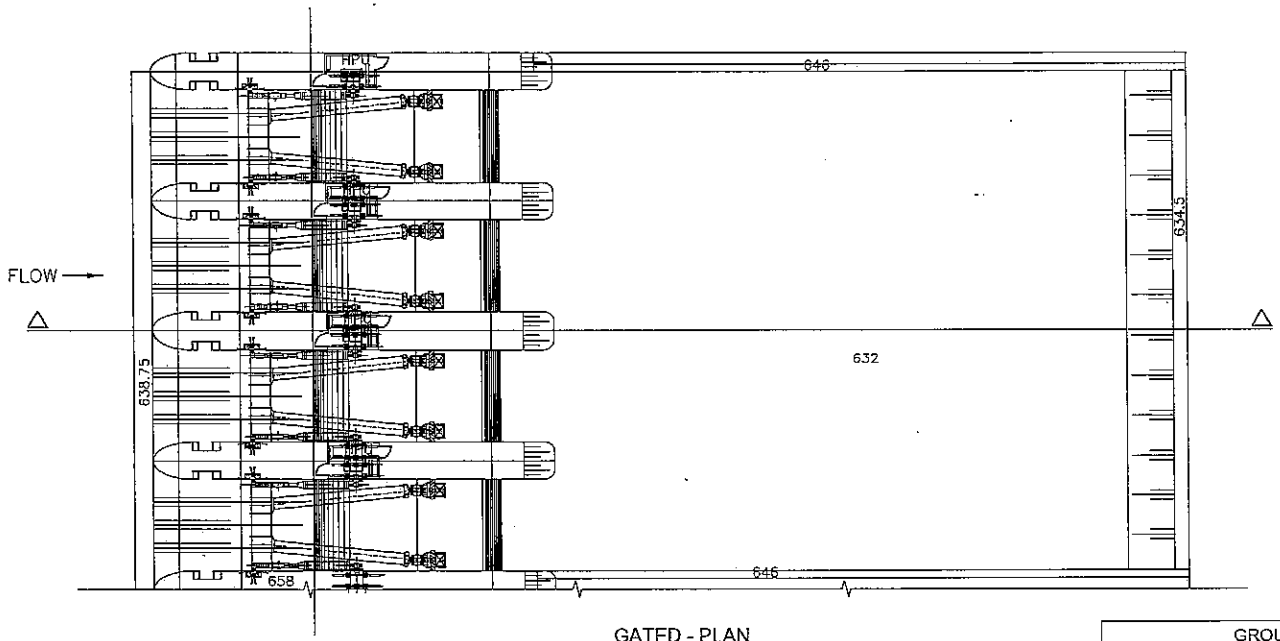
SHIGO KAS HYDROPOWER PROJECT

OVERFLOW SECTION
PLAN AND SECTION

(SHEET 1 / 1)

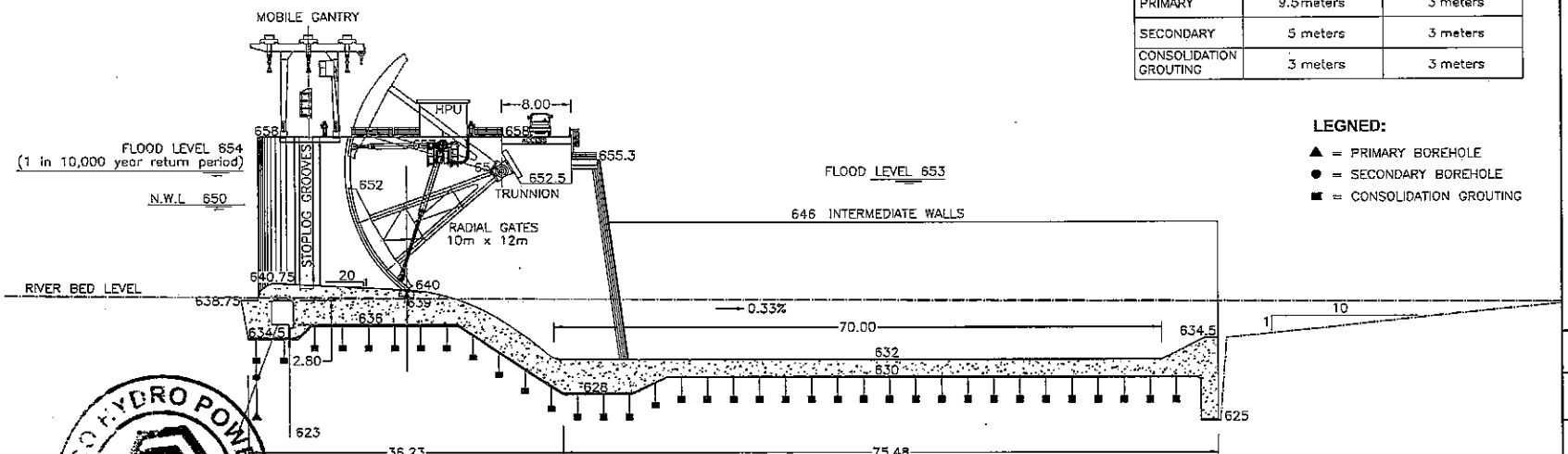
CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2013
DESIGN:	ASIF	FIGURE NO.	8.6
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE.	1 : 300



GATED - PLAN

GROUTING DETAIL		
HOLE	DEPTH	SPACING C/C
PRIMARY	9.5meters	3 meters
SECONDARY	5 meters	3 meters
CONSOLIDATION GROUTING	3 meters	3 meters



GATED - SECTION

LEGNED:

- ▲ = PRIMARY BOREHOLE
- ● = SECONDARY BOREHOLE
- ■ = CONSOLIDATION GROUTING

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.

SAIFCO HYDRO POWER LIMITED
SAIFCO GROUP

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

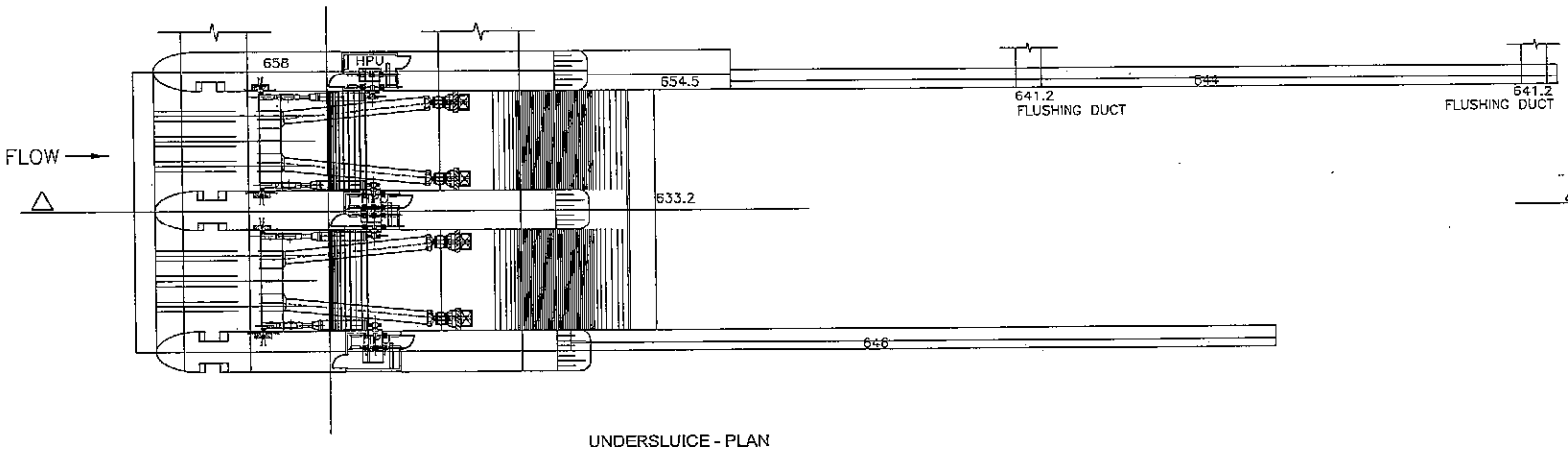
FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HYDROPOWER PROJECT

GATED SECTION
PLAN AND SECTION

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.7
CHECKED:	M.H.F	SCALE.	1 : 550
APPROVED:	M.H.F		



UNDERSLUICE - PLAN

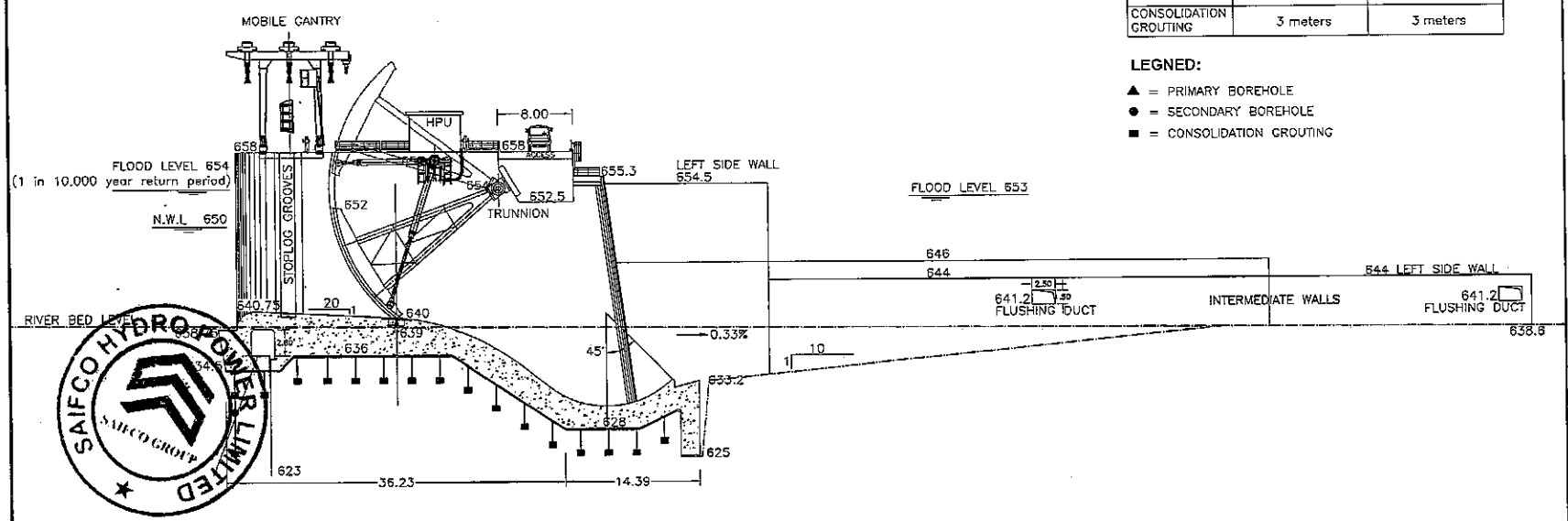
GROUTING DETAIL		
HOLE	DEPTH	SPACING C/C
PRIMARY	9.5meters	3 meters
SECONDARY	5 meters	3 meters
CONSOLIDATION GROUTING	3 meters	3 meters

LEGNED:

▲ = PRIMARY BOREHOLE

● = SECONDARY BOREHOLE

■ = CONSOLIDATION GROUTING



UNDERSLUICE - SECTION

SAIFCO HYDRO POWER LIMITED
SAIFCO GROUP

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

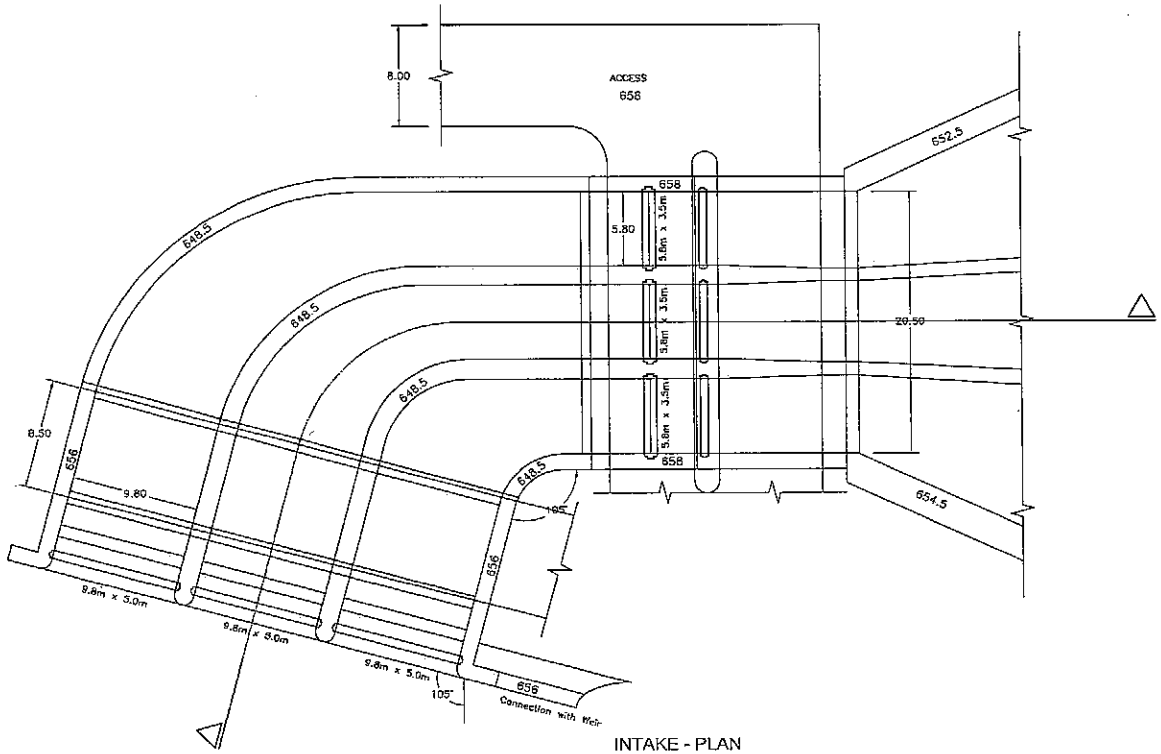
SHIGO KAS HYDROPOWER PROJECT

UNDERSLUICE - SECTION
PLAN AND SECTION

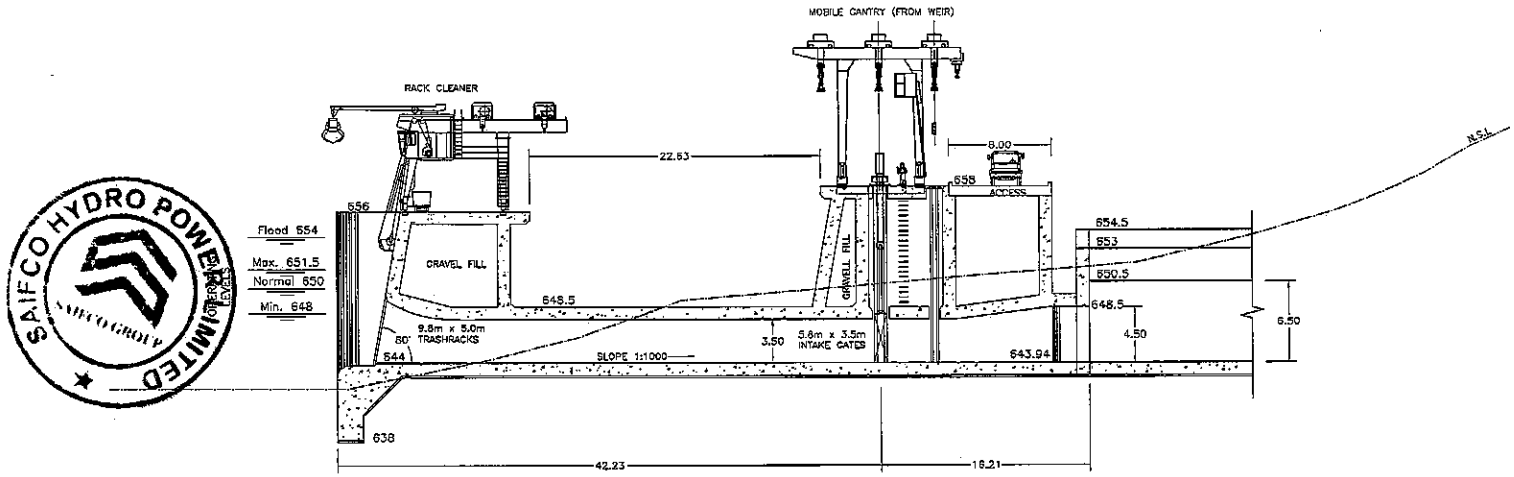
SHEET 1/1

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.8
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE.	1 : 500



INTAKE - PLAN



INTAKE - SECTION

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

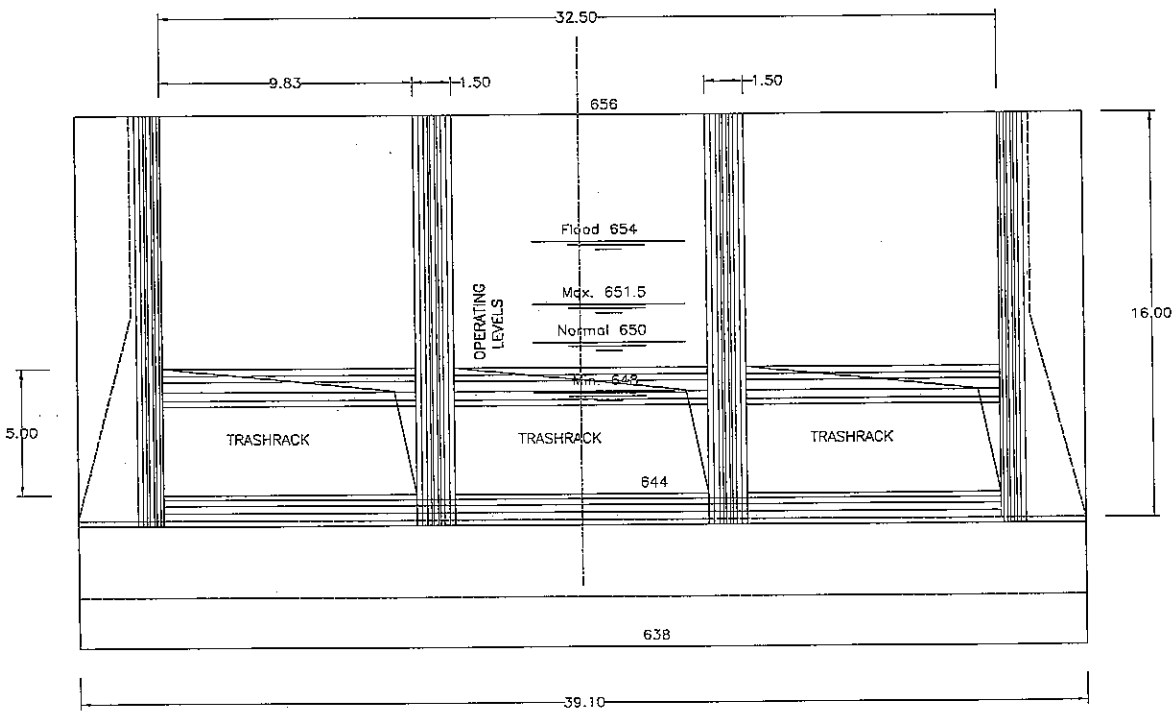
SHIGO KAS HYDROPOWER PROJECT

INTAKE
PLAN AND SECTION

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.9
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE.	1 : 400

SAIFCO HYDRO POWER LIMITED



INTAKE - FRONT ELEVATION

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

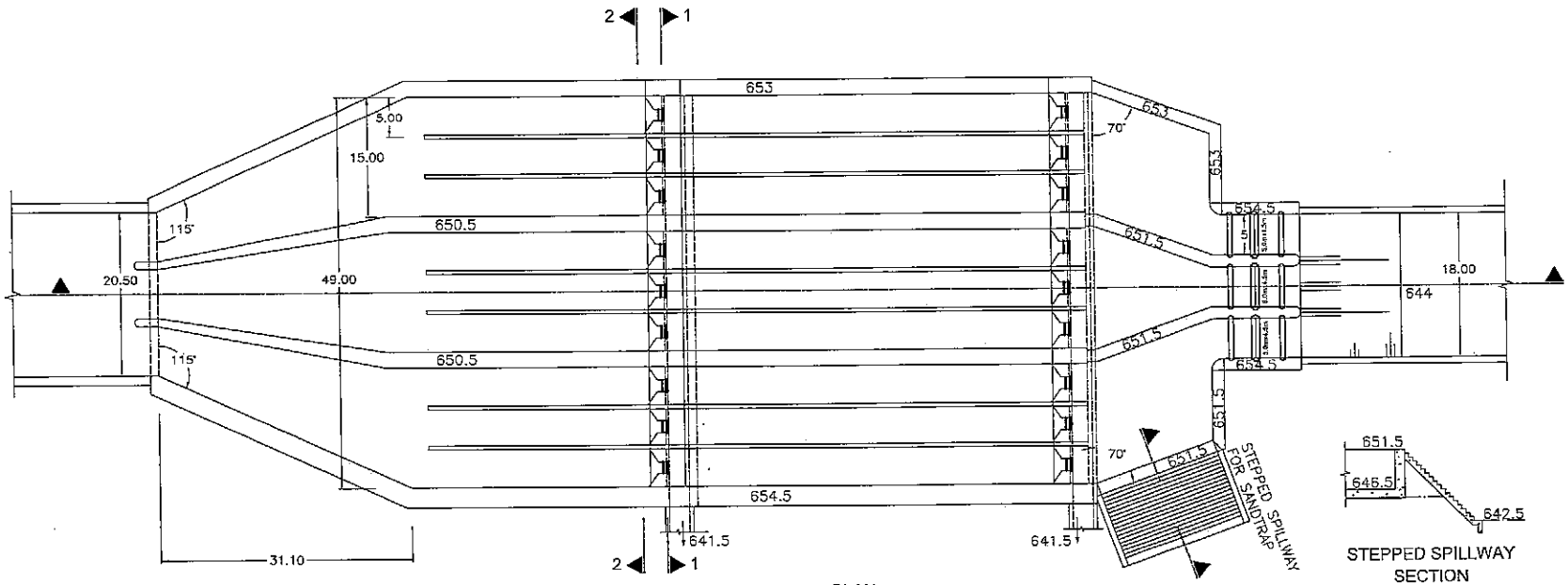
SHIGO KAS HYDROPOWER PROJECT

INTAKE
FRONT ELEVATION

(SHEET 1 / 1)

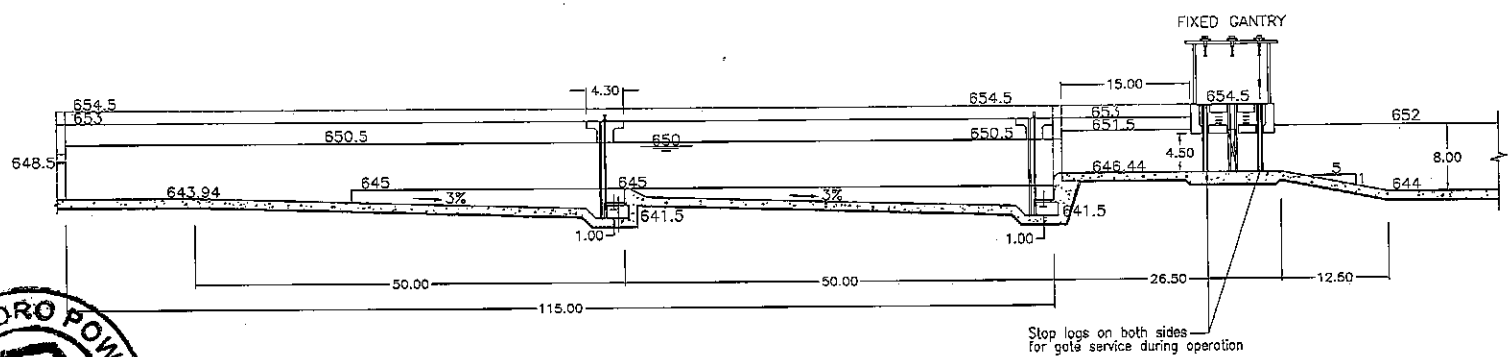
CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.10
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE.	1 : 200



SANDTRAP - PLAN

STEPPED SPILLWAY SECTION



SANDTRAP - LONGITUDINAL SECTION

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HYDROPOWER PROJECT

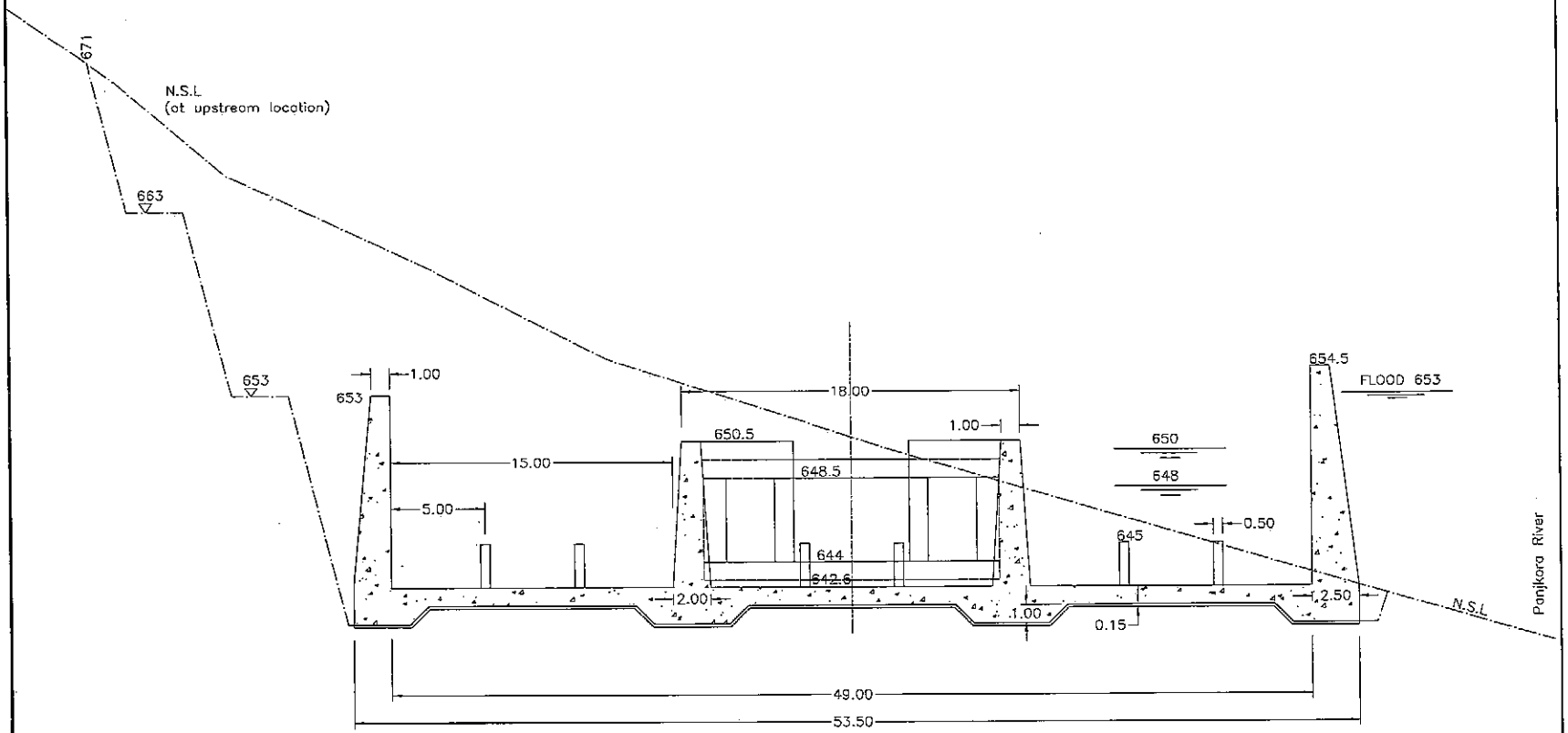
SANDTRAP
PLAN AND LONGITUDINAL SECTION

(SHEET 1/1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.11
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE	1 : 600

HYDRO POWER LIMITED



SECTION 2 - 2

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

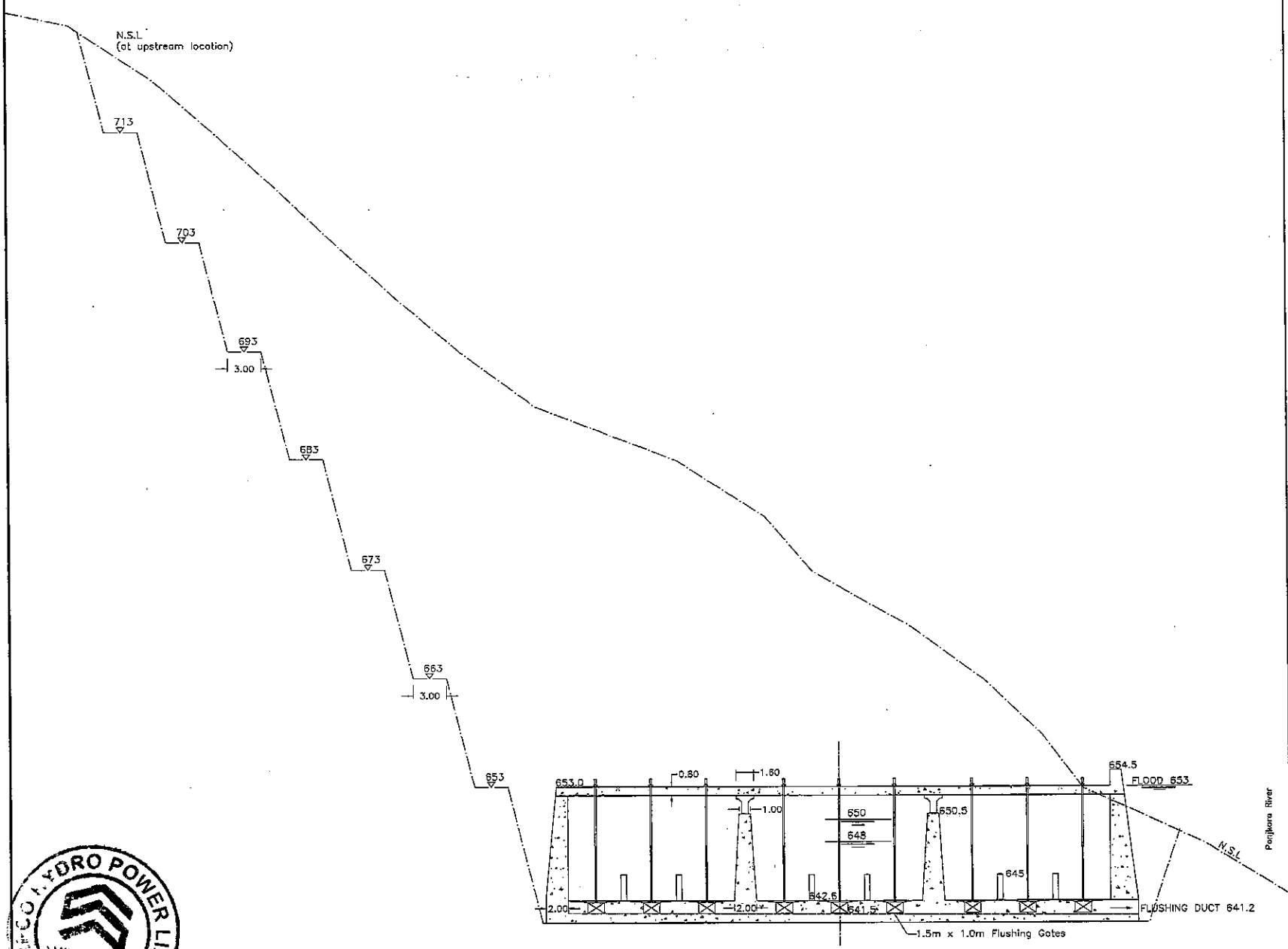
SHIGO KAS HYDROPOWER PROJECT

SANDTRAP
SECTION 2 - 2

(SHEET 1 of 1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.12
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE.	1 : 250



SECTION 1 - 1

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HYDROPOWER PROJECT

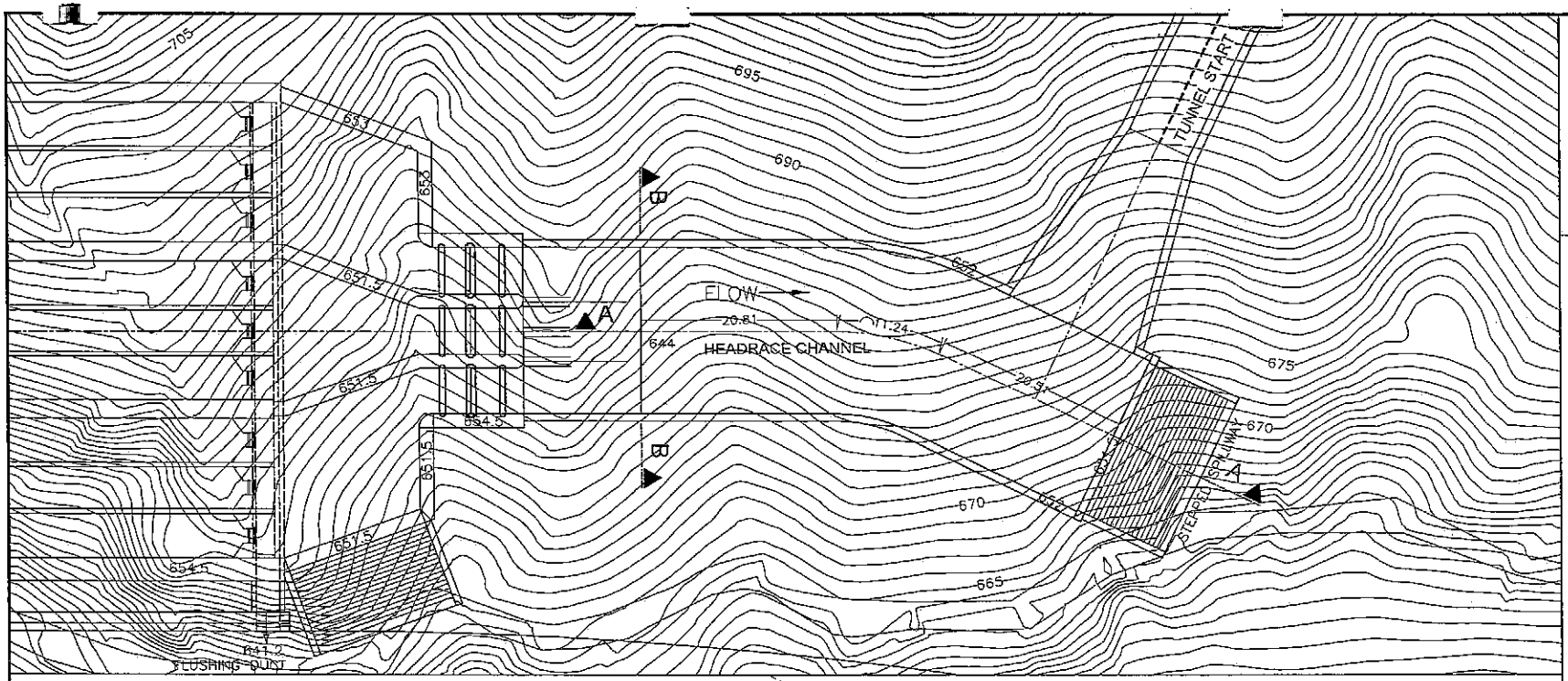
SANDTRAP
SECTION 1 - 1

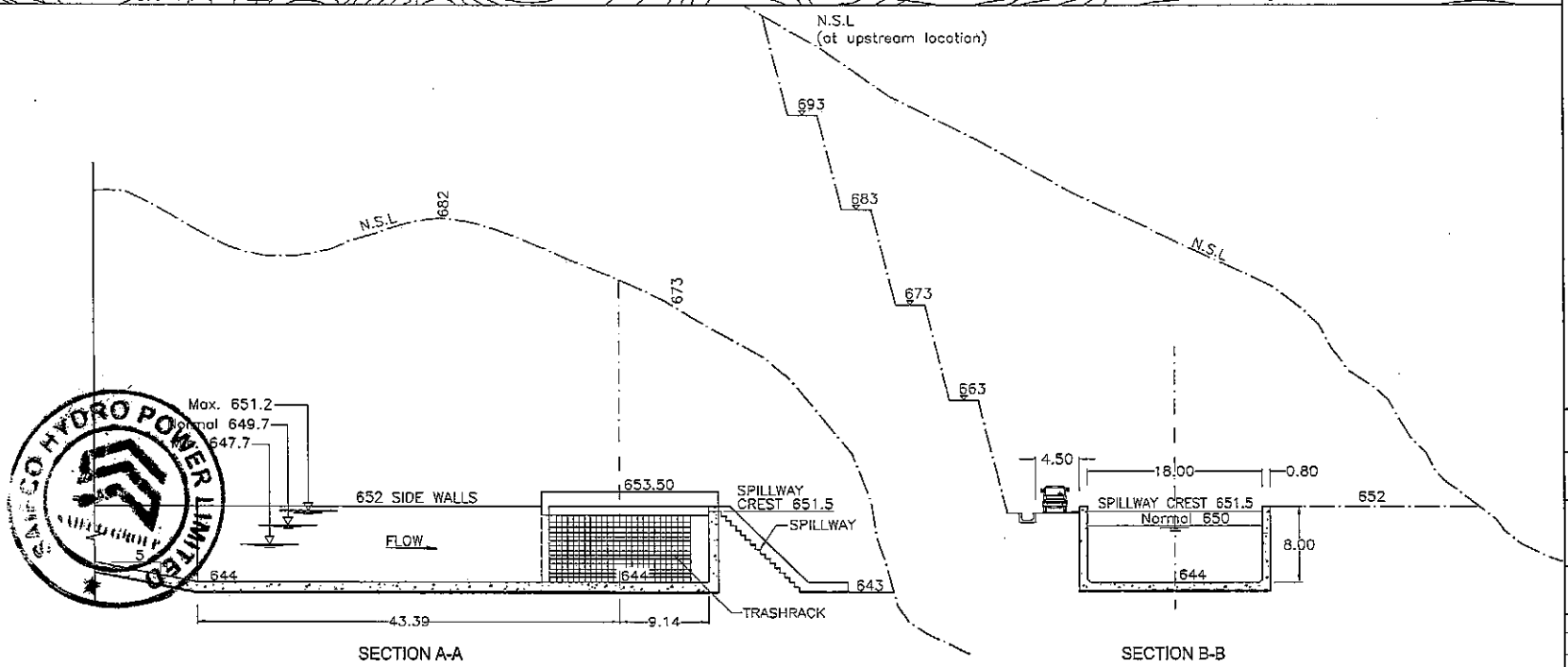
(SHEET 1/1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.13
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE	1 : 350

SAIF HYDRO POWER LIMITED





NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HYDROPOWER PROJECT

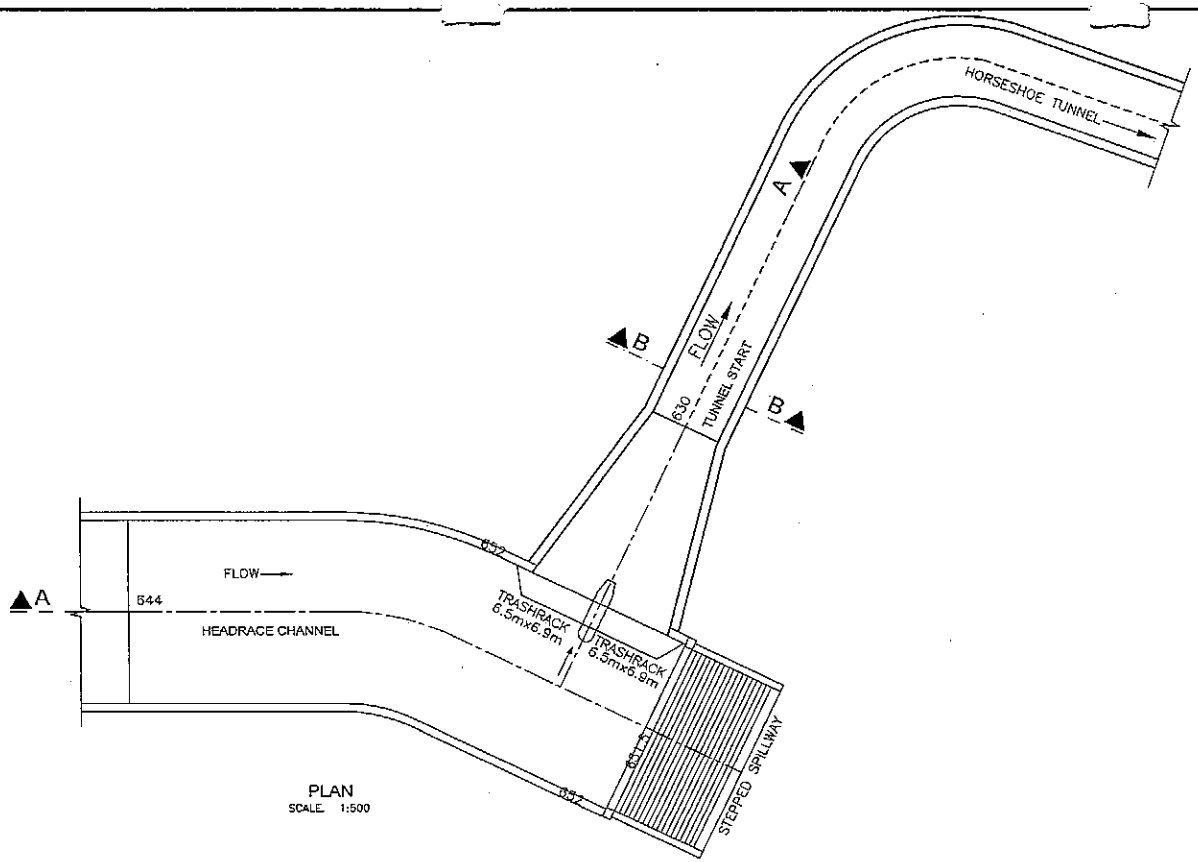
HEADRACE CHANNEL
PLAN AND SECTION

SHEET 1 / 1

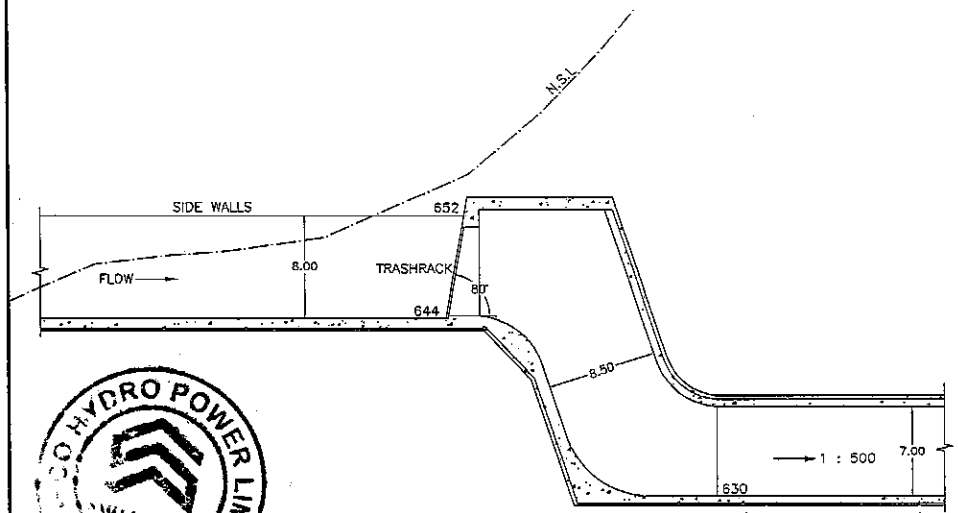
CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.14
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE	1:500

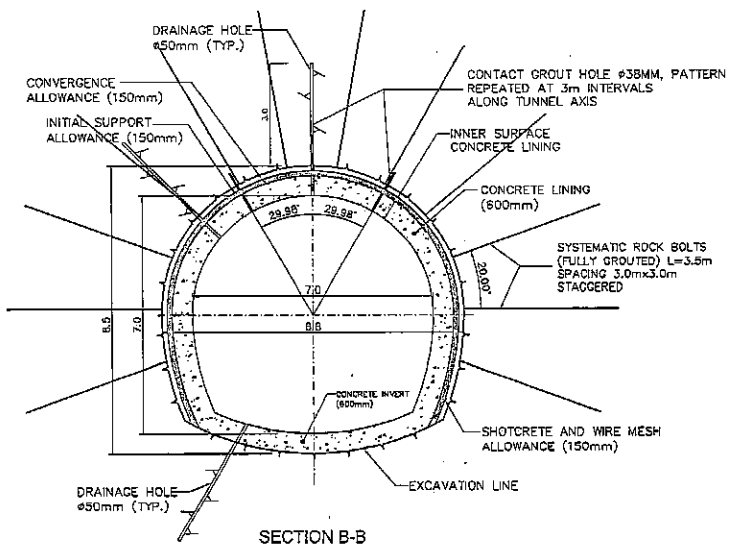
SHIGO KAS HYDRO POWER LIMITED



PLAN
SCALE 1:500



SECTION A-A
SCALE 1:400



SECTION B-B
SCALE 1:150

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

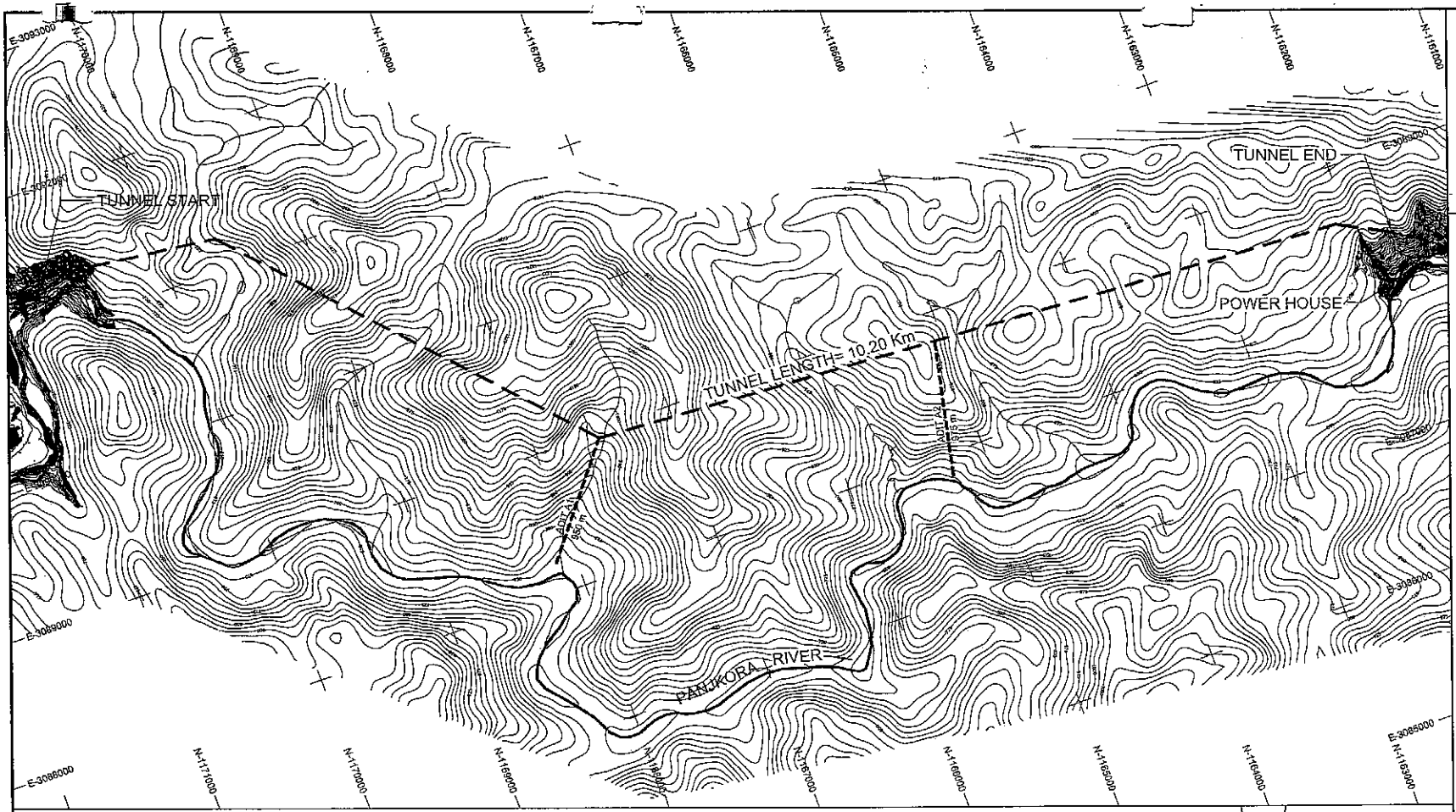
SHIGO KAS HYDROPOWER PROJECT

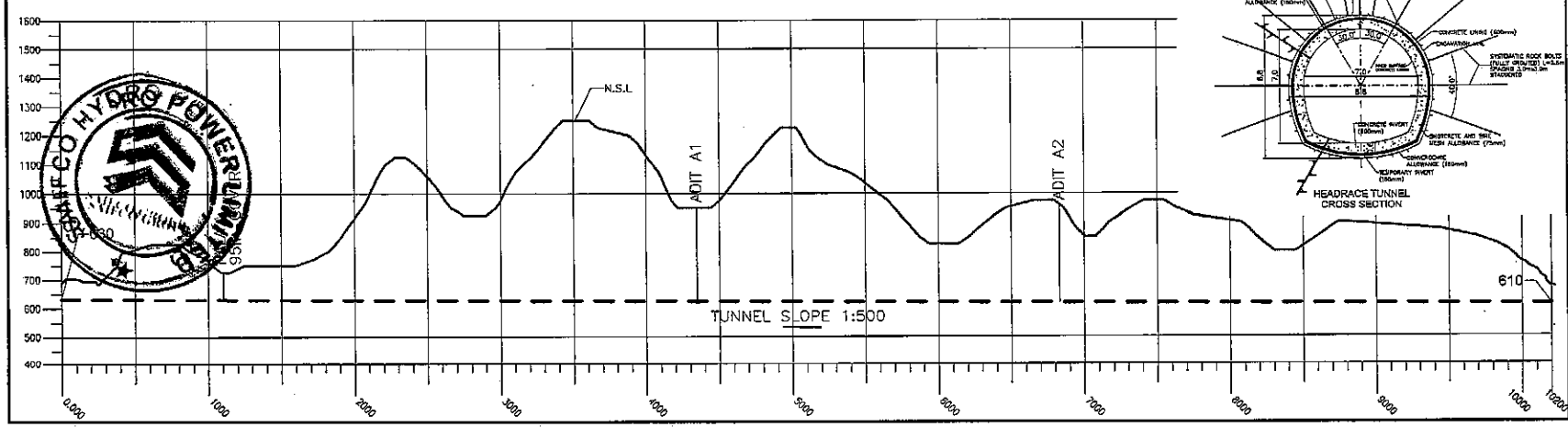
TUNNEL INLET
PLAN AND SECTION
(SHEET 1 of 1)

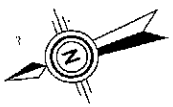
CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.15
CHECKED:	M.H.F	SCALE	As Shown
APPROVED:	M.H.F		

SHIGO HYDRO POWER LIMITED







NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METERS UNLESS OTHERWISE INDICATED.

LEGEND

RIVER.....

NULLAH.....

HOUSES/SHOPS.....

MOSQUE/SCHOOL.....

ROAD.....

TRACK.....

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HYDROPOWER PROJECT

TUNNEL
PLAN AND PROFILE
(SHEET 1 / 1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
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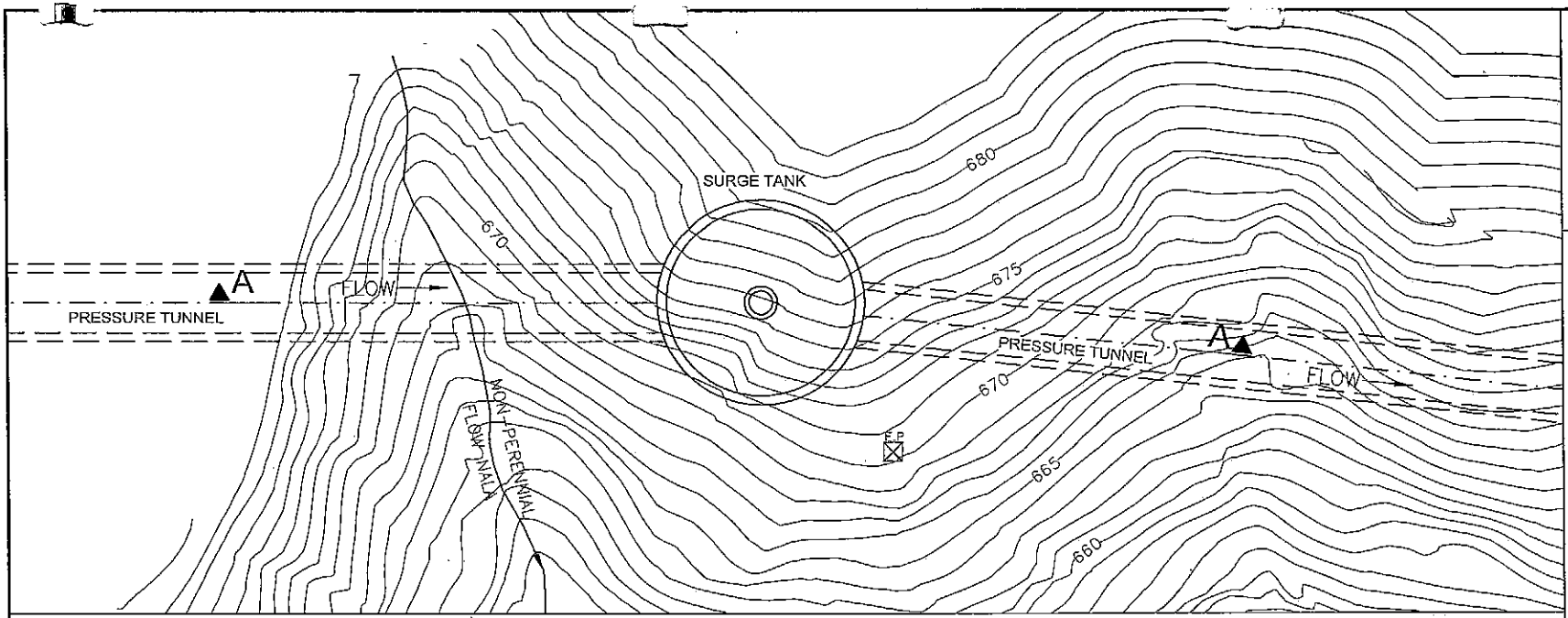
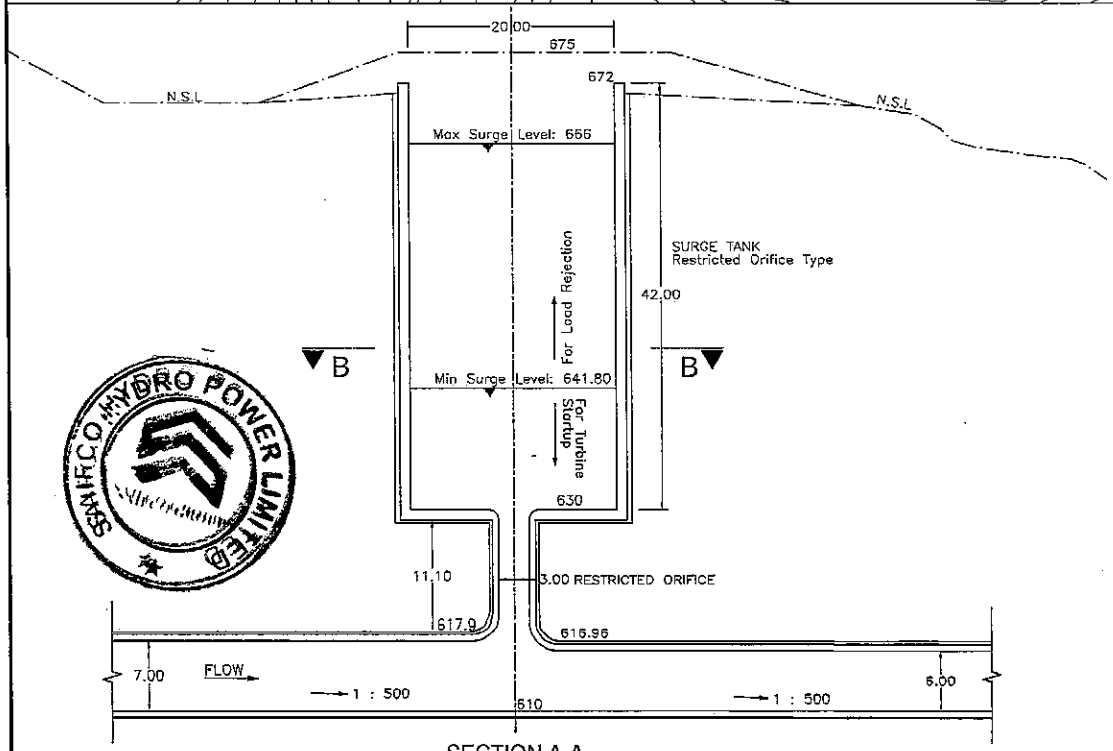
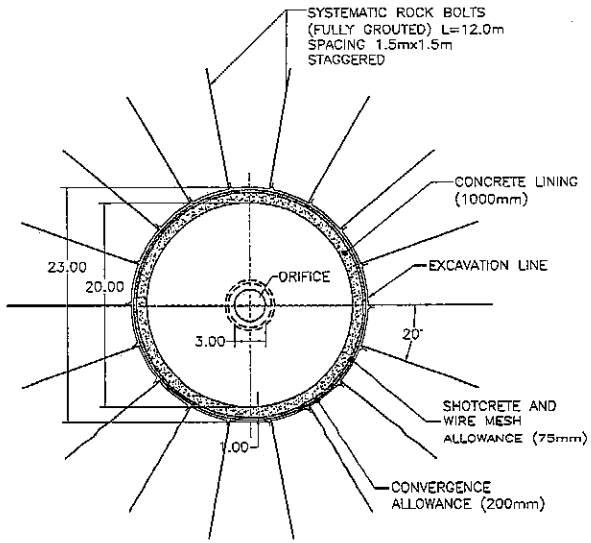
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE.	1 : 30,000





SECTION A-A



SECTION B-B

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HYDROPOWER PROJECT

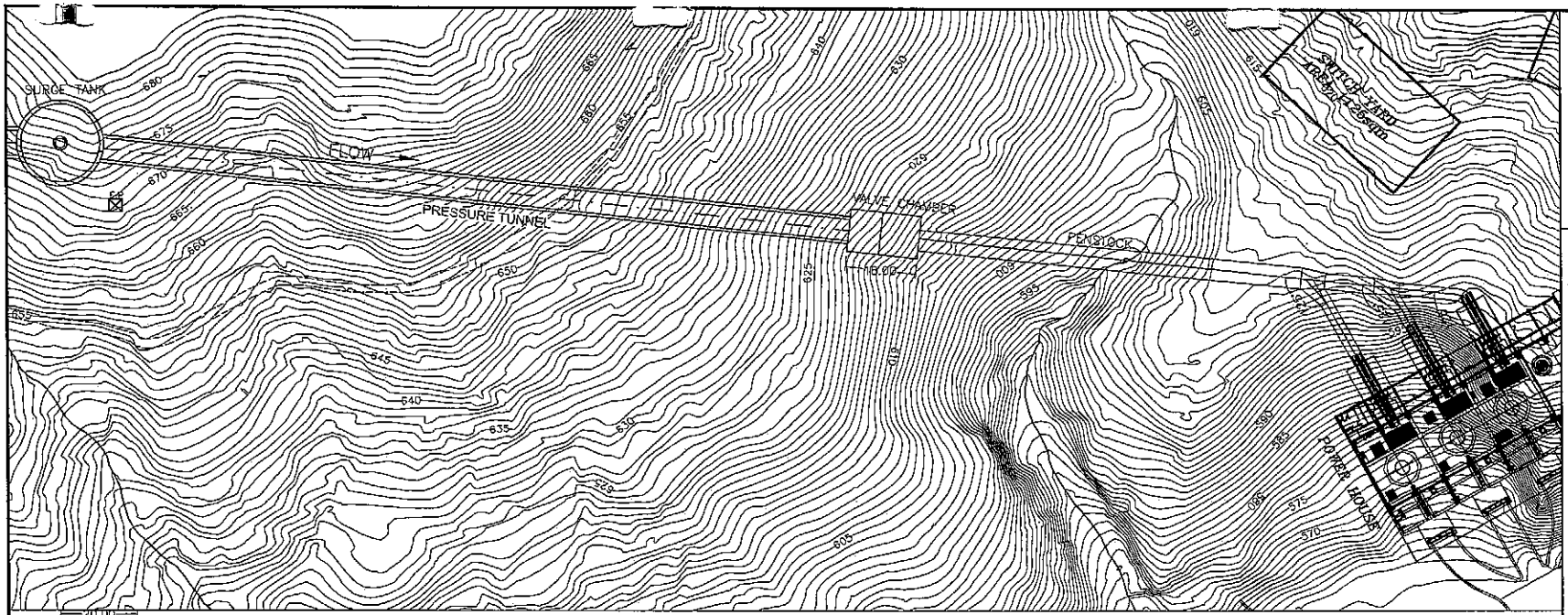
SURGE TANK
PLAN AND SECTION

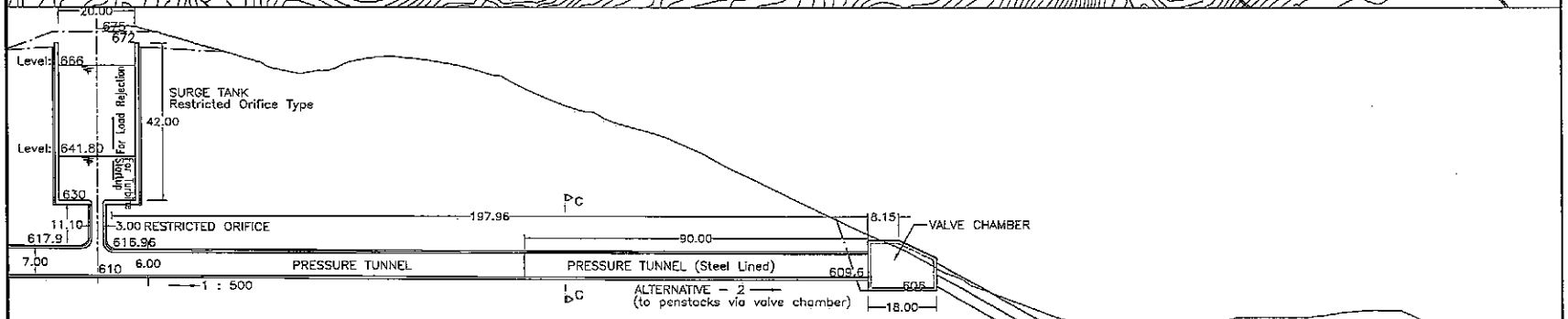
(SHEET 1/1)

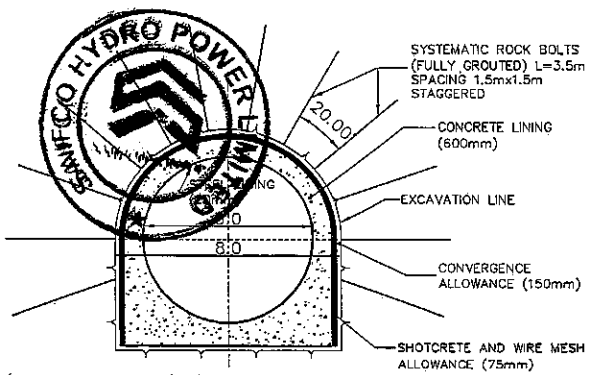
CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.17
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE.	1 : 500

SHAHCO HYDRO POWER LIMITED







SECTION C-C
PRESSURE TUNNEL

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

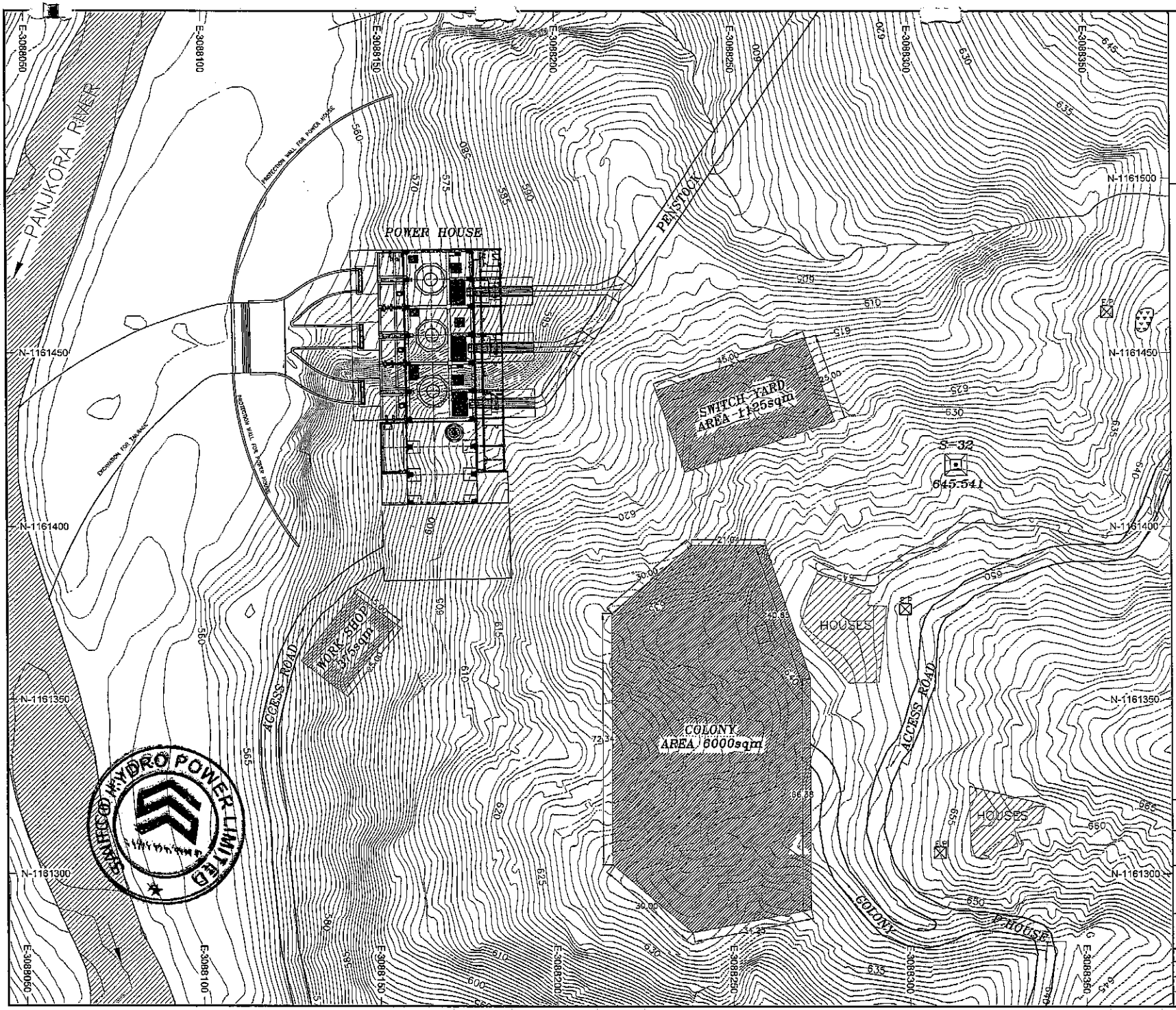
SHIGO KAS HYDROPOWER PROJECT

PRESSURE TUNNEL - PENSTOCK
PLAN AND SECTION

(SHEET 1 / 1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.18
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE.	1 : 1200



NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
. SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

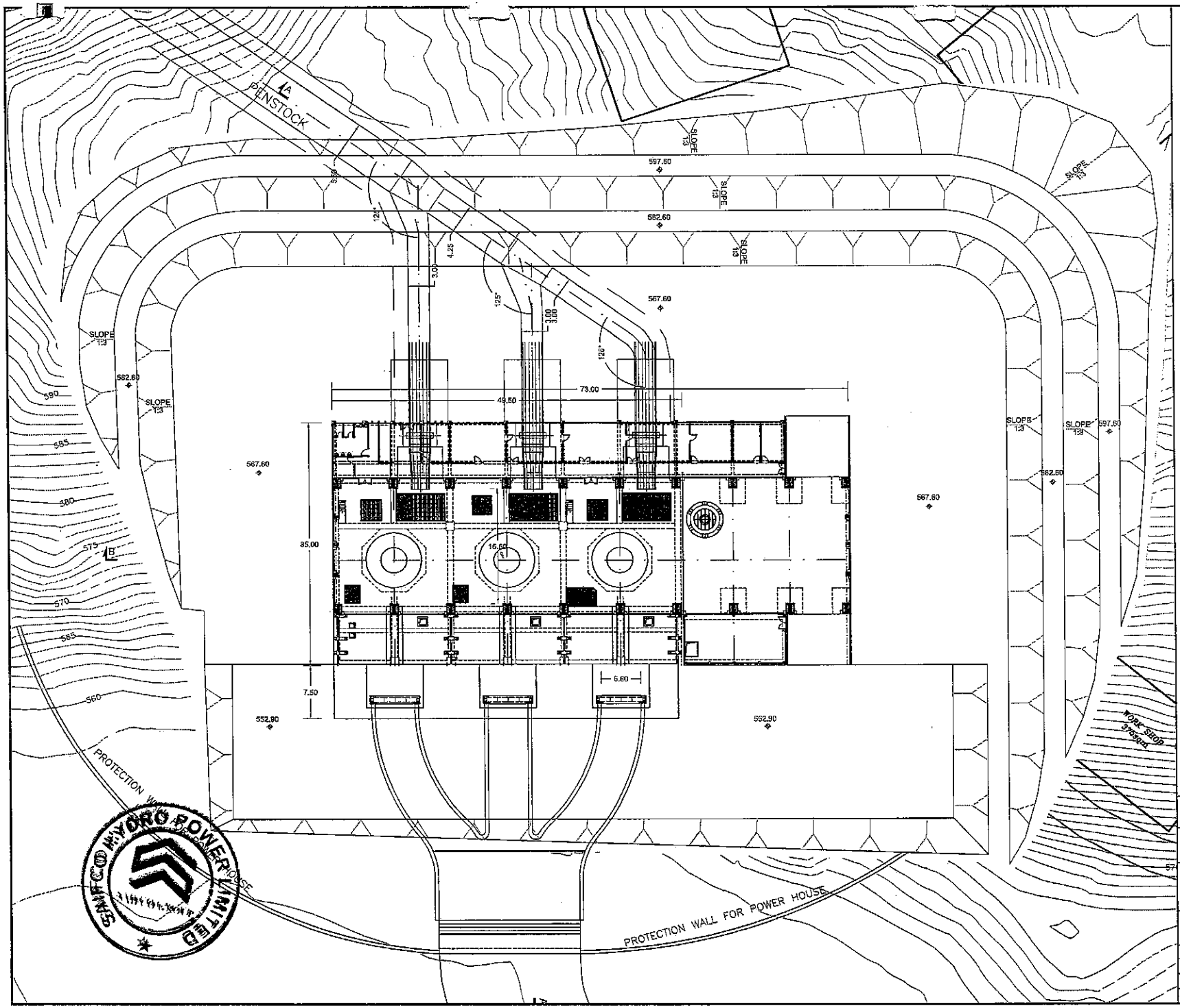
SHIGO KAS HYDROPOWER PROJECT

POWER HOUSE, COLONY & SWITCHYARD LAYOUT PLAN

(SHEET 1/1)

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.19
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE	1 : 1000



NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HYDROPOWER PROJECT

POWER HOUSE
PLAN

(SHEET 1 of 1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.20
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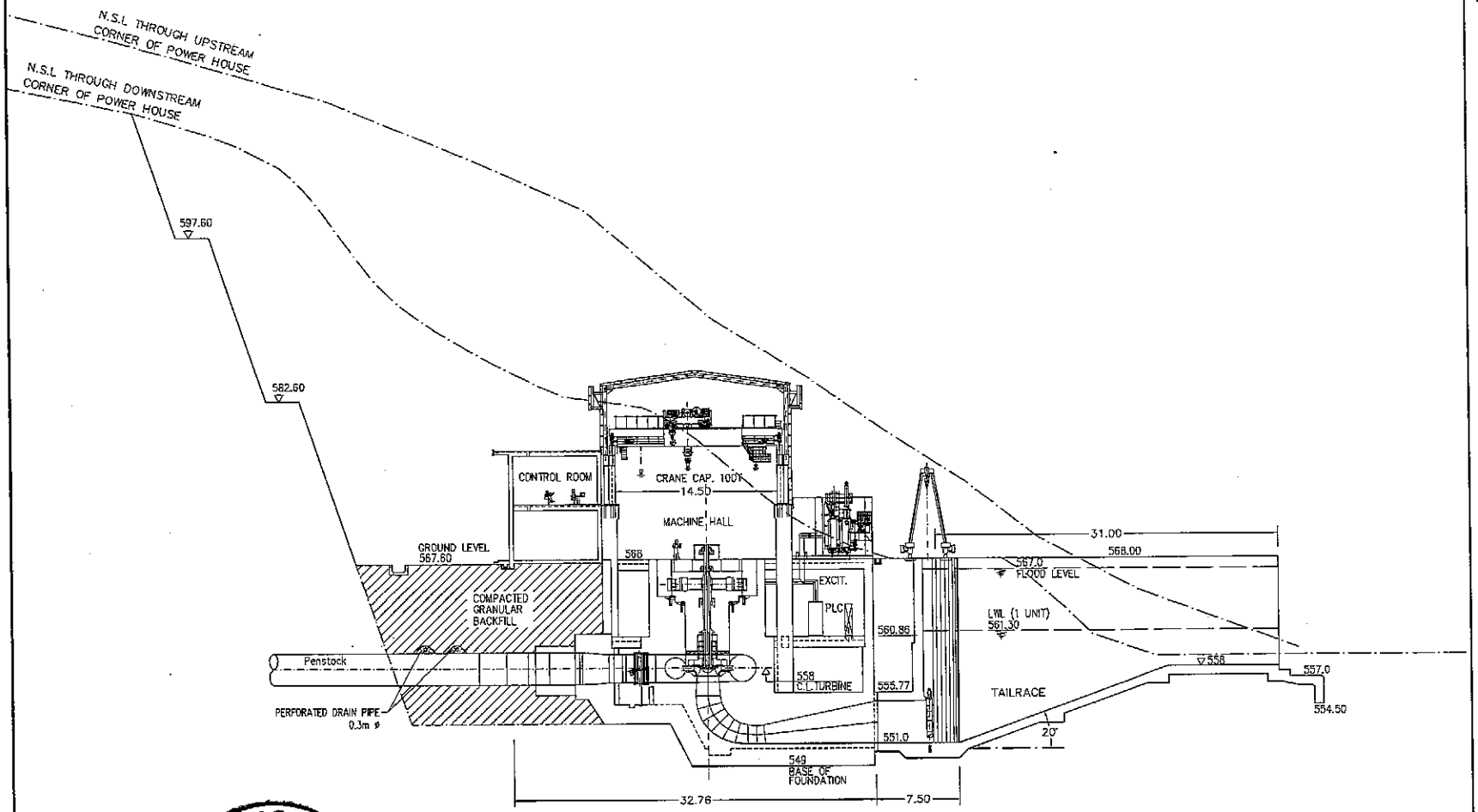


POWERHOUSE - SECTION

NOTES

1. ALL DIMENSIONS AND ELEVATIONS ARE IN METRES UNLESS OTHERWISE INDICATED.

SHANCO HYDRO POWER LIMITED

PEDO
PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HYDROPOWER PROJECT
POWER HOUSE
SECTION
(SHEET 1/1)

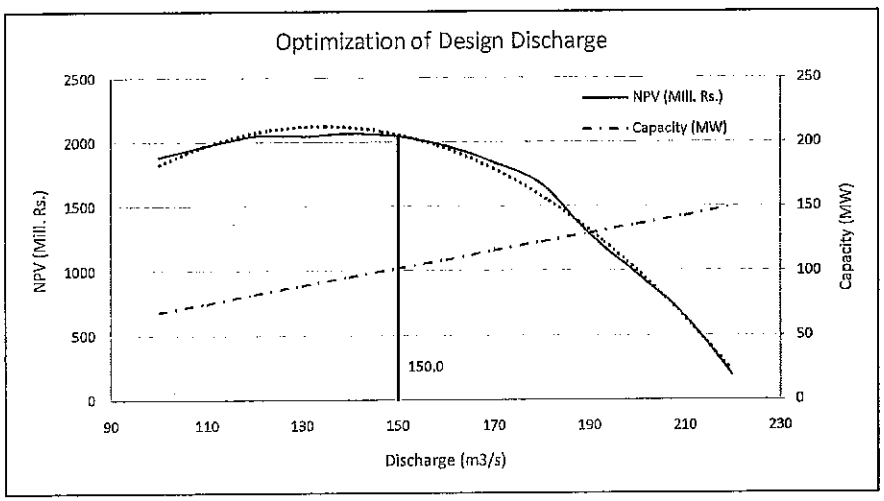
CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MARCH, 2014
DESIGN:	ASIF	FIGURE NO.	8.21
CHECKED:	M.H.F		
APPROVED:	M.H.F	SCALE	1 : 400

SHIGO - KAS HPP
Optimization of Design Discharge (Installed Capacity)

Sr. #	Discharge	Capacity	Energy	Cost		NPV	B/C Ratio	EIRR	Installation Cost
	(m^3/s)	(MW)	GWh	Civil	E & M	(Mill. Rs.)		(%)	(Mill. Rs./MW)
1	100	68.0	398.9	12022.2	4741.4	1887.02	1.15	13.72%	246.4
2	110	74.8	422.95	12662.9	5147.6	1975.45	1.15	13.70%	238.0
3	120	81.6	446.36	13287.0	5553.7	2051.61	1.15	13.67%	230.8
4	130	88.4	467.23	13896.7	5959.8	2048.02	1.14	13.58%	224.5
5	140	95.2	488.53	14493.4	6366.0	2068.91	1.13	13.52%	219.0
6	150	102.0	506.70	15078.1	6766.3	2050.00	1.12	13.40%	214.1
7	160	108.8	526.45	15652.8	7172.4	1972.95	1.12	13.33%	209.7
8	170	115.7	542.87	16217.9	7578.5	1842.56	1.10	13.20%	205.8
9	180	122.5	557.98	16774.3	7984.6	1671.88	1.09	13.05%	202.2
10	190	129.3	566.92	17322.6	8390.7	1285.77	1.07	12.78%	198.9
11	200	136.1	577.89	17863.6	8796.7	978.00	1.05	12.58%	195.9
12	210	142.9	588.03	18397.6	9202.8	645.86	1.03	12.37%	193.2
13	220	149.7	594.57	18925.2	9608.8	189.17	1.01	12.11%	190.6

SHIGO - KAS HPP



SHAHGO HYDRO POWER LIMITED

SHIGO KAS HYDROPOWER PROJECT

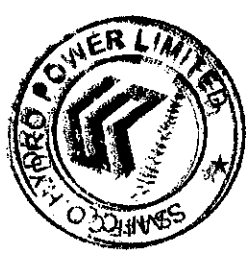
OGEE TYPE WEIR WITH OVERFLOW AND GATED SECTIONS

FLOOD DISCHARGE:		
Return Period	10000	(years)
Peak Discharge	5600	(m3/s)
Normal Op. Level	650	(masl)
Max. Flood Level	654	(masl)
Tailwater Level	640.5	(masl)
River Bed Level	639	(masl)
Freeboard	1	(m)
Height of Weir	11	(m)
Crest Length	108	(m)

GATES:	Overflow	Radial	Flap	Sluice	Non-overflow
Select	yes	yes	no	yes	no
Quantity (no.)	1	4		2	
Crest Level (masl)	650	640.75		640.75	
Width (m)	25	10		10	
Height (m)	11	12		12	
Design Head (m)	4	13.25		13.25	

PIERS:	Overflow	Radial	Flap	Sluice	Non-overflow	
Pier Width (m)	0	4		4		
No. of Piers	1	3		1		
Type of Pier	P2	P2		P2		
Type of Abutment	A1	A2		A2		
Kp	0.01	0.01		0.01		0
Ka	0.2	0.1		0.1		0

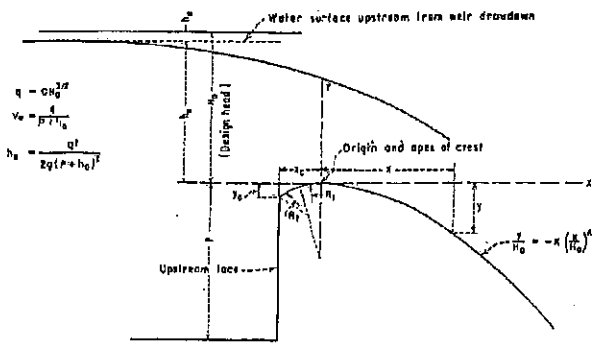
DISCHARGE:	Overflow	Radial	Flap	Sluice	Total 'Q'	
P/H	2.75	0.132075		7.25		
Cd	2.18	2.178593		1.995		
Crest Length (m)	25	52		24		0
Effective Crest (m)	23.32	36.555		17.085	N/A	
Discharge (m3/s)	500	3841.02		1716.562		6057.58
Check - Q					OK	



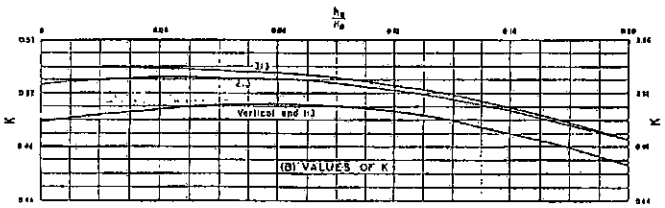
SHIGO KAS HYDROPOWER PROJECT
GEOMETRY (OGEE SHAPE)

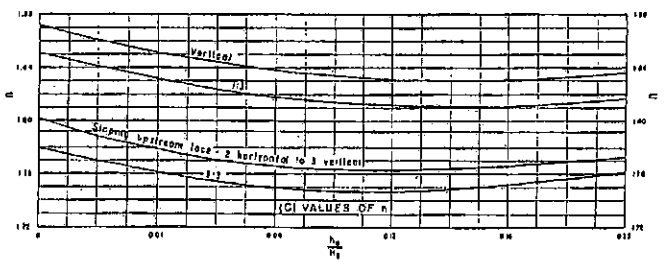
CREST GEOMETRY (OGEE SHAPE)

Discharge capacity	Q	=	500.0	m^3/s	
Width	L	=	25.0	m	
Unit discharge at design head	q	=	20.00	$m^3/s/m$	
Maximum flood surcharge	H_{max}	=	4.00	m	
Height of crest above NSL	P	=	11.00	m	(overflow section)
Approach velocity	$V_a = q/(P+H_o)$				
Approach velocity	V_a	=	1.33	m/s	
Approach velocity head	$h_a = \frac{q^2}{2g(P+H_o)^2}$				
Approach velocity head	h_a	=	0.091	m	
and h_a / H_{max}		=	0.023		



(A) ELEMENTS OF NAPPE-SHAPED CREST PROFILES





Parameters of the crest geometry are determined from the above figure.

SAIFCO HYDRO POWER LIMITED

SHIGO KAS HYDROPOWER PROJECT
GEOMETRY (OGEE SHAPE)

	K	=	0.504		n	=	1.860
	X_c / H_{max}	=	0.284		Y_c/H_{max}	=	0.127
	R_1 / H_{max}	=	0.517		R_2/H_{max}	=	0.220
Slope of weir d/s of crest	$S_{d/s}$	=	1.00	H/V			

The origin of X - Y axis is at the crest of spillway and X_c is distance from the u/s face to crest.

UPSTREAM OF THE ORIGIN / CREST

Distance from u/s face to crest	X_c	=	-1.136	m
Elevation from u/s face to crest	Y_c	=	-0.508	m
Larger / second radius	R_1	=	2.066	m
Smaller / first radius	R_2	=	0.881	m

DOWNSTREAM OF THE ORIGIN / CREST

$$\frac{Y}{H_o} = -K\left(\frac{X}{H_o}\right)^n$$

	X	=	-2.744	Y^0.538
	Y	=	-0.153	X^1.86

LOCATION OF TANGENT POINT

The ogee curve will terminate at tangent point and after that the chute will follow the given slope.

X-coordinate of tangent point

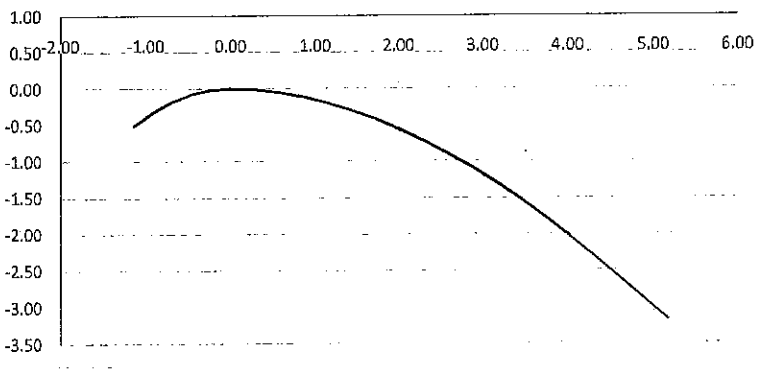
$$X_t = \left(\frac{1}{S_{d/s} n K H_{max}^{1-n}}\right)^{\frac{1}{n-1}}$$

" " " " " X_t = 4.313 m

Y-coordinate of tangent point

$$Y_t = -H_{max} K\left(\frac{X_t}{H_{max}}\right)^n$$

" " " " " Y_t = -2.319 m



X	Y
-1.14	-0.51
-0.91	-0.33
-0.68	-0.18
-0.45	-0.08
-0.23	-0.02
0.00	0.00
0.29	-0.02
0.58	-0.05
0.86	-0.12
1.15	-0.20
1.44	-0.30
1.73	-0.42
2.01	-0.56
2.30	-0.90
2.88	-1.30
3.45	-1.78
4.03	-2.32
4.31	-2.32
5.18	-3.18

SHIGO POWER LIMITED

SHIGO KAS HYDROPOWER PROJECT
DESIGN OF BASIN (GATED SECTION)

HWL		=	650.0	m
TWL		=	643.0	m
Crest Level		=	640.00	m
Design Flood	Q	=	506.0	m^3/s
Width	L	=	10.0	m
Unit discharge at design head	q	=	50.60	$m^3/s/m$
Maximum flood surcharge	H_{max}	=	10.00	m
Velocity at crest	V_C	=	5.06	m/s
Flow Depth entering the Jump	D_1	=	2.752	m
Bed Level of stilling basin	BL_{sb}	=	630.0	masl

$$h_f = n^2 V_C^2 L \frac{1}{R^{4/3}}$$

n = 0.014

Friction Loss	h_f	=	0.18	m		approx L = 15.56
Flow velocity entering the jump	V_1	=	18.39	m/s	⇐	$V_1 = q / D_1$
650.00		=	650.00			$WL_{u/s} = BL_{sb} + D_1 + \frac{V_1^2}{2g} + h_e + h_f$
RHS		=	LHS			
Froude Number	F_1	=	3.540			$F_1 = \frac{V_1}{\sqrt{gD_1}}$
Conjugate Depth	D_2	=	Oscillating 12.5	m		$\frac{D_2}{D_1} = 0.5\left(\sqrt{1+8F_1^2} - 1\right)$
Corresponding Water Level		=	642.5	masl		

(Check if this water level is higher than the level from Tailwater Rating Curve)

Required Minimum TWL	TWL_{min}		642.18	
Check Jump Sweepout		=	O.K.	
Required Bed Level of Basin	BL_{sb}	=	629.91	masl
Check Bed Level of Basin		=	Excavate 0.09	m

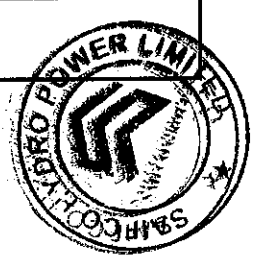
Increase by 10%

LB / D2 = 5.57 against Froude no LHS (from Paterka)

Length of Stilling Basin	L_B	=	69.5	m	⇐	L_B / D_2 = 5.57
Height of walls of basin	H_B	=	$D_2 + 0.1 * (D_1 + V_1)$			
" " " "	H_B	=	13.60	m		

Type - II	
Recommended Curve for L / D_2	
F_1	L / D_2
4.00	3.60
5.00	3.85
6.00	4.05
7.00	4.15
8.00	4.20
9.00	4.30
10.00	4.32
11.00	4.35
12.00	4.35
13.00	4.35
14.00	4.30
14.50	4.25

Min TWL	
From Paterka for Basin-II	
F_1	TW/D_1
1.00	1.00
2.00	2.50
4.00	5.00
6.00	7.50
8.00	10.50
10.00	13.00
12.00	16.00
14.00	18.75
16.00	21.50
18.00	24.50



SHIGO KAS HYDROPOWER PROJECT
WEIR GATED SECTION

Parabolic Chute

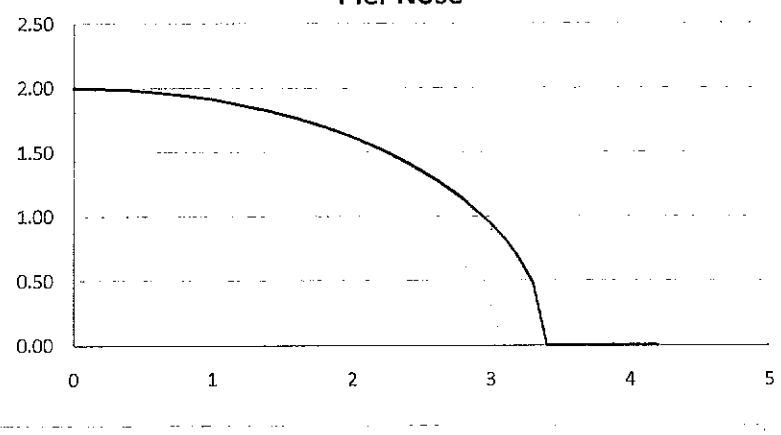
$$-Y = X\tan\theta + \frac{X^2}{4HCos^2\theta}$$

TWL		643.00	m asl
Q flood		850	m^3/s
HWL		650.00	m asl
Head on the center of gate	H	= 10	m
Slope of chute u/s of gate		= 0.05	
Angle of u/s slope with horizontal	Θ	= 0.05	radians
Maximum 'Y'		= 10.75	
Maximum 'X'		= 19.7323	

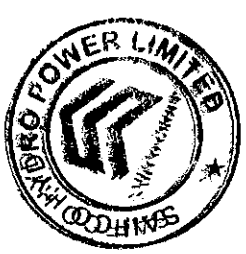
Pier Nose

$$Y = 0.5a\sqrt{1-\left(\frac{X}{b}\right)^2}$$

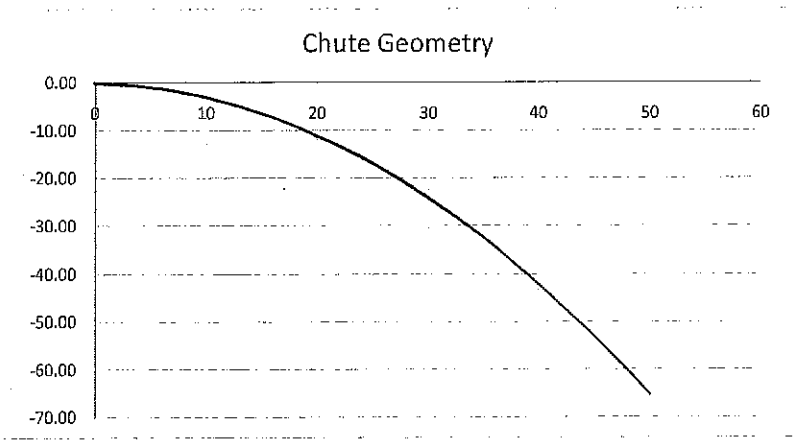
Width of Pier	a	= 4	m
Length of Pier Nose	b	= 3.4	m



Y	X
0	2.00
0.2	2.00
0.4	1.99
0.6	1.97
0.8	1.94
1	1.91
1.2	1.87
1.4	1.82
1.6	1.76
1.8	1.70
2	1.62
2.2	1.52
2.4	1.42
2.6	1.29
2.8	1.13
3	0.94
3.1	0.82
3.2	0.68
3.3	0.48
3.4	0.00



SHIGO KAS HYDROPOWER PROJECT
WEIR (GATED SECTION)



X	Y
0	0.00
1	-0.08
2	-0.20
3	-0.38
4	-0.60
5	-0.88
6	-1.20
7	-1.58
8	-2.00
9	-2.48
10	-3.01
11	-3.58
12	-4.21
13	-4.89
14	-5.61
15	-6.39
16	-7.22
17	-8.09
18	-9.02
19	-10.00
20	-11.03
21	-12.10
22	-13.23
23	-14.41
24	-15.64
25	-16.91
26	-18.24
27	-19.62
28	-21.05
29	-22.53
30	-24.06
31	-25.64
32	-27.26
33	-28.94
34	-30.67
35	-32.45
36	-34.28
37	-36.16
38	-38.09
39	-40.07
40	-42.10
41	-44.18
42	-46.31
43	-48.49
44	-50.72
45	-53.00
46	-55.33
47	-57.71
48	-60.14
49	-62.63
50	-65.16

SHIGO HYDRO POWER LIMITED

SHIGO KAS HYDROPOWER PROJECT

DESIGN OF INTAKE AND CONNECTING CHANNEL

INTAKE

Design discharge	Q_d	=	150.00	m^3/s	
Maximum Intake discharge	Q_i	=	165.00	m^3/s	10% increase
Maximum Operating Level	FSL	=	651.50	m asl	
Normal Operating Level	NOL	=	650.00	m asl	
Minimum Operating Level	MOL	=	648.00	m asl	
Required velocity at intake	v_i	=	1.20	m/s	
Maximum velocity at intake	v_{max}	=	1.50	m/s	
Required flow area	A_i	=	137.50	m^2	
Height of intake openings		=	5.00	m	
Width of intake openings		=	9.80	m	
Number of intake openings		=	3	no	
Discharge capacity		=	176.40	m^3/s	OK
Invert level of gates/opening		=	644.00	m asl	
Top level of opening		=	649.00	m asl	
Velocity at MOL		=	1.40	m/s	OK

CONNECTING CHANNEL

$$V = \frac{1}{n} S^{1/2} R^{2/3} \qquad Area = (b + zy)y$$

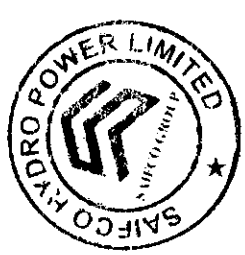
$$Perimeter = b + 2y\sqrt{1 + z^2}$$

$$Topwidth = b + 2z(y + fb)$$

Rectangular Channel

Freeboard	0.50	y_{min}	7.50	m			
Long. Slope	0.001	A	135.0	m^2			
Manning "n"	0.016	P	33.0	m	Side slope	z	0.0
		R_h	4.1				

Width of connecting channel	b	=	18.00	m	
Discharge capacity at MOL	Q_c	=	682.49	m^3/s	
Maximum velocity in channel	v_c	=	5.06	m/s	(at MOL)
Bottom level of channel at start		=	644.00	m	
Top level of channel at start		=	652.00	m	
Velocity at normal operating level		=	1.53	m/s	(in channel)
Velocity at Maximum operating level		=	1.22	m/s	(in channel)
Top width of channel		=	18.00	m	
Required flow area for gates	A_g	=	82.50	m^2	
Height of gates		=	3.50	m	
Width of gates		=	4.50	m	
Velocity through gates		=	2.62	m/s	



SHIGO KAS HYDROPOWER PROJECT
OPTIMIZATION OF TUNNEL DIAMETER

Design Data

Tunnel shape	Horseshoe	
Tunnel length	10200	m
Number of Tunnels	1	no.
Design discharge	150	m^3/s

Cost Data

Energy cost	6.5	Rs./KWh
Cost of rock bolts	250	Rs./kg
Cost of shotcrete	14700	Rs./m^3
Cost of concrete lining	11500	Rs./m^3

Discount factor	12	%
Useful life of tunnel	30	years
Construction Period	5	years

	Rock	*Shotcrete*	*Concrete*
Manning's coefficient (shotcrete)	0.033	0.026	0.014

Rock Condition	Good	Average	Poor	
% of tunnel length	50	30	20	%
Concrete lining thickness (radial)	300	350	500	mm
Shotcrete thickness (radial)	100	125	150	mm
Convergence allowance (radial)	50	100	150	mm
Excavation cost	6800	5300	4100	Rs./m^3
Spacing of rock bolts	30	20	15	m

Formulae

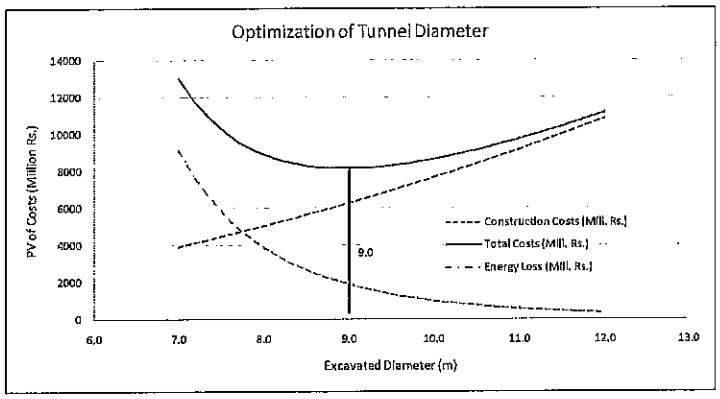
Head loss = $$h_f = \frac{n^2 Q^2}{A^2} \frac{L}{R^{4/3}}$$

Wastage Factors

Excavation	10	%
Shotcrete	20	%
Concrete	10	%
Rock bolts	10	%

Sr. #	Excavated Diameter (m)	Flow Area (Average)	Hydraulic Diameter			Losses		PV of Costs (Million Rs.)						
			(Good)	(Average)	(Poor)	(Head Loss)	(Energy Loss)	(Excavation)	(Shotcrete)	(Concrete)	(Bolts)	(Sub-Total) all tunnels	(Energy Loss)	(Total)
1	7.0	28.38	6.10	5.85	5.40	33.18	174.13	2649	67	343	13	3904	9117	13021
2	7.1	29.36	6.20	5.95	5.50	30.28	158.95	2725	68	348	13	4009	8323	12331
3	7.2	30.35	6.30	6.05	5.60	27.69	145.33	2803	69	353	14	4115	7609	11724
4	7.3	31.37	6.40	6.15	5.70	25.35	133.06	2881	70	358	14	4222	6967	11189
5	7.4	32.39	6.50	6.25	5.80	23.25	122.02	2960	71	364	14	4331	6389	10720
6	7.5	33.44	6.60	6.35	5.90	21.35	112.04	3041	72	369	14	4441	5866	10308
7	7.6	34.50	6.70	6.45	6.00	19.63	103.02	3123	73	374	14	4553	5394	9947
8	7.7	35.58	6.80	6.55	6.10	18.07	94.86	3205	74	379	15	4666	4967	9633
9	7.8	36.67	6.90	6.65	6.20	16.66	87.45	3289	75	384	15	4781	4579	9359
10	7.9	37.78	7.00	6.75	6.30	15.38	80.72	3374	76	389	15	4896	4226	9123
11	8.0	38.91	7.10	6.85	6.40	14.21	74.59	3460	77	394	15	5013	3906	8919
12	8.1	40.06	7.20	6.95	6.50	13.15	69.02	3547	78	399	15	5132	3614	8746
13	8.2	41.22	7.30	7.05	6.60	12.18	63.93	3635	79	404	16	5252	3347	8599
14	8.3	42.40	7.40	7.15	6.70	11.29	59.28	3724	80	409	16	5373	3104	8477
15	8.4	43.59	7.50	7.25	6.80	10.48	55.03	3815	81	414	16	5496	2881	8377
16	8.5	44.80	7.60	7.35	6.90	9.74	51.13	3906	82	419	16	5620	2677	8297
17	8.6	46.03	7.70	7.45	7.00	9.06	47.56	3998	83	425	16	5745	2490	8235
18	8.7	47.27	7.80	7.55	7.10	8.44	44.28	4092	84	430	16	5872	2319	8191
19	8.8	48.53	7.90	7.65	7.20	7.86	41.27	4186	85	435	17	6000	2161	8161
20	8.9	49.81	8.00	7.75	7.30	7.33	38.50	4282	86	440	17	6130	2016	8146
21	9.0	51.10	8.10	7.85	7.40	6.85	35.95	4379	86	445	17	6260	1883	8143
22	9.1	52.41	8.20	7.95	7.50	6.40	33.59	4477	87	450	17	6391	1761	8152
23	9.2	53.74	8.30	8.05	7.60	5.99	31.42	4576	88	455	17	6526	1645	8171
24	9.3	55.08	8.40	8.15	7.70	5.60	29.41	4676	89	460	18	6661	1540	8201
25	9.4	56.44	8.50	8.25	7.80	5.25	27.55	4777	90	465	18	6798	1444	8240

Sr. #	Excavated Diameter (m)	Flow Area (Average)	Hydraulic Diameter			Losses		PV of Costs (Million Rs.)						
			(Good)	(Average)	(Poor)	(Head Loss)	(Energy Loss)	(Excavation)	(Shotcrete)	(Concrete)	(Bolts)	(Sub-Total) all tunnels	(Energy Loss)	(Total)
26	9.5	57.82	8.60	8.35	7.90	4.92	25.83	4879	91	470	18	6935	1353	8288
27	9.6	59.21	8.70	8.45	8.00	4.62	24.24	4982	92	475	18	7075	1269	8344
28	9.7	60.62	8.80	8.55	8.10	4.34	22.76	5087	93	480	18	7215	1192	8407
29	9.8	62.05	8.90	8.65	8.20	4.07	21.39	5192	94	486	19	7357	1120	8477
30	9.9	63.49	9.00	8.75	8.30	3.83	20.11	5298	95	491	19	7500	1053	8553
31	10.0	64.95	9.10	8.85	8.40	3.61	18.93	5406	96	496	19	7645	991	8636
32	10.1	66.43	9.20	8.95	8.50	3.40	17.82	5515	97	501	19	7791	933	8724
33	10.2	67.92	9.30	9.05	8.60	3.20	16.80	5624	98	506	19	7938	879	8818
34	10.3	69.43	9.40	9.15	8.70	3.02	15.84	5735	99	511	20	8087	829	8916
35	10.4	70.96	9.50	9.25	8.80	2.85	14.94	5847	100	516	20	8237	782	9020
36	10.5	72.50	9.60	9.35	8.90	2.69	14.11	5960	101	521	20	8389	739	9127
37	10.6	74.06	9.70	9.45	9.00	2.54	13.33	6074	102	526	20	8541	698	9239
38	10.7	75.63	9.80	9.55	9.10	2.40	12.60	6189	103	531	20	8696	660	9355
39	10.8	77.23	9.90	9.65	9.20	2.27	11.92	6306	104	536	20	8851	624	9475
40	10.9	78.84	10.00	9.75	9.30	2.15	11.28	6423	105	541	21	9008	591	9599
41	11.0	80.46	10.10	9.85	9.40	2.04	10.68	6541	106	547	21	9167	559	9726
42	11.1	82.10	10.20	9.95	9.50	1.93	10.12	6661	107	552	21	9326	530	9856
43	11.2	83.76	10.30	10.05	9.60	1.83	9.60	6781	108	557	21	9487	502	9990
44	11.3	85.44	10.40	10.15	9.70	1.73	9.10	6903	109	562	21	9650	477	10126
45	11.4	87.13	10.50	10.25	9.80	1.65	8.64	7026	110	567	22	9814	452	10266
46	11.5	88.84	10.60	10.35	9.90	1.56	8.20	7150	111	572	22	9979	429	10408
47	11.6	90.56	10.70	10.45	10.00	1.48	7.79	7274	112	577	22	10146	408	10553
48	11.7	92.30	10.80	10.55	10.10	1.41	7.40	7400	113	582	22	10314	388	10701
49	11.8	94.06	10.90	10.65	10.20	1.34	7.04	7527	114	587	22	10483	369	10852
50	11.9	95.84	11.00	10.75	10.30	1.28	6.70	7656	115	592	23	10654	351	11004
51	12.0	97.63	11.10	10.85	10.40	1.21	6.37	7785	116	597	23	10826	334	11159



SHIGO KAS HYDROPOWER PROJECT
DESIGN OF SANDTRAP

BASIC DATA

Design discharge (turbines)	Q_T	=	150.00	m^3/s	
Add 10% sediemnts flushing flows					
Design capacity of sandtrap	Q_D	=	165.00	m^3/s	
No. of chambers	n_c	=	3	no.	
Discharge per chamber	Q	=	55.00	m^3/s	
Critical sediment grain size	d	=	0.20	mm	
Density of sand	ρ	=	2.60	ton/m^3	or g/cc

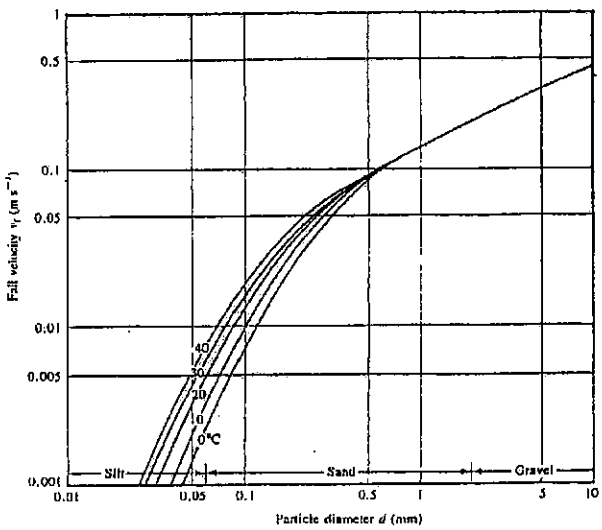
FLOW & SETTLING VELOCITIES

FLOW VELOCITY

Flow velocity (required) $v_d = a\sqrt{d}$ cm/s *Ref: Mosonyi*

Coefficient	a	=	44	
Maximum flow velocity in sandtrap	v_d	=	19.68	cm/s
Maximum flow velocity in sandtrap	$v_{d'}$	=	0.20	m/s

SETTLING VELOCITY



Settling velocity in standing water $v_{s'}$ = 0.0251 m/s *Ref: GTZ*

Alternatively: $v_{s'} = \frac{100}{9d}\left(\sqrt{1+1.57*10^2 d^3} - 1\right)$ mm/s

(for T 20° & grain to water density ratio of 2.65) *Ref: ESHA Guide*

Settling velocity in standing water	$v_{s'}$	=	27.89	mm/s
" " " "	$v_{s'}$	=	0.0279	m/s

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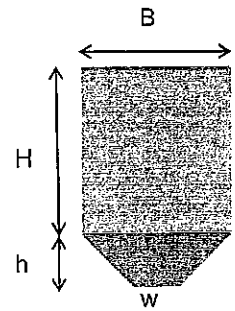
(select the larger value of settling velocity from above)

Selected settling velocity	$v_{s'}$	=	0.0279	m/s

SANDTRAP GEOMETRY & CRITICAL VELOCITY CHECKS

Required cross sectional area	A_r	=	279.51	m^2	(required)
Allowable max. height to width ratio	H/B	=	0.85	dimensionless	
Width of chamber	B	=	**18.20**	m	
Effective settling depth of chamber	H	=	**15.50**	m	(at start)



Ref: Mosonyi

Reduction factor $\alpha = 0.132/\sqrt{h}$

Reduction factor	α	=	0.034	

Settling velocity in flowing water $v_s = v_{s'} - \alpha v_d$

" " " "	v_s	=	0.0213	m/s

Length of chamber $L = \dfrac{v_d H}{v_s - 0.04\, v_d}$

Length of chamber (required)	L	=	152.36	m

Alternatively:

Transit time $t = \dfrac{H}{v_{s'} - \alpha v_d}$

Transit time	t	=	727.99	sec

Length of chamber $L = v_d t$

Length of chamber (required)	L	=	143.25	m
Length of chamber (provided)	L	=	**153.00**	m

Width of chamber $B = \dfrac{Qt_d}{LH}$ where $t_d = \dfrac{L}{v_d}$

Therefore width of chamber $B = \dfrac{Q}{v_d H}$

Width of chamber (required)	B	=	18.13	m
Width of chamber (provided)	B	=	18.20	m

CRITICAL VELOCITY

Roughness coefficient	$1/n$	=	66.67	

$$v_{cr} = \frac{1}{n}\left(\frac{HB}{2H+B}\right)\sqrt{\frac{0.03(\rho-1)\rho}{1000}}$$

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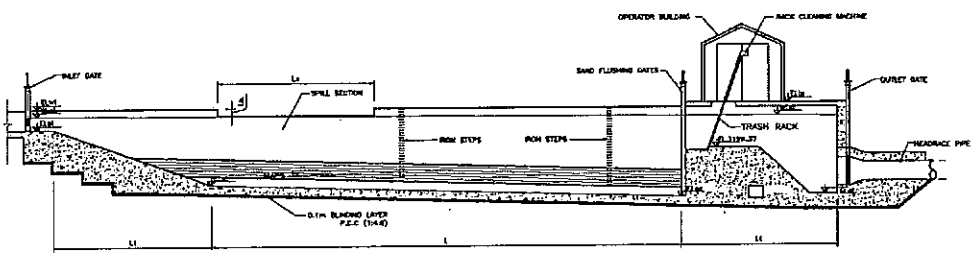
Critical velocity $v_{cr} = \frac{1}{n}\left(\frac{HB}{2H+B}\right)\sqrt{\frac{0.03(\rho-1)\rho}{1000}}$ m/s

Ref: ESHA Guide

Critical velocity	v_{cr}	=	1.184	m/s
Check	$v_{cr} \geq v_d$	=	O.K.	✓
Slope of sedimentation tank	S	=	3.00	%
Effective depth of chamber at start	H_1	=	15.50	m
Effective depth of chamber at end	H_2	=	20.09	m
Mean area of chamber	A_m	=	323.87	m^2
Mean velocity in chamber	v_m	=	0.170	m/s
Check	$v_{cr} \geq v_m$	=	O.K.	✓



LONGITUDINAL SECTION (S1-S1)

TRAP EFFICIENCY

Percentage of sediments retained $P = (1 - e^{\frac{-Lv_s}{v_m H}}) * 100$ *Ref: L.W. Mays*

Constant	e	=	2.718				
Particle size / diameter (mm)	d	=	0.50	0.25	0.20	0.10	0.05
Settling vel. in standing water (m/s) (at 20°C, in water)	v_s	=	0.079	0.038	0.028	0.008	0.002
Percentage of sediments retained	S	=	99%	90%	81%	39%	12%

FINAL DIMENSIONS

Freeboard in sandtrap	$f.b.$	=	0.50	m
Thickness of top slab	t_t	=	0.00	m
Hopper Depth	d_{ho}	=	2.40	m
Width of side walls at top	w_{st}	=	1.00	
Width of side walls at bottom	w_{sw}	=	2.00	m
Thickness of bottom slab	t_b	=	1.00	m

$d_{ho} = \frac{B - W}{2}$

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Thickness of top slab	t_t	=	0.00	m	
Width & height of flushing duct	W_{fc}	=	2.50	m	(inside the sandtrap)

Total height of chamber

$$H_{TS} = f.b. + t_t + H + \frac{B - W_{fc}}{2} + W_{fc} + t_b$$

Total height of chamber (at start)	H_{TS}	=	6.50	m	
Total height at deepest point (at end)	H_{TE}	=	9.00	m	⬅

Total width of sandtrap

$$W_T = w_{sw}(n+1) + Bn$$

Total width of sandtrap	W_T	=	49.00	m	⬅
Total length of sandtrap	L_T	=	115.00	m	⬅

7. TRASHRACK

Rack Cleaning Machine		=	no	(yes or no - in small letters)

Width of Trashrack

$$b_{ra} = nt + b_{ch}$$

Ref: GTZ Publication "High Head Hydropower"

Number of rack bars

$$n = \frac{b_{ch}}{b} - 1$$

Width of rack bars	t	=	12.0	mm
Clearance between rack bars	b	=	150.0	mm
Inclination of trashrack	z	=	4.0	z V : 1 H
Angle of bars with horizontal	α	=	76.0	degrees

Width of Trashrack

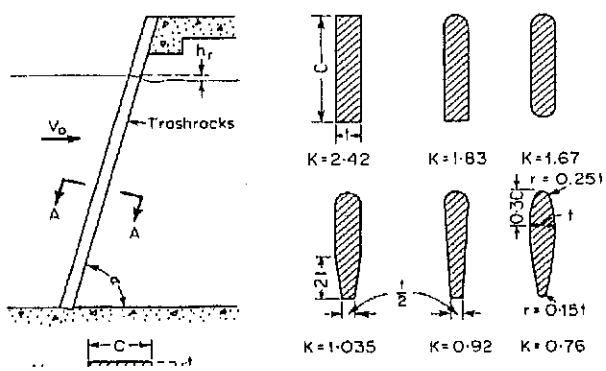
$$b_{ra} = W_T - 2.0w_{sw}$$

Width of Trashrack	b_{ra}	=	45000.0	mm
Height of trashrack	h_{ra}	=	6440.0	mm
Channel width / diameter	b_{ch}	=	41677.8	mm

Number of rack bars

$$n = \frac{b_{ra} - b}{b + t}$$

" " "	n	=	276.9	no.



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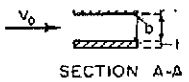



Entrance velocity at trashrack	v_e	=	0.52	m/s	
Average flow velocity between bars	$v_{bars} = v_e \frac{t+b}{b}$				*Ref: Mosonyi "Vol-I: page # 537"*
Average flow velocity between bars	v_{bars}	=	0.0025	m/s	

HEADRACE (PIPE OPTION)

Effective head from center of pipe	h_e	=	3.2	m	
Diameter of bellmouth for pipe	D_{bm}	=	3.8	m	$D_{bm} = 1.5D$
Entrance velocity in bellmouth	v_{bm}	=	13.23	m/s	

HEADLOSSES

FRICTION LOSS

Friction headloss (Manning) $h_f = n^2 \frac{V^2 L}{R^{4/3}}$

Flow area (per chamber) $A = BH + W_{fc}\left(\frac{W_{fc}+B}{2}\right) + \left(\frac{B-W_{fc}}{2}\right)^2$

Flow area (per chamber)	A	=	369.60	m^2

Wetted perimeter (per chamber) $P = 2H + 2\frac{(B-W_{fc})/2}{\cos 45°} + 3W_{fc}$

Wetted perimeter (per chamber)	P	=	60.70	m
Hydraulic Radius	R	=	6.09	m
Friction headloss (per chamber)	h_f	=	0.00012	m

ENTRANCE LOSS

$h_L = K\frac{v^2}{2g}$ *Ref: Mosonyi*

K = 0.10

Entrance headloss	h_{LE}	=	0.05	m

GATE SLOT LOSS

$$h_{l,s} = 1.2\frac{v^2}{2g}\left[(1-\beta)^2 + \left(\frac{1-\alpha}{\alpha}\right)^2\right]$$

Where $\beta = \frac{F}{F_y} = \frac{Bh}{Bh + 2y^* h + yB}$ *Ref: Mosonyi "Vol-I: page # 530"*

and Weisbach coefficient $\alpha = 0.63 + 0.37\beta^3$

Velocity (just before the slots)	v_{in}	=	3.00	m/s
Width of entrance flume	B	=	3.25	m

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Depth of entrance flume	h	=	0.90	m
Width of gate slot	e_g	=	0.20	m
Depth of gate slot	d_g	=	0.10	m

if $d > 0.2e$ *then* $y^* = 0.2e$
& if $d <= 0.2e$ *then* $y^* = d$

For gate slots	y_g^*	=	0.04	m
Coefficient (gate slots)	β_g	=	0.935	
Weisbach coefficient (gate slots)	α_g	=	0.933	
Head loss at gate slots	h_{LG}	=	0.005	m

U/S TRANSITION LOSS (CONTRACTION LOSS)

Ref: IIT, Roorkee "page # 38"

$$h_L = K\frac{\left(v_1^2 - v_2^2\right)}{2g}$$ K = 0.30

Headloss in u/s transition	h_{Lut}	=	0.14	m

D/S TRANSITION LOSS (EXPANSION LOSS)

Ref: IIT, Roorkee "page # 38"

$$h_L = K\frac{\left(v_1^2 - v_2^2\right)}{2g}$$ K = 0.20

Headloss in d/s transition	h_{Ldt}	=	0.02	m

TRASHRACK LOSS

$$h_{l,ra} = K\left(\frac{t}{b}\right)^{4/3}\frac{v_{bars}^2}{2g}\sin\alpha$$

Ref: Davis: page # 24-15 "Hydraulics Handbook"

Coefficient depending on bar shape	K	=	2.42	
Rack losses	$h_{l,ra}$	=	0.0001	m

TOTAL HEADLOSS IN SANDTRAP (Entrance + Gate Slot + Transitions + Trashrack + Friction)

Total headloss in sandtrap	h_{LT}	=	**0.23**	m

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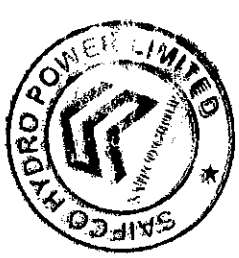
CHAPTER

8

PROJECT LAYOUT AND DESIGN



ANNEX

8A

FLOW DURATION CURVE
&
ANNUAL ENERGY CALCULATION

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ANNEX

8B

DRAWINGS

ANNEX

8C

DESIGN CALCULATION

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CHAPTER 8

PROJECT FINAL LAYOUT & DESIGN

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8.0 GENERAL

The projects site is located 10 km downstream of Timergara. The proposed weir site is located near village Shigo kas and powerhouse will be situated on the left bank Panjkora River just downstream of Utala village. The Project is located on the left bank of Panjkora River and is accessible through mettaled road from Chakdara to Timergara. Panjkora River is the main artery of the area which joins to the Swat River some 40 km downstream of Timergara. Timergara-Dir road provides access to the left bank of the project area.

The project will utilize the flows of Panjkora River to generate 102 MW (3 x 34MW) with average energy output of 520 GWh. The rated discharge and rated net head for the project have been revised at 150 m^3/s and 78.5 m respectively. Shigo Kas Hydropower Project consists of following major components;

- Diversion weir
- Intake structure
- Sandtrap
- Connecting channel
- Headrace tunnel
- Surge tank
- Pressure shaft and valve chamber
- Penstock manifold
- Surface powerhouse
- Tailrace channel
- Switchyard
- Transmission line

8.1 Criteria

- Design flood water level upstream of weir should not submerge the Dir road.
- Minimum compensation flows should be constantly released from weir.



8.2 Design Data for Selected Layout

After the layout screening studies the Consultants embarked upon the task to collect additional and more extensive data related to topography, geology, environment and hydrology. The

design data used at this stage for layout planning and hydraulic dimensioning is briefly described below.

8.2.1 Contour Map

Topographic survey of Shigo Kas Project has been conducted in 2013. Planning and layout studies for the selected option are based on Topographic maps developed. Using the horizontal and vertical control established in the project area, topographic survey was carried out using total stations in the form of random spot elevation survey to create digital model. All man-made and natural features visible on the ground were surveyed and plotted. Field survey data was acquired in digital format on electronic media and the same was downloaded to the computer thus avoiding all the sources of human error likely to be caused in manual entry of field data.

Base map of Patrak Shringal Hydropower Project was prepared using the remote sensing and GIS. Latest available high resolution satellite image was procured to digitize the land features, whereas SRTM elevation data was utilized to generate contours. Large scale and highly accurate survey points collected during field topographic survey were also embedded into it to improve the map quality. Latest cartographic environment was then used to prepare the GIS maps.

8.2.2 Design Flood

Design flood adopted for the design of headwork corresponds to a return period of 10,000 years. This is very high return period considering the size of the project. However, it is a binding limitation because the nearby arterial road is of strategic importance and it must not be submerged at any cost because of the weir structure of Shigo Kas project. Same criteria have been adopted in the feasibility report/design of Koto project by ACE in the past with the guidance of PEDO. More discussion on design flood is available in the chapter on hydrology and sedimentation.

8.2.3 Normal Headwater Level

The river bed level at proposed weir site is at El. 639 masl. The river bed slope at weir site is very mild (0.33%) and because of narrow section of river at the bend, the flood level is quite high (El. 654 masl corresponding to 10,000 year design flood). These aspects pose serious challenges for design of head works. We have to make high walls for intake and sand trap structures to safe guard against overtopping in the event of design flood. Similarly we have to raise the gate hoisting systems for weir gates to higher elevation as well.

The design discharge for power generation has been optimized at 150m^3/s. Due to the huge suspended sediment load of Panjkora River; a large sand trap structure is required to handle

this design discharge to ensure long term safety of turbines against sediment induced damages. For this purpose deeper sand trap would be more efficient and economical as well because a lot of excavation would be required at the left bank of river to accommodate the huge sand trap structure. The flushing ducts/galleries of sand trap must open into the river at or above El. 641 masl. For this purpose the normal headwater level will have to be raised to maximum extent possible if we want to use the same head works site as suggested by GTZ. That is the core reason why GTZ proposed a much higher dam (40 m) at this site.

After careful examination of above mentioned aspects and site conditions it has been decided to use 650 masl as normal headwater level for power plant operation. This would require higher and more expensive gates for weir structure however the hydraulic efficiency of sand trap would increase significantly and we can also justify the economics of making higher intake structure and wing walls for the weir structure.

8.2.4 Design Discharge

Design Discharge adopted for Shigo Kas HPP is 150m^3/s. More discussion on selection and optimization of design discharge is available in the chapter 04 "Hydrology and Sedimentation".

8.2.5 Geology and Geo-technical Data

At weir site, Panjkora River has narrow valley and the weir structure would be founded on metamorphic rock after excavation of alluviums and river bed deposits up to maximum three meters as per present stage of investigations. Three number boreholes have been drilled along the weir axis.

Intake and Sand trap structures will also be founded on metamorphic rock as per surface geological mapping. One number of borehole each has been drilled for Sand trap and Intake area.

As per surface geological mapping of both options of Power house, sound metamorphic rock is well spread under the foundation at both locations.

8.3 Selected Layout of the Project

The layout for hydropower projects is unique and depends primarily on site specific features, viz., topography, geology, hydro-meteorology, environment etc. No practice can, therefore, be generalized in case of hydel-civil design and presented as best practice. Besides performing structural calculations, design and detailed dimensioning, the construction stage design shall include adaptation of the layout and design corresponding to the situations arising during the construction process.

The brief description of the feasibility stage layout is given below. For layout drawing refer to **Annexure-8B.**

The head works site from GTZ report has been recommended by the Client and therefore adopted by the Consultants. The head works comprises of a low height concrete weir with gated and un-gated (free overflow) sections. The intake of water is located on the left bank of Panjkora River. The sand trap is located immediately after the intake. Three chambered sandtrap has been proposed along the left bank for sediment exclusion. From the end of the sandtrap, the water is conveyed through 65 m long headrace channel up to the inlet portal of headrace tunnel. The headrace tunnel is 10.22 Km long and the section is horseshoe shaped with finished cross-sectional area of 40.63 m^2. Surge-shaft is located at end of the tunnel and is exposed to the surface. The height of the surge-shaft is 42 m and the finished diameter of 20m. About 270 m long high pressure waterway (steel lined shaft or penstocks) conveys water further and bifurcates before feeding three generating units accommodated in the Powerhouse in open cut on the left bank of Panjkora River. The powerhouse site is located downstream Utala which is about 9.5 km downstream of the GTZ dam site measured along the river centerline. A 31m long tailrace channel conveys water from powerhouse and discharges into the Panjkora River.

The project will utilize 150 m^3/s flows to generate 102 MW at a net head of 78.5 m. The headwork has been designed to pass the 10,000 year flood without any increase in the upstream water level as compared to the 'without project' conditions. Power generation can continue in minor floods however, the criteria for allowable sediment concentrations reaching the turbines may dictate otherwise.

The layout plan of Shigo Kas Hydropower Project is shown in **Figure 8.2.**

8.4 Energy Output

The flow duration curve of Panjkora River at Shigo kas weir site is provided at **Annexure-8A.** For energy calculations the headwater is assumed constant at 650 masl, while varying tail water levels have been used as per the rating curve of river at tailrace outlet. The project has gross head of about 91.5 m while the rated net head is 78.5 m for design discharge of 150m^3/s.

The turbine and generator efficiencies have been assumed as 93% and 97% respectively. 5m^3/s environmental releases have been excluded in winter season. The forced and scheduled outages have been assumed as 6 days each.

The Excel based software used for energy estimation is capable of using variable turbine efficiency data for Francis units. The energy is calculated using Flow Duration Curve method.

and the time interval for calculation is taken as 5 days. The head losses have been calculated for each discharge. The model will shut down a Francis turbine if the discharge falls below 40% of the rated unit discharge specified for that turbine.

The average annual energy output comes out to be 520 GWH with a plant factor of about 58%. Turbine unit-1 to unit-3 will be available for 345, 235 and 180 days respectively in an average year. Calculations are attached at **Annexure-8A.**

8.5 Hydraulic Design

The feasibility level design of project components is described below. For drawings of hydraulic structures refer to **Annexure-8B**.

8.5.1 Weir

The layout plan of head works is shown in **Figure 8.3 & 8.4**. The front elevation of weir is shown in **Figure 8.5**. The weir of Shigo Kas project will have three sections as listed below.

- Overflow section (crest length 25m)
- Gated section with stilling basin (4radial gates 10m wide and 12m high)
- Gated section with roller bucket (2 radial gates 10m wide and 12m high)

The overflow section has been provided at the right bank of river. It will mainly be used to spill excess flows upto 100 m^3/s during normal operation of project, during the period when the average flow availability in Panjkora River at weir site ranges between 150 to 250 m^3/s. This section will be in operation most of the time.

The gated section with stilling basin will be provided in the center of existing river course. It will be used to spill excess flows and small floods in summer season while the powerhouse is still in operation. It has a discharge capacity of up to 2000 m^3/s at normal operating level of 650 masl.

The gated section with roller buckets will be provided at the left bank. It will only be used during extreme floods when the tailwater level is sufficiently high for proper operation of roller buckets. It will also be used occasionally to flush the river bed load which has been deposited in front of the power intake.

The average slope of river bed at weir site is 0.33%. The combined discharge capacity of weir is 5600 m^3/s corresponding to a flood level of 654 masl. More details on the three sections of weir are provided in the following text.

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8.5.1.1 Overflow Section

The crest level of 25 m wide overflow section has been fixed at normal operating level of 650 masl. The criterion for normal headwater level is described in previous section of this chapter. Total length of structure in the flow direction is 24.1m. This section can pass about 100m^3/s with an allowable surcharge of 1.5 m, thus allowing more head for power generation. When the water level goes above El. 651.5 masl the gated section will come into operation. The maximum discharge capacity of overflow section will be about 500m^3/s during the weir design flood of 5600 m^3/s corresponding to 10,000 year return period. The plan and longitudinal profile of overflow section are shown in **Figure 8.6**.

The crest is ogee shaped with vertical upstream face. The downstream face of overflow section is stepped at 0.5m height and width up to El.638.2 masl. Energy dissipation is further enhanced through the provision of a roller bucket of 2.5 m radius having a lip level at El. 638.1 masl.

For scour protection, a vertical cut-off extending up to El. 632 masl has been provided at the downstream end of concrete floor. The cut-off will extend into the right bank of the river under the right side wing wall to increase the length of the seepage path round the right side of structure. The elevation of upstream right sidewall has been fixed at El. 656 masl corresponding to 10,000 year flood level of 654 masl. For downstream right side wall it has been fixed at El.646 masl.

Grout curtain from gated section of weir has been extended under the overflow section as well. The gallery invert will be at El. 637 masl. As this weir is not supposed to be used as river crossing by any traffic therefore the bridge from gated section is not extended over the overflow section. A boat can be used to access right bank for inspection of right sidewall during operation and maintenance phase.

8.5.1.2 Gated Section with Stilling Basin

This section of weir will discharge into the existing river course. It is the central section of the weir with 4 no. radial gates, each 10m wide and 12 m high. There will be 2m freeboard for gates at normal operating level of 650 masl. Headwater level can be raised safely upto 651.5 masl during the period when the overflow section is spilling the excess flows upto 100 m^3/s. When fully open the 4 no. gates of this section can pass about 2000 m^3/s while maintain the headwater level at 650 masl. The maximum discharge capacity of this section will be 3500 m^3/s for the design flood of 10,000 year return period. The plan and longitudinal profile of this section are shown in **Figure 8.7**.

The invert level of gates has been fixed at El. 640 masl which is only 1m high than the existing river bed level at the centerline. The trunnion of gates will be at El. 654 masl and the hydraulic hoisting system will be at El. 657 masl. Stop logs has been provided on the upstream sides of gates. The mobile gantry from intake structure would be used for installation or removal of stop logs. The gates are separated by 4 m wide piers. The hydraulic power units (HPU) for radial gates are provided on the top of piers at El. 658 masl. The piers are connected through two bridges; one bridge for gantry crane and general maintenance while the other dedicated for installation or removal of radial gates.

The concrete floor upstream of gate invert will have a slope of 1v:20h towards the flow direction. The highest apron level along the concrete floor is 640.75 masl just upstream of the stop logs location. The chute profile downstream of gate invert confirms to parabolic curve governed by the design head and slope of upstream floor. The total length of concrete floor, including stilling basin, is 112.5 m.

Due to very low height of concrete section there will be very little difference in water levels upstream and downstream of weir in the event of design flood. There will be no need for energy dissipation arrangement for design flood event however, during average summer season operation there will be significant head across the weir when spilling at normal head water level of 650 masl. USBR Type-II stilling basin has been provided for this purpose. The length of stilling basin is 70m with floor level at El. 632 masl. A 2.5 m high solid end sill has been provided at the downstream end of stilling basin. Concrete cutoff at the downstream end will extend into the river bed up to El. 625 masl. The excavation from the existing river bed up to end sill will be done at 1v:10h to provide smooth transition.

The tailwater level corresponding to 10,000 year flood is 653 masl. The elevation of downstream side walls has been fixed at El. 646 masl corresponding to 1600 m3/s (5 to 10 year flood).These walls will be referred to as 'intermediate walls' in the remaining text of this chapter. The height of intermediate walls has been kept at a lower level for economic reasons. In case of extreme floods the tail water will be spread in a wider area and therefore the overtopping of these walls will not have any serious consequences. The sand trap structure at left bank will be protected by a higher sidewall. Grout curtain has been envisaged throughout the entire width of gated section upto El. 623 masl. The gallery invert will be at El. 636 masl.

8.5.1.3 Gated Section with Roller Bucket

This section of weir is provided on the left bank, in front of the intake structure. The profile of concrete floor is same as for the section with stilling basin but instead of stilling basin a roller bucket has been provided with the lip level at El. 633.2 masl. The total length of concrete floor

is 51.5m which is significantly lesser than the total length of stilling basin section. There will be 2 no. radial gates in this section. These gates will not be operated very often because at lower tailwater levels there will be high scour potential at the downstream of roller bucket. This section will contribute only in the event of larger floods. In the design flood event it will have a maximum capacity of 1500 m^3/s. This section will be operated, less frequently, to flush out the river bed load deposited in front of power intake.

The left side wing wall of this section will extend upto the entire length of sand trap. The elevation of this wing wall is 644 masl because above this level the right sidewall of sand trap structure will rise upto El. 654.5 masl giving a freeboard of 1.5 m for sand trap in the event of 10,000 year design flood. The two flushing ducts from sand trap will release the flushing flows downstream of roller bucket through the openings in left wing wall at El. 641.2 masl. The plan and longitudinal profile of this section are shown in **Figure 8.8.**

8.5.1.4 HEC-RAS Model for Weir

The discharge capacity of weir structure has been checked through 1D numerical modeling using HEC-RAS software. About 3 Km length of Pankjora River has been modeled which includes 2200 m long reach of river upstream of weir axis and about 800 m long reach of river downstream of the proposed weir axis. The simulation results confirm that 10,000 year flood water level will not submerge the Timergara road when all gates are fully open.

The screenshots of RAS model for Shigo Kas project are shown in **Figures 1 to 4.**

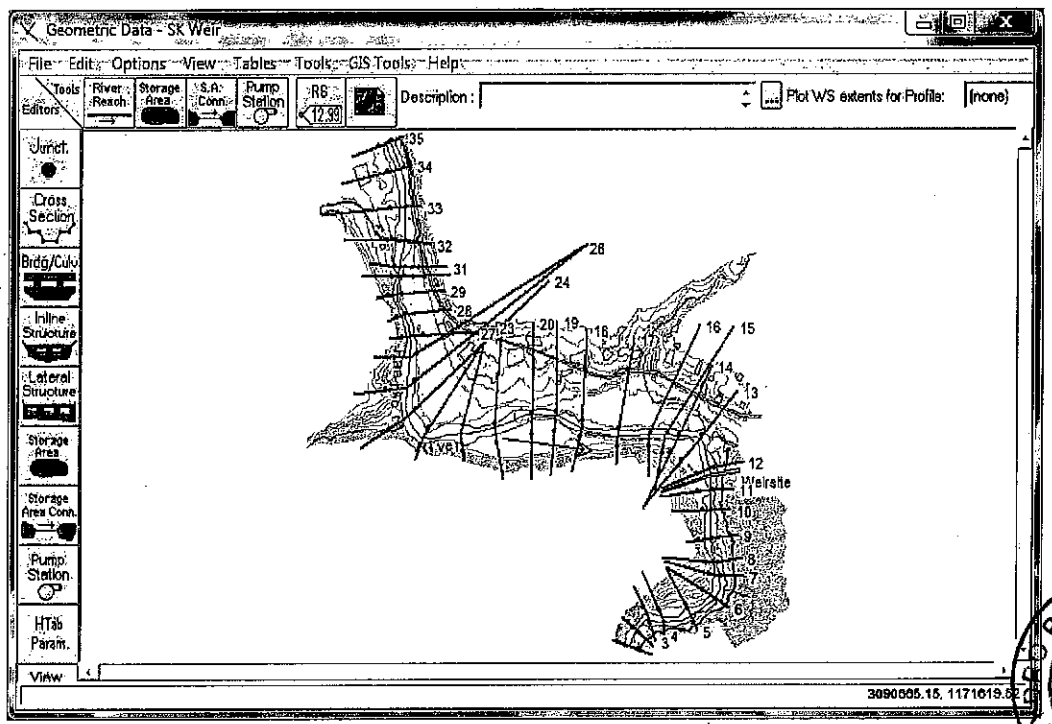

Figure- 1: Geometric Data for HEC-RAS Model

Figure 1: Geometric Data for HEC-RAS Model

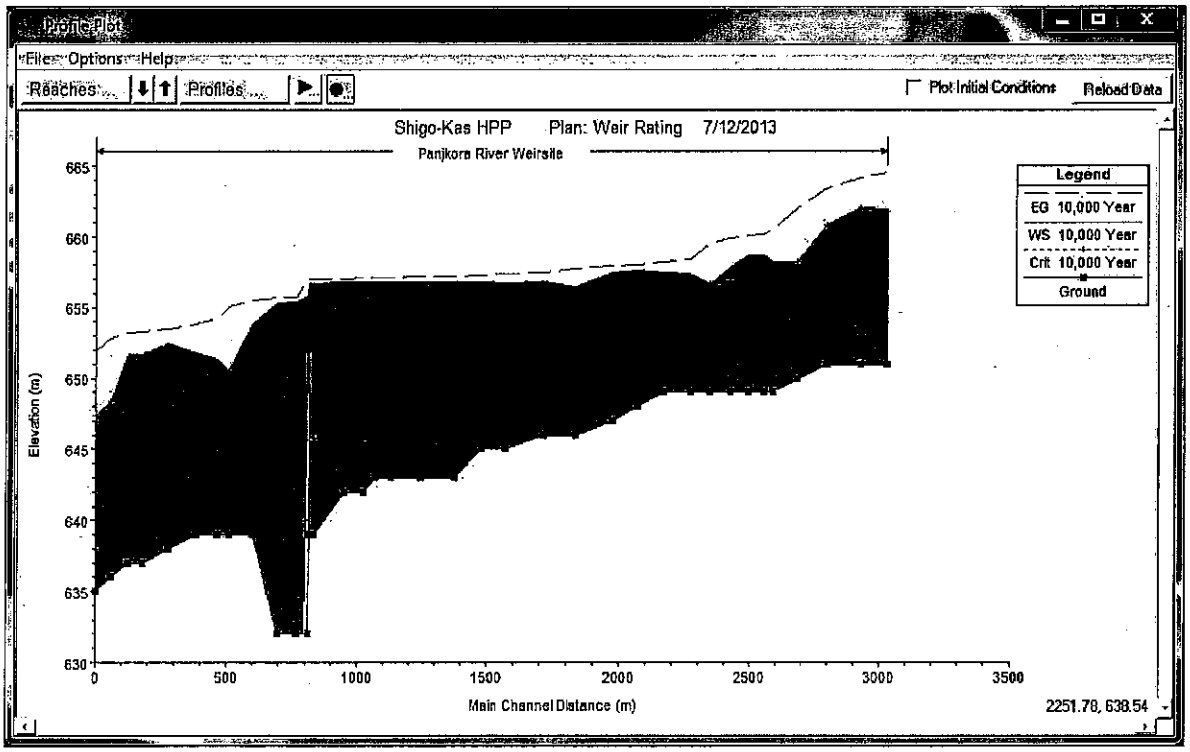

Figure 2: Water Surface Profile for 10,000 Year Flood

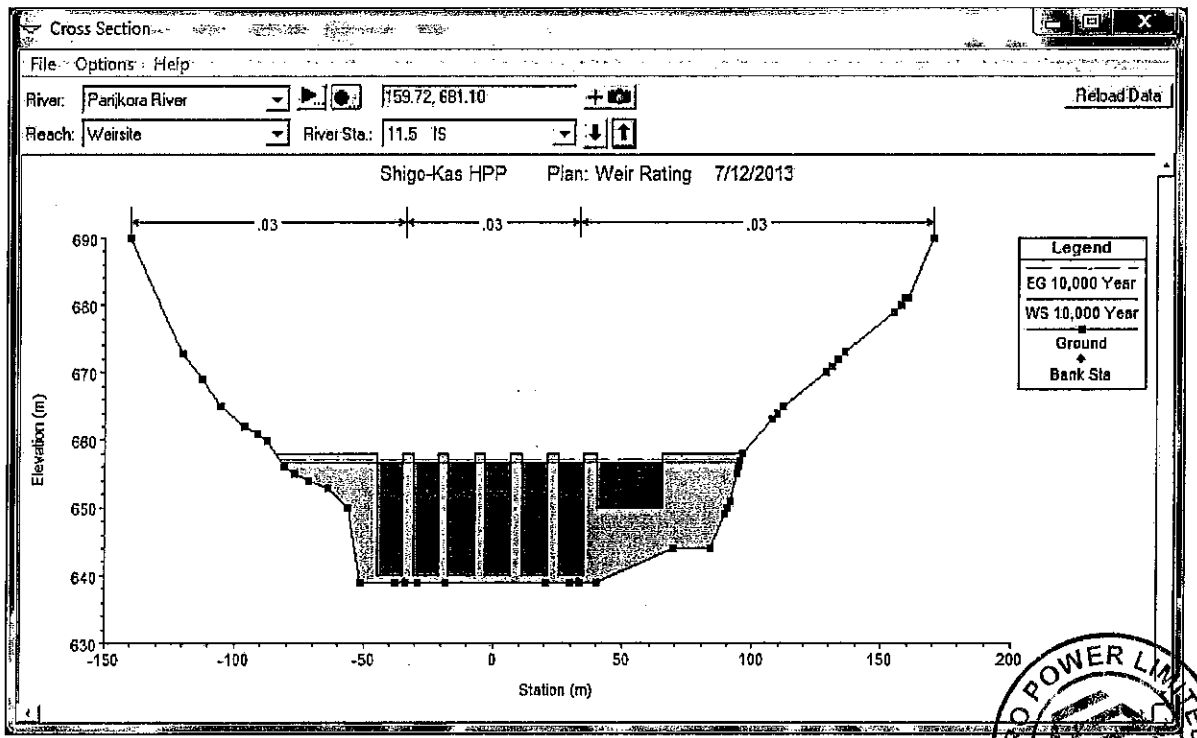

Figure 3: All Gates Open at 10,000 Year Flood

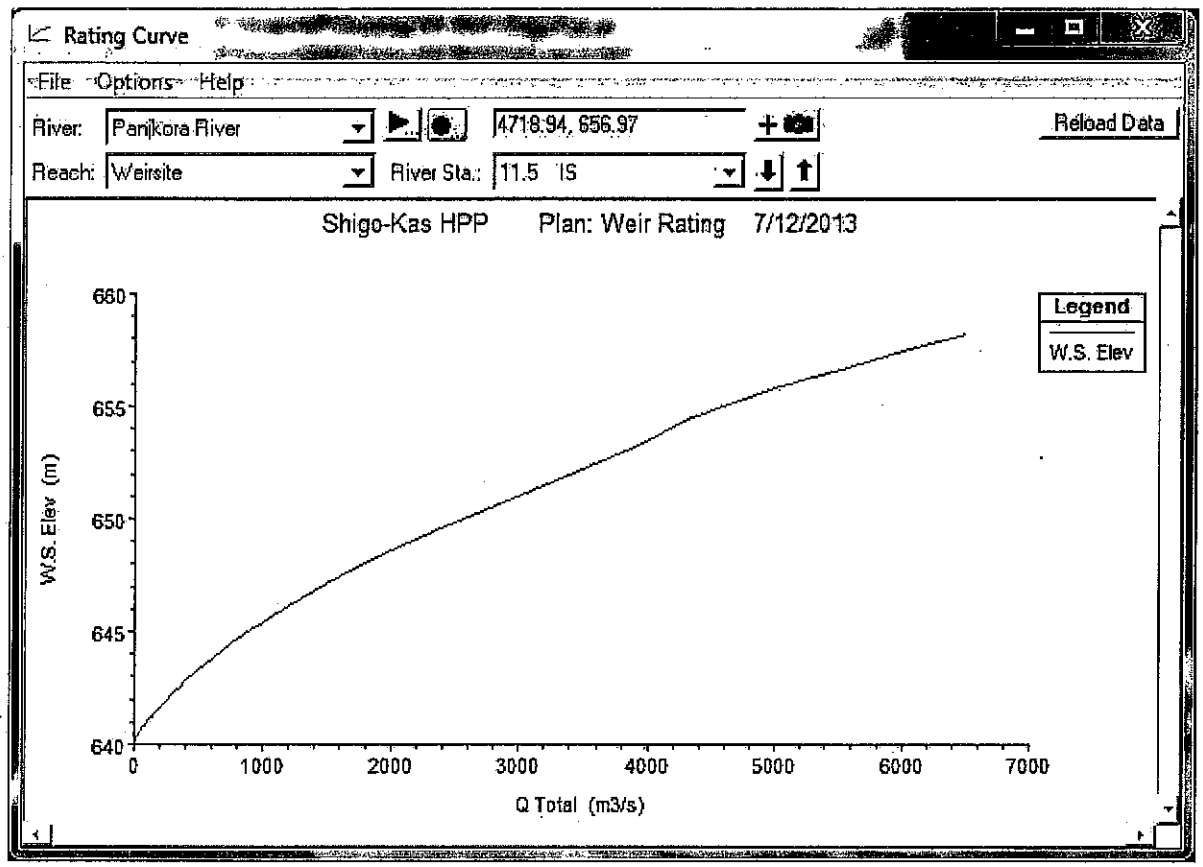

Figure 4: Rating Curve of Shigo Kas Weir Structure

8.5.2 Power Intake

The power intake structure will be located on the left bank. The axis of intake has been aligned at an angle of 105° from the weir axis for better hydraulic entry conditions. The intake and left most pier of gated section of weir are connected through 8 m long concrete retaining wall having elevation 656 masl. The plan/longitudinal section and front elevation of intake structure are shown in **Figure 8.9, 8.10** respectively.

The intake consists of 03 no. culvert inlets each 9.8m x 5m. The invert level of inlets is at El. 644 masl which is 3.25m higher than the apron level of adjacent weir structure. The inlets are separated through 1.5 m wide piers with top level at El. 656 masl. Total width of intake including piers but excluding side walls is 32.5 m. Each inlet is equipped with vertical stoplogs and trashrack inclined at an angle of 80° with the horizontal floor on intake. A rack cleaning machine is proposed which will also be used to insert the stoplogs in front of trashracks.

The height of inlet gradually reduces from 5 m to 3.5 m through a parabolic profile of roof curve. The width of inlets remains constant upto 15 m length, from where the walls of culverts start bending towards the natural flow direction of river. The total bend angle is 105° until the culvert walls become perpendicular to the weir axis. The total width of structure after bend is 20.5 m. 3

no. vertical lift type intake gates, each 5.8m x 3.5m, are provided after the bend. There is provision of stoplogs at the downstream side of intake gates in order to carry our repairs of one gate while the other 2 gates are still open and transferring flows to the sandtrap. Same mobile gantry for weir stoplogs will be used for stoplogs and intake gates.

Total length from inlets to the centerline of intake gates is 42.2 m. The culverts have constant width for 15m from the centerline of intake gates upto the inlet of sandtrap. The height of culvert roof gradually increases from 3.5m to 4.5m in this 15 m length upto the inlet of sandtrap. The access bridge also crosses the intake over this length to connect the left bank access road to the weir structure.

The maximum, normal and minimum operating levels for intake structure will be 651.5, 650 and 648 masl respectively. The flow velocity at the inlet trashracks for normal operating level will be 1.2 m/s and it will increase to about 1.5m/s for diverting the total design discharge at minimum operating level.

The orientation of the intake entrance to the flow is a crucial factor in minimizing debris accumulation which can cause plant stoppages. It is recommended to carry out physical scale modeling for optimization of intake alignment.

8.5.3 Sandtrap

A conventional gravity flushing type sandtrap is envisaged for Shigo Kas HPP. The inlet of sandtrap is located 15m downstream of the centerline of gates for intake structure. The sandtrap structure will be located on the left bank and its centerline is perpendicular to the weir axis. The plan, longitudinal section and cross sections of sandtrap structure are shown in **Figures 8.11, 8.12 and 8.13** respectively.

The inlet width of sandtrap is 20.5 m which gradually increases to its maximum width of 49m in a length of 31.1 m. The sandtrap is divided into three main chambers each 15m in width. At normal operating level the flows in three chambers will be separated by divide walls. The height of intermediate dividing walls is kept at El. 650.5 masl. The three chambers will be connected automatically at maximum operating level of 651.5 masl. Each chamber can handle flows upto 60 m^3/s. Each chamber has been further divided into three compartments through vertical vanes/walls. The width of each compartment is 4.5m which will facilitate the flushing of deposited sediments. The height of vanes is fixed at El. 645 masl. The longitudinal slope of the floor of sandtrap is 3%.

There will be two locations for flushing ducts/galleries along the entire 115 m length of sandtrap. This arrangement is required because the optimal depth of sandtrap could not be

achieved due to the relatively mild slope of river viz-a-viz the lower elevation of sandtrap flushing ducts as compared to river bed level. Intermittent flushing will be carried out by two rows of sluice gates located at a distance of 65m and 115m from the inlet of sandtrap. Each row will have 9 no. sluice gates each 1.5m x 1m. The invert level of flushing duct at the left most gate is 641.5 which slopes down to 641.2 at the exit of ducts. The two flushing ducts will exit into the left bank of river through the left wing wall of weir structure. The flushing ducts will have rectangular cross section 2.5m wide and 1.5m high.

The left side wall of sandtrap is fixed at El. 653 masl while the right sidewall has El. 654.5 masl corresponding to the 10,000 year flood. The right sidewall will join the left wing wall of weir at El. 644 masl. This will result in significant reduction in the height of left wing wall of weir.

The sandtrap width will gradually decrease to 18 m at the outlet to confirm to the top width of rectangular headrace channel which will carry the flows to the inlet of headrace tunnel located about 65m downstream of the outlet of sandtrap structure. The outlet of sandtrap will be equipped with three vertical lift type gates each 5m x 4.5m. These gates will have stoplogs arrangements at both sides to allow for gate repairs while the project is still operational at maximum headwater water level. Fixed gantry has been provided for stoplogs and for gate removal. There is provision of a stepped spillway on the right sidewall of sandtrap besides the outlet gates.

8.5.3.1. Frequency of Flushing System

The sandtrap has been designed for the particle size of 0.2mm given the sufficient length for settling of particles size of 0.2mm and above. During the high flow season the environmental flows will be released through sandtrap flushing pipe. The sandtrap structure has been designed for 10% above design discharge. It is anticipated that 80% to 85% of particles entering into system will be settled in the sandtrap structure and disposed back to Panjkora River through flushing pipe.

During winter season or low flow period it is apparent that the sediment concentration of Panjkora River is very low thus sediment entered into sandtrap will not be too much and most of the sediment will settled down which will be flushed out.

The frequency of flushing will be required once after every two weeks during winter season with complete drawdown. However flushing may also be carried out through flushing pump without drawdown, which will save shut down of the plant.

8.5.4 Headrace Channel

The inlet for headrace tunnel is located at a geological favorable location 65 m downstream of the outlet of sandtrap. The flows from sandtrap will be carried to the tunnel inlet through a concrete lined headrace channel excavated along the left bank of river. The design data for headrace channel is given in **Table 8.1** below;

Table 8.1: Headrace Channel Design

Section	Length	Bed Width	Height	L-Slope
Rectangular	65 m	18 m	8 m	1:1000

The plan and profile of headrace channel is shown in **Figure 8.14**.

The channel invert at RD 0+000 is at El. 644 masl. There will be freeboard of 2m for normal operating water level. A freeboard of 0.5 m will still be available for operation at maximum headwater level. The design flow velocity at normal operating level will be 2.1 m/s using a Manning's roughness coefficient of n=0.016.

There will be a 4.5m wide service/access road along the left bank of channel. A drain, 1.2m wide, has been provided at the toe of cut slope to handle small hill torrents and rainwater flows. The channel will have drainage arrangements under the bottom slab throughout the entire length. Nallah crossings, if required, will be provided over the top of channel through concrete slabs.

8.5.5 Headrace Tunnel

The tunnel invert level at inlet is at El. 630 masl. This level has been selected on the basis of hydraulic transient analysis and design requirements for surge tank at the downstream end of tunnel. To achieve this level a vertical shaft of 13.93m depth (invert to invert) will be provided at the inlet where the invert level of headrace channel is at El. 643.93 masl. The design data for headrace tunnel is given in **Table 8.2** below;

Table 8.2: Headrace Tunnel Design

Section	Length	Lining	Hyd. Dia.	L-Slope
Horseshoe	10.22 Km	Concrete	7 m	1:500

The plan and longitudinal section of tunnel & profile is shown in **Figure 8.15 & 8.16.**

The hydraulic diameter of headrace tunnel has been optimized at 7m for horseshoe shape which will give an average flow velocity of 3.5m/s for the powerhouse design discharge of

150m^3/s. The cross sectional area of tunnel will be 40.63 m^2– finished. The total head loss in the tunnel would be 13.1m including the minor losses at bends and adit junctions.

The tunnel will be lined with 0.6m thick reinforced concrete. There is a radial allowance of 150mm for convergence (squeezing of ground around the excavated section of tunnel) and another 150mm for initial shotcrete support. Therefore, the total diameter of excavated section will be 8.8m. Fully grouted rock bolts, 4.5m in length, will be provided at 3m x 3m spacing (staggered). Drainage holes will be provided to facilitate the release of pore pressure in case of dewatering of tunnel for maintenance or inspection purposes. There will be a 150mm thick temporary invert which will be used by mucking vehicles.

Two construction adit along the proposed tunnel alignment are planned. The location of first adit (950m long) will be at RD 4+350 (975 m long) of headrace tunnel & second one (975 m long) is at RD 8+830 of headrace tunnel.

8.5.6 Surge Tank

Due to long length of headrace tunnel it becomes necessary to make provision for surge protection arrangements. A vertical standing surge tank has been envisaged at the end of headrace tunnel. Preliminary hydraulic transient analyses have been conducted to select the elevation, diameter and type of surge tank for Shigo Kas project. The Plan and section of surge tank is shown in **Figure 8.17**.

A 'restricted orifice type' surge tank has been selected because of relatively smaller height as compared to the simple surge tank. The finished diameter of 20m has been verified through Thoama's criteria. The diameter of orifice at the inlet of surge tank is 3m. The total height of surge tank will be 42m including 6m freeboard. The height of orifice will be about 13m. The center of tank and orifice has been aligned so that same pilot hole can be used for raise boring of both shafts.

The invert level of headrace tunnel at surge tank location is at El. 610 masl. The maximum surge level will be 666 masl for a full load rejection of all units in 15 seconds while the minimum surge level will be 641.80 masl for load acceptance at 2 minute intervals between unit uploads. There will be no air entry into the tunnel in case of full load acceptance. Due to restricted orifice all turbine units can be uploaded at 2 minute intervals which give an advantage in peaking operation. The peaking storage available in reservoir between El. 651.5 masl and El. 648 masl is about 724600 m^3 which will give about 80 minutes of full load peaking generation. The live storage at normal HWL of 650 masl will provide about 40 minutes of full load peaking. The volume of water available in first 6.5 Km length of headrace tunnel can also be used to

supplement the peaking operation. The storage in this section of tunnel will provide 30 minutes of full load peaking operation.

The transient analysis has been carried out using an equivalent circular diameter of headrace tunnel having a Manning's roughness value of n=0.014. The inputs and outputs of transient model are shown in **Figure 5 to Figure 9** below.

The surge tank will be located at contour level of El. 675 masl and only 3m excavation would be required up to the top level of surge tank. The existing access road is at a distance of about 60m from the surge tank site. The surge tank will be concrete lined. The details like lining thickness, rock bolts, allowances for convergence and shotcrete etc. are shown in **Figure 8.17.**

Considering the reduced cover over the tunnel from surge tank onwards the hydraulic diameter of headrace tunnel will be reduced to 6m upto the location for pressure shaft. Steel lining will start 50m before the centerline of pressure shaft

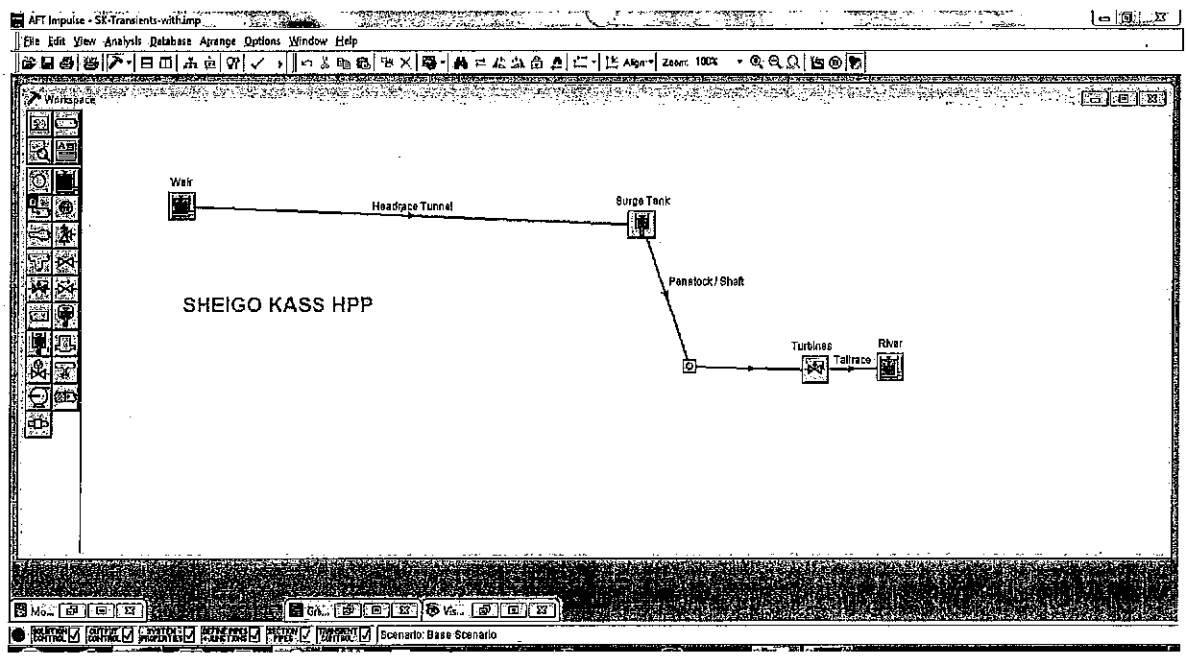

Figure 5: Project Profile for Hydraulic Transient Analysis

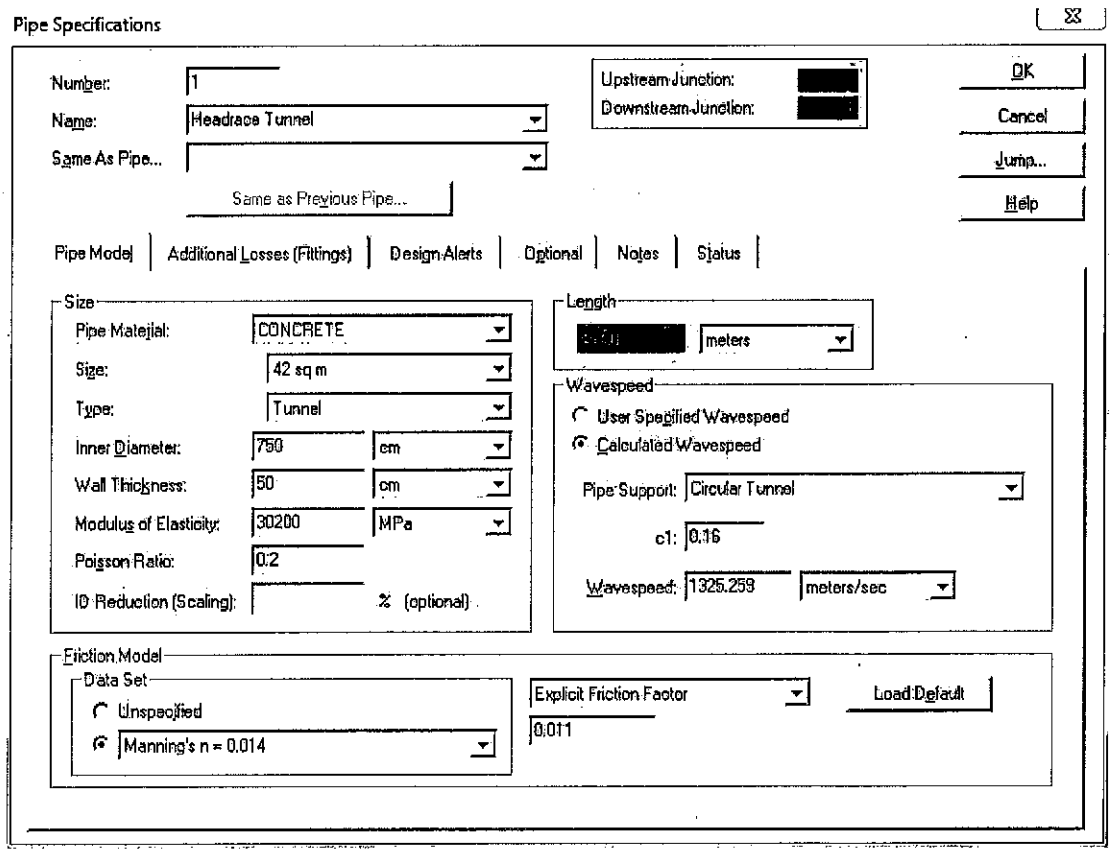

Figure 6: Headrace Tunnel Data for Hydraulic Transient Analysis

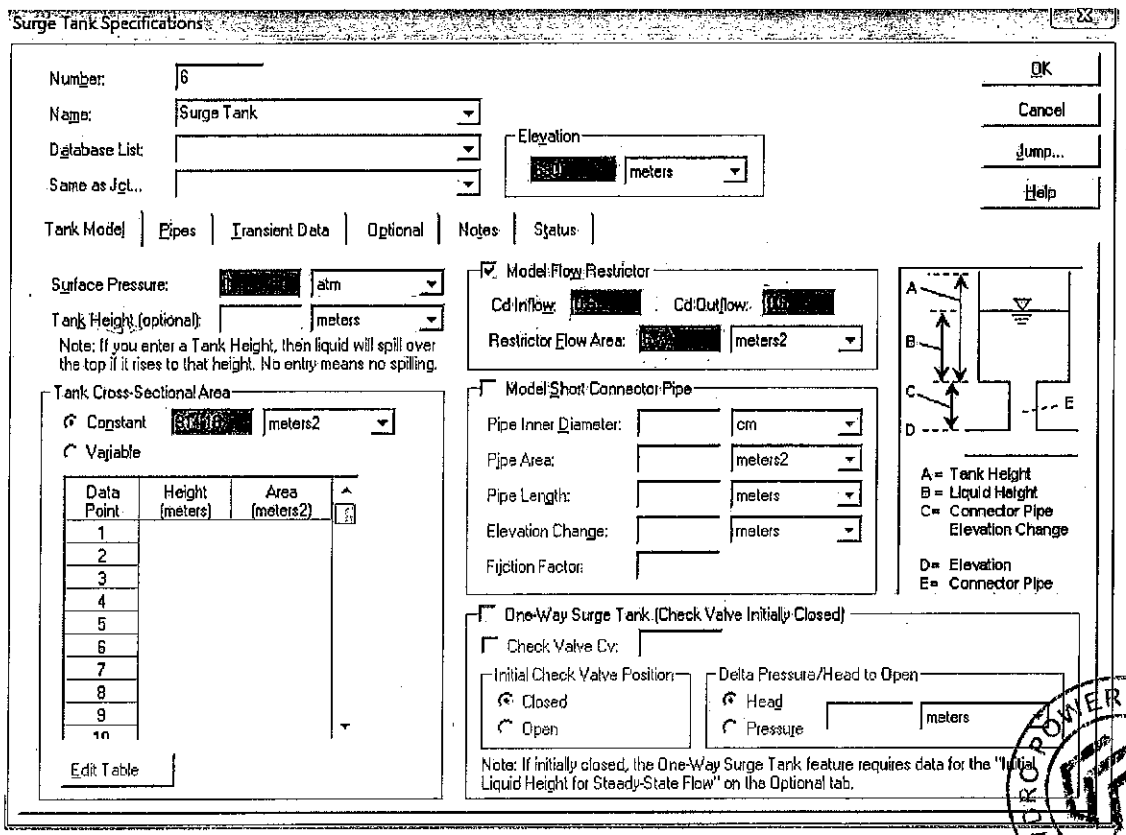

Figure 7: Surge Tank Data for Hydraulic Transient Analysis

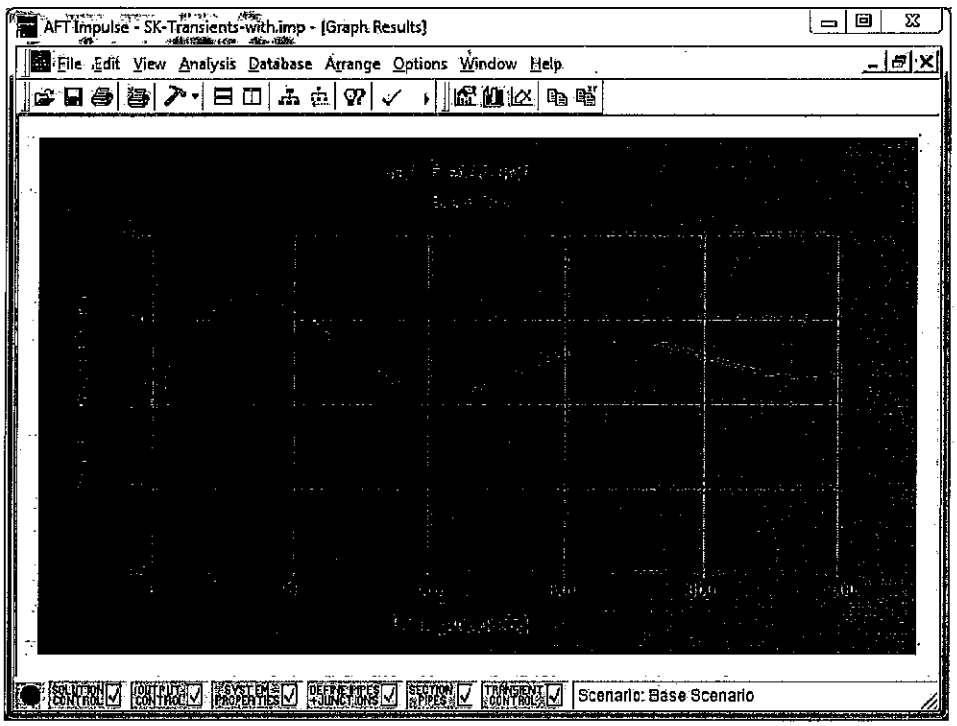

Figure 8: Full Load Rejection in 15 seconds

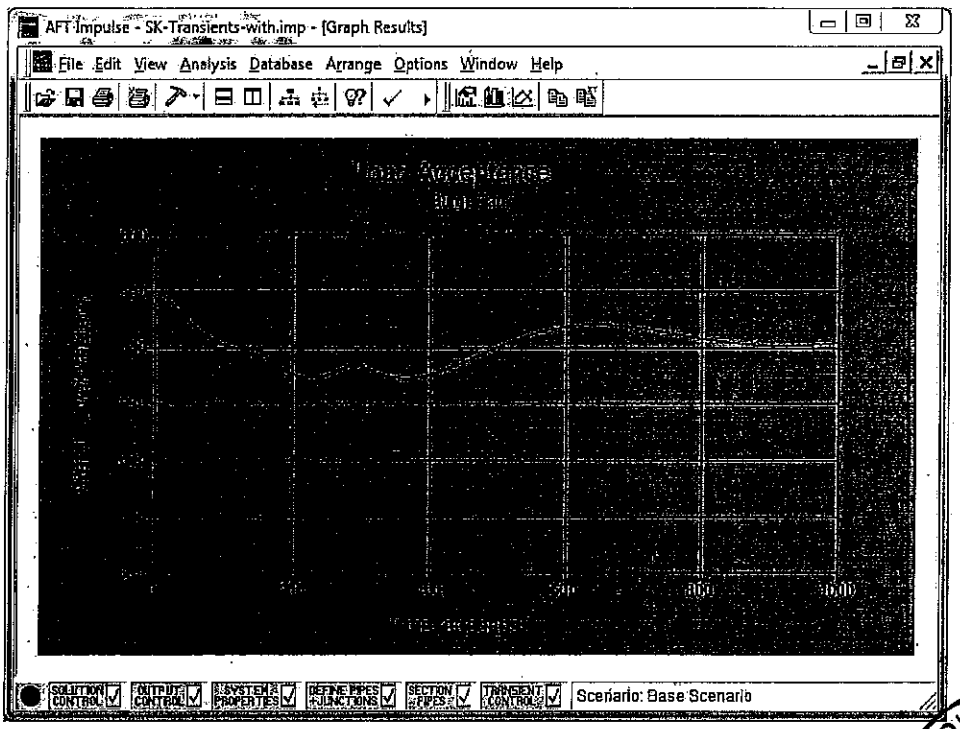

Figure 9: Load Acceptance at 2 minute intervals between unit uploads

8.5.7 Pressure Shaft / Penstocks

A 197.96m horizontal pressure tunnel having 6m inner diameter, comprises of two sections 107.96 concrete lined and 90m steel lined, leads to a valve chamber at El. 606. An inclined Penstock 112m having diameter 5.5m will drop from valve chamber at El. 606 masl upto El. 564 masl from where penstock manifold starts, branches to the three units. The arrangements are shown in **Figure 8.18.**

8.5.8 Powerhouse

A surface type powerhouse in open cut will be provided on the left bank on the inner side of a small bend of river. The length of concrete lined tailrace channel from draft tube outlet gates to the Panjkora River is about 31m. The powerhouse will be equipped with three Francis turbine units having vertical axis. The plan and section of powerhouse are shown in **Figures 8.19 & 8.20** and the longitudinal section is shown in **Figures 8.21**.

The powerhouse building has been designed as reinforced concrete frame structure having a total length of 73m including the loading bay area. The length of machine hall floor will be 49.5m. The total width will be 35m including the control room and other offices. The width of machine hall will be 14.5m.

The deepest foundation level is at El. 549 masl which is 7.5m below the river bed level at tailrace outlet. The turbine centerline has been fixed at El 558 masl. The machine hall floor level and the transformers base level have been fixed at El. 568 masl corresponding to 10,000 year flood level of 566.5 masl in Panjkora River at powerhouse location. The hoisting platform for tailrace gates has been provided at El. 567.5 masl.

The proposed sites for switchyard and colony are located at approximately 80m and 150 m respectively from the entrance of powerhouse building. The existing access road comes down upto El. 645 masl and it is only 100m away from the proposed powerhouse location. The powerhouse building is located at about 400m distance from the surge tank site.

8.5.9 Tailrace

The concrete lined tailrace length is about 31m from the draft tube outlet gates upto the left overbank of Panjkora River. Beyond that about 70m length of tailrace will be excavated but no lining is foreseen. The tailrace floor is rising from El. 551 masl (draft tube invert at outlet gates) at an angle of 20° from horizontal upto the platform at the downstream side. The tailrace invert at the terminal platform will be at El. 558 masl to avoid the entry of river bed load into the tailrace. Stepped floor will join the El. 558 masl to the river bed level. 2.5m deep cutoff has been provided at the end of concrete floor of tailrace, shown in **Figure 8.22.**

8.6 STRUCTURAL DESIGN

8.6.1 Salient Structures and Components

Detailed description of the project structures is provided below. Where needed part of the description is included here in the discussion on structure's design, addressing (a) – Functional requirements of structure and / or component(s), (b) – Considerations involved in establishing the basic design, (c) – Structures design parameters and / or criteria requirements; (d) – Live, hydrostatic, seismic and other design loads, (e) – Governing load conditions, (f) – Design approach and methodology; etc.

S-No	Structure / Description	Figure No
1	Project Selected Layout Plan	8.2
2	Plan of Main Weir and Intake, sandtrap	8.3
3	Weir Front Elevation	8.5
4	Overflow Weir Section	8.6
5	Weir gated section with Stilling Basin, Structural Details	8.7
6	Weir Gated Section with Roller Bucket, Structural Details	8.8
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Tailrace Channel, Foundation Treatment and / or Grout Curtain – as part of Seepage Control Measures under different structures are discussed in chapter 5 and 6 – Geology, Geotechnical Engineering, and Construction Materials and Geotechnical design

8.6.2 Design References

References used for the design of the project structures in the Feasibility Design Stage, are listed below. Each reference is assigned a number in box bracket e.g. [3], [4] etc. Where necessary in the text, a particular reference is mentioned by this number in box bracket, without mentioning the complete title.

[1] ACI 318-95 Building Code Requirements for Structural Concrete

[1.1] ACI Handbook Volume 2 – Columns,

[2] ACI 350R-89 Environmental Engineering Structures

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[3] ACI 207.2R-95 Effect of Restraint, Volume Change and Reinforcement on Cracking of Massive Concrete Structures,

[11] USBR Engineering Monograph No 14 – Begg's Deformeter Stress Analyses of Single Barrel Conduits,

[12] US Army Corps of Engineers EM 1110-2-2901, Tunnels and Shaft in Rock,

[21] Raynolds C E – RC Designer's Handbook

[22] Nilson A H – Design of Concrete Structures

8.6.3 General Design Criteria

Except the powerhouse superstructure and residences, all project structures fall in the category of hydraulic structures. Design criteria requirements of general applicability, and method of design of hydraulic structures is given in the ensuing paragraphs. Particular design requirements for a specific structure will be discussed separately under the design of that structure.

8.6.3.1 Strength and Durability Requirements

Concrete Strength: Concrete strength requirement is established for use in (a) – Structures design, (b) – Estimation of the unit cost of concrete of specified strength and (c) – Drafting the materials specifications.

Minimum Cement Contents: Specified concrete strength is based on provisions of ref [1] and ref [2]. The project is located in seismic zone. Minimum specified (cylinder) strength of concrete for structures needs to be 21MPa (C20) in conformance with provisions of ref [1]. Due to considerable hydro-static pressure in some components and other considerations (permanent exposure to flowing water), concrete of strength 28MPa (C28) shall be used in power tunnel and stilling basin. Consideration of minimum cement content in concrete of specified maximum size of aggregate (MSA) is also necessary for durability in compliance to provisions of ref [2]. Depending on the MSA, the minimum specified cement content – for structural durability of non-massive structures e.g. tunnel lining, varies from 310kg/m^3 to about 350kg/m^3. Actual strength of concrete mix with minimum cementitious material contents maintained in conformance with provision of ref [2] often exceeds 21Mpa strength.

Reinforcement: The reinforcement design is based on grade 425 (grade 60) reinforcement bars conforming to ASTM A 615 or an equivalent standard, with yield strength = 425MPa, for use as both main and distribution reinforcement in general structures. Plain round grade 250 (mild steel) bars Y10 (#3), and Y12 (#4) may be used as column ties, beam stirrups, or dowels (between the First Stage and Second stage Concrete), with fy = 250MPa (36ksi).

8.6.3.2 Unit Weight of Materials

For calculating imposed load and / or pressures on a structure or component thereof, the unit weight of principal material are listed **Table-8.3.**

Table-8.3 – Unit Weight of Materials (kN/m^3)

Water	(Dry) Earth	Rock	Concrete	Structural Steel
9.81	18 to 20	25 to 27	24	78

8.6.3.3 Dead Loads

Dead load shall comprise of the self-weight of structure component, permanent finishes and fixtures. However, finishes and permanent fixtures are generally not provided in hydraulic structures, and are rather limited to Powerhouse superstructure and Control Room etc.

8.6.3.4 Live Loads on Categories of Structures (kN/m2)

Live load comprises imposed loads and forces, which may vary in magnitude and duration, in the service life of the structure; and include (I) – Imposed loads, (II) – Hydrostatic loads, (III) – Gate loads, (IV) – Earth pressure, and (V) – Wind loads etc.

- For Powerhouse Loading Bay or Erection Bay Floors: Weight of the heaviest equipment in the assembled form, 40kN/m^2, or as specified by the manufacturer
- For Powerhouse Storage Areas: 20kN/m^2 or as specified by the manufacturer
- For Powerhouse Roof – in the event of gust / high wind: 2 kN/m^2
- For Floor of Office Buildings: 5 to 6 kN/m^2
- For Roof of Office Buildings: 4 kN/m^2

8.6.3.5 Earth Pressure

Calculation of Earth Pressure shall be based on Mononobe-Okabe or other classical methods. Earth pressure co-efficient in the case of massive structures – considered immovable, shall be considered for 'At Rest' condition.

When the construction equipment or other vehicles can come within a horizontal distance from the top of the structure, equal to one half of the height of retained earth behind the structure, a uniform surcharge on the full height of structure shall be considered equivalent to 0.60m (2ft) of additional fill.

8.6.3.6 Categories of Loads, Load Factors, Allowable Increase in Stresses

A Categories of Loads:

- Normal or Category 1 Loads: Include normal persistent loads viz. Dead and imposed, Live loads including equipment load and operational Impact, Hydrostatic and Earth pressure including surcharge and Uplift pressure,
- Exceptional or Category 2 Loads: Includes Construction loads, Gust, Operational dynamic loads, Operating Basis Earthquake (OBE) and Design Flood loading etc.

- Extreme or Category 3 Loads: Includes Maximum Design Earthquake (MDE) load, Peak Maximum Flood (PMF) load, etc

B Design Load Factors other than Power Tunnel:

As required by the ACI code, design loads are increased by the following load factors for all structures other than the power tunnel, wherein the design is based on ultimate strength design (USD) method.

- For Dead Loads (D) – including the member's self weight, permanent finishes and fixtures like the monitoring or gate hoist equipment = 1.40
- For Live Loads (L) – as specified by the general building code or the plant manufacturer = 1.70
- For hydrostatic and (retained) earth pressures (H) = 1.70
- Wind loads (W) = 1.70
- For temperature effects (T) = 1.40
- Seismic Loads (E) = 1.875
- Allowance for impact (vibration) applied to rotating machinery e.g. Turbine; and / or moving load suspended (lifted) by mechanical component e.g. Gantry Crane; i.e. Impact Factor (I) = 0.10 to 0.30*(L) – as included for moving vehicles on bridge, added over and above the (live) loads. Load factor applied to (I) = 1.70.

C Design Cases and Load Factors for Power Tunnel:

Load Factors for power tunnel shall be based on **Table 8.4** – Design Cases and Recommended Load Factors for Power Tunnel, ref [12], as reproduced below:

Table8.4: Cases and Recommended Load Factors for Power Tunnel[1]

Load / Case	1	2	3	4
Dead load[2]	1.3	1.1	1.1	1.1
Rock Load[3]	1.4	1.2	1.4	1.2
Hydrostatic operational[4]	1.4	-	-	-
Hydrostatic transient[5]	-	1.1	-	-
Hydrostatic external[6]	-	-	1.4	1.4
Live load	-	-	-	1.4

Case 1: Minimum loading for bending, Case 2: Shattered zone previously stabilized, Case 3: Squeezing rock, Case 4: Swelling rock, Additional factor applied to vertical and horizontal rock pressures for Excavation by Blasting = 1.30, (Refer 'General Recommendations for Loads and Distortions' ref [12] chapter 9)]

Notes for Table-7.4.6-1

[1] This table applies to reinforced concrete linings

[2] Self weight of the lining,

[3] Rock loads are the loads and / or distortions derived from the rock-structure interaction assessments

[4] Maximum internal water pressure, minus the minimum external water pressure, under normal operating conditions,

[5] Maximum transient internal water pressure, for example, due to water hammer, minus the minimum external water pressure,

[6] Maximum ground water pressure, acting on an empty tunnel.

Note: The effects of net internal hydrostatic loads on the concrete lining may be reduced by considering interaction between lining and the surrounding rock.

D Allowable Increase in Stresses:

[I] – Normal Loading: When only category 1 loads are acting on the structure, the load combination is termed as normal, no increase in allowable stress is considered in the design, and the factor for design strength (say F(d) = 1).

[II] – Exceptional Loading: When a category 2 load combines with category 1 load the load combination is termed as exceptional. Increase of 25 percent in the allowable stresses is permitted by ref [1] in this case. Alternately a factor = 0.80 is applied to factored design forces (BM, shear, thrust etc) to cater for the increase in allowable stresses. Refer load combinations.

[III] – Extreme Loading: When a category 3 load combine with category 1 loads or two category 2 loads combine, the load combination is termed as extreme. 33 percent increase in the allowable stresses is permitted by ref [1]. Alternately factor = 0.75 is applied to the factored design forces and moments, to cater for the allowable increase. Refer load combinations.

8.6.3.7 Required Strength (U) other than Power Tunnel

Structures shall be proportioned for minimum required strength equal to or in excess of that required by the following load combinations:

A - U = 1.4D + 1.7L

B - U = 1.4D + 1.7L + 1.7(I)

C - U = 1.4D + 1.7L + 1.7(I) + 1.7H

D - U = 0.80(1.4D + 1.7L + 1.7(I) +1.7W)

E - U = 0.80(1.4D + 1.7L + 1.7(I) + 1.875OBE)

F - U = 0.75(1.4D + 1.7L + 1.7(I) + 1.875MCE)

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In the design of structures PMF loads shall not be combined with seismic or wind forces, neither the gust forces combined with seismic forces. In the design of hydraulic structures hydraulic factor shall be applied over and above the listed load factors in specified case e.g. F(h)*[1.4D + 1.7L + 1.7(I) + 1.875H], wherein F(h) = hydraulic factor, detailed later in this section. Hydraulic factor is not applied to load combinations with seismic forces.

8.6.3.8 Required Strength for Power Tunnel

Required strength for power tunnel shall be worked out similarly, using the load factors for power tunnel listed in Table-7.4.6-1.

8.6.3.9 Strength Reduction Factors

To allow for the probability of under strength due to variation in material strength and member dimensions etc, design strength of a member in flexure, axial loads, shear, etc, shall be taken as the nominal strength calculated in accordance with the requirements of ref [1], multiplied by strength reduction factor (□), considered according to provisions of ref [1], listed in **Table 8.5.**



Table 8.5: Strength Reduction Factors as per ACI 318-01

Force	Reduction Factor
Flexure without axial loads	0.90
Axial tension, and axial tension with flexure	0.90
Axial compression, and axial compression (Except for members with spiral reinforcement)	0.70
Shear and Torsion	0.85
Bearing on concrete	0.70

8.6.3.10 Method of Design

ACI ultimate strength design (USD) method shall be used in general for the design of structures. For hydraulic structures hydraulic factor is applied to the loads over and above the load factors used in the load above combinations. ACI Alternate Design Method is not used for the design of hydraulic structures to avoid application of hydraulic factor to design forces, using allowable stresses in concrete and reinforcement. This approach is considered overly conservative.

8.6.3.11 Load Combinations

General Load combinations are listed above. Any special combination – if required in a particular component shall be considered on case to case basis.

8.6.3.12 Uplift Forces

For the stability analyses, uplift considered under the (weir) structure is based on hydrostatic head in the NPL condition upstream, and minimum tail-water level (TWL) downstream, considering anisotropic conditions. Quantified value varies from (a) – Maximum at upstream (Distance 0m) corresponding to EL 650m, to (b) – Minimum (at downstream / Distance 12.38m). Force is considered effective over 100 percent of area subjected to uplift.

8.6.3.13 Sizing of Structures and Component Thickness

Sizing of structures and components is established in consideration of their hydraulics, construction, functional and operational requirements. Effects of the dead and imposed loads, impact, contact of the structure with water, watertight-ness under hydrostatic head, uplift forces, buoyancy effect, structural (movement) joint location; are taken into consideration; keeping in view the structure's durability and serviceability. The component thickness of 39m wide Reservoir Intake Structure (Figure-8.9) is governed by the buoyancy force acting on the submerged structure in the gate closed condition – partly disregarding backfill load on top of structure. In the design of powerhouse substructure, ratio of the stationary sub-structure mass to the revolving mass, shall be = 5 to 10, according to the provisions contained in references.

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8.6.3.14 Design Earthquake Factors

Factor for pseudo-static stability analyses in the OBE and MDE (MCE) condition given below is adopted from Chapter 7 – Seismic Hazards. 'Seismic Factor' considered in the stability analyses of the weir and other structures shown in **Table 8.6**, is adopted after modification made in the 'Value at Site', considering (a) – Damping of ground motions, (b) – Structures ductility, and (c) – Incoherence of earthquake vibrations in the structures entire base width along the height, and surrounding water mass (in case of water retaining structures).

Table 8.6: Seismic Factor considered for Pseudo-static Stability Analyses

Description	Factor for OBE	Factor for MCE
Value at Site as per Report	0.31	0.62

A Operating Basis Earthquake (OBE)

Operating Basis Earthquake represents a level of ground motions which, the powerhouse, its equipment, and related facilities should withstand while remaining functional. Damage, if any, should be of non-structural nature and easily repairable. It implies that the stresses in structure should not increase by more than about 20 to 25 percent compared to the normal operation condition.

B Maximum Credible Earthquake (MCE)

Principal structural plant components should withstand that level of motions without collapsing. However, occurrence of significant structural or non-structural damage could be acceptable under MCE would present no risk (by sudden collapse) to life of plant operation personnel. It also implies that the stress in reinforcement at any point shall not exceed the yield strength.

8.6.3.15 Design Response Spectrum

The Response Spectrum used for dynamic analyses of structures shall be based on Tabas (Iran) Earthquake of 1980, or other accepted spectrum used on recent project.

8.6.3.16 Factors of Safety (FOS) for Stability Analyses

After establishing the basic sizing of structures subjected to lateral dynamic (seismic) forces, their (pseudo-static) stability is ensured in the seismic conditions. This stability shall be checked in at-least the OBE condition. The following (minimum) FOS shall be aimed at checking the pseudo-static stability of structures shown in **Table 8.7.**

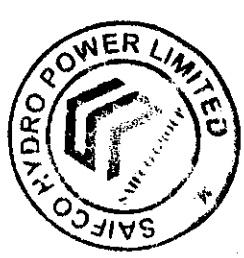

Table-8.7: Stability Criteria

Loading Conditions	Sliding		Overturning		Uplift
	Peak	Residual	U/S	D/S	
Usual	3	1.5	1.2	1.2	1.2
Flood	2	1.2	1.1	1.1	1.1
Earthquake	1.3	1	1	1	1

Note: Friction Factor of Safety in Sliding = [∑w * tan □/Sliding Force]

8.6.3.17 Factors of Safety (FOS) in Flotation

Minimum FOS in flotation shall be as given in the **Table 8.8.**

Table 8.8: Minimum FOS in Flotation

Condition	Normal	Exceptional	Extreme
FOS	1.25	1.15	1.05

8.6.3.18 Factor of Safety (FOS) for Allowable Pressure on Foundation

The FOS used in deciding the allowable (bearing) pressure on foundation of submerged structures shall be based on the allowable pressures on submerged strata. This aspect is detailed in Chapter 5 – Geology, Geotechnical Engineering and Construction Materials.

8.6.3.19 Hydraulic Factor for Design of Reinforcement

Project structures generally fall in the category of hydraulic structures i.e. structures remaining in contact with backfill soil or water in the in-service condition. Hydraulic Factor – as recommended in ref [2], will be applied to design (factored) forces acting on all structures in contact with water, as follows

- Bending Moment = 1.30
- Shear Force = 1.30 – limited to shear to be taken by reinforcement
- Direct Tension = 1.65 – tension tie and similar components

Note: Also refer discussion provided in Section 7.4.10 – Method of Design.

8.6.3.20 Impact of Moving Vehicles on Culverts and Bridge Super-structures

Impact effect (I) on the top slab of culverts and slab and main girders of bridge due to moving traffic shall be based on the criteria I = 50/(L+125), wherein L = Design span in ft. Maximum value of impact I shall be:

- 10 percent, for Military Loading,

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- 30 percent for vehicles with tires like trailers and trucks,

Impact effect (I) on the crane beam due to movement of gantry crane, shall be 10 percent of the crane Gantry Crane capacity.

8.6.3.21 Buoyancy

Buoyancy effects corresponding to the loss of weight of submerged portion of the structure, has been considered. In SHIGO KAS HPP, the only submerged structure is the Reservoir Intake detailed in Figure-8.9

8.6.3.22 Seismic Inertial and Hydrodynamic Forces due to Earthquake

In the pseudo-static stability analyses, unidirectional seismic inertial force is considered at the center of gravity of structure, equal to product of (a) – Weight of the structure in dry, and (b) – The seismic factor.

Hydrodynamic forces act on the structures in the event of earthquake in addition to hydrostatic force on structures retaining water, like the Main Weir, (inner and outer) walls of Sand Trap, etc. Calculation of hydro-dynamic forces is based on the Westergaard method detailed in the Harza Design Guide No DG-16 – Hydrodynamic Forces on Structures.

8.6.3.23 Wind Loads

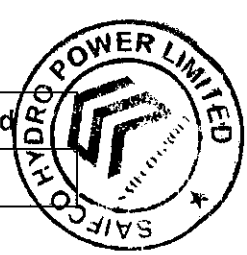
Wind pressure shall be applied to the exposed surfaces of the components like the powerhouse superstructure and gate hoisting device, in accordance with the American National Standards Institute (ANSI), detailed in ANSI Code 1995. Wind velocity of 160km/hr (100mph) acting horizontally at a height of 10m, shall be considered in the design. Importance Factor for the powerhouse to be taken = 1.25. Wind pressure on the exposed part of the conveyance conduit, is unlikely to govern the design of this massive structure. Except any exposed part of the conveyance conduit and powerhouse superstructure, wind force is generally not a major force on other structures.

8.6.3.24 Pour Length of Concrete and Spacing of Construction Joints

To limit shrinkage cracks in the project structures movement (expansion and contraction) joints shall be provided at suitable interval, and the length of concrete pours (spacing of vertical construction joints) shall be limited to a value given below, depending on the structures end restraint condition see **Table 8.9**. Depending on the ambient temperature, time lapse for concrete pouring in panels adjoining a construction joint, shall be staggered by about 7 to 10 days.

Table 8.9: Spacing of Vertical Construction Joints in Structures (m)

End Restraint Conditions	Structurally Restrained	Un-Restrained
Spacing of Vertical Joints (m)	10 to 12	14 to 16



8.6.3.25 Water-Stops

Types and Material: In general water-stops shall be provided in all vertical construction, contraction and expansion joints in water retaining structures, and foundations subjected to uplift pressure. Water-stops used shall be (a) – Without bulb (straight or dumbbell) type I in construction joints, (b) – With central bulb (type II) in contraction and expansion joints [The bulb shape depends on (I) – The magnitude of movement at the joint, and. (II) – Hydrostatic pressure at joint location]; (c) – Type T with central bulb, placed on blinding concrete layer. Material of water-stop may be either synthetic, like rubber, Hypalon, or PVC; or metallic (e.g. copper). Copper water-stops are more resilient, and can better accommodate probable movements at joints. Criteria for selection of the width of water-stop, is discussed later. [Note: Although theoretically not the ideal solution, for construction ease, often only one type of water-stop e.g. PVC with center bulb, is used].

Location: Water-stop may be provided:

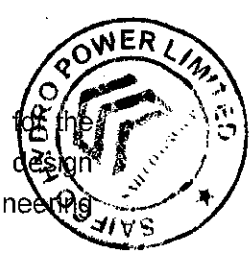
- In the middle of member thickness, in thin members
- At about 200-400mm from the water face, in minimum 600mm thick members, or thicker members with two rows (layers) of water-stop.

Two Rows of WS: Where (I) – The hydrostatic or the uplift pressure is high, or (II) – Probability of (a) – Differential settlement between adjacent components at the movement joint in member retaining water under hydrostatic head, or (b) – Washing out of fines exists; two rows of water-stops at 400 to 900mm distance in-between, in massive components, e.g. joints in powerhouse sub-structure, are used. In view of exposure of the substructure to high tail-water, contraction joints in powerhouse substructure below EL 549 shall also have double layer of water-stop.

Water-stop Width: References do not provide specific criteria rules for the required width of water-stop in a given condition. Width of water-stop is influenced by the factors like:

- The type of foundation strata (Rock or Soil),
- Probability of differential settlement (a) – During construction arising from construction sequence, or (b) – During Maintenance: One unit dewatered for maintenance – in the in-service condition, while the other unit is full of water,
- Width of the expansion gap,
- Hydrostatic pressure at the joint, and
- Member dimensions,

Minimum width of water-stop is generally about 250mm (10 inch). The width specified for the weir and powerhouse may be 300mm (12 inch), and shall be reviewed at the detail design stage. The width of water-stop is decided in consideration of the listed parameters. Engineering



judgment is applied in the final selection of the water-stop restricting the number of different types to one or two, for construction ease.

8.6.3.26 Temperature Variation Effects

Temperature variation equal to 20^0 C will be considered in the analyses carried out using standard software, to include thermal stresses. To restrict the secondary stresses, provision in the form of (I) – Appropriate (vertical) construction joint locations, and (II) – Shrinkage reinforcement – discussed later, shall be incorporated. Provisions of document ACI 207.2R-95 – Effect of Restraint, Volume Change and Reinforcement in Massive Concrete Structures, and ACI 350R-01 – Environmental Engineering Structures; shall be followed.

8.6.3.27 Shrinkage and Temperature Reinforcement

Minimum amount of this reinforcement as a ratio of gross cross section area of the structure component shall be as in **Table 8.10.**

Table 8.10: Shrinkage and Temperature Reinforcement, Ratio of Gross Area

Structure Condition	Structures In Dry (*)	Hydraulic Structures
Reinforcement Percentage	0.0020	0.0028

(*) – Structures in dry include powerhouse superstructure, residences etc

8.6.4 Design of Main Weir and Stilling Basin Structures

A – Main Weir – Overflow Section

Available Freeboard under the Bridge for Spilling Flow: The weir is basically a concrete gravity overflow section of crest length about 25 m. The crest is set at EL 650 m.

Hydrostatic Head in NPL Condition: The crest level is EL 650 m and the general foundation level EL 638.75m. The foundation (Excavated River Bed) level is EL 636 m. Hydrostatic head in the Normal Pool Level (NPL) condition is 14 m. Stability analysis has been carried out for this head.

Gated Section With Stilling Basin : Four 10m x 12m openings for gates are provided in the center part of weir to the left side of overflow weir. The invert level of gates has been fixed at El. 640 masl which is only 1m high than the existing river bed level at the centerline. The trunnion of gates will be at El. 654 masl and the hydraulic hoisting system will be at El. 657 masl. Stoplogs has been provided on the upstream sides of gates. The mobile gantry from intake structure would be used for installation or removal of stoplogs. The gates are separated by 4 m wide piers. The hydraulic power units (HPU) for radial gates are provided on the top of piers at El. 658 masl. The piers are connected through two bridges; one bridge for gantry crane and general maintenance while the other dedicated for installation or removal of radial gates.

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USBR Type-II stilling basin has been provided. The length of stilling basin is 70m with floor level at El. 632 masl. A 2.5 m high solid end sill has been provided at the downstream end of stilling basin. Concrete cutoff at the downstream end will extend into the river bed upto El. 625 masl. Drainage Gallery is shown in the basic design, for relief in uplift pressure under the weir base (structure foundation). In the stability analyses, uplift pressure is considered accordingly.

Gated Section With rolling buckets: This section of weir is provided on the left bank, in front of the intake structure. The profile of concrete floor is same as for the section with stilling basin but instead of stilling basin a roller bucket has been provided with the lip level at El. 633.2 masl. The total length of concrete floor is 51.5m which is significantly lesser than the total length of stilling basin section. There will be 2 no. radial gates in this section.

Bridge: The road bridge is overall 6m wide (railing to railing). Allowing 0.4m for curb and railing / barrier on either side, the net available roadway is 5.2m that is considered appropriate for two-way light traffic or one-way heavy traffic.The bridge deck elevation is EL 859m.

Surface Layer: The main (mass) construction may be in concrete with cement paste volume about 22 percent (±) by mass – say C15 concrete. 0.75m thick layer of C25 concrete is provided On outer surface and bottom of the weir. Reinforcement is also placed in this (skin / surface) layer.

Impervious Blanket against Uplift: To reduce the uplift pressure, about 20m long impervious (clay) blanket is proposed. Grout curtain is not considered to be effective in the type of strata (alluvium) encountered in the river bed.

Stability Analysis: Pseudo-static stability of the weir structure is carried out in the (a) – NPL, (b) – OBE, and HFL conditions. In view of the (I) , and (b) – High seismic factor, stability check is important. The stability analyses is based on OBE Factor = g/8 (0.125g).

B – Main Weir – Non-Overflow Section

Structure: The non-overflow weir is also a concrete gravity section. It is separated from the overflow weir by a contraction joint. The top is set at EL 658 (the bridge deck level). Unlike the overflow weir, where the main (mass) is in C15 concrete, specified concrete strength in this 21kN/mm^2.

Stability Analysis: Pseudo-static stability of the non-overflow weir structure is not checked separately at this stage.

C – Stilling Basin

Dimensions: In plan view, the stilling basin is separated by the weir by a transverse (flow) contraction joint, provided at the toe of weir. Floor of the stilling basin is set at EL 632m. The basin length from contraction joint at the downstream of main weir to the downstream sill is

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70m. The width of the stilling basin, is about 58m provided to the gated section only consist of four gates

Basin Floor: The basin floor slab is proportioned against the uplift. Minimum specified strength of concrete shall be C21. Bed rock in this area is at some depth. The visible strata in the river bed, is sandy gravel with little cobbles. The floor thickness is maintained 2 m. Anchors (Dia 0.075m) of depth 2m are proposed below EL 630 / bottom of stilling basin floor in 1m x 1m area, so that part of the uplift force is catered by self-weight of slab, and remaining by the rock anchors. The 2 m slab thickness is also sufficient to meet the anchorage requirement of anchors embedded into the strata below. For more detail refer chapter 6 of Volume 1.

8.6.5 Intake Structure

Structure Description: The power intake structure will be located on the left bank. The axis of intake has been aligned at an angle of 105° from the weir axis for better hydraulic entry conditions. The intake and left most pier of gated section of weir are connected through 8 m long concrete retaining wall having elevation 656 masl. The plan, longitudinal section and front elevation of intake structure are shown in Figure 8.7, 8.8 respectively.

The gate sill elevation is EL 644m. The structure has 4 bays (openings) each 9.8 m wide separated by 1.5 m wide piers. Overall width works out = 33 m. Three 1.5 m wide (internal) concrete piers and equally wide abutment piers are integral with the floor and roof of the intake. At the junction of intake with the remaining structure (of transition conduit), is separated by a contraction joint, which is later separated by the adjoining conduit another contraction joint. Gate hoisting frame is placed on Gate Operation Platform at EL 658 m.

8.6.6 Conveyance Conduit (Cut and Cover Channel)

Location and Dimensions: The conveyance conduit (cut and cover channel) is located on the left abutment. Starting from the sandtrap structure at upstream, it ends at the tunnel portal at the downstream. The length of this structure is 65 m (refer Figure-8.12 – Layout Plan). The design data for headrace channel is given in Table-1 below:

Headrace Channel Design

Section	Length	Bed Width	Height	L-Slope
Rectangular	65 m	18 m	8 m	1:1000

Joints: At the upstream, the conduit structure is separated by the sandtrap Structure by a transverse to axis (flow) contraction joint. 300mm wide PVC / rubber water-stop are provided in

the expansion joints, the disposal is similar, except that double row of water-stop provided in the floor and exterior walls.

8.6.7 Sand Trap

Structure Configuration: Sand Trap is about 133m long reinforced concrete structure, consist of upstream & downstream transition and chamber section, bounded by expansion joints at both upstream (at the junction with Conveyance Conduit) and downstream (junction with Power Intake Structure). Foundation level of the structure varies along the length from EL 643m to about EL 640m. Total height at the upstream is about 6.5m and at the downstream about 9m. Three (03) 15m wide, Hopper Bottom like, chambers are provided in the (internal) 49m wide (at top) structure, separated by two (02) internal divide walls. Each chamber has been further divided into three compartments through vertical vanes/walls. The width of each compartment is 4.5 m which will facilitate the flushing of deposited sediments. The height of vanes is fixed at El. 645 masl. The longitudinal slope of the floor of sandtrap is 3%.

Outer Wall Design: Thickness of the outer walls was shown 2.5m uniform in Figure-8.11. The earthquake load case – involving (a) – Seismic inertial, and (b) – Hydrodynamic forces, is not governing, and the reinforcement design is based on static condition disregarding the outside earth pressure [Hydraulic factor is not applicable in seismic case, and the total bending moment is reduced to ¾ to account for allowable increase in stresses].

Spill Section: The spill (overflow) section is provided on the right wall of the downstream transition, and is 15.5m wide. The crest is at EL 651.5m and top EL 652m.

Construction and Expansion Joints: Beside the expansion joints at the upstream and the downstream ends of the structure, four more expansion joints are provided within the 142m length at (a) – Start of Central Piers, (b) – at the first flushing section, (c)-at the second flushing section (d) – Downstream massive bottom slab + Power intake; for normal expansion and contraction which takes place in the structure. Additionally eight (08) more construction joints – required for construction ease and limit concrete pour length to around 15m (±), needs to be provided in the four segments of the structure. Construction and expansion joints shall have (a) – One water-stop provided in the mid thickness in the middle wall, and (b) – Double (row of) water-stop provided in the outer walls and bottom slab.

Center (Divide) Wall: In all two (2) Divide walls are involved. Thickness shown is 2.5m uniformly along the height. Due to the structure configuration, these walls are not subjected to imbalanced hydrostatic pressure in the in-service condition. Length in plan view of the wall is about 86m. In the seismic condition, intermediate wall is subjected to seismic inertial and hydrodynamic forces. Water level considered on either side = EL 650. In the event of earthquake, maximum hydrodynamic head (on one side) and water suction (on the other side) is about 9m, which poses considerably high flexural moment on the cantilever wall. However, including the seismic inertial force and magnification effects, the calculated reinforcement based on factored moment without increase by hydraulic factor, is quite excessive. To curtail

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reinforcement and forestall possibility of high magnification of seismic forces in the 2.5m thick and 9m high wall, With this thickness, the probable magnification of seismic forces and calculated design reinforcement is within normal range – given that curtailment of reinforcement along the structure height will be done. Reinforcement design of these walls is governed by earthquake forces [hydrodynamic force on one side, and suction force on the other; in addition to seismic inertial forces].

Downstream (End) Wall: The downstream wall abuts the Power Intake structure block and may be considered part of power intake. The 11.1m length structurally spans between the (exterior) longitudinal walls between EL 646.5 to EL 654.5 – height of 8m. As a horizontal slab, it is proportioned (a) – Against earth-fill on the outer side, and (b) – Hydrostatic pressure from the inside – partly disregarding earth pressure. In the design, the wall is considered restrained at the bottom (three sides restrained). Due to the considerable (horizontal) span, the adopted structural thickness is 1.5m.

Bottom Slab: In the 115m long maximum section, water head on the bottom slab is about 9m. In the basic design, adopted thickness in this part, from considerations of (a) – Impermeability (watertight-ness), and (b) – Transfer of cantilever wall moments to the base.

Structures Stability: Due to (a) – Favorable structures geometry (height to width ratio = 9/49), (b) –large uplift – due to location near to the reservoir, and (c) – Passive resistance available from the soil mass which abuts; stability of this structure as a whole, is considered in the event of earthquake.

8.6.8 Power Intake

Power Intake structure block at the downstream of Sand Trap is integral part of Sand Trap structure. It houses the trash-rack and control gate on the upstream. The invert elevation is set at EL 646.5m. The Sand Trap (and Power Intake structure) is separated from the downstream conduit by an expansion joint. In view of the requirement of double row of water-stop in the expansion joint, and somewhat larger section dimensions due to bell mouth, outer wall thickness of this block, is maintained = 750mm. As the block is monolithic with / part of Sand Trap, structurally the Intake is not treated as an independent structure. Design approach of this block is similar to box culvert (conduit). Gate Hoist Frame is installed at EL 654.5m. Hoist Frame height and configuration is decided by E&M considerations.

8.6.9 Power Tunnel

General: The tunnel starts from power intake structure – integral with Sand Trap. Max operating level in the Sand Trap – which acts as Intake, is EL 650m. The EL of centerline of tunnel at downstream end (surge shaft floor EL 630m, is 613.5. The tunnel length is about 10.22Km. Internal dimension of the horseshoe tunnel is 7m. Reinforced concrete lining thickness is 600mm. Steel lining, often provided in power tunnels, is not foreseen in Shigo Kas HPP case, as explained later. For rock strata details Refer chapter 6 of Volume 1.

External Hydrostatic Pressure: Power tunnel starts from the Sand Trap. Upstream of the tunnel is not directly exposed to reservoir, and the surrounding strata is not subjected to external

hydrostatic pressure [Phreatic Line: External hydrostatic pressure reducing towards downstream, magnitude depends on the distance from the reservoir, tail-water level, and permeability of the strata]. As determined by geo-tech investigations, external water pressure is generally not encountered, and does not influence the design; exception being a causeway, an aqueduct, or non-perennial stream encountered in the tunnel alignment. Site topography and duration of flow in the stream may warrant consideration of some external hydrostatic pressure.

Rock Loads: The foreseen method of excavation of tunnel is blasting, for which the Engineering Manual EM 1110-2-2901, specifies 30 percent increase in external rock pressure on sides compared to the tunnel driven by boring machine. External rock pressure – disregarding internal pressure, governs the structural design of concrete lining.

Design Loading Case – Typical Tunnel: The section is designed primarily against the external vertical rock loads with or without horizontal rock loads. Rock loads depending on rock quality (good, average and poor).

Design of Concrete Lining: The structures design is based on conventional method using spreadsheet. 250mm thick concrete lining without reinforcement shall be provided on the outer face.Refer Figure-8.15 – Tunnel cross section.

Consolidation Grouting: The surrounding rock strata shall be subjected to consolidation grouting, all round, under the specified pressure, based on the requirements determined after the actual ground condition is exposed, after the construction of lining.

Contraction Joints: These joints are provided to limit the total contraction in concrete. The tunnel, is about 10.2km long. The vertical portal is separated from tunnel by transverse to flow, vertical contraction joints. The longitudinal reinforcement will be stopped at these joints, and two components connected by dowels. Vertical contraction joints shall have water-stop in mid-thickness.

Partial contraction joint between the segments of the tunnel lining may be formed by providing 60mm deep groove (0.10 of lining thickness) to arrest formation of cracks in the tunnel length between contraction joints. This type of joint may be easier to construct, as construction can be carried out in 60 to 70m long segments. Viability of such joints in this tunnel will be investigated further in the detail design stage. Water-stop shall be provided in these joints.

Construction Joints: The term is applied specifically to transverse vertical construction joints. Horizontal (lift) joints are not addressed. Full longitudinal reinforcement crosses the construction joint. If the adopted spacing of contraction joints is as proposed, then structurally there may be no need of construction joints between the contraction joints. Where provided construction joints with water-stop is for convenience in construction – as normal.

8.6.10 Surge Shaft

Salient features of the surge shaft are given below:

- Design internal diameter = 20m

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- Bottom (floor) level = 630m
- Top of shaft level = 672m
- Height of shaft = 42m
- Concrete lining thickness = 1000mm,
- Permanent lining shall be in-situ concrete,

Circular Shape: Circular shape is most favorable for opening stability and lining design. Sufficient rock mass is present all around the 22.6m diameter excavation to impart the needed stability to a vertical bore and accommodate rock bolts.

Excavation: Minimum excavation diameter of the shaft is 22.6m. Excavation may be done (a) – As the size is large enough to accommodate a road-header machine, the rock is not too hard, and the minimum rock strength expected to be more than 15MPa; excavation may be done without blasting, using crane service, or (b) – By controlled blasting [Shaft blasting is more difficult and more confined than tunnel blasting. Typically shorter rounds are pulled and powder factor is greater than for a tunnel in the same rock]. The shaft may pass through variety of ground conditions – including overburden and fractured rock. At the location of Surge Shaft, rock is fairly good, and ground water is not likely to be present, which may facilitate the excavation and ground supporting work.

Ground Supporting: Available methods of ground support for the given size of shaft and relatively limited magnitude of work may only be shotcreting – with wire-mesh, and rock bolts. The spacing of #8 rock bolts will 1.5m (±) – measured on the shaft perimeter, and about 1.5m (±) – measured vertically. Location of rock bolts is staggered in vertical alignment). Fiber reinforced shotcrete is more ductile. Welded wire fabric usually applied between the first and second coat of shotcrete for increased ductility is (a) – Laborious, (b) – Costly to place, (c) – It is difficult to obtain good shotcrete quality around and behind wires due to rebound, and (d) – Often result in greater required shotcrete volumes, because the fabric cannot be draped close to the rock surface on irregularly shot surface. When circularity is well controlled, circular shafts generally do not require internal bracing.

Consolidation Grouting: Consolidation grouting carried out after the construction of the shaft fills in the fissures and cracks present in the rock mass and is an important step in rock supporting high vertical rock cuts. During construction of concrete lining, grout holes are left in the lining at the specified spacing and interval, using thin-walled steel pipe or other suitable means, to facilitate the grouting process. Care is exercised to avoid interference with rock bolts by staggering the vertical spacing of the two processes. Grouting in rock is usually with cement. Shaft grouting typically starts with the drilling of two or three rows of grout holes around the shaft perimeter, spaced 1.5 to 2m. Grout injection is usually performed from bottom up using packers.

Shaft Construction: Most shaft construction requires initial construction of a shaft collar structure that supports overburden and weathered rock near the surface and construction loads

adjacent to the top of shaft. It also serves as a foundation of the temporary head-frame used for construction of the shaft.

Contact Grouting: Contact grouting is usually required in about 120° region around the crown in horizontal tunnels, to obtain good contact between the lining and surrounding rock. Contact grouting is not foreseen in the vertical shaft construction, as the fluid concrete develops sufficient bond with the vertical rock mass in the process of strength gain.

Design of Concrete Lining: The concrete lining is mainly subjected to compressive force due to external rock pressure (opposite of Hoop Stress) and the vertical load of self weight. Due to compressive nature of radial stress, buckling of lining is one of the involved considerations. Dowels protruding from the rock surface will not only assist in restraining the buckling, but also transferring part of the load to rock interface. Dowels shall be provided and anchored into the concrete lining. Floor of the shaft will be made sufficiently thick and reinforced adequately to span a circle of 20m diameter supporting part of the shaft lining weight. In view of the fact that the finished internal diameter of shaft will be 20m constant along the height, and the lining thickness is constant, it implies that the excavated shaft surface is in one alignment all along the height.

Reference Figure: Structural Details of Surge Shaft are shown in Figure-8.17 – Surge Shaft plan & Structural Details.

8.6.11 Steel Liner

Hydrostatic Pressure: Max water level in the Sand Trap – which acts as Intake for power tunnel, is EL 650m. The EL of centerline of tunnel at downstream end is 613.5m. It implies that average hydrostatic pressure inside the tunnel is about 36.5m. Due to this level difference, the tunnel is not critically pressurized. Reinforced concrete lining thickness of 600mm is considered sufficient to withstand this pressure without excessive reinforcement.

AISI Document Explanation: According to Part V – Design and Construction of Steel Tunnel liners, of the document 'AISI' (American Iron and Steel Institute) – Steel Penstock and Tunnel Liners, a liner is required along certain reaches of the tunnel to provide positive control of leakage and / or to withstand the internal design pressure. Concrete lining would be adequate to withstand the internal pressure.

Tunnel Shape: Handling and transportation of large number of cans and their field welding (at can-joints) require the liner cans to be (preferably) complete circle. Spider support is the general method of maintaining circularity of cans during transportation in the field. Any other shape (of can) is more difficult and time consuming. With the tunnel shape modified from circle to horseshoe, it is more feasible to omit steel liner.

Provision of Steel Liner: (1) – If steel liner is provided, minimum thickness against handling (non-circular steel liner can of 7m dimension), would be about 20mm. Cost impact of providing 20mm steel liner with external stiffeners (needed for adequate anchorage of the liner into concrete mass); in about 10.22Km long tunnel; will be quite substantial on the overall project cost. (2) – Provision of steel liner is also likely to affect the foreign exchange component of the project. (3) – Construction time is also affected due to requirement of (a) Fabrication, (b) –

Transportation, (c) – Alignment, and (d) – In-situ welding and radiography of the welded joints, needed for joining one steel can with the other; in the stringent construction conditions and remote site location.

8.6.12 Steel Penstock and Manifold

Penstock: Penstock starts from downstream of surge shaft. Its function is to deliver water from the tunnel to the power units through the manifold block. Liner thickness is 20mm. Design internal diameter is 5.5 m while at the manifold it varies from 4.25 to 3 m.

Material: The penstock may be built with steel plates conforming to ASTM A 36 (yield strength = 250MPa or 36,000psi), or other (higher strength) material (A 516, A 588 etc yield strength = 345MPa or 50,000psi). In case of steel plates conforming to ASTM A 36, (a) – Weld-ability of the plate material itself, and particularly with other steel sections (flats, tees etc used in croth-girder in manifold block or elsewhere) is better than other types of steel pates (A 588 etc); (b) – Is more readily available in the market, and (c) – Considered easier to fabricate. The design thickness is based on steel with f_y = 345MPa. However steel plates conforming to ASTM A 36, may as well be used in the penstock. In view of the corroding nature of this material, corrosion allowance of 2mm shall need to be added to the design plate thickness. Steel plates conforming to ASTM A 516 are also manufactured / available in Pakistan.

Design: The penstock is proportioned against internal hydrostatic pressure separately including water hammer effects, and checked for hydrodynamic loads added to hydrostatic pressure, disregarding water hammer.

Finishes: On the inner surface – where water flow under pressure is persistent, thee coats of coal-tar epoxy or other suitable finish is necessary. On the outer surface, similar or other corrosion resistant finish is normally provided.

Manifold Block: The manifold block divides the flows from a single steel penstock to more than one generating units, transferring the flow into lesser diameter pipes. The design head is 78.5m (±). Considerations related to the design and material selection of this block are similar to the penstock.

8.6.13 Powerhouse

8.6.13.1 Features

General features of powerhouse structure are listed below:

- Generation capacity (each Unit) 34MW,
- No of generating units three
- Type of generating units Vertical Francis
- Max size in plan view – including Erection Bay, about 73 *35m (overall),
- Foundation level ~ EL 549m

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- Draft tube invert level: EL 551m
- Centerline Turbine EL: 558m
- Generator Floor level: EL 568m
- Gantry crane rail bracket top level: EL 580.09m
- Clearance between gantry crane rails to bottom of roof girders ~ 4.75m
- Structural depth of roof structure = 1.5m (±) – including finishes,
- Minimum tail water EL 558.50m,
- Maximum tail water level EL 566.50m,
- Reference figures (a) – 8.20 – Powerhouse Plan View, (b) – 8.20 – Powerhouse Cross Section.

8.6.13.2 Powerhouse Overall Structural Configuration

The powerhouse has two (02) distinct blocks (I) – About 49mx35m (L*W) Machine Hall, and (II) – About 24mx35m Control Room Block. The Machine comprises (a) – Unloading (Offloading) and Erection Bay plus Power Unit 1, (b) – Power Unit 2 plus Power Unit 3 Block. Control Room (24mx35m) block – located adjacent to Machine Hall, is a separate block. Due to considerable difference in the headroom and foundation levels of Machine Hall and Control Room, this Block is structurally separated from Machine Hall by an expansion joint.

Upstream and Downstream Walls of Machine Hall: In powerhouse in Pakistan, conventionally the upstream and downstream walls of Machine Hall – supporting (heavy) gantry crane loads are provided in reinforced concrete. In the recent past deviation from this practice is observed in projects generally contracted on Engineering, Procure and Construct (EPC) basis, both by WAPDA and probably also PEDO. Above the generator floor, reinforced concrete columns were provided in lieu of the RC walls. However, considering the (unsatisfactory) law and order situation obtaining in the country, RC walls of uniform thickness 1.4m along the height, are provided in the entire length of the powerhouse, up to EL 580.09 / Gantry Crane rail bracket top level. Above this level, the wall has openings for ventilators and is 250mm thick, strengthened by 250*300 mm pilasters provided under the pre-cast girders supporting roof slab, at about 2.5m (±) spacing

8.6.13.3 Machine Hall General Details

(a) Unloading (Offloading) Bay and Power Unit 1 Block: From the outer face of the external wall to the expansion joint between power Units 2 and 3 block, this about 30m high block is overall about 35m long. Width is same as the other blocks. In the plan view, the block is integral with the power unit 1 in the machine hall floor at EL 568. During assembly of the power units, the floor slab at EL 568 (machine hall) supports the equipment loads in the range of 50kN/m^2. Provided thickness of Erection Bay slab in the

stretch of this block is maintained equal to 1m. Foundation level of the Power Unit 1 is EL 556m and of the Unloading Bay about EL 567m. The two level extremities are joined at a constant slope.

(b) Power Unit 2 and 3 Block: This block houses the Power Units 2 and 3, and has width from face of outer wall of compressor room to expansion joint between Units 1 and 2

8.6.13.4 Structures Design of Machine Hall

Structures design of Machine Hall includes the outer walls designed for seismic and wind loading, discussed later. Other component is the massive substructure housing the draft tubes and openings (cable gallery, pipe gallery, stair, elevator / lift, dewatering sump, access gallery, oil storage tank etc), required for operation and maintenance. Raft foundation under the block is proportioned for the maximum loads.

8.6.13.5 Control Room Block

This single storey lightly loaded structure is located adjacent to the Machine Hall. It houses (a) - The Control Room, (b) – RE Room, (c) – DC Battery Room, (d) – Record Room, and (e) – Infra-structure / allied facilities like reception, telephone operator's desk, secretary's desk, toilet, ablution, kitchen, prayer room, security guard post etc. The floor level is flush with machine hall floor.

8.6.13.6 Control Room Structure Design

The floor level is EL 568m – well above maximum tail-water level. Including about 1.5m for foundation depth, the foundation level of this block is around EL 567.2m. Due to the considerable difference in the design loading, headroom and foundation levels with reference to Machine Hall, Control Room Block is structurally separated from powerhouse by an expansion joint, and is separate (third) block. From durability and security considerations, both the outer and inner walls are 300mm reinforced concrete. It will be more feasible (economical) to provide strip foundation under these walls, proportioned for dead, live and seismic loads.

8.6.13.7 Contraction Joints in Machine Hall Sub-structure

Raft slab is considerably thick. Vertical contraction joints have structurally suitable shear key and double layer of 300mm (or more) wide PVC / rubber water-stops all around, to forestall probability of ingress of water under pressure from below, into the vertical joint.

8.6.13.8 Roofing System and Roof Insulation of Machine Hall

Clear headroom between operating floor (EL 568) to bearing level of supporting girders (EL 583.5 is about 15.5m. In view of the high headroom, the construction needs to be pre-cast type. Due to moderate span (15m clear), either (a) – Double tee roofing sections, (b) – Prestressed I-girders with pre-cast core slab panels, or (c) – Similar (pre-cast) roofing system may be adopted. The roof insulation (on top) will be conventional type applicable to flat surface – involving bitumen, polythene sheet, 50mm high density polystyrene foam, second layer of polythene sheet, mud + husk layer, and brick (or concrete) roof tiles.

8.6.14 Switchyard

Conventional Switchyard is adopted. The foundation of transformers and other equipments (Line Trap, Takeoff Gantry, Bus Bar etc) will be designed for line pull, equipment dead loads and wind loads in accordance with the requirements of NEMA Standards Publication No SG-6, or an equivalent standard. Cable trenches are designed as concrete open channel structures covered with pre-cast concrete cover slabs. Drainage of both the surface runoff and the cable trenches is important consideration. Elaborate drainage system comprising open trenches and RC pipes, shall be provided for surface runoff. Slotted PVC pipe network provided under the cable trenches for collection of water shall discharge into the manholes for surface runoff. Disposal of the collected water shall be provided to well away from the switchyard premises.

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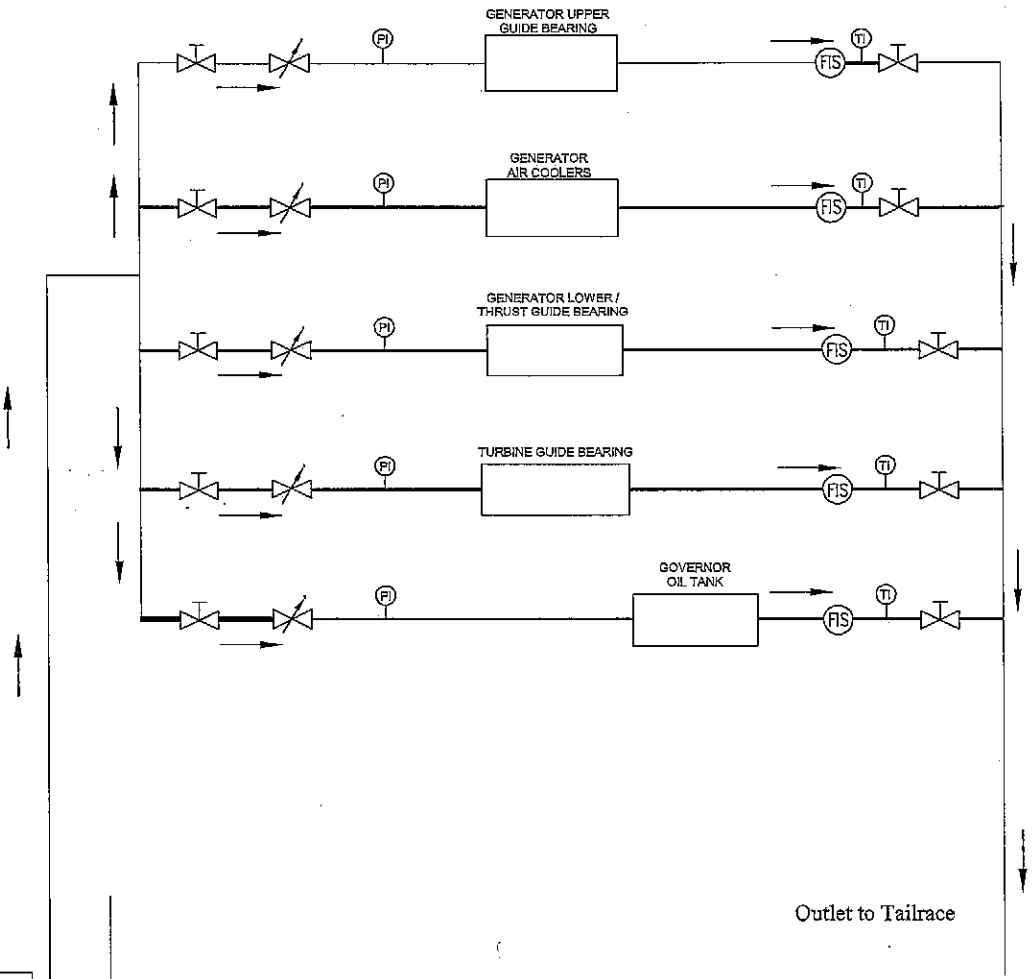
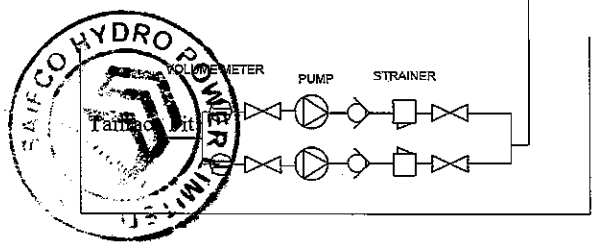
Max Cooling water demand	115 l/sec
Each unit demand	29.5 l/sec
Auxillary demand	24 l/sec





LEGEND:

- PUMP
- STRAINER
- MANUALLY OPERATED VALVE
- THROTTLE VALVE
- PRESSURE INDICATOR
- TEMPERATURE INDICATOR
- VOLUME METER
- NON RETURN VALVE

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FEASIBILITY STUDY OF
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IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

COOLING WATER SYSTEM

(SHEET 1 / 1)

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	MAY, 2014
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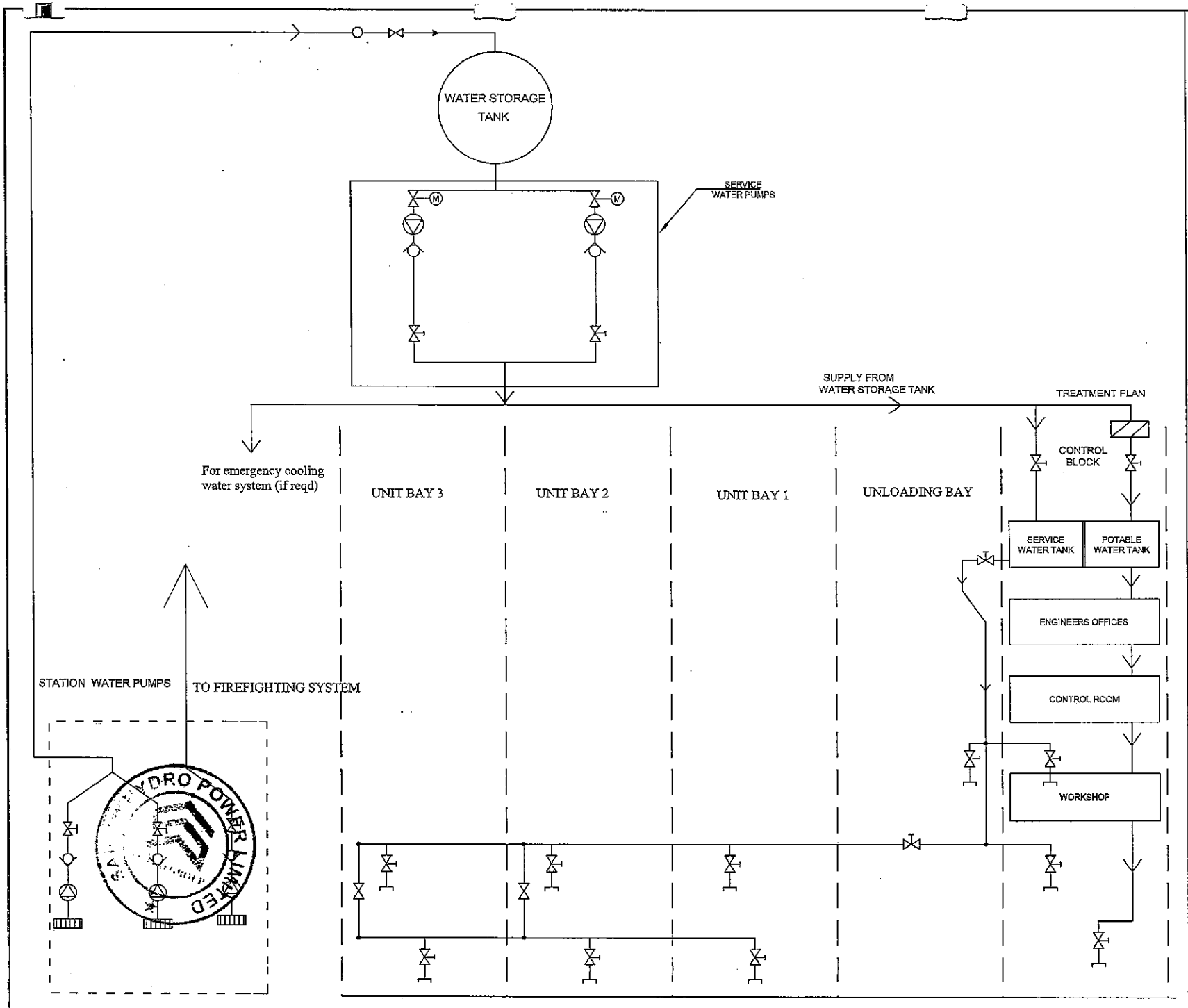
CHECKED:	M.ZJ		
APPROVED:	M.H.F	SCALE.	N.T.S



LEGEND:

- PDS — PRESSURE DIFFERENTIAL SWITCH
- PUMP
- MANUALLY OPERATED VALVE
- MOTORISED VALVE
- NON RETURN VALVE

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IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

SERVICE AND PORTABLE WATER SYSTEM

(SHEET 1/1)

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

DRAWN:	ALI	DATE:	MAY, 2014
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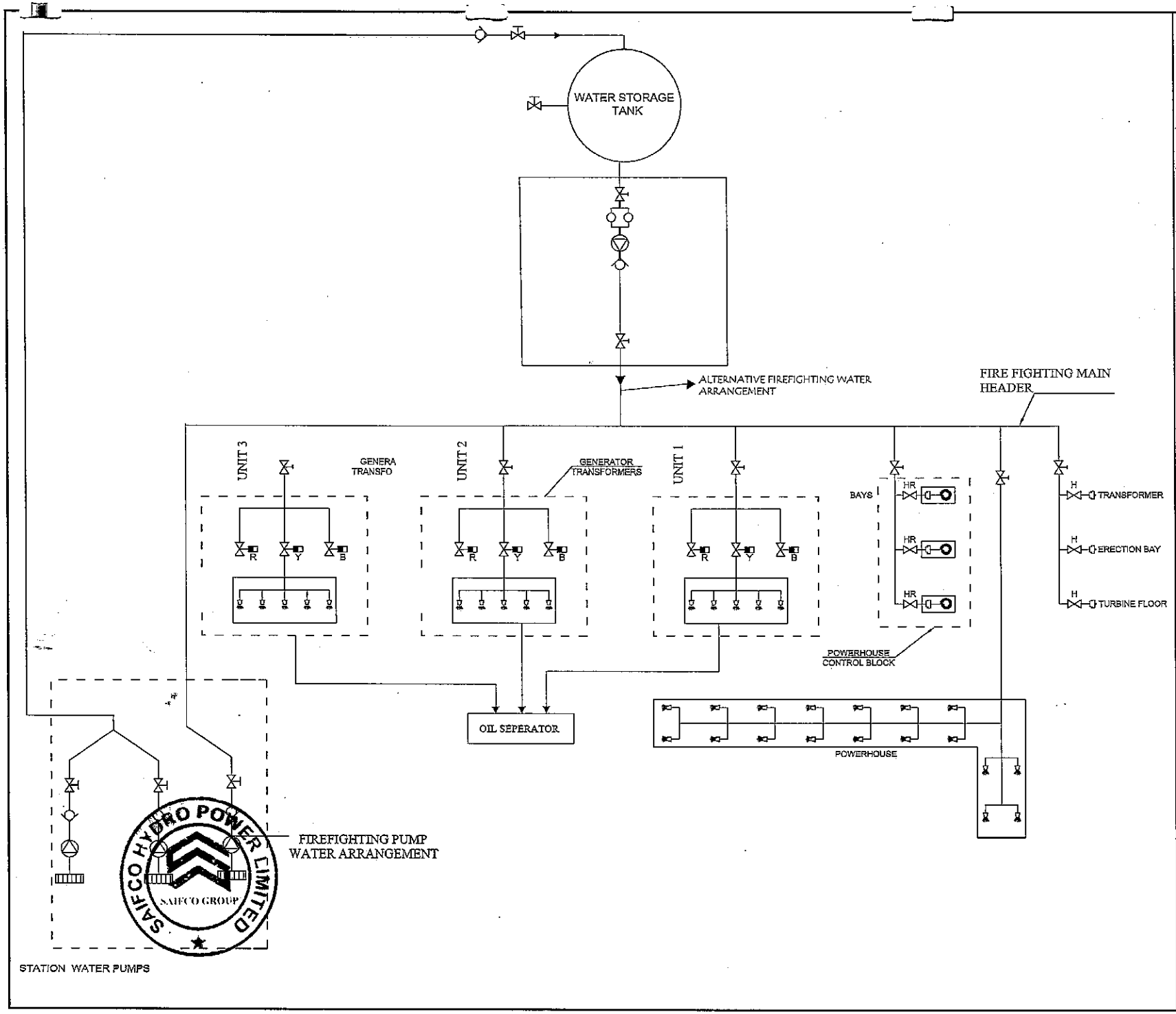
CHECKED:	M.Z.I		
APPROVED:	M.H.F	SCALE:	N.T.S



LEGEND:

- PUMP
- MANUALLY OPERATED VALVE
- MOTOR OPEN VALVE
- PRESSURE REDUCING VALVE
- DUPLEX COARSE FILTER
- AUTOMATIC BACK FLUSHING ROTARY FILTER
- PDS — PRESSURE DIFFERENTIAL SWITCH
- SPRINKLER NOZZLE
- DELUGE VALVE
- HR — HOSE REEL
- H — HYDRANT

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IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

FIRE FIGHTING SYSTEM

(SHEET 1/1)

CONSULTANTS:
ELECTRA CONSULTANTS in association with INTEGRATION

DRAWN:	ALI	DATE:	MAY, 2014
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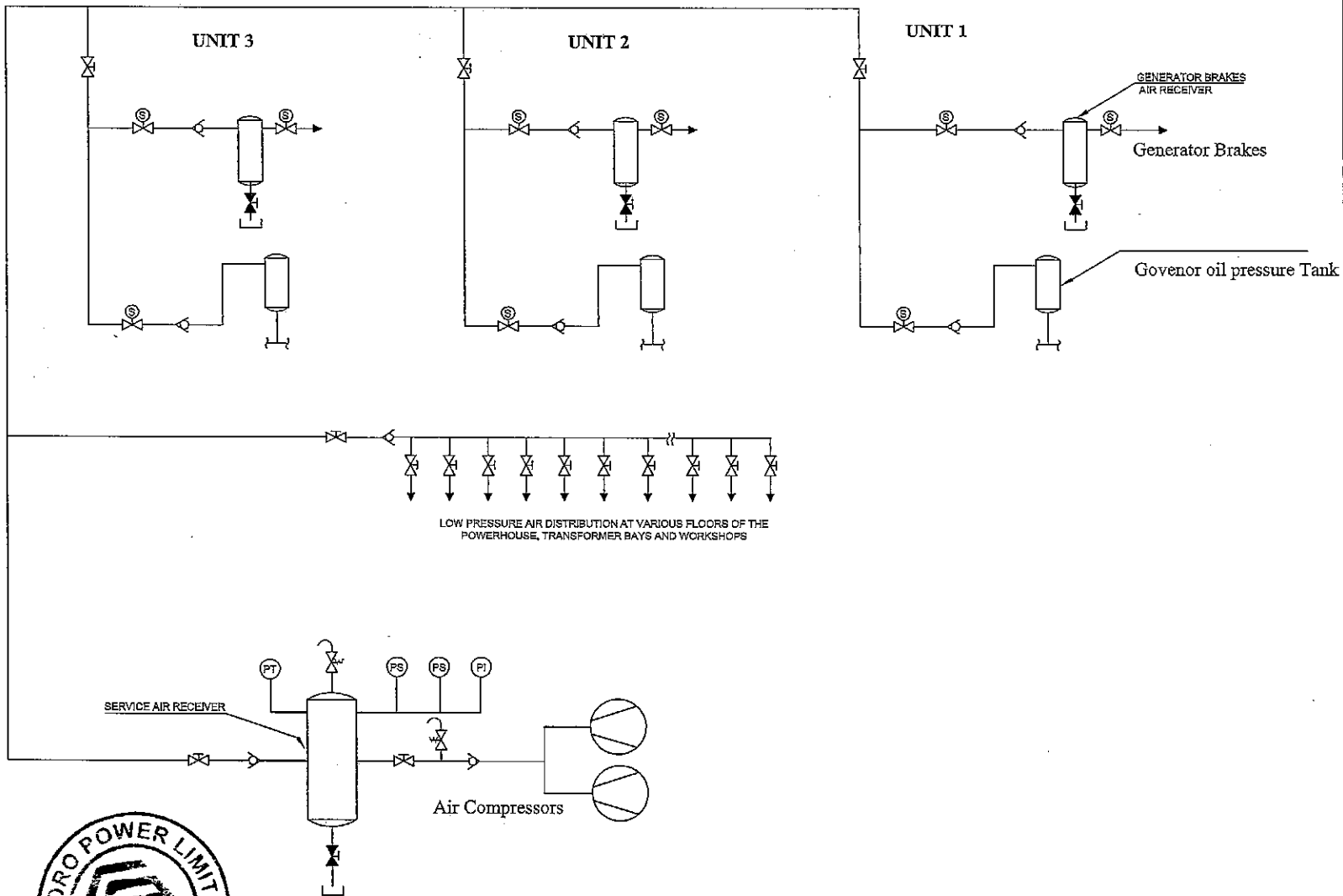
APPROVED:	M.H.F	SCALE.	N.T.S



LEGEND:

- SAFETY VALVE
- SOLENOID VALVE
- MANUALLY OPERATED VALVE
- NON RETURN VALVE
- PS — PRESSURE SWITCH
- PI — PRESSURE INDICATOR
- PT — PRESSURE TRANSMITTOR

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IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

COMPRESSED AIR SYSTEM

(SHEET 1 / 1)

CONSULTANTS:
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DRAWN:	ALI	DATE:	MAY, 2014
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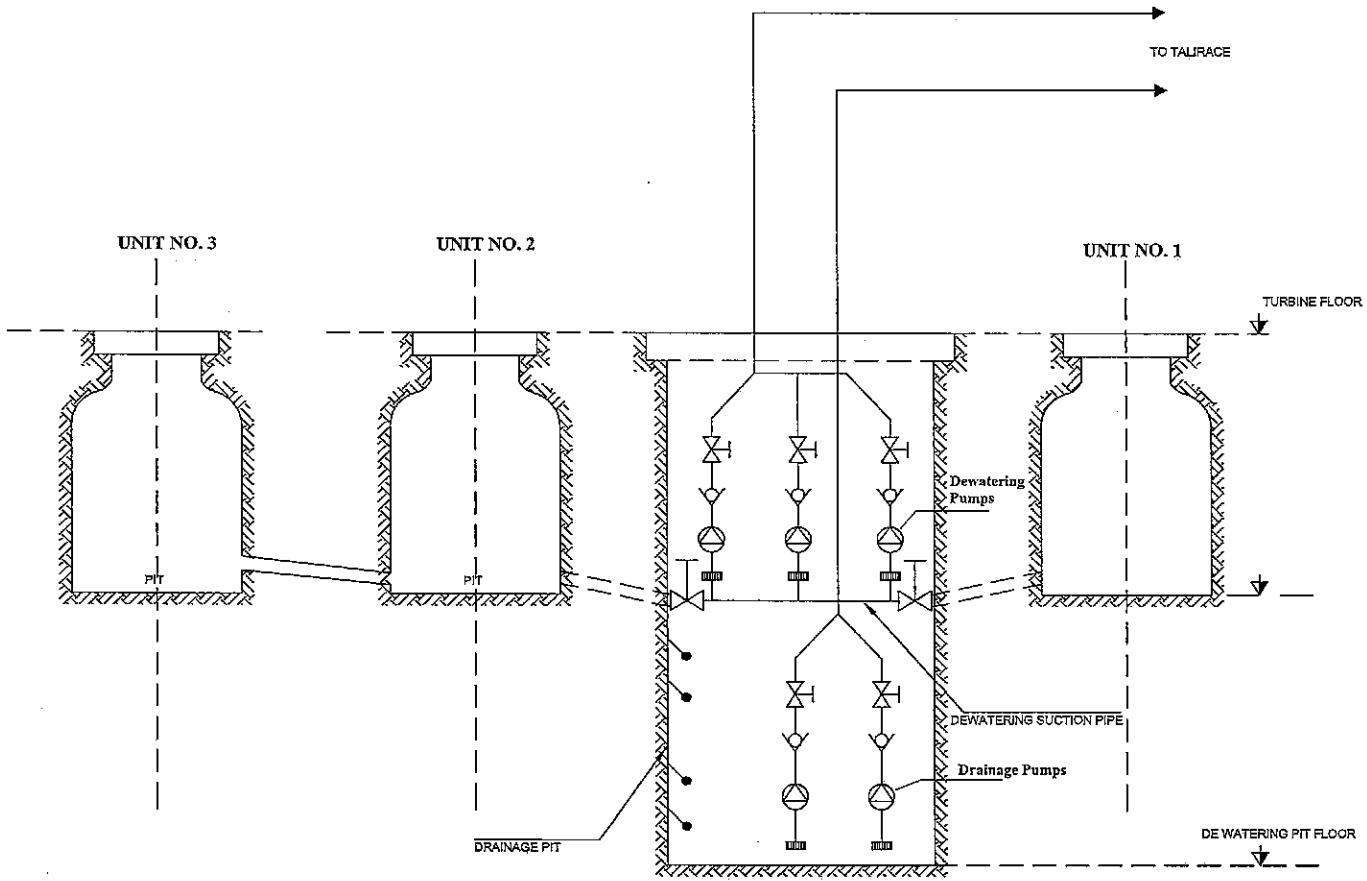

LEGEND:

- NON RETURN VALVE
- MANUALLY OPERATED VALVE
- SUBMERSIBLE PUMP WITH STRAINER
- FLOAT SWITCH

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SHIGO KAS HPP

DEWATERING & DRAINAGE SYSTEM

(SHEET 1/1)

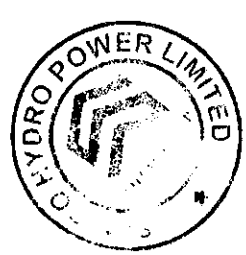
CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

DRAWN:	ALI	DATE:	MAY, 2014
DESIGN:	M.ZJ	FIGURE NO.	9.5
CHECKED:	M.ZJ		
APPROVED:	M.H.F	SCALE.	N.T.S

CHAPTER

9

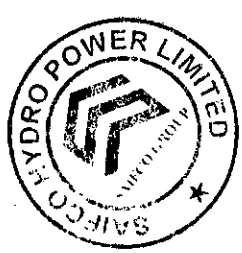
MECHANICAL EQUIPMENT STUDIES



ANNEX

9A

MECHANICAL DRAWINGS



CHAPTER 9

MECHANICAL EQUIPMENT STUDIES

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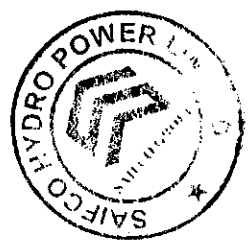
Fig 9.7: Francis Turbine Solution Summery

Fig 9.8: Francis Turbine Solution Summery



MECHANICAL EQUIPMENT STUDIES

9.0 GENERAL

This section includes the information about Mechanical equipment directly related to generating units and mechanical equipments for general services. It also covers the characteristics of these equipments and various factors used to establish the size and configuration of such type of equipments.

9.1 MAIN DESIGN PARAMETERS

9.1.1 Water Flow

A single value of flow has no significance. It is very necessary to know the flow regime, commonly represented by the Flow Duration Curve shown **Figure 9.1**. In Shigo Kas HPP the flows vary from 21.79 m^3/s to 540.64 m^3/sec. Considering the flow pattern against various months the optimum selected discharge will be 150 m^3/sec.

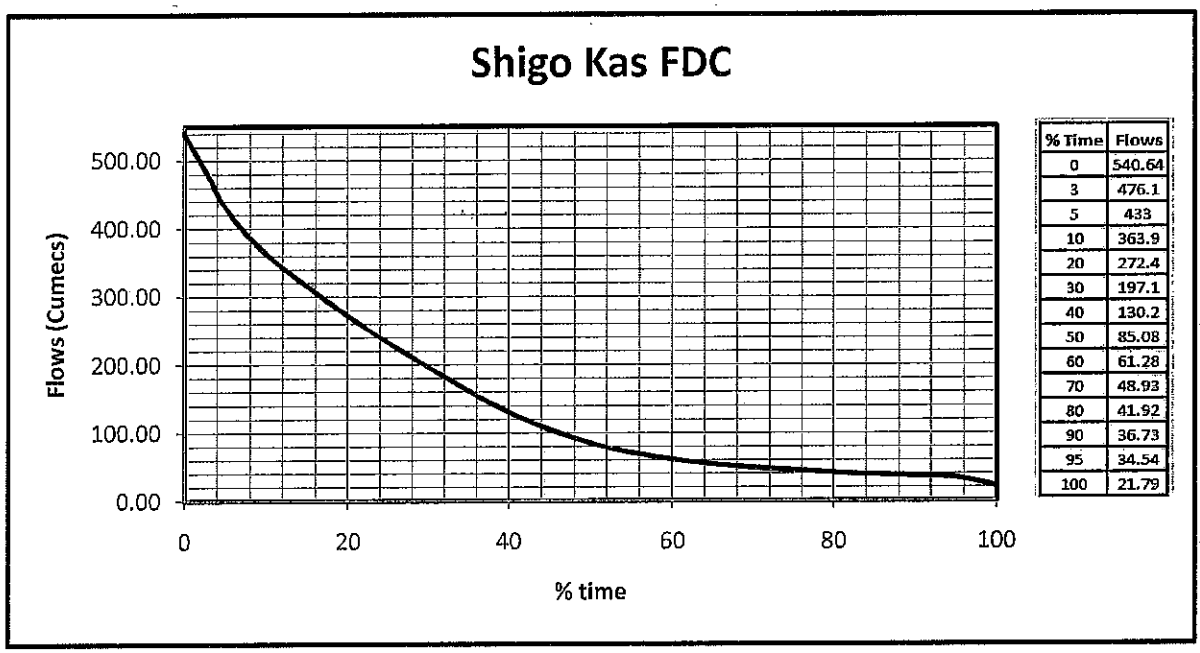


Figure 9.1: Flow Duration Curve for Panjkora River at Shigo Kas Site

9.1.2 Water Head

9.1.2.1 Gross head

On the basis of selected water levels calculated gross head will be:

Maximum Gross Head: 91.5 meter

9.1.2.2 Head losses

Major Head losses in hydro power project are in the water ways due to friction. In case of Shigo Kas HPP, the preliminary calculation of waterway head losses from the weir to the tailrace outlet portal indicated that the total maximum head losses are about 13.5 m.

9.1.2.3 Rated net head

Considering the total head losses and turbine runner central line arrangement the selected rated net head is as follows:

Rated Net Head: 78.5 meter

9.2 PLANT CAPACITY

The Power has been carried out according to the following formula:

$P = \rho \times g \times Q \times H \times \eta/1000$

where

P= Power (MW)

ρ = Density of water = 1 (tonne/m^3)

Q = Discharge (m^3/sec)

H = Available head (m)

g = Acceleration due to gravity (9.81 m/sec^2)

η = overall Efficiency coefficient (%)

On the basis of selected rated discharge of 150 m^3/sec and rated net head of 78.5 meter and overall efficiency of turbine, generator & transformer, the Plant output capacity will be 102 MW.

9.3 TURBINE SELECTION CRITERIA

The type, geometry and dimension of the turbine will be fundamentally conditioned by various criteria's such as:

- Net head
- Range of discharges through the turbines
- Turbine rotational speed
- Cavitations problems

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- Cost

Among the above criteria net head and discharge are the basis ones, while other supports them.

9.3.1 Net Head

As a first criterion for the selection of type of hydel turbine, is the head at which it is operated. In case of Shigo Kas Hydro power project gross head will be 92 m and selected rated net head is 78.5 m. It is a medium head hydro power project and Francis type turbine is best and appropriator solution.

9.3.2 Range Of Discharges through the Turbines

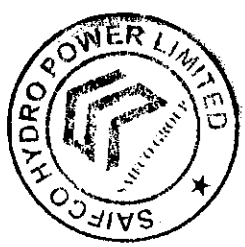
Shigo Kas HPP is a medium discharge and medium head hydro power project. The flows vary from 540.64m^3/sec to 21.79 m^3/sec. The selected rated discharge 150 m^3/sec is available for 37% of time. Keeping in view the flow pattern in various months and selected rated head Francis turbine is more appropriate solution.

For the selection of turbine, procedures outlined in the USBR "Engineering Monograph No: 20" Selecting Hydraulic Reaction Turbine is adopted. Furthermore Excel based worksheets and computer software TURBNPRO is used for Turbine and other mechanical equipments sizing and design.

9.4 NUMBER OF UNITS

Normally it is most cost effective to have a minimum number of units at a given installation; however multiple units may be necessary due to various reasons. Thus for selecting number of units following factors should be considered.

- Efficient water use
- Getting Max energy
- Space limitation for civil structure
- Transportation Problems
- Maintenance View point
- Cost effectiveness



9.4.1 Efficient Water Use

Efficient use of available water and getting maximum energy from Hydropower station is necessary to maximize the profitability.

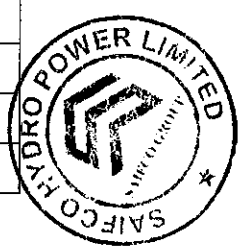
Selection of number of units plays a bridge role to achieve this target. On the feasibility stage three different alternatives having 2, 3 or 4 units of same capacity is considered.

One major factor for evaluation of number of units is how the power station will anticipate in operation. Particularly for Shigo Kas HPP, with 3 or 4 units operational reliability is more as compared to 1 or 2 units. This operational advantage will also contribute in the annual energy produced by the project. With 3 or 4 units, generation can be continued more efficiently for flows down to the minimum historic discharge whereas with 1 or 2 unit this flexibility reduces.

Table 9.1 shows the comparison of basic data for three alternatives:

Table 9.1: Basic Data for Three Alternatives

Shigo Kas Hydro Power Project				
Net Head	m	78.5		
Plant Rated Flow	m^3/sec	150.0		
Number of Units		2	3	4
Each Unit Discharge	m^3/sec	75.0	50	37.5
Rated Turbine Capacity	MW	53.7	35.4	26.54
Over all Plant Capacity	MW	102.25	102	101.85
Unit efficiency at rated discharge	%	92.0%	92.0%	92.0%
Turbine Speed	Rpm	200	272.7	333/350
Runner outer diameter	m	3.08	2.46	2.15
Crane capacity	Tonne	130	100.0	65
Crane Span	m	16.7	13.3	11.6
Setting	m	-5.61	-3.3	- 2.17



9.4.2 Space Limitation for Civil Structure

Space limitation for geologic characteristic may dictate larger or smaller units. In case of Shigo Kas Hydro Power Project for selected alternatives, turbine capacity lies between 53.7 MW to 26.54 MW each unit. From the Civil structure & Geologic viewpoint no major hindrance found,

in power house side, considering any of these alternatives. However civil work and E & M cost will vary accordingly with alternates.

9.4.3 Maintenance View Point

More the number of units higher the O&M (operation and maintenance) cost, lesser the number of units less will be maintenance cost. But for the system stability and avoid the complete shutdown of powerhouse more than one unit is strongly recommended.

9.4.4 Transportation

The transportation of heavy construction and permanent equipment (turbine Runner, Generator rotor, stator, transformers) to the site is a matter which needs careful attention.

In Case of Shigo Kas HPP transportation limitations are not known exactly at the present stage. Limited available data indicate that the bridges and culverts in project area are designed for less loading capacity. More over steep slopes and sharp bends are imposed restriction.

Considering available data & specially transportation limitation 3 or 4 units are consider more suitable.

9.4.5 Cost effectiveness

Higher the number of units more the E&M and total project cost. In case of 3 or 4 units the difference in energy benefits is very less, however by increasing units from 3 to 4 cost will considerable increase. Thus 3 units are more suitable.

9.4.6 Recommendation

Considering all above parameters/aspects **3 units** are the most favorable solution from the technical and economical point of view.

9.5 POWERHOUSE MECHANICAL EQUIPMENT

The powerhouse will be equipped with three vertical axis Francis turbines. The total plant out capacity of Shigo Kas HPP is 102 MW with a turbine rated power producing capacity of 35.4 MW each. The turbine shall be capable to operate within a wide range of head and discharge at maximum attributable efficiency. Each turbine is connected to the penstock via a butterfly type valve.

Type of Turbine	Vertical Francis

No. of Units	03	
Plant Capacity	P_{Total}	=102 MW
Plant Discharge	Q_{total}	= 150 m^3/s
Unit Discharge	Q_{unit}	= 50 m^3/s
Min Unit Discharge	Q_{min}	= 19.8 m^3/s
Rated Net Head	H_n	= 78.5 m
Rated Turbine Output at shaft	P	= 35.4 MW

Followings are the main powerhouse mechanical equipments.

- ✓ Turbines
- ✓ Inlet Valves
- ✓ Governors
- ✓ Cooling and Service Water Systems
- ✓ Dewatering and Drainage Systems
- ✓ Potable water system
- ✓ Sewage and water treatment
- ✓ Compressed air Systems
- ✓ Oil handling system
- ✓ Heating Ventilation & Air-conditioning System
- ✓ Fire protection system
- ✓ Powerhouse Crane
- ✓ Powerhouse elevator
- ✓ Workshop equipment etc

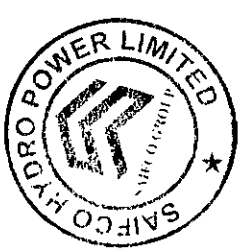
9.6 TURBINES

Vertical axis Francis Type turbine is selected for Shigo Kas hydro power project.

9.6.1 Main data

9.6.1.1 Turbine rated output

The turbine rated output is expressed by the following equation:



$Pt = 9.81 \times Q \times Hn \times \eta t$

Where

Pt = Turbine out Power (KW)

Q = Discharge (m^3/sec) = 50.0 m^3/sec

Hn = Rated Net Head (m) =78.5 m

ηt = Efficiency of turbine (%) = 92

= 9.81*50*78.5*0.92 = 35424 KW

Rated Turbine Output at shaft P = 35.4 MW

9.6.1.2 Turbine speed

The main data for comparison of some turbine speeds is made in **Table 9.2**.

Table 9.2: Comparison of Turbine Speeds

Turbine Speed	272.5 rpm	300 rpm
Runner outlet diameter	2.46 m	2.23 m
Runner weight	10.6 ton	9.82 ton
Turbine setting approx.	-3.3 m	-3.76 m
Maximum turbine efficiency	92 %	92%
Generator-rotor weight	86.32 ton	79.8 ton

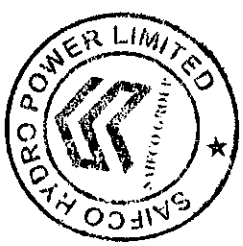
The turbine runner sediment abrasion increases considerably with increasing speed, whereas the wear of the guide apparatus decreases slightly with increasing speed.
Increasing speed will also make the turbine runner more vulnerable to cavitations caused by smaller surface errors.
Although the maximum efficiency increases slightly with increasing speed, the operational area where the efficiency is high will be smaller with increasing speed, and especially the low load performance will be reduced.
As a conclusion, a turbine speed of 272.7 rpm is selected.

9.6.2 Approximate data

9.6.2.1 Runaway speed

The unit runaway speed as determine by TURBNPRO comes out to 504 rpm, However an accurate value is guaranteed by the turbine manufactures.

Runaway speed: = 504 rpm



9.6.2.2 Setting

The turbine has to place sufficiently below the tailrace level to ensure that there is an adequate submergence. The proposed setting for Shigo Kas vertical Francis turbine is about -3.3m.

9.6.2.3 Components Dimensions

The turbine major components dimension and layout have been workout by software TURBNPRO, the solution summary is given in **Figures 9.7 to 9.8** and are summarized in **Figures 9.2 to 9.6**:

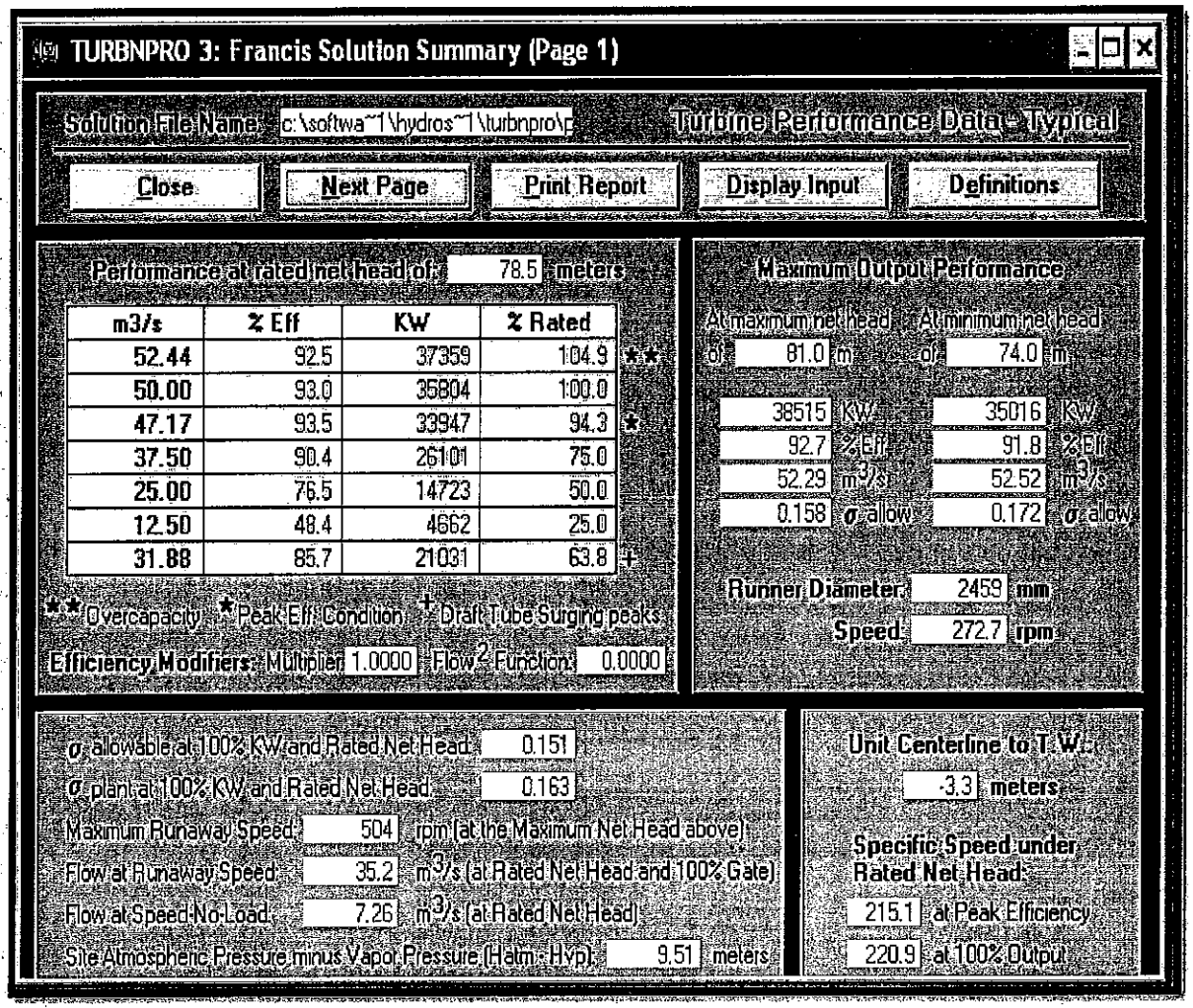


Fig 9.2: TURBNPRO Workout

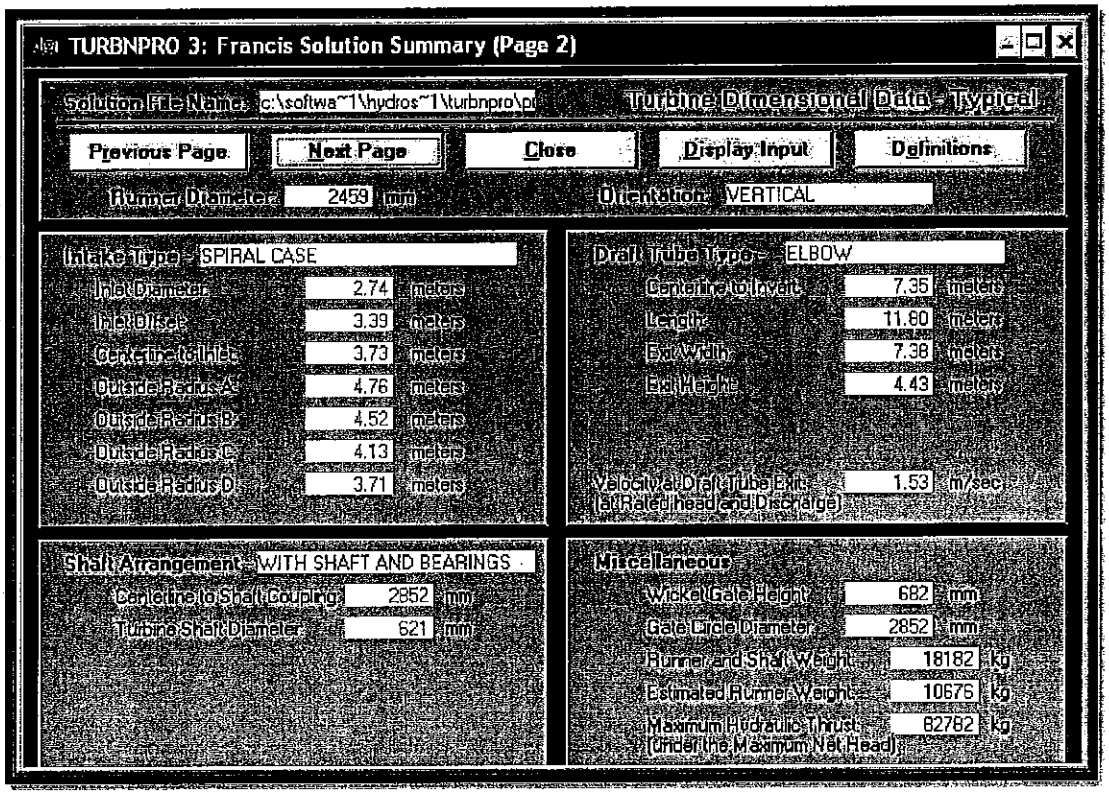


Fig 9.3: TURBNPRO workout

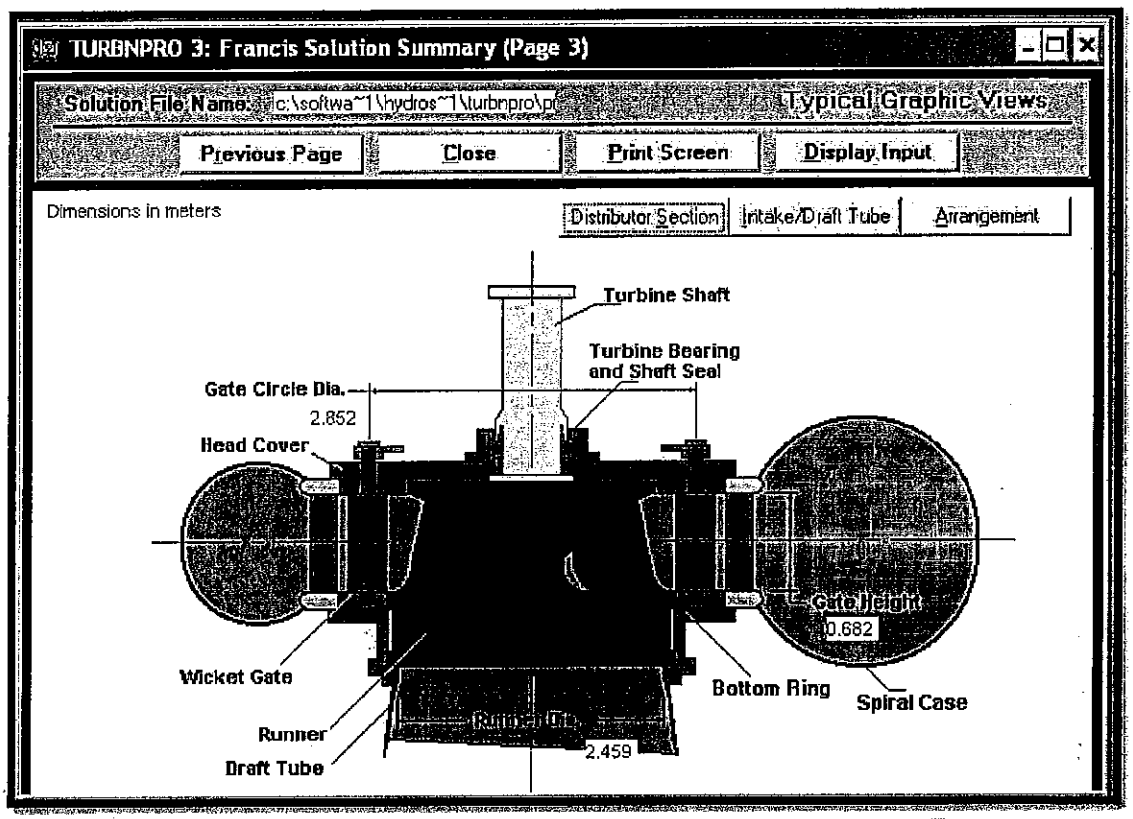


Fig 9.4: TURBNPRO workout

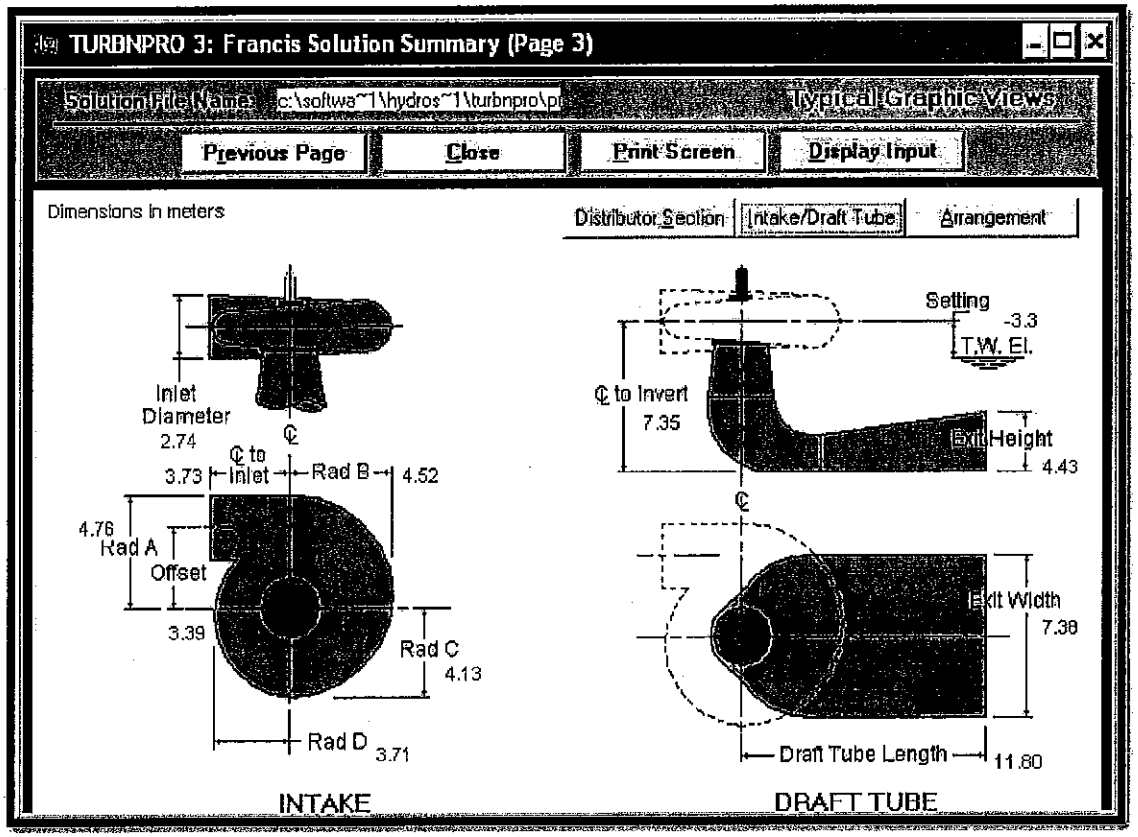


Fig 9.5: TURBNPRO workout

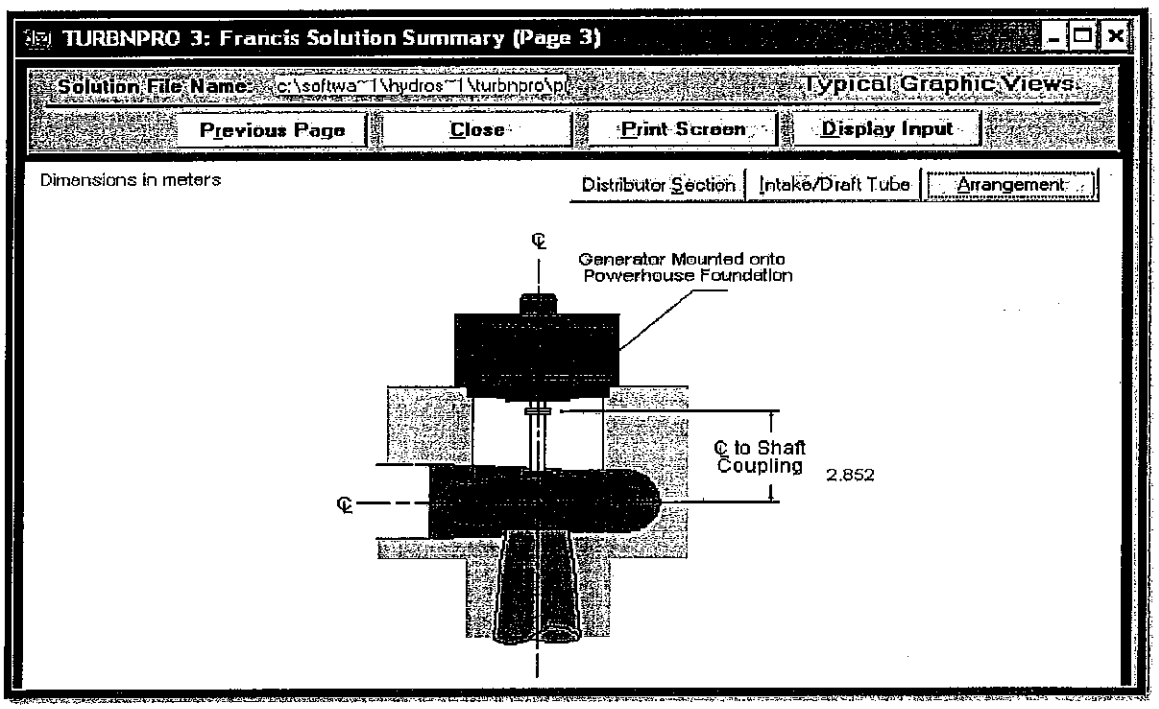


Fig 9.6: TURBNPRO workout

Fig 9.7: Francis Turbine Solution Summery

TURBNPRO Version 3 - FRANCIS TURBINE SOLUTION SUMMARY

Solution File Name: d:\zeesha~1\hydros~1\turbnpro\shigokas

TURBINE SIZING CRITERIA

Rated Discharge:	1765.5	cfs	/	50.0	m3/s
Net Head at Rated Discharge:	257.5	feet	/	78.5	meters
Gross Head:	301.8	feet	/	92.0	meters
Site Elevation:	1831	feet	/	558	meters
Water Temperature:	59	Degrees F	/	15	Degrees C
Setting to Tailwater:	-10.8	feet	/	-3.3	meters
Efficiency Priority:			7		
System Frequency:			50 Hz		
Minimum Net Head:	242.8	feet	/	74.0	meters
Maximum Net Head:	265.7	feet	/	81.0	meters

FRANCIS TURBINE SOLUTION DATA

Arrangement:	VERTICAL WITH RUNNER ON TURBINE SHAFT			
Intake Type:	SPIRAL CASE			
Draft Tube Type:	ELBOW			
Runner Diameter:	96.8	inches	/	2459 mm
Unit Speed:	272.7	rpm		
Multiplier Efficiency Modifier:	1.000			
Flow Squared Efficiency Modifier:	0.0000			

Specific Speed at Rated Net Head -	(US Cust.)	(SI Units)
At 100% Turbine Output:	57.9	220.9
At Peak Efficiency Condition:	56.4	215.1

SOLUTION PERFORMANCE DATA

At Rated Net Head of: 257.5 feet / 78.5 meters

% of Rated Discharge	Output (KW)	Efficiency (%)	cfs	m3/s
** 105.1	37420	92.5	1855.5	52.5
100	35804	93.0	1765.5	50.0
* 94.3	33947	93.5	1665.6	47.2
75	26101	90.4	1324.1	37.5
50	14723	76.5	882.7	25.0
25	4662	48.4	441.4	12.5
+ 63.8	21031	85.7	1125.7	31.9

** - Overcapacity
* - Peak Efficiency Condition
+ - Peak Draft Tube Surging Condition

At Maximum Net Head of: 265.7 feet / 81.0 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.158	38605	92.7	1851.1	52.4

At Minimum Net Head of: 242.8 feet / 74.0 meters

Sigma Allowable	Max. Output (KW)	Efficiency (%)	cfs	m3/s
0.173	35048	91.8	1856.8	52.6

TURBNPRO Version 3 - FRANCIS TURBINE SOLUTION SUMMARY

Solution File Name: d:\zeesha~1\hydros~1\turbnpro\shigokas

MISCELLANEOUS DATA

Maximum Runaway Speed (at Max. Net Head):	504 rpm		
Turbine Discharge at:			
Runaway Speed (at Rated Net Head & 100% gate):	1244 cfs	/	35.2 m3/s
Synchronous Speed-No-Load (at Rated Net Head):	256 cfs	/	7.3 m3/s
Site's Atmospheric Pressure minus Vapor Pressure:	31.2 feet	/	9.5 meters
Sigma Allowable (at 100% Output & Rated Net Head):	0.151		
Sigma Plant (at 100% Output & Rated Net Head):	0.163		
Maximum Hydraulic Thrust (at Max. Net Head):	182120 lbs	/	82782 kg
Approximate Runner and Shaft Weight:	40001 lbs	/	18182 kg
Vel. at Draft Tube Exit (at Rated Head & Discharge):	5.0 fps	/	1.5 m/s

DIMENSIONAL DATA

Intake Type: SPIRAL CASE

	inches	/	mm
Inlet Diameter:	108.0		2743
Inlet Offset:	133.6		3393
Centerline to Inlet:	146.8		3729
Outside Radius A:	187.6		4764
Outside Radius B:	178.1		4525
Outside Radius C:	162.6		4131
Outside Radius D:	146.2		3713

Draft Tube Type: ELBOW

	inches	/	mm
Centerline to Invert:	289.3		7348
Shaft Axis to Exit Length:	464.7		11803
Exit Width:	290.4		7377
Exit Height:	174.3		4426

Shafting Arrangement: VERTICAL WITH RUNNER ON TURBINE SHAFT

	inches	/	mm
Centerline to Shaft Coupling:	112.3		2852
Turbine Shaft Diameter:	24.5		621

Miscellaneous:

	inches	/	mm
Wicket Gate Height:	26.8		682
Wicket Gate Circle Diameter:	112.3		2852

*** All information listed above is typical only. Detailed characteristics will vary based on turbine manufacturer's actual designs.

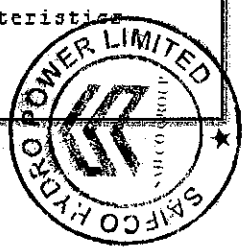


Fig 9.8: Francis Turbine Solution Summery

9.6.3 Special design criteria

The turbine and its various components shall be designed to operate at a maximum load and to bear the stresses produced corresponding to 35.8 MW turbine shaft output power.

9.6.3.1 Overpressure

The maximum pressure in the spiral casing in the most unfavorable condition of head and sudden discharge, with or without wicket gate closing, will not exceed a pressure rise of about 20%.

9.6.3.2 Over speed

The maximum momentary speed rise will not exceed 45% of the rated speed in the most unfavorable.

9.6.3.3 Runaway speed

The turbine will withstand the maximum runaway speed in the most unfavorable head and gate condition safely and without any abnormal reaction.

9.6.3.4 Critical speed

The first critical speed of the combined turbine generator unit will be at least 25% higher than the maximum runaway speed.

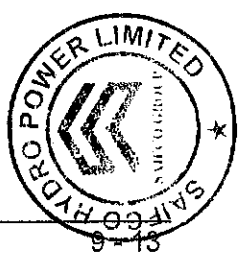
9.6.4 Turbine Major Components

9.6.4.1 Runner

The runner is the energy conversion element of turbine. Francis runners use stainless steel blades, bands and crowns. Special alloys are also used to minimize erosion. In this project the runner will be a cast or welded construction of 13% chrome, 4% nickel steel. The runner shall be designed and manufactured to operate at any load, head and speed within the limits given, as well as the runaway speed at maximum head with exceeding the allowable stresses and without undue cavitations and vibration.

All surface of the runner exposed to the flow of water will be carefully machined and finished smooth to the templates.

Turbine Runner outlet dia = 2.46 m



9.6.4.2 Turbine shaft

The turbine shaft shall be made of forged mild steel with integrally forged flanges. It shall be of ample size to operate safely in combination with the generator shaft and at any speed up to the maximum runaway speed without producing excessive vibration or distortion. The shaft diameter shall be co-ordinate with the generator shaft diameter.

The generator and turbine shaft flanges shall give an accurate fit and easy site alignment.

9.6.4.3 Turbine guide bearings

The bearing system for hydraulic turbine-generator units typically consists of guide bearings and a thrust bearing. The turbine bearing shall be of oil lubricated type and shall work as a guide bearing with removable segments with bearing metal. The entire thrust from rotating parts and the hydraulic load shall be taken by the upper generator thrust bearing. The bearing oil circulation shall be activated by the rotation of the shaft.

9.6.4.4 Spiral casing

The spiral casing shall be manufactured from steel plate sections as a welded construction. The number of sections shall be suitably chosen so that the water does not abruptly change its flow direction. Although the spiral casing will be embedded in the concrete, it will be designed to withstand, without any support the surrounding concrete, the internal pressure due to the maximum head (including maximum water hammer).

Spiral casing inlet dia = 2.74 m

9.6.4.5 Stay Ring and Stay vanes

The stay ring will consist of cast steel or solid welded steel upper and lower rings, in sections, with cast or welded steel vanes jointing the upper and lower ring segments.

9.6.4.6 Head Cover, Bottom Ring and Discharge Ring

The head cover, bottom ring and discharge ring assembly of the turbine will be made of fabricated welded steel plate and will be sectionalized as necessary to meet shipment limitations and facilitate dismantling.

9.6.4.7 Shaft seal

The shaft seal provides the interface between the pressurized turbine water passage and atmospheric pressure at the location of the turbine shaft. To protect the shaft seal against sand

erosion, the seal should be of a type where pressurized filtrated lubricating water is supplied, runner against an exchangeable wear ring on the shaft. Alternatively the turbine may be of a design preventing unclean water from entering the seal box during operation. A simple labyrinth seal of wear resistant materials may then be provided combined with a standstill seal, which is automatically activated as an integrated part of the start/stop sequence of the respective generating unit.

9.6.4.8 Wicket gates/Guide vanes and operating mechanism

The turbine will be provided with an appropriate number of interchangeable stainless steel wicket gates/guide vanes. These shall be made of stainless steel, integrally cast forged design and operated by two servomotors, pressurized by the accumulator or the governor oil pressure system. The guide vane position is feedback as an electrical signal to the governor cubicle.

Wicket gates/Guide vane shafts and all moving parts of the operating mechanism shall as a main alternative run in self-lubricating, long life bushings. Guide vane shaft bushings shall be protected against sand intrusion. Addition of grease lubrication to prevent sediments from entering should be considered.

9.6.5 Governor System

Each turbine shall be equipped with suitable electro-hydraulic or electronic governor (PID type) conforming to IEC No. 308. The governor shall be of proven design capable of controlling speed / output under all operating conditions. The governing system shall comprise oil pressure system, governor actuator (Mechanical), governor electronic regulator, speed signal generator, oil pipe lines and deflector position restoring mechanism. The electronic regulating functions of governor i.e., speed / gate setting, deflector limit setting, start, stop, main circuit breaker position, shutdown etc. shall operate the unit in manual mode in case governor electronic regulator is non-operative. Local control unit have the indicators for deflector position, speed of the unit and power generated by the unit.

The control should be possible

1) Locally at the governor for the control of individual components and for maintenance purposes

2) From the main control board for starting, synchronizing, loading and stopping the unit

3) From the control room for supervising the function and operating the unit in connection with the main grid and for the local network.

9.6.5.1 Governor head

Each governor head to be assembled in the main control board of the power station shall be equipped with

- Start and stop switches
- Quick shut down
- Speed setting
- Speed drop setting
- Change-over-switch for two/four nozzle operation

All necessary buttons, indicators, instruments and limit switches and the control equipment for the automatic start, synchronizing and stopping sequence should be provided.

9.6.6 Turbine Instrumentation, Control and Safety Devices

Each turbine shall be provided with a complete set of instruments, gauges, controls and safety devices for unit control board for monitoring the conditions of the unit during normal running and emergencies. The instruments and gauges for the turbines include, inter alia, pressure gauges, level indicators, temperature and flow indicators, position indicator, indicating lamps for status indication etc. The safety devices shall comprise equipment and devices for sensing abnormal operating conditions, for giving visual and audible annunciation and shut down the unit.

9.6.7 Inlet Valve

9.6.7.1 Turbine inlet valves

A Butterfly type shut off valve will be required at the powerhouse end at upstream of each turbine. It will allow the penstock flow to be shut off in case of turbine malfunction, maintenance or an emergency.

Three butterfly type valves will be installed. The valve diameter will be 2.75 m. considering the pressure rise of 20 % above maximum static water head the design pressure of inlet valve will be 110.5 m WC. The valve shall be suitable for all operating conditions of transient and maximum water hammer. The valves shall be operated by oil, pressure and closed by oil pressure/counterweight, so that it is capable of being closed under all emergencies. All associated equipments such as servomotors, oil pressure units, counterweights, etc., shall be included in the offer. The valve shall close automatically under normal and emergency shutdown conditions. The valve will be complete with inlet pipe, outlet pipe with expansion

joint, by-pass arrangement for equalization of pressure on either side of the valve, etc. Both, the inlet valve and bypass valve, will be operated by oil pressure from the turbine governors.

Main data

Valve type	= Butterfly type
Design head	= 78.5 m
Approximate diameter	= 2.75 m
Sealing system, main seals	= Steel / Carbon Steel
Operating system	= Pressure oil

9.6.7.2 Pressure relief valves

Each unit will be equipped with one Relief and Bypass valve to protect the penstock pipe from overpressure in case of sudden closure of turbine wicket gates, which are supposed to close in minimum possible time to ovoid over speeding of turbine, in case of sudden load rejection or tripping from full load operation.

9.6.8 Auxiliary Systems

The auxiliary systems in a power plant have a vital role in the power plant's successful operation. Auxiliary systems shall include the various functions like cooling water, potable and service water , oil handling, drainage, detecting and suppressing fire, compressing air, Heating and ventilation of powerhouse, handling of various parts, workshop facilities etc.

To have a well functioning, easy to operate, and easy to maintain power plant, all the auxiliary systems have to be carefully considered and conceived. A major design concern for auxiliary installations (such as compressors, strainers, and pumps) is their location, performance and maintenance access. The items requiring maintenance or monitoring shall be installed in easy-to-access areas for convenience.

9.6.9 Water System

9.6.9.1 Cooling water system

The cooling water system is very essential for various powerhouse equipments, like Generator and Transformer, Turbine and generator bearings, air compressors, heating ventilation and air conditioning system and various other auxiliary equipments.

9.6.9.1.1 Generator cooling

Generator cooling is among the major uses of cooling water systems. An ample supply should be provided but over cooling shall also be avoided to protect condensation from forming on stator winding when generator is shutdown. Additional open / close valve on down stream of coolers shall control the cooling water flow to make sure the coolers remain full of water and the generator maintains an even temperature.

9.6.9.1.2 Transformer Cooling

Transformer cooling water supply pressure shall be selected very carefully to eliminate the possibility of contaminating the transformer oil.

At maximum load 35.8 MW turbine shaft power per unit, the generator efficiency is about 98.0% and the transformer efficiency about 98.5% and the heat dissipated will be about 1.242 MW per unit. Including other losses, the cooling water system should be designed as follows:

	MW	l/s
Max. cooling demand per unit	1.242	29.5
Auxiliary services cooling demand, units operating		24
Max. cooling demand power station operating		115

The total max cooling water demand will be **115 l/sec.** The cooling water system shall include pumps, piping, valves, gauges and accessories from main supply point to the unit points.

9.6.9.1.3 Source of cooling water

There are in principle two different ways of supplying the cooling water:

- Direct cooling with water pressure reduced from the headwater, leakage water from the turbine labyrinth seals, or pumped from the tail water. Most frequent a combination is used.
- The second system is mainly used when the raw water is heavily contaminated, and the first heat exchangers can be designed in such a way that they are easy to clean

The first system is the traditional system, and will work well if the amount of trash can be kept within reasonable limits, and the water is sufficiently clean to avoid organic growth.

The second system is mainly used when the raw water is heavily contaminated, and the first heat exchangers can be designed in such a way that they are easy to clean. The system is, however, expensive due to the additional heat exchangers, and will also increase the amount of cooling water needed due to the reduced temperature differences. The circulating cooling water can be treated to avoid organic growth and calcium deposits.

For the purpose of this feasibility study, the first system is selected, but this will be reviewed during the detailed design.

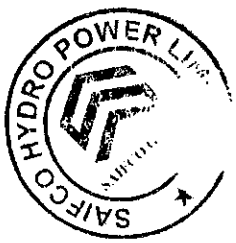
Direct cooling with water pumped from the tail water is as follows:

Water will be taken from the pit provided in tailrace. Water will be stored in the pit during the operation of units. Two pumps will be provided in the pit for each unit. One pump will operate continuously while other pump will act as stand by. Total Six pumps of appropriate capacity will be provided in the tail race pit for units and one extra pump will also be provided for firefighting system.

Water is pumped from the main line downstream of the strainers by a separate pump up to the double make up tanks. The tanks will be provided with sediment flushing facilities, and the water will be used for the transformer coolers, shaft seals, ventilation equipment, as well as some minor purposes. Furthermore, the tanks will provide standby cooling water for the bearings in case of emergency closing of the units.

Shaft seals, as well as other minor components, will have their own additional fine filtering systems, with pumps, fine filters and hydro-cyclones to exclude all sediments.

The pumps pumping water to the makeup tanks will be started and stopped according to the tank water level, independent of the operation of the units. Water for the firefighting equipment can additionally be pumped from the tail water.



9.6.9.2 Service and potable water

Water supply is also required for the following purposes:

- For drinking
- For fire extinguishing
- For workshops
- For washing and sanitation

Normally supply of water for portable and services use is made from deep well or through municipal supply. But due to location of the project both possibilities are over ruled. Thus a

common supply and storage system, along with a comprehensive filtration and water treatment facility will be provided. Service water is required for wash down and other application where potable water is not needed. The sources may be connected on the cooling water supply with a booster pump. Service water outlets shall also be provided on draft tube deck. Carbon steel pipe shall be used for lines over 35 to 75 mm. Smaller lines shall be from brass pipe or copper water tubing.

9.6.9.3 Waste and sewage water

Septic tank for lavatory disposal has been foreseen, the settled sludge will be periodically removed by using sludge pump or trolley and the sewage will be drained to downstream, away from the tail race pit through drain pipe.

9.6.9.4 Dewatering and drainage system

9.6.9.4.1 Tunnel and penstock dewatering

Tunnels and Penstocks are drained occasionally for inspection and maintenance purposes. During draining / dewatering process, the failure to admit sufficient air can result in collapse of the penstock. Therefore penstock shall have vent valves at different locations to meet the air demand.

The drainage mechanism of penstock and tunnel involves dissipating substantial potential energy stored in water. During this process the head in water will range from maximum static head to zero. At Shigo Kas hydropower project turbine will be used to drain the tunnel and penstock by operating off line at speed less than the synchronous.

9.6.9.4.2 Turbine dewatering system

The turbine dewatering system shall be pressure-piping system drained by gravity to closed system. The system shall permit draining the spiral casing and draft tube to tail water level and then pumping remaining below the tail water level to the sump. The dewatering sump will also act as rescue drainage sump in case of an accident or flood. Three pumps are used; one of the three will handle the max drainage to the sump, pumping to the highest tail water level. Spiral case drain shall take off from the low point of the invert and shall have a suitable valve in the vertical run. An air / vacuum valve to permit dewatering and filling shall be provided on the highest point on spiral case and a guard valve should protect them.

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9.6.9.4.3 Powerhouse drainage system

A gravity drainage system consists of floor drain and various equipment drains like compressors, gland leakage and condensate that drain to sump. The drainage system will also

carry wastewater, oil from a spill or combination of both. The water in the sump shall be pumped into the tailrace. Pumps shall be sized to meet the required estimated seepage. Two pumps are preferred. One pump will work as standby. These pumps shall operate alternatively for equal wear and tear. Water level switches will start / stop the first with the second pump starting if the first pump fails to handle the inflow.

9.6.10 Compressed Air System

A compressed air system will be provided for the service and maintenance purpose. The capacity of the system shall be sufficient to cater to all the generating units. The compressed air system shall be of the automatic start-stop design operating under pressure switches control sensing the pressure in the receiver. The compressors will be electrically driven.

The whole system of compressed air supply shall comprise 3 systems, as follows:

Compressed air for workshop equipments

Compressed air for governors pressure oil tanks.

Service air (for generator brakes and operation of equipments etc)

The station compressed air system will consist of two air compressors (one working one stand by). The system supply air at a rate of not less than $65m^3/hr$, the compressors shall be vertical or horizontal type, two stage electric motor drive. One air receiver of about 1.5 m^3 capacity shall be provided with system including supporting floor stand. The Compressed air system shall be supplied complete with all piping, valves, fittings and accessories for all required connections.

9.6.11 Oil Handling System

The oil storage and handling system is required to store a quantity of oil equivalent to the volume necessary for use of one unit. After continuous use the oil becomes contaminated with some impurities like dust, water etc and thus it loses its required viscosity. Therefore this dirty oil is centrifuged for its reuse, which is done by the oil purification plant provided in the system.

The system has two oil tanks one for clean or regenerated oil and other for dirty oil. A stationary pump is provided to circulate the oil towards the units through a distribution circuit. A portable pump with flexible hoses and quick-connect coupling is used to pump the dirty oil from units towards tank (called as dirty oil tank) through a specific pipe line circuit. From this tank the oil is passed through oil purification plant for its treatments, from here this clean oil is pumped into the clean oil tank or towards the units.

9.6.12 Heating, Ventilation and Air Conditioning System

Necessary arrangement for Ventilation, cooling and heating will be provided, according to powerhouse area requirements.

The proposed air conditioning system for this project calls for providing year – round air conditioning and ventilation to provide comfortable and required ambient conditions for people and sensitive equipments in the specified areas.

The design criteria are, to maintain indoor temperatures at 22 ~ 24 °C. In order to maintain that temperature in offices and control room an independent air conditioning system (Split type or Package units) or heating shall be provided.

The power station building will have a forced ventilation system, circulating air through filters. A fresh air intake will add constantly about 10% fresh air to the recirculation system, moreover battery rooms will have their own exhaust air system. Layout, dimensioning and arrangement of air-conditioning equipment will be defined during preparation of construction drawings of powerhouse building.

9.6.13 Fire Protection System

The fire protection system is an important auxiliary system for any powerhouse. This system mainly consists of the equipments required for detecting and extinguishing fire in the powerhouse. There will be three common systems for fire protection:

- Water Spraying System
- CO_2 Fire protection System
- Potable Fire Fighting cylinders

Fire hydrants at different locations in control building, service area and administrative areas are to be provided. In general, about 6-kg hand held and 25-kg mobile fire extinguishers shall be placed at most wanted locations in powerhouses. . In addition the power station will be provided with several taps for fire hoses. The water for the fire fighting system shall be taken directly from the tailrace by using pumps.

Transformer fire is most common in hydro plants, thus special care and arrangement is required to overcome. Water deluge system seems to be the most successful, safest and from most aspects preferred method for fighting transformer fire. The water will be used from service water supply tank having desired water pressure with back up of fire / booster pump.

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Carbon dioxide (CO_2) filled fire extinguisher will be placed at different floors to extinguish electrical fires. Oil storage rooms shall also be provided with CO_2 filled cylinders with auto release system initiated by smoke and fire detectors installed in the room.

The National Fire Protection Association (NFPA) Technical subcommittee on Fire Protection for Hydroelectric Plants has developed a recommended practice. Publication No NFPA.851 shall be referred to fulfill the subject requirement.

9.6.14 Powerhouse Crane

9.6.14.1 Bridge 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 heaviest part in the machine hall is the generator rotor, which is expected to be 86.32 tons. 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 inlet valve floor.

Main hoist capacity, expected	100 ton
Auxiliary hoist capacity	10 ton
Crane Span	13.3 m

The hoist is mounted on a trolley of compact design enabling minimum operational hook distance from the walls and maximum lifting height. The main hoist is equipped with one hook, cable and drum , with possibility of changing the corresponding values of lifting capacity and hoisting speed with push- button from the crane drivers cabin,

Provision shall be made on the powerhouse roof above the erection bays for easy replacement of the trolleys.

9.6.14.2 Mobile crane

In addition to powerhouse bridge crane, suitable capacity mobile crane (~15 T) is also provided for:

Erection of the transformer

Erection o f the machine hall crane

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Loading and unloading the equipment

9.6.15 Power House Elevator

One elevator has been foreseen at power plant to be used for transportation of goods from service bay to the equipment gallery and for transporting the passengers from the control room to the inlet valve gallery. Capacity requirement will be worked out during the detail design.

9.6.16 Workshop Equipment and Tools

The complete maintenance workshops will be provided inside the powerhouse with access form outside for preventive maintenance and repair of powerhouse equipments. The maintenance workshop will consist of followings:

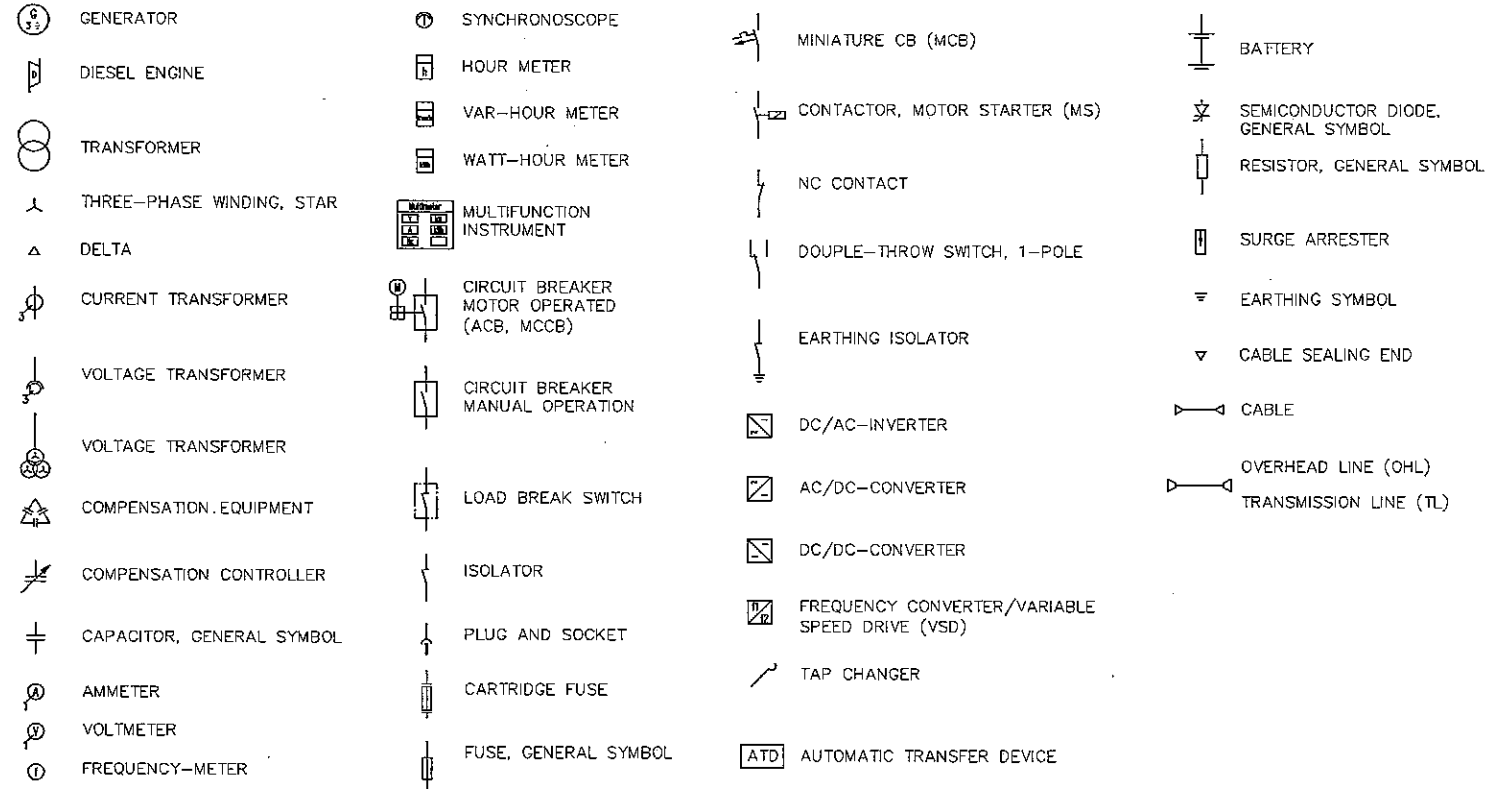
- Electric shop
- Machine shop
- Portable equipment

Workshop equipment and tools should be sufficient to perform the day to day maintenance requirements such as:

For dismantling and assembly of turbine parts and other components related to the power plant.

Necessary tools for components repair or renewal which do not need specialized skill or experience like welding machine, portable drill machine, small lathe, electric grinder etc.

All special tools, slings, lifting devices, jacks, turn buckles, foundation plates/ bolts, etc. required for erection of the equipments shall be listed and supplied. First filling of oil and grease (if applicable) with 10% extra quantity (included in the overall scope) shall be supplied along with equipment. Welding electrodes as required for site welding and paint for finishing coat shall be supplied by the contractor.



21	DISTANCE RELAY
21N	EARTH FAULT–DISTANCE RELAY
21FL	DISTANCE RELAY–FAULT LOCATOR
23	TEMPERATURE CONTROL DEVICE
24	OVERINDUCTION RELAY
25	SYNCHRONIZING OR SYNCHRONISM–CHECK DEVICE
26	TEMPERATURE MONITORING DEVICE
27	UNDERVOLTAGE RELAY
27	NO–VOLTAGE RELAY
30	ANNUNCIATOR RELAY
32	DIRECTIONAL ACTIVE POWER RELAY
32	DIRECTIONAL REACTIVE POWER RELAY
32	REVERSE ACTIVE POWER RELAY
32	REVERSE REACTIVE POWER RELAY
37	UNDERCURRENT RELAY
37	UNDERPOWER RELAY
40	EXCITATION FAULT RELAY
40	LOSS OF EXCITATION RELAY
46	PHASE–BALANCE OR REVERSE–PHASE CURRENT RELAY
49	THERMAL RELAY
50	OVERCURRENT RELAY
50BF	BREAKER FAILURE RELAY
50N–51	OVERCURRENT NEUTRAL–TIME–LAG OVERCURRENT RELAY
51	INVERSE TIME OVERCURRENT RELAY
51N	TIME–LAG OVERCURRENT RELAY, NEUTRAL
51V	TIME–LAG OVERCURRENT RELAY WITH VOLTAGE RESTRAINT
55	POWER FACTOR RELAY
56	EXCITATION RELAY
59	OVERVOLTAGE RELAY
59N	NEUTRAL ZERO SEQUENCE, OVERVOLTAGE RELAY
60	VOLTAGE BALANCE RELAY
60	CURRENT BALANCE RELAY
63	PRESSURE SWITCH
64	EARTH FAULT PROTECTION RELAY
64R	ROTOR EF PROTECTION
64S1	STATOR EF 95% PROTECTION
64S2	STATOR EF 100% PROTECTION
67	DIRECTIONAL OVERCURRENT RELAY
67N	DIRECTIONAL HOMOPOLAR OVERCURRENT RELAY
68	POWER SWING BLOCKING RELAY
71	LEVEL SWITCH
74	ALARM RELAY
78	PHASE–ANGLE MEASURING/OUT OF STEP PROTECTION RELAY
79	RECLOSING RELAY
81	FREQUENCY RELAY
87	DIFFERENTIAL PROTECTION RELAY
87G	GENERATOR DIFFERENTIAL PROTECTION RELAY
87MT	MAIN TRANSFORMER DIFFERENTIAL PROTECTION RELAY
87N	DIFFERENTIAL PROTECTION RELAY (E/F)
95	BUCHHOLZ RELAY

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FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

ELECTRICAL EQUIPMENT
LEGEND
(SHEET 1/1)

CONSULTANTS:
ELECTRA CONSULTANTS IN ASSOCIATION WITH INTEGRATION

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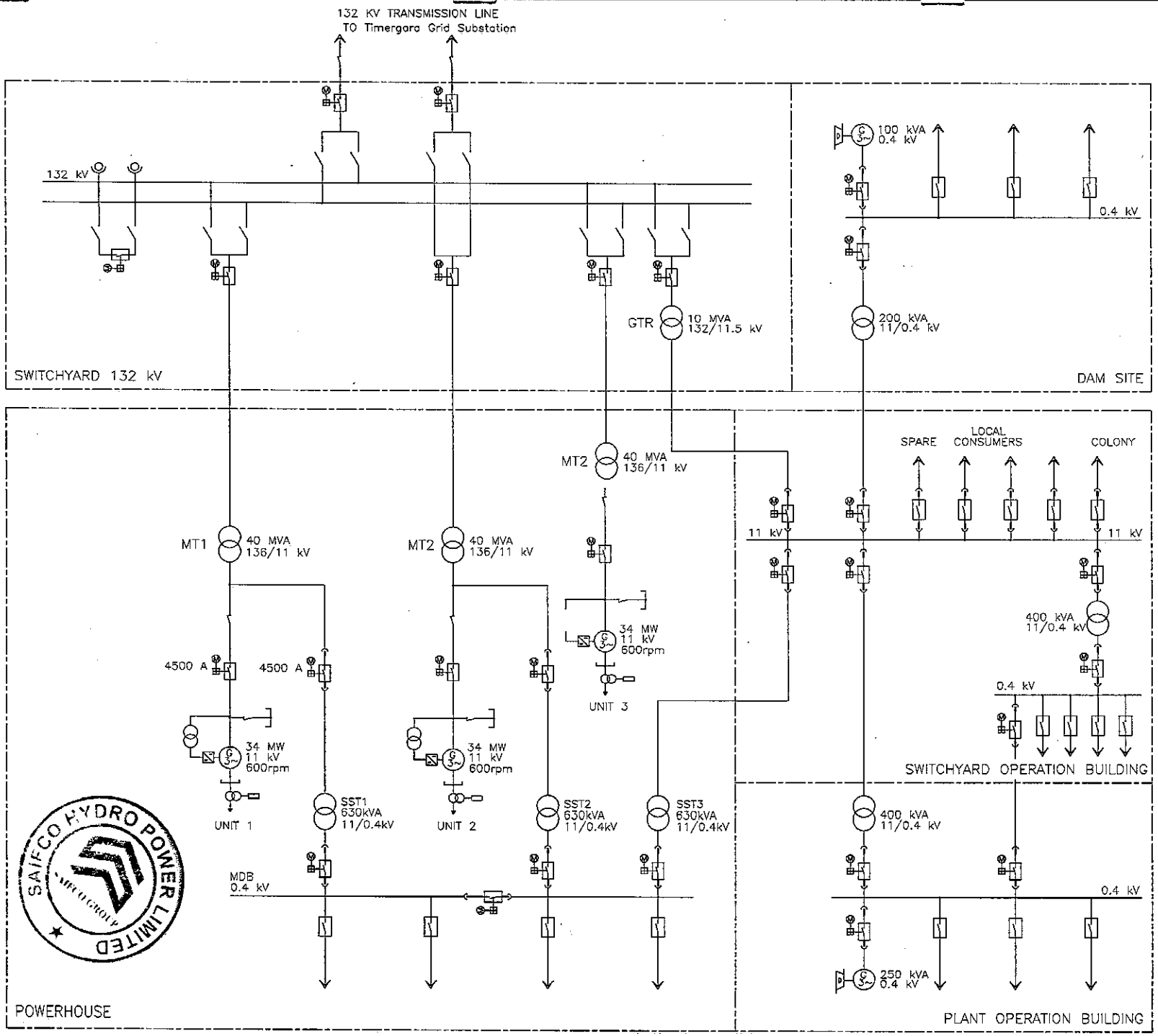
DESIGN:	M.AWAN	FIGURE NO.	10.1
CHECKED:	M.AWAN		
APPROVED:	M.H.F	SCALE.	N.T.S



NOTES

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2. ALL GENERATORS SIMILAR IN DETAILS TO GENERATORS 1 & 2 INCLUDING PROTECTION
3. UNIT AUX. TRANSFORMERS ONLY ON GEN.1&2
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ELECTRICAL EQUIPMENT
OVERALL SINGLE LINE DIAGRAM
(SHEET 1 of 1)

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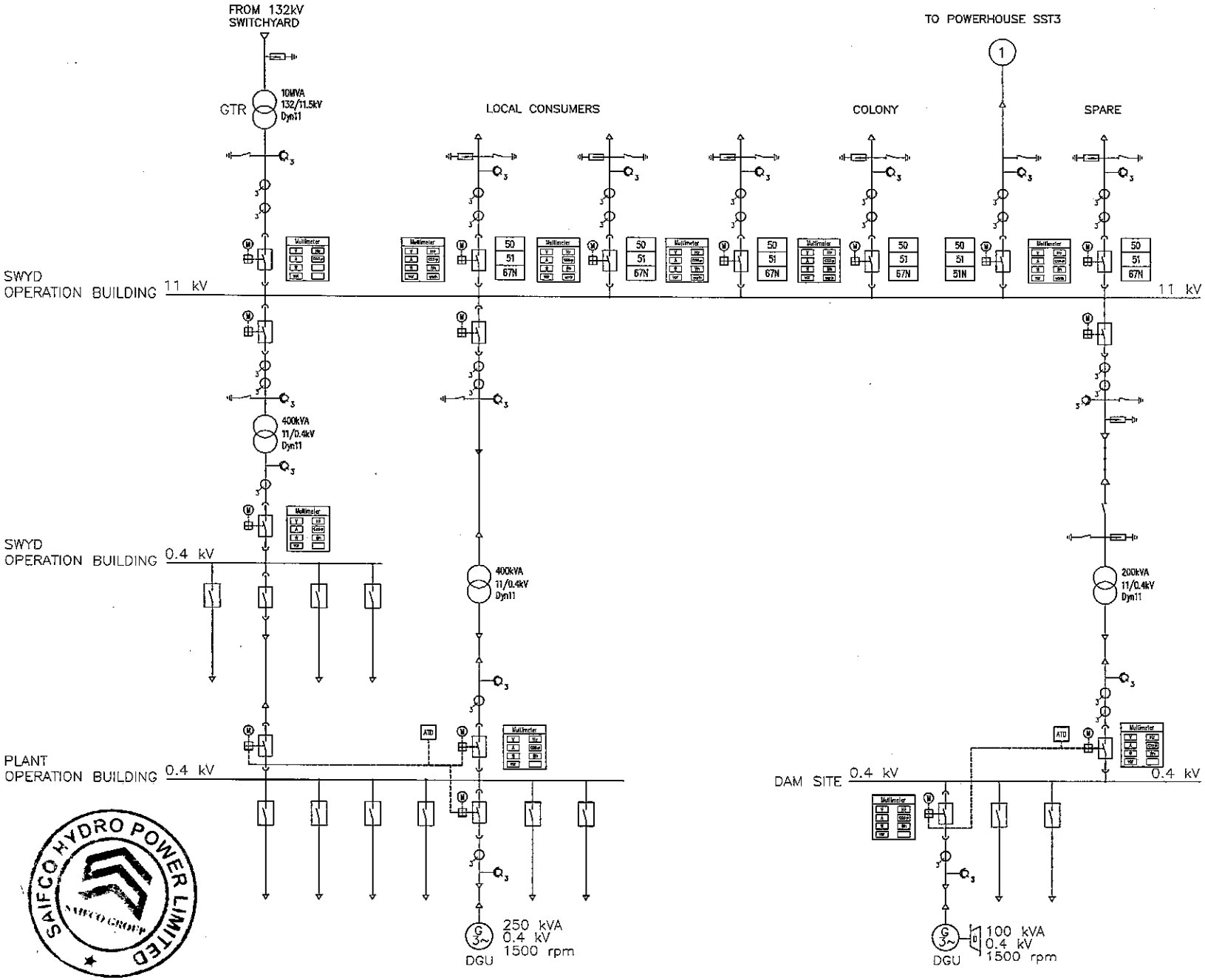

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IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

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MV/LV AUXILIARY SUPPLY SYSTEMS PLANT, SWYD & DAM OPERATION BUILDING, SINGLE LINE DIAGRAM

(SHEET 1 / 1)

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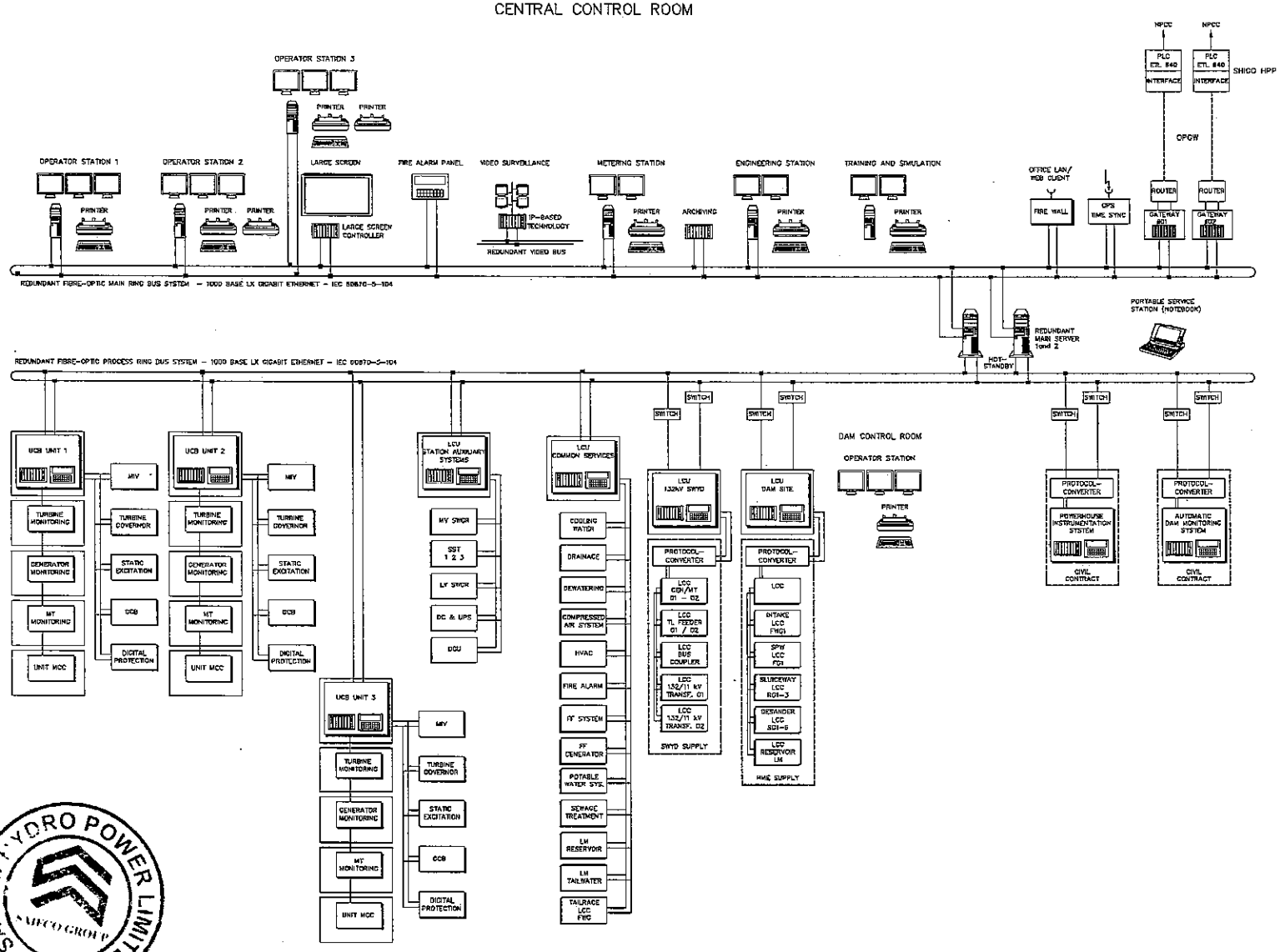

LEGEND:

SYMBOL	DESCRIPTION
CCS	COMPUTERISED CONTROL SYSTEM
DGU	DIESEL GENERATING UNIT
DS	DOWNSTREAM
FF	FIRE FIGHTING
FG	FLAP GATE
FWG	FIXED WHEEL GATE
FOC	FIBRE OPTIC CABLE
GCB	GENERATOR CIRCUIT BREAKER
HME	HYDRO MECHANICAL EQUIPMENT
IP	INTERNET PROTOCOL
LAN	LOCAL AREA NETWORK
LCC	LOCAL CONTROL CUBICLE
LCU	LOCAL CONTROL UNIT
LM	LEVEL MEASUREMENT
LV	LOW VOLTAGE
MIV	MAIN INLET VALVE
MT	MAIN TRANSFORMER
MV	MEDIUM VOLTAGE
NPCC	NATIONAL POWER CONTROL CENTRE
RG	RADIAL GATE
SG	SLIDING GATE
SPW	SPILLWAY
SST	STATION SERVICE TRANSFORMER
TL	TRANSMISSION LINE
US	UPSTREAM

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FEASIBILITY STUDY OF
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COMPUTERIZED CONTROL SYSTEM
SYSTEM ARCHITECTURE
(SHEET 1 / 1)

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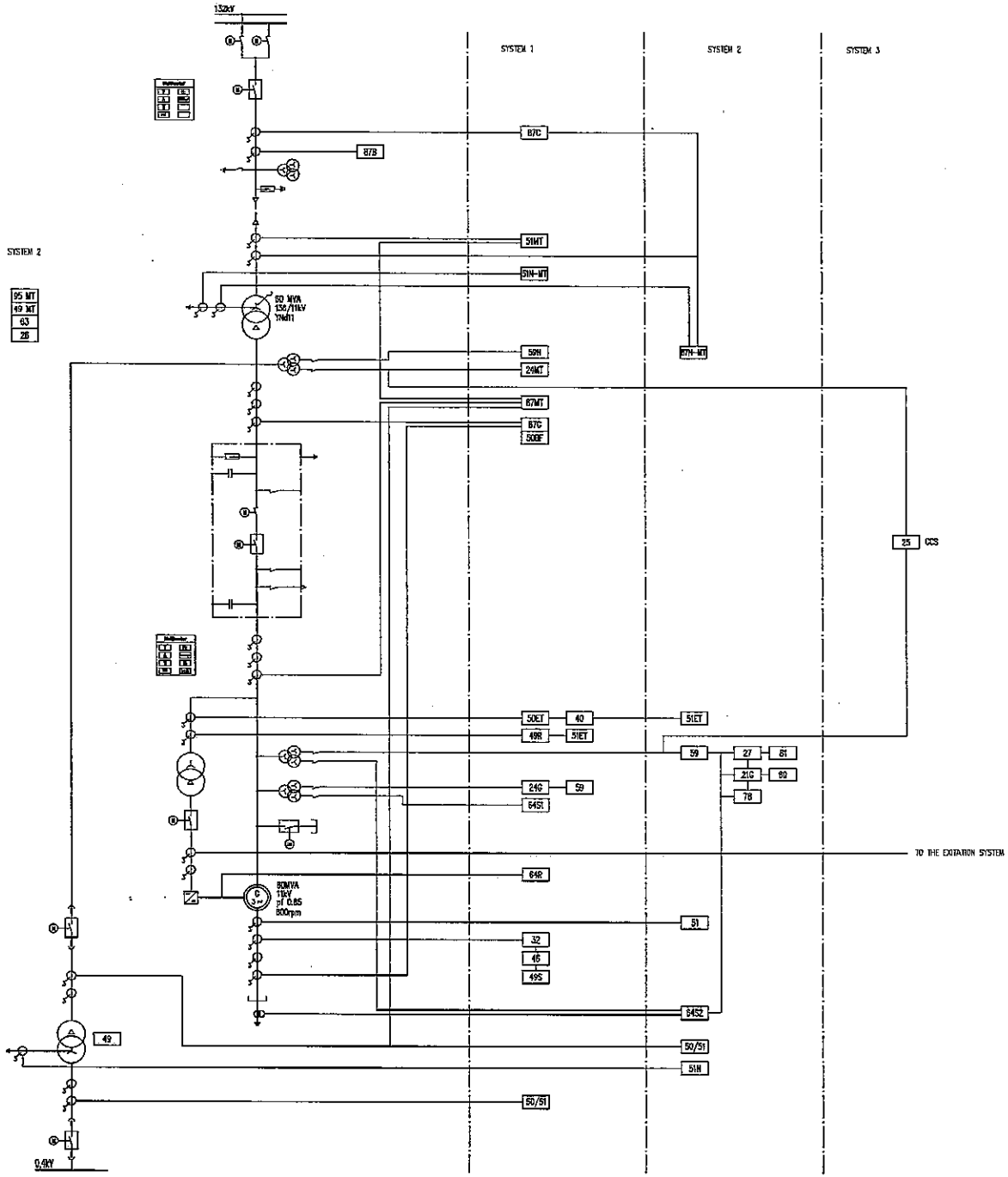

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NOTES

1. FOR LEGEND AND ABBREVIATIONS SEE DRAWING LEGEND

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FEASIBILITY STUDY OF
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GENERATOR AND MAIN TRANSFORMER
TYPICAL SINGLE LINE DIAGRAM
(SHEET 1/1)

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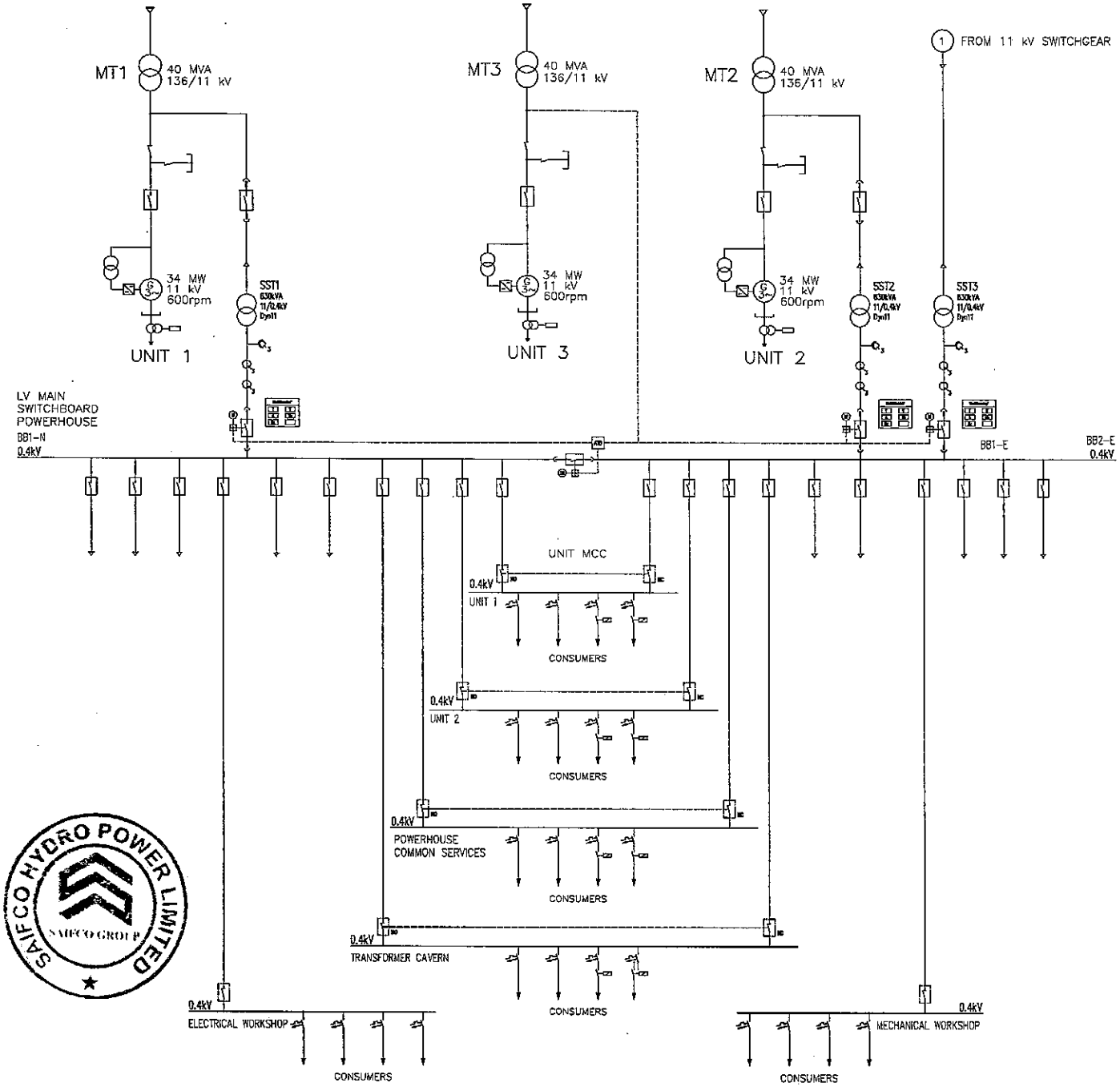

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NOTES

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IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

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POWERHOUSE LV AC AUXILIARY SUPPLY SYSTEM
GENERAL SINGLE LINE DIAGRAM
(SHEET 1 / 1)

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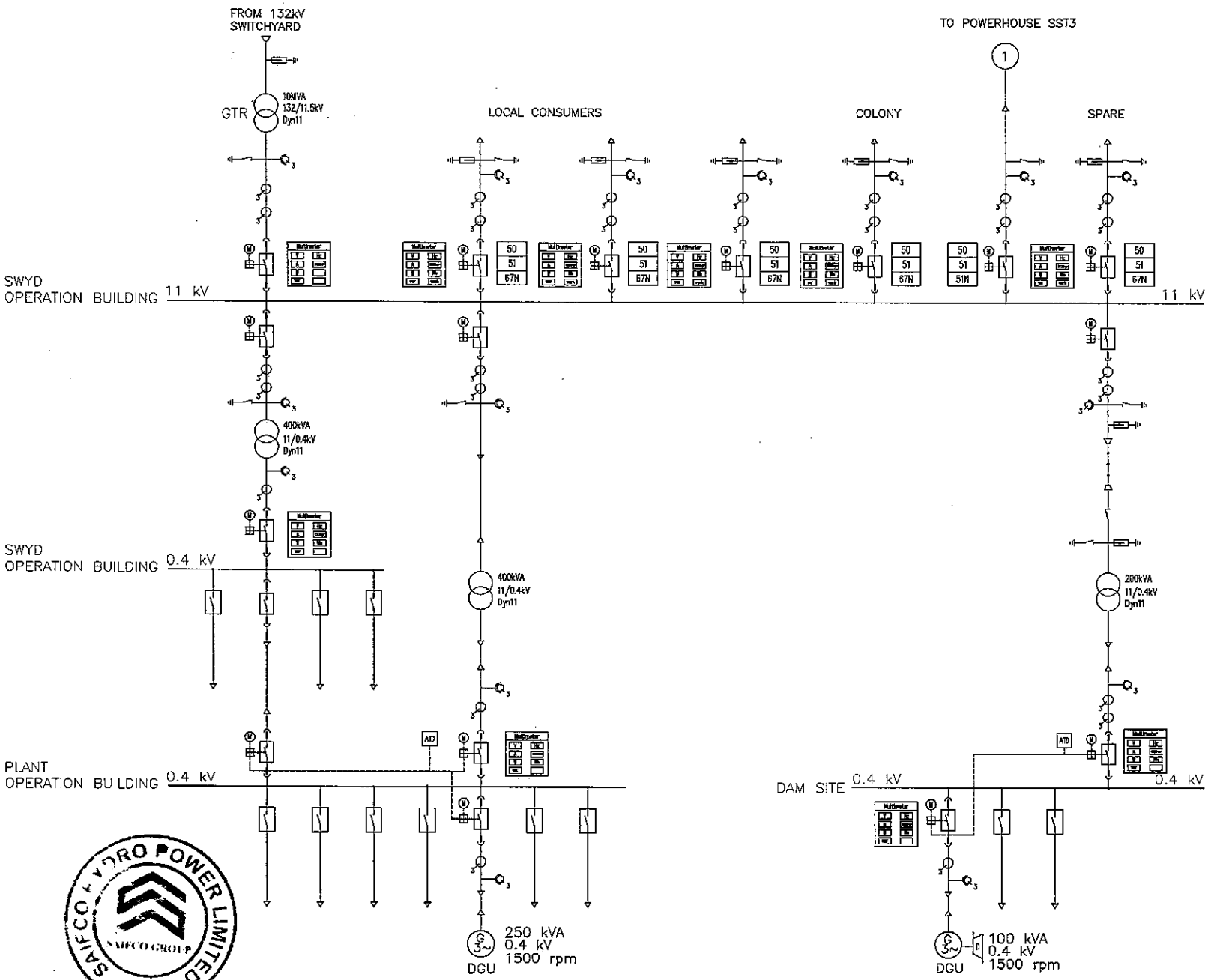

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PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa

FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

MV/LV AUXILIARY SUPPLY SYSTEMS PLANT, SWYD & DAM OPERATION BUILDING, SINGLE LINE DIAGRAM

(SHEET 1/1)

CONSULTANTS:
ELECTRA CONSULTANTS *IN ASSOCIATION WITH* INTEGRATION

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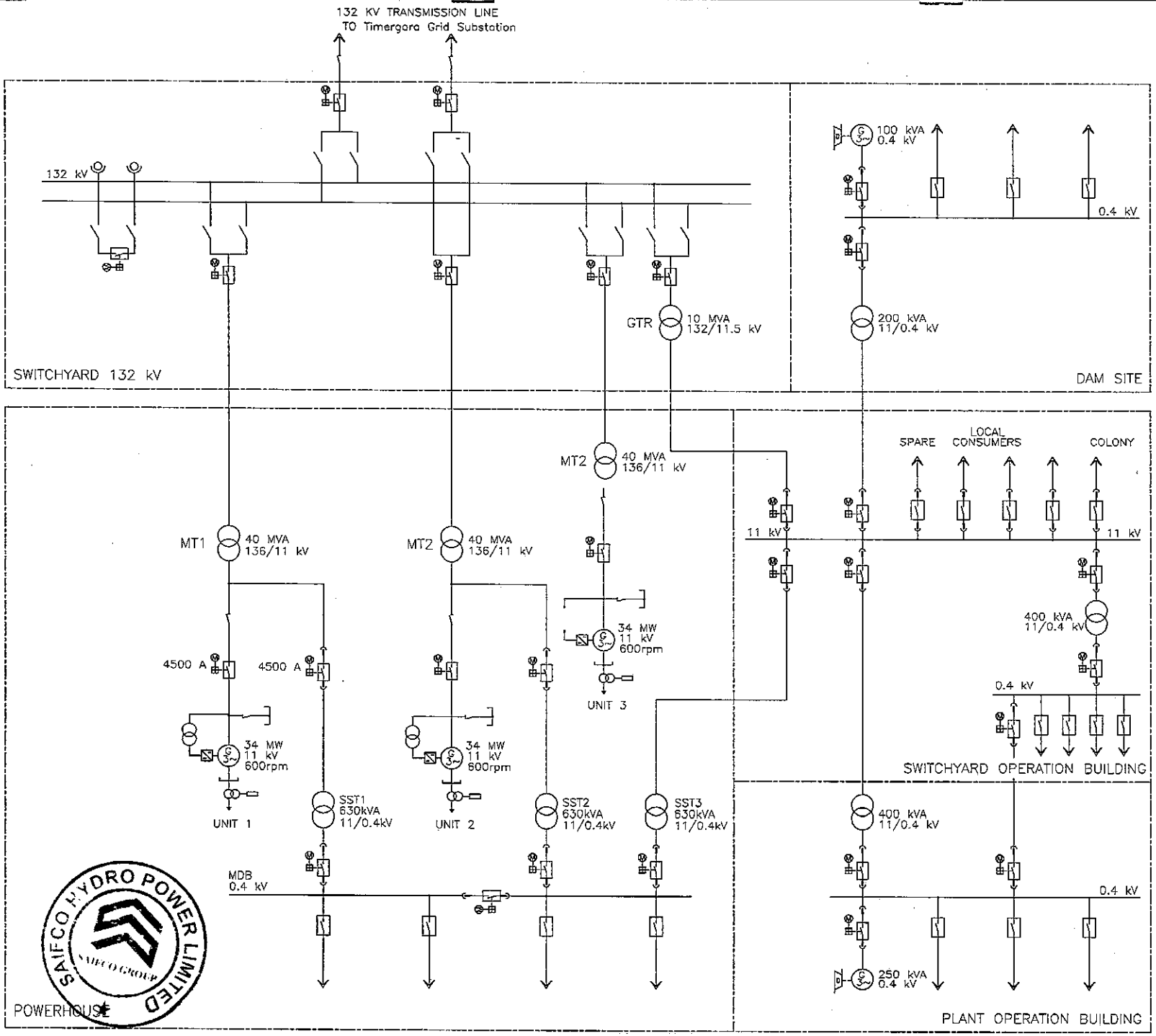

NOTES

1. ALL BAYS ARE SIMILAR AS REGARDS METERING.Total ... boys.
2. ALL GENERATORS SIMILAR IN DETAILS TO GENERATORS 1 & 2 INCLUDING PROTECTION.
3. UNIT AUX. TRANSFORMERS ONLY ON GEN.1&2.
4. FOR LEGEND AND ABBREVIATIONS SEE DRAWING NO.

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FEASIBILITY STUDY OF
SHIGO KAS HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

ELECTRICAL EQUIPMENT
OVERALL SINGLE LINE DIAGRAM
[SHEET 1/1]

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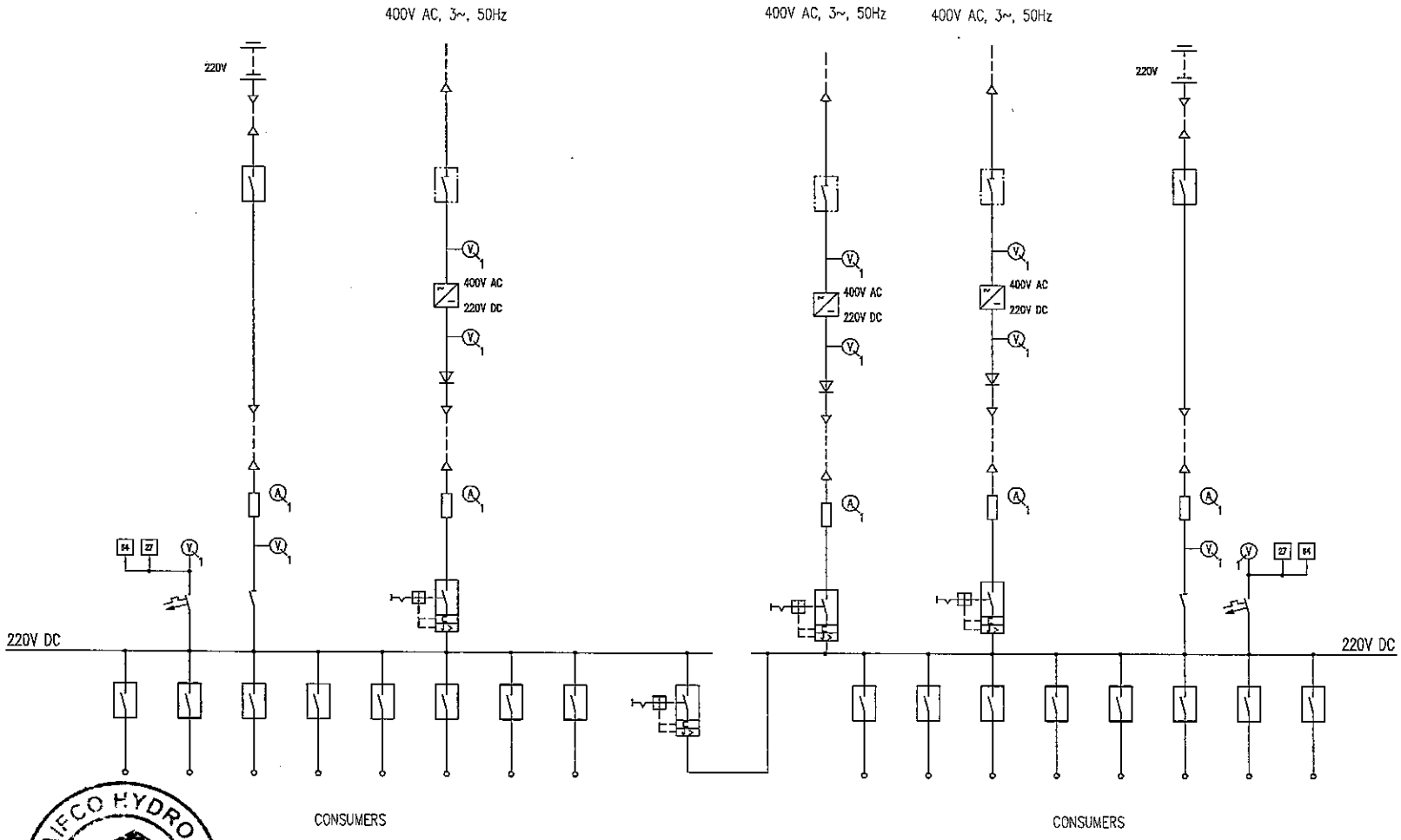

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FEASIBILITY STUDY OF
SHIGO KAŠ HYDROPOWER PROJECT
IN DISTRICT LOWER DIR KHYBER PAKHTUNKHWA PROVINCE

SHIGO KAS HPP

POWER HOUSE 220 V DC SYSTEM
TYPICAL SINGLE LINE DIAGRAM

(SHEET 1/1)

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CHAPTER 10

ELECTRICAL EQUIPMENT STUDIES

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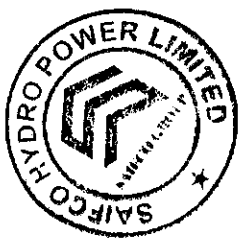
List of Abbreviations

American Standards of Testing Materials (ASTM)
American National Standards Institute (ANSI)
Closed-circuit Television (CCTV)
Control of Substances Hazardous to Health (COSHH)
Current Transformer (CT)
Direct Current/ Alternating Current (DC/AC)
Electromagnetic Compatibility (EMC)
Electrostatic Discharge (ESD)
Global Positioning System (GPS)
High Voltage/Low Voltage (HV/LV)
Institute of Electrical and Electronics Engineers (IEEE)
International Electro-technical Commission (IEC)
Light Emitting Diode (LED)
Local area network (LAN)
National Power Control Centre (NPCC)
National Transmission and Dispatch Company (NTDC)
Optical Ground Wire (OPGW)
Polyvinyl Chloride (PVC)
Private Automatic Branch Exchange (PABX)
Programmable Logic Controller (PLC)
Supervisory Control and Data Acquisition (SCADA)
Ultrahigh Frequency (UHF)
Uninterrupted Power Supply (UPS)
Voltage Transformer (VT)



ELECTRICAL EQUIPMENT STUDIES

10.1 OPERATING CONDITIONS AND DESIGN PHILOSOPHY

1. For the design and configuration of the various electrical systems the following operation and safety philosophy shall be applied:

- Electrical consumers indispensable to maintain continuous and full load power production at the generator terminals shall be fed (main power/control power) from two different sources alternately connected in case of failure of one.
- Redundant cable routes for duplicated main - and control power supply cables shall be used wherever the general layout and the available space will permit it.
- Emergency power supply from an independent and self-supported source shall be provided and distributed to all electrical consumers essential for safe shut-down of plant.
- For fire fighting installations, the relevant codes of NFPA shall apply.
- Upon failure of an electrical protection device either a parallel back-up device or the next co-ordinated device upstream of the fault shall clear the same.
- Destruction due to failure of one piece of equipment shall be limited to the same or the nearest surrounding and shall not cause subsequent damage.
- Unless otherwise noted, the protection class of all equipment shall not be less than IP 42 according to IEC standards.
- Measuring, monitoring and control equipment shall be provided for any component or group of components to the extent necessary for proper surveillance and safe operation/shut-down under any service conditions.

Detailed record of equipment failure shall be given locally with facilities for individual and grouped remote signalisation.

2. Distribution of auxiliary power such as DC, normal and essential AC (e.g. for space heaters, internal illumination etc.) shall meet the following principles:

- Power supply cables shall be terminated in panels, boards, cubicles etc. at terminals of the switching type if no other isolating facilities are provided.
- Wherever the power supply is looped through various locations, every such location shall be provided with miniature circuit breakers (MCB) for selective fault clearance.
- DC power supply to important switchgear installations such as HV/MV/Main LV switchgear shall have individual feeders directly connected to the related switchboard; subordinate services may be looped.

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- Back-up DC power shall be provided for all important switchgear installations to keep the signalisation operable in case of main supply failure.

10.1.1 Electrical Codes and Standards

1. Regardless of any national standard which may be accepted or approved, the recommendations of the International Electro technical Commission (IEC) shall be followed as "reference standards".

   The documents shall be based on the reference standards, but the use of alternative standards of recognised national standard associations may be considered.
2. In case of conflicts between applicable standards covering the same material or equipment, the standard which provides the higher quality and more suitable application shall prevail.

10.2 GENERATORS

The generators shall be totally enclosed, vertical salient-pole type, using air as the primary and water as the secondary coolant. They shall be designed to run without undue noise or vibration over the full load range up to the maximum continuous rating, within the specified limits of frequency and voltage variation. The generators shall comply with the relevant IEC Standards.

The generators shall have a combined thrust and guide bearing above the rotor and a second guide bearing below the rotor.

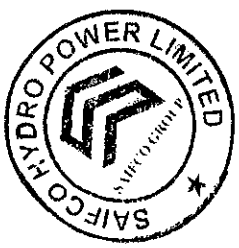
The scope of work shall comprise the following:

- Three generators
- Two sets of related auxiliary plant to provide complete, ready for service installations;
- One set of special tools and appliances;
- One set of special spare parts.

10.2.1 Principal Design Features

Main Characteristics

- Number of units	No. 3
- Type of construction	IM8425/W41
- Rated output	34 MW
- Synchronous condenser operation	not required
- Rated speed	272.7 rpm
- Runaway speed	504.0 rpm
- Direction of rotation	anticlockwise, viewed from top
- Rated power factor	0.85
- Rated frequency	50 Hz



- Rated voltage	11 kV
- Rated range of voltage regulation	±5 %
- Range of frequency variation	±3 %
- Flywheel effect	Approx. 435 tm²
- Insulation class Rotor/Stator	F/F
- Stator winding connection	Star (Y)
- Protection class	IP 44
- Cooling raw water temperature	20 °C
- Cold air temperature	40 °C
- Short circuit ratio	p.u. >1
- Transient reactance Xd'	To be determined by the manufacturer
- Sub transient reactance Xd"	To be determined by the manufacturer

Output and Efficiencies

The continuous rating of the generators shall be 40 MVA, measured at the unit terminals at rated speed, voltage and power factor. This rating shall be achieved with Class B temperature rise limits with one heat exchanger out of service and shall be guaranteed without tolerance. The maximum continuous output within Class F temperature rise with all heat exchangers operational shall be stated by the manufacturer.

The manufacturer shall include a generator capability diagram plotted for rated voltage and for the upper and lower limits of the specified voltage range. The manufacturer shall guarantee the values of the generator output and weighted average efficiency.

The rated output of the generator shall be guaranteed within the specified limits of temperature rise at rated power factor and at any voltage and frequency in the specified operating range.

The efficiencies of the generator shall be guaranteed at the specified rated output of 40 MVA with terminal voltage of 11 kV and 0.85 power factor and specified temperature rise limits. Individual losses and the efficiencies shall be determined according to IEC. The related bearing and static excitation equipment losses shall be included in the generator losses. The method to determine the losses and efficiencies shall be proposed by the manufacturer.

The guaranteed weighted average efficiency of the generator shall be computed with the following formula:

$$\text{ETA av} = \frac{\Sigma\,(WF \times ETA_P)}{\Sigma\,WF}$$

ETAP = are the efficiencies at loads (P) of 100%, 90%, 80%, 70%, 60%, 50%, 40% and 30% of the rated output of the generator at rated voltage and power factor.

WF = weighting factors for the generator part loads at:

P (p.u.)	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
WF	3	5	8	12	16	19	19	18

The output and weighted average efficiency guarantees shall be verified with the output and efficiency obtained from the field acceptance tests in accordance with the relevant IEC Standards.

Reliability

The reliability indices shall be as follows:

- Availability factor: > 99.5%
- Mean time to failure (MTTF): 18,000 h
- Time interval between major overhauls: > 10 years.

Insulation and Temperature Rise Limits

The stator and rotor pole winding insulation shall be of epoxy type Class F.

The stator and rotor winding temperature rise, while delivering continuously 40 MVA, at any voltage and frequency in the specified operating range shall not exceed the following temperature rises over the temperature of the cooling air not exceeding 40°C:

- Stator 80 K
- Rotor 90 K

The cooling raw water temperature is expected not to exceed 20°C.

The manufacturer shall guarantee the above temperature rise limits and suitable means for their measurement shall be provided in the stator and rotor.

The maximum temperature rise, measured by embedded temperature detectors, of any part of the stator core not in contact with insulated windings, including the clamping and flux-shielding arrangements, shall not exceed the permitted temperature rise for parts in contact with insulated windings by more than 10 K at maximum continuous rated load and at lagging and leading power factors.

Short Circuit Withstand Capability

The generator shall be capable of withstanding a three phase short circuit at the generator terminals when operating at rated output and power factor at 105% rated voltage.

Wave Form and Poly-phase Symmetry

The wave form of the emf between terminals of the generator on open circuit shall be practically sinusoidal. The wave form shall be accepted as practically sinusoidal if none of its instantaneous values vary from instantaneous value of the same phase of the fundamental wave (50 Hz) by more than 5% of the peak value of the fundamental wave.

The poly-phase voltage system of each generator shall be practically symmetrical. The poly-phase voltage system is considered as practically symmetrical if neither the negative sequence nor the zero sequence components exceeds 5% of the positive sequence component.

Special measures shall be taken to eliminate harmonics from voltage wave which may cause inductive interference with communication circuits or resonance in the transmission system. The telephonic harmonic factor shall not exceed 1.5%.

The calculated no-load harmonics in the voltage wave form shall be furnished in the Bid.

Stability and Performance

The generators shall operate satisfactorily in parallel with each other, with other units connected to the grid and in isolated systems. The generators shall be capable of operating on sudden application or loss of maximum load and during momentary short circuits and sustained earth faults without causing any abnormal vibration or resonant conditions.

The generators shall be capable of operating continuously on an unbalanced system with none of the phase currents exceeding the rated current and under fault conditions with the product of $(I2/In)^2$ and the time (t) in seconds not exceeding 40.

Runaway Speed Withstand Capability

The generator shall be designed and constructed to safely withstand, without incurring damage, the maximum runaway speed of the turbine for a period of five minutes, with cooling water flow available.

The runaway speed test shall be considered successful, if after applying the test speed for 2 min no damage is apparent.

After this test the generator shall withstand the high voltage test at 80% of the dielectric test voltage.

10.2.2 Particular Design and Construction Requirements

The generators shall be capable of safely withstanding maximum stresses during normal operation, runaway-speed conditions, two phases and three phases short-circuit conditions, single phase earth fault, 120° out-of-phase synchronisation, magnetic unbalance at nominal speed with 50% of the poles short circuited, brake application etc. Seismic forces shall also be taken into consideration for design of the generators.

The thrust bearing shall be capable of supporting the generator loads, the maximum hydraulic thrust loads and weights of the turbine rotating parts.

The construction of the generator shall be such that the rotor poles, stator bars and generator air / water heat exchangers can be removed without disassembly of the upper bearing bracket.

The design of thrust bearing housing shall provide easy access to the bearing pads. Openings with removable covers shall be provided for this purpose. The thrust bearing pads and the thrust faces shall be capable of being reached and inspected through windows, after emptying the bearing oil, removal of heat exchangers and with the rotor jacked up.

Sectionalising of large and heavy components shall be considered with regard to the transport limits.

The stator frame, core and winding shall either be supplied in factory assembled condition to the maximum extent possible within the transport limits, or assembled at site. The stator joints shall not be near the phase terminals. The stator assembly and testing can also be performed in the generator pit.

The rotor construction shall facilitate the replacing the rotor poles. The poles shall be interchangeable. The rotor shall be supplied in the maximum possible assembled condition. The design of the generator shall consider the assembly and disassembly using the powerhouse crane.

Generator Housing

The concrete housing for the generator shall be air tight. The fabricated steel top cover which shall be provided with tapped holes or equivalent for lifting. To prevent damage to the threads, the tapped holes shall be provided with threaded plugs.

Suitable platforms, walkways, stairs, handrails and inspection door in generator housing shall be provided for inspection and maintenance of bearings, slip rings, heat exchangers etc. The housing shall be equipped with at least two steel doors with locks operative from inside the housing. All platforms, walkways, stairs shall have safe non slip surface. Suitable covers shall be provided between the turbine and generator.

(1) The top cover shall have access openings to facilitate removal of the air/water heat exchangers during operation of the unit.

(2) Any kind of metal housing or enclosure shall be constructed of rigid steel profiles, heavy sheet metal, and sound-absorbing and flame-resistant filler material to achieve protection class IP 44.

(3) The lower steel cover shall have a hinged hatch in a location to enable convenient access to the generator bearings and brakes. Latches operable from both sides shall secure the hatch. A suitable ladder shall be provided.

(4) Access doors to the generator pit shall be included, fitted with door limit switches to prevent operation of the deluge system or to give alarm unless the doors are fully closed.

(5) Both the upper and lower cover shall be strong enough to support the weight of men working and the upper cover shall be capable of carrying the additional weight of minor generator components during erection or dismantling. The minimum live load shall be 5 kN/m².

(6) All concrete surfaces forming part of the closed air circuit shall be adequately painted prior to erection to positively prevent concrete dust during erection and later operation.

Stator

(1) Stator Frame

The stator frame shall be made of a welded plate steel structure suitably ribbed for rigidity and shall be of robust design to withstand maximum forces acting on it under the worst

combination of operation stresses. The segments shall have bolted flange faces for jointing at site or shall be prepared for proper welding. The frame shall have suitable openings for mounting the generator air/water heat exchangers. The stator frame shall have robust foundation plates rigidly attached to the frame for mounting and bolting on the foundations.

The stator base plates, anchor bolts, nuts and liners necessary for stator installation in the concrete pit. If necessary, suitable steel ladders shall be provided to facilitate inspection.

(2) Stator Core

The stator core of laminated construction shall be of high grade non-ageing cold rolled silicon steel. After punching the core laminations shall be coated on both sides with insulation varnish of Class F type to minimise eddy current losses. Core lamination sheets with a loss coefficient of not more than 1.1 W/kg at 1 T and 50 Hz shall be used.

The core-laminations shall be adequately dovetailed or keyed to the stator frame and shall be clamped to provide evenly distributed permanent pressure and preventing vibration and noise during operation. The stator core shall be stacked at site with overlapped core laminations.

The stator core design shall facilitate the flow of cooling air into and through ducts with minimum friction and noise.

(3) Stator Winding

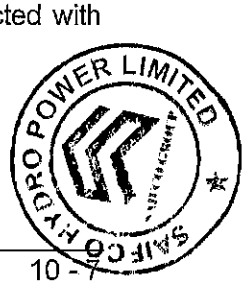
The stator winding shall be of bar type, insulated throughout with Class F insulation. The insulation shall be fire resistant. The bars shall have suitable transposition in the slot portion to reduce the eddy current loss. The winding shall be given low resistance treatment in the slot portion and graded where the winding bars leave the slot. This shall ensure an essentially corona free winding at rated voltage.

The stator windings shall be star (Y) connected, having a suitable number of parallel paths per phase. Three line terminations and three neutral terminations shall be brought out of the generator housing at a suitable location. The windings shall be adequately braced to withstand any movement caused by forces caused by short circuit at the terminals.

The main and neutral terminals shall be brought out from the generator pit and shall be suitable for flexible connection to isolated phase bus ducts. The terminals shall have sealed non-magnetic metal barriers to prevent air exchange between the generator housing and the surrounding area.

The terminals shall be clearly designated and the phase sequence marked. Inside the generator pit the line and neutral side connections shall be adequately protected.

The winding design shall minimise the circulating current losses. The end connections of the windings shall be rigidly supported and braced to prevent vibration or displacement in case of short circuits. The neutral side conductors of the stator windings shall be connected with enclosed bus bars to current transformers and the neutral earthing equipment.



Rotor and Shaft

(1) General

The rotor shall comprise the hub, spider, rim and the poles with their windings. The design and construction of the rotor shall be in accordance with best modern practice. The rotor shall be with rim ventilation. The factor of safety at runaway speed based on the yield points of the materials shall not be less than 1.5.

(2) Rotor Hub and Rim

The rotor hub shall be made of the best quality cast carbon steel or welded steel. The shaft extension shall be made of the best quality forged steel properly heat treated.

The hub shall be of ample size to operate at all speeds, including maximum runaway speed, excessive vibration or distortion and shall be able to withstand short circuit and other stresses without any damage. The hub shall have a hole of not less about 300 mm bored axially through the entire length sufficiently smooth to permit inspection of the metal in the interior of the hub and possible handling of the turbine runner by use of the powerhouse crane. The rotor hub shall be accurately machined.

The rotor hub shall have a matching integral flange for coupling to the shaft flange by means of pre-stressed bolts in compliance with the coupling standard ANSI/IEEE 810-1987 "Hydraulic Turbine and Generator Integrally Forged Shaft Couplings and Shaft Run-out Tolerances" and IEEE Std 1095 - 1989 "Guide for Installation of Vertical Generators/Motors for Hydroelectric Application"

The rotor rim shall be constructed of flat steel plates stacked overlapped at site. Fixing and clamping of these laminations shall have a tight fit between spider arms and rim which will be maintained up to an over speed at full load rejection (governor in service) plus 5%.

"Floating rim design" with a tight fit rim up to 115% nominal speed will be acceptable, providing the manufacturer can proof a 10 years construction track record for this type of design.

The pole pieces shall fit to the rim by accurately machined or die-punched dovetails matching similar slots in the rotor rim and secured in place by means of tapered keys. The keys shall be locked in place on both sides of the rim such as to positively prevent loosening of same under all operating conditions. The pole pieces shall be removable with the rotor in place.

An appropriate number, adequately sized radial ducts shall be provided in the rotor rim to pass through the cooling air for cooling of stator by the fan action of rotor.

The rotor shall be provided with a suitable brake ring. The wearing surface of the brake ring shall be made in segments which shall be easily removable and renewable.

(3) Shaft

The generator shaft shall be made of high quality forged steel properly heat-treated. It shall be of ample size to operate safely in continuation with the turbine shaft at any speed up to the maximum runaway speed without detrimental vibration and distortion and shall be free from injurious flaws and imperfections.

A forged thrust block with thrust collar shall be provided separately, mounted to the shaft with slight shrink fit and fixed to the shaft by a lock ring.

(4) Poles and Field Winding

The poles shall be built of thin steel laminations bolted under high pressure with sturdy end pieces. Dovetails shall be provided to fit with corresponding slots of the rotor rim.

The pole winding inter-turn insulation shall be Class F with operating temperature rises limited to Class B and shall be of special epoxy impregnated mica/synthetic paper and insulation of glass laminates.

The rotor winding shall be capable of withstanding all electrical, thermal and mechanical stresses shall be imposed during normal operation or by the specified maximum runaway speed of the turbine. The field coils shall be adequately braced to withstand the stresses due to both short circuit current and also due to centrifugal forces. The connections from field coils to the collector rings shall be suitably braced to prevent damage due to vibrations or other mechanical forces.

A damper winding of the manufacturer standard type shall be provided to improve stability under fault conditions, to reduce distortion under conditions of single-phase faults and to allow flow of the specified inverse current. The damping rings shall consist of hard drawn copper with silver-plated contact surfaces.

All connections between coils and the leads to the slip-rings shall be highly flexible, specially insulated and supported to prevent vibration and wear. Bolted joints or other approved means of locking shall be used for these connections.

Means for measurement of the field winding temperature shall be provided on the rotor.

It shall be possible to remove and replace a pole without withdrawing the rotor. All necessary tools and devices for this procedure shall be provided.

Slip rings and Slip ring Compartment

(1) The slip rings shall be made of stainless steel and shall have helical grooved surface. They shall be well insulated with epoxy glass insulation and designed for use with carbon brushes. The slip rings shall be spaced sufficiently apart or separated from each other by a barrier to prevent any accidental short circuit. The slip rings shall be easily accessible for inspection during operation and for maintenance. The brushes shall consist of a number of carbon graphite and copper blocks placed in a massive ring. The arrangement and length of the field leads shall enable to reverse the connections to the slip-rings without removing and dismantling the field leads or collector rings. Suitable carbon dust collectors and exhaust systems shall be provided to prevent escape of carbon dust to the generator. Field leads from the collector rings to the field breaker cubicle shall be routed in suitable ducts.

(2) The slip rings shall be of the self-ventilated type and accommodated in a separate compartment above the top cover of the generator provided with suitable access doors and windows for easy inspection. Easy replaceable filters shall be provided at the air inlets and outlets to ensure that no carbon dust is released to the powerhouse.

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(3) The brush gear shall be designed to enable normal operation for a minimum of six months without replacement of brushes. Easy access shall be provided to the brush gear so that brush pressures can be adjusted or brushes renewed conveniently.

(4) The compartment shall be fitted with lighting and temperature monitoring.

Thrust and Guide Bearings

(1) The generator shall have a combined thrust/guide bearing located above the rotor and a guide bearing located above the rotor.

(2) The thrust bearings shall be of a self-oil circulation, segment, rigid or hydraulically supported type, with Babbitt metal lined pads and shall have sufficient capacity to support the total weight of the rotating parts of the unit together with unbalanced hydraulic thrust of the turbine runner under all conditions of operation (starting, normal and emergency stopping, continuous rating and runaway conditions).

The thrust bearing shall be equipped with one AC high pressure oil injection pump and one DC high pressure oil injection pump. Special consideration shall be given to the power supply of these pumps.

The thrust/guide bearing shall be mounted on a bracket, supported on the stator.

(3) The guide bearings shall be of oil-immersed, self-circulation, segment type. The bearing segment shall be lined with Babbitt metal which shall be cast or plated so that it will not separate from the base metal.

(4) The bearing design shall consider the following bearing metal temperature limits for rated output condition:

- Maximum permissible operating metal temperature: 70°C
- Alarm temperature: 75°C
- Trip temperature: 80°C

The proposed bearing temperatures shall be indicated in the Bid.

(5) The bearings shall safely operate without any damage at the following conditions:

- Continuous operation at any speed from 80% to 110% of rated speed.
- Operation for a period of at least 5 min under maximum runaway conditions with cooling water flowing.
- Operation for a period of at least 15 min at maximum allowed load and rated speed without cooling water, followed by safe shut-down.

(6) The thrust and guide bearings shall be of the self-lubricated type with external oil/water heat exchangers. The design of the heat exchangers shall be based on a cooling raw water temperature not exceeding 20°C.

The cooling system shall be complete with cooling water pipes, fittings, valves, flow indicating devices, flow relays and all other accessories. All internal pipes shall terminate with a flange and shut-off valve outside the generator pit for connection with the plant cooling water system.

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Treated cooling water in closed circuits will be provided under "Mechanical Equipment".

Baffles and guides shall be provided in the oil reservoirs to assist correct oil distribution and to prevent splashing. The bearings shall be fitted with oil mist exhaust systems with oil separators which allow the cleaned air to be released into the powerhouse. Provisions shall be included to prevent oil vapour from entering into the generator. The oil reservoirs shall have suitably protected sight gauges for visual inspection of the oil level.

The tubes of the oil/water heat exchangers shall be of Cupro-Nickel and shall have adequate capacity to allow for some 10% blocking of cooler tubes.

(7) The guide bearing shall be adequately insulated to prevent any harmful circulating currents passing through the bearing surfaces. This insulation shall be arranged to break the possible path of such currents in not less than two places in series so that positive test for ground currents can readily be made. Continuous monitoring of shaft current shall be provided and contacts shall be available for alarm and automatic shutdown of unit in case of excessive shaft currents.

(8) Complete self-contained lubricating systems including oil reservoir, strainer, oil piping, valves, oil pumps and necessary appurtenances shall be provided. The oil reservoirs shall have oil level gauges. Inlet and outlet oil piping adjacent to each bearing oil reservoir shall be provided with valves and hose connections of the flexible metallic type.

The thrust bearing shall have a high pressure injection system for high-pressure oil to be injected to the bearing surfaces during starting and stopping of the unit. The bearing and lubrication system shall also allow the safe start and stop of the unit without pressurised oil.

As far as possible, the same type of oil shall be used for electrical and mechanical equipment.

Air Cooling System

(1) The air/water heat-exchangers shall be of the frame-mounted type with heat-exchanger tubes made of Cupro-Nickel alloy. The cooling system shall be complete with heat-exchanger, cooling water pipes, fittings, valves, flow indicating devices, flow relays and all other accessories. All internal piping shall be terminated at flanges outside the generator pit for connection with the plant cooling water system. The surface air heat exchangers shall have sufficient capacity to maintain an air temperature not exceeding 40°C at the outlet of the heat exchangers with a water inlet temperature of 20°C when one cooler is out of service and the unit is operating at rated conditions. The proposed number, the normal working pressure, pressure drop and temperature rise in the heat exchangers shall be indicated and supported by calculations. The pressure drop across each heat-exchanger shall be limited to 0.05 MPa. Connections shall be provided at the bottom of the air/water heat exchangers to facilitate complete drainage. The heat exchangers shall be designed for a nominal pressure of at least 0.7 MPa.

(2) Air vents with drain pipes shall be provided at the top to prevent air locks in the air/water heat exchangers. Lifting lugs shall be provided to facilitate the removal of any heat-

exchanger through the top of the generator cover. Each heat-exchanger shall be provided with a pocket for inserting thermometer at the discharge side. The cooling water pipes inside the pit shall be suitably coated and insulated to prevent damages due to condensation water.

The circulation of the cooling air shall be accomplished by means of rotor rim ventilation.

(3) Necessary plates shall be provided for the closing the space vacated by the heat-exchanger removed for overhaul. Each air/water heat exchanger shall have adequate capacity to allow for 10% blocking of the air/water heat exchanger tubes. Tubes shall be interchangeable and shall be connected to the mild steel water boxes by ferrule connections. All air/water heat exchangers shall be tested at 1.5 times the nominal pressure for 60 min.

Brake and Jacking System

(1) Mechanical Braking System

Pneumatically operated mechanical braking system shall be provided for stopping the unit under normal and emergency conditions. The brakes shall be applied at 25% of the nominal speed.

When the unit is at determined speed, the mechanical braking system shall be automatically activated. Manual operation of the mechanical braking system shall also be provided from the brake control panel and the UCB.

The total braking time from rated speed to complete stand still for normal and emergency shut-down shall be indicated in the Bid.

The brake shoes shall be provided with suitable, non-asbestos, easily replaceable brake lining.

The brake shoes shall operate on a polished circular steel brake ring bolted to the bottom of the rotor rim.

Compressed air with a pressure of 0.5 to 0.7 MPa for operation of the brakes shall be provided by the station low pressure compressed air system. Each unit shall be provided with an air receiver of requisite capacity equipped with pressure gauges, piping and all fittings required for braking of the unit terminated with valves at the generator pit. Each brake cylinder shall be provided with a limit switch with auxiliary contacts to provide starting interlocks and "ON"/"OFF" indication on the UCB. A pressure switch shall also be provided for starting interlock.

The brake system shall be operated locally, from the UCB and the CCS.

(2) Jacking System

The brake cylinders shall be designed to serve as hydraulic jacks to lift the generator rotor to an adequate height to facilitate removal and adjustment of bearing pads. Provision shall be made for mechanically locking the rotor in the raised position for an extended period of time. A limit switch for operation of an indicating lamp shall be provided to indicate when the maximum permissible raised position of the rotor is reached. Mechanical indication shall also be provided.

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For the purpose of jacking, one portable 3-phase, 50 Hz, 400 V AC motor/manually operated high pressure oil pump along with pressure gauge on the discharge side of the pump, an oil level sight gauge for oil reservoir, necessary piping and fittings shall be provided common for all units. Flexible hoses with standard couplings shall be provided for the connection between oil pump and the brake control panel.

All necessary piping connections, valves, control switches, interlocks etc. to make the braking and jacking systems complete in all respects. The control system shall be suitable to work with the automatic unit control and the CCS.

(3) Electrical Braking System

The electrical braking shall be activated at about 50% rated speed to nearly zero. In this case, the stator winding shall be short-circuited by a 3-pole braking switch with the rotor winding energized via the static excitation equipment from an independent power source.

The braking current circulating in the short-circuited stator winding shall be limited to 100% rated current. The total braking process from 50% rated speed to zero shall be automatically controlled with the excitation current adjusted by the AVR. Precautions shall be taken against overheating of the stator winding, if necessary by reducing the braking current.

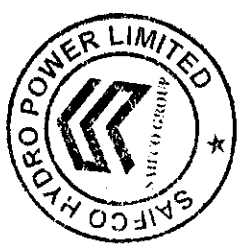
The equipment required for the changeover from the main excitation system to the auxiliary feeder source and all other means necessary for braking shall be included in the scope of work. All devices for the automatic control of the braking process shall be installed in the UCB.

Anti-condensation Heating and Lighting

Suitable, evenly distributed space heaters shall be provided to prevent condensation of moisture on the windings during shut down period. The heaters of various sections shall be connected together to form a balanced 3-phase load. A suitable space heater and lighting terminal cabinet shall be provided at a convenient location for connection to the 3-phase, 50 Hz, 400 V AC supply. ON/OFF control devices shall be provided for the heaters for automatically maintaining sufficient temperature difference between generator pit and outside air. The heater control gear shall be mounted in a panel to be located outside the generator enclosure.

An adequate number of fluorescent lighting fixtures shall be fitted to provide general lighting inside generator housing and the slip ring compartment. A minimum of four socket outlets for small electric tools and two extension lights shall be provided within the generator housing. The cabling shall be neatly arranged and connected to a terminal box for single phase, 50 Hz, 230 V AC supply.

The units shall be fitted with a beacon light for indicating unit operation/stop.



Monitoring Systems

The generators shall be provided with the following monitoring devices:

(1) Creep detector

A suitable creep detection device with manual/automatic reset facility will be provided by the turbine manufacturer to give an alarm and initiate application of brakes on detection of creep running of the generator. The creep detector will be automatically disengaged during normal starting of the units to avoid false alarm.

(2) Vibration detectors

Two vibration detectors (displacement type) shall be installed on each bearing bracket, at right angles to each other;

One vibration detector shall be installed on thrust bearing support;

These vibration detectors shall form an integral part of the vibration monitoring system.

(3) Moisture detector

Solid state type instruments based on the resistance principle with probe immersed in the thrust and guide bearing oil reservoirs shall be provided to give signal to an indicating unit or relay after sensing the presence of moisture in the bearing oil reservoirs.

(4) Partial discharge monitoring system

For continuous monitoring of the behaviour of the stator winding insulation system, partial discharges resulting from high electrical fields or from current chopping due to bar vibrations shall be measured. A measuring system for measuring the amount and frequency of partial discharges together with equipment for analysing the data shall be supplied. The monitor with its control accessories shall be portable and common for all generators.

(5) Shaft current detector

A suitable type of shaft current detector with alarm contacts shall be provided. The shaft current detector shall consist of shaft current transformer and relay unit. The relay unit shall have testing switch and alarm indication.

(6) Air Gap Monitoring System

A suitable type of Air Gap Monitoring System shall be provided.

10.2.3 Fire Fighting Systems

The generators shall be equipped with "Total Flooding Clean Agent Fire Extinguishing System" type fire-fighting systems, provided with the "Fire Protection Systems".

The systems shall be coordinated with the generator layout.

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The generator design shall consider the application of this type of fire-fighting system.

10.3 EXCITATION SYSTEMS

This section covers the detailed requirements for the excitation systems for three synchronous, hydraulic turbine driven generators, comprising excitation transformers, rectifier assemblies, field circuit breakers, field flashing and field suppression equipment, automatic voltage regulators, electrical braking and line charging features, protection and control devices.

The scope of work shall comprise the following:

- Three sets of excitation systems with excitation and braking transformers;
- Three sets of related auxiliary plant to provide ready for service, reliable installations;
- One set of special spare parts;
- One laptop for testing, commissioning and setting of parameters.

10.3.1 Principal Design Features

General Requirements

The excitation systems with the related parameters, performances, scope and methods of testing the excitation system components shall be in compliance with the respective IEC, IEEE or other approved Standards.

The excitation system shall be of the static type based on the latest technology and requiring minimum maintenance.

The equipment and shall be installed in metal clad cubicles providing easy access for installation, inspection, maintenance, repair and adjustment.

The proposed system shall be a standard product of a competent manufacturer with proven, reliable operation record.

The rectifier assemblies shall be directly fed from the excitation transformer, connected to the generator main circuit by means of bus ducts or cables.

The excitation equipment shall be designed for supplying without exceeding the continuous rating, ample excitation for the generator operating at its maximum capability at rated frequency, rated power factor and at 105% rated voltage.

Separate current and voltage transducers shall be provided in the excitation cubicles to transmit the generator and excitation current/voltage values to the CCR.

The excitation systems shall be suitable for the following operation modes:

- Generator operation, over and under excited;
- Joint control;
- Electrical braking of the unit;
- Line charging.

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The control features shall include Local/Remote/Manual/Automatic control of the systems from the excitation control cubicle, the UCB and the CCR. A bus system with interface to the CCS shall be used for the data exchange.

The excitation systems shall include the following features and functions:

- Local, remote, manual and automatic control modes;
- AVR 1,2 and 3 with manual FCR;
- Reactive power/power factor control;
- Joint control with equalising of stator reactive currents;
- Power system stabiliser;
- Stator and rotor current limiter;
- Excitation and impulse current limiter;
- U/f control and limiter;
- Under excitation limiter;
- Voltage regulation maintaining the voltage within the specified limits at all permissible
- load conditions;
- Voltage adjustment for synchronising;
- Impulse blocking in case of overcurrent in the excitation transformer secondary circuit;
- Separate impulse control modules for auto and manual control;
- Follow-up regulation for auto/manual channels to guarantee smooth change-over;
- Field winding temperature measuring system;
- Digital type set point adjusting devices;
- Redundant power supply for the regulator and control modules;
- Transducers for current and voltage measurements;
- Monitoring and protection devices;
- Interface to CCS.

Main Characteristics

The main characteristics of the excitation system shall be the following:

- Ceiling excitation voltage at Urated	3.0 p.u.
- Ceiling excitation current	2.0 p.u.
- Forcing duration, voltage/current	20 s
- Excitation system voltage response time during forcing not more than	0.05 s
- Accuracy of the voltage related to the set static characteristic	±0.5 %
- Nominal voltage of AC auxiliary supply system	400 V
- Nominal voltage of DC auxiliary supply system	220 V



10.3.2 PARTICULAR DESIGN AND CONSTRUCTION REQUIREMENTS

Excitation Transformer

The excitation transformers shall be of the indoor dry type with natural cooling. The insulation level shall correspond to the generator main circuit equipment.

The main characteristics of the excitation transformer shall be the following:

- Number of units	3 Nos.
- Type	3-phase, cast resin
- Location	Indoor, powerhouse
- Rated output	kVA by Manufacturer
- Primary voltage	11 kV
- Rated frequency	50 Hz
- Impulse withstand voltages:	
- Power frequency	38 kV
- Lightning	95 kV
- Vector group	by Bidder
- Insulation class	HV/LV F/F
- Type of HV termination	Busduct or cable
- Type of LV termination	Cable
- Maximum temperature rise	90 K
- Maximum ambient temperature	50 °C
- Enclosure protection class	IP 23
- Cooling type	AN

The transformer shall be accommodated in a sheet steel cubicle and shall include all necessary equipment for connecting the primary side to isolated phase ducts or XLPE cables and for connecting the secondary side to the excitation cubicle. The transformer shall be supplied with all terminations, temperature monitoring devices and accessories.

The braking transformers shall be of similar design. The power supply for the braking/line charging mode shall be derived from the LV AC auxiliary supply system.

Following the operation sequences an automatic change-over between the transformers shall take place.

Rectifier Assembly

The rectifier assembly shall consist of two or more parallel connected fully controlled three phase thyristor bridges.

The rectifier assembly shall meet the following requirements:

- The rectifier assembly shall consist of two individual bridges (2x100%) fulfilling the n-1 criterion. The system shall supply the nominal excitation current at rated generator conditions with one bridge out of service. The thyristor bridges shall be 50% loaded.

Each thyristor bridge with pertinent auxiliary equipment shall be installed in a separate cubicle;

- The thyristor bridges shall be fitted with monitored fast acting fuses. The thyristors and thyristor fuses shall be mounted on modules designed for individual isolating, easy removal and replacement. The connections to the modules or assemblies shall be bolted. The failure of thyristors shall initiate an alarm signal;
- Current-limiting fuses shall be provided in each thyristor circuit to isolate the circuit and to protect other thyristors and their fuses from damage if a thyristor fails;
- Each thyristor bridge shall be equipped with temperature monitoring devices;
- The components of the thyristor bridges shall be interchangeable. Replacement of individual components shall be possible without disturbance of adjacent equipment;
- For cooling the rectifiers each cubicle shall be provided with a fan, related control and monitoring devices. The air intake openings shall be fitted with appropriate screens and simply replaceable filter mats;
- An automatic generator field flashing system shall be provided taking the power supply from the AC and DC auxiliary supply systems, respectively;
- The DC leads between the field breaker and the brush-gear shall consist of insulated copper bars and single core cables, adequately routed and fixed;
- LV control equipment cabling and wiring shall be shielded and isolated from AC and DC power circuits.

Field Circuit Breaker and Field Discharge Equipment

The field circuit breaker shall be an air circuit breaker suitable for use in DC circuits. The breaker's operating mechanism shall be electrically and mechanically trip-free. The field breaker shall be provided for local and remote operation. The breaker shall be rated for the maximum continuous current of the circuit under any of the specified operating conditions of the generator and shall also be capable of interrupting the field circuit successfully under maximum possible short circuit and voltage conditions. The contacts shall be readily accessible for inspection and replacement.

The field breaker shall be provided with a mechanical position indicator and auxiliary contacts of NO and NC type as necessary for control and indicating purposes.

In case of normal or emergency shut down the field shall be rapidly suppressed and discharged by means of fully automatic field discharge equipment. The field discharge equipment shall comprise a discharge circuit breaker, a non-linear discharge resistor and control modules for the simultaneous changeover of the thyristor sets from the converter to the inverter mode.

Voltage Regulators

The excitation equipment shall be provided with a system for manual and automatic voltage regulation, excitation control and indication.

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The excitation system shall be controlled by two automatic voltage regulators (AVR) with integrated manual field current regulation (FCR). One regulator shall be in operation and the other one shall be maintained in "hot stand-by". The stand-by regulator shall be actuated automatically in case the service AVR fails.

In case AVR1,2 and 3 fail the system shall automatically change to the manual control and maintain the actual status. Returning to the automatic mode shall be carried out manually.

Each AVR system shall be equipped with related CT and VT.

The AVR shall be of the digital type regulator with microprocessor-based control, functional modules including self-diagnostic functions.

Follow-up control shall be provided to guarantee a smooth change-over between the different control channels.

The AVR shall regulate automatically, accurate and rapidly the generator voltage to a set value by detecting the three-phase voltage signal from the generator terminals.

The AVR shall maintain the generator voltage under steady-state load conditions without hunting within ±0.5 % for any load condition within the capability of the generator.

The excitation system complete with AVR shall be capable of:

- Automatic start-up of the unit to be connected to the power system by automatic or manual synchronisation;
- Securing stable operation at no-load running of generators;
- Generator operation on the system within the power output from zero to rated capacity;
- Forcing of excitation with per unit current value;
- Field suppression at normal and emergency shut-down;
- Maintaining the pre-set excitation current;
- Limiting the maximum and minimum rotor current;
- Limiting the excitation current sustained overload;
- Maintaining the set point voltage to an accuracy of ± 0.5%;
- Equalising of stator reactive currents with generators operating in parallel

The range of the automatic voltage regulating and setting device shall be from 80% to 110% of the rated voltage with the generator connected to the network or in the no-load operation condition.

AVR setting adjustment shall be possible:

- From the excitation cubicles;
- Remotely from the UCB and the CCR.

The excitation system shall be designed mainly for automatic regulation mode. In case of AVR failure the system shall switch over to the manual mode.

For this purpose each AVR shall include a manual field current control channel (FCR). The manual voltage adjusting device shall allow the adjustment between zero and 110% of the

generator voltage which will be necessary for primary current injection and other generator/protection tests.

Control and Protection Equipment

The voltage regulating and excitation control equipment shall be suitable for local, remote, manual and automatic control. Adequate computer based control systems shall be installed to provide a good overview and to guarantee a reliable and easy operation of the systems.

The voltage regulating and excitation control equipment shall be capable to communicate with the unit controller. All data interchange shall be via communication bus with appropriate interfaces to the CCS.

All information shall be displayed on the screen installed in the cubicle and transmitted to the UCB and CCR.

The monitor can either be of the touch screen type or a monitor with keyboard.

Interfaces for the CCS and the commissioning tool shall be provided.

The system shall be suitable for "tele diagnostic".

Field winding temperature measuring systems with local and remote indication in the UCB and CCR shall be provided.

The excitation equipment shall be provided with at least the following protection features:

- Limitation of excitation current and forcing level;
- Stator current limiter;
- Transformer over current and temperature protection;
- Loss of field protection;
- Over current and short-circuit protection for the thyristors, conduction monitoring;
- Temperature monitoring of thyristors and excitation cubicles;
- Over and Under voltage protection for thyristors and field windings;
- Additional protection devices proposed by the Bidder shall be listed in the price Schedule.

Current Transformers

For the excitation transformers current transformers of the dry synthetic resin type with separate secondary cores for metering and for protection shall be installed.

Electrical Braking and Line Charging System

The excitation systems shall be fitted with all hard and software necessary for fully functioning systems for manual and automatic operation of:

- Electrical braking of the unit;
- Charging of transmission lines.

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The braking transformer shall be fed by the LV AC auxiliary supply system. The changeover between the excitation and braking transformer shall be automatic.

Cubicles

The excitation equipment shall be accommodated in a cubicle assembly consisting of:

- Field breaker and field discharge cubicles;
- Rectifier cubicles;
- AVR and excitation control cubicles;
- Braking and line charging cubicle;
- Excitation transformer cubicle.

The proposed arrangement and location of the excitation cubicles is shown on the Drawings.

Generator Main Circuits

For connecting the generators with the main transformers and to provide feeders for the excitation and station service transformers, busduct systems, generator circuit breakers and utility type 11 kV switchgear assemblies shall be installed.

Neutral earthing cubicles shall be provided for the generator neutral points.

The generator main circuit configuration with basic data is shown on the single-line diagrams. The typical equipment arrangement is shown on the Layout Drawings.

The scope of work shall comprise the following:

- Three sets of air-insulated (IPB) busduct systems;
- Three 11 kV generator circuit breaker assemblies;
- Three 11 kV switchgear assemblies;
- Three generator neutral earthing cubicles;
- One set of special tools and appliances;
- One set of special spare parts.

10.3.3 Busduct Systems

General

The busduct systems for the main circuits connecting the generator line terminals with the generator circuit breaker and the main transformer LV terminals shall be of the air insulated phase-isolated type (IPB). The excitation and station service transformers shall be connected by IPB or copper bars and single core XLPE type cables, respectively.

Due consideration shall be given to the routing and space requirements.

Main Characteristics

The busduct systems shall have the following main characteristics:

- Nominal system voltage 11 kV

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- Rated voltage	17.5 kV
- Rated frequency	50 Hz
- Rated short time withstand current (3s)	60 kA rms
- Rated peak withstand current	100 kA peak
- Rated current	4,500 A
- Power frequency withstand voltage	38 kV rms
- Lightning withstand impulse voltage	95 kV peak
- Protection class	IP 65
- Cooling	AN
- Installation	Indoor

Particular Design and Construction Requirements

(1) The continuous current carrying capacity shall be based on the maximum generator current and the following permissible temperatures:

- Enclosure (inaccessible surfaces)	80°C
- Enclosure (accessible surfaces)	65°C
- Conductor and joints (accessible surfaces)	105°C

The generated heat shall be emitted by natural radiation and convection. Forced air cooling shall not be applied.

(2) The current density of conductors shall be such that the temperature rise of conductors and joints does not exceed the above figures. The continuous current rating of the main busbars and tie branches shall comply with the design rating of the pertinent main components including a 10% safety margin.

(3) The busducts shall withstand without damage and deterioration the electromechanical and thermal stresses imposed to the complete system by the asymmetrical short circuit current and the mean symmetrical fault current as determined by the feeder sources assuming a three-phase fault at the end of any of the tie branches. The system short-time current rating shall be based on 3 s fault duration.

(4) The cross section of all enclosures shall withstand the thermal stresses of a double-pole earth fault current ($I''_{k2} = \sqrt{3}/2\ I''_{k3}$) for a duration of 3 s not exceeding a metal temperature of 150°C.

(5) The electrical design and mechanical construction shall consider electrical surges, dynamic and thermal stresses under the prevailing normal and transient operating conditions. Suitable means of expansion shall be provided to absorb the thermal dilatation and contraction of the conductor and enclosure and to facilitate the alignment of the busducts. Vibrations occurring on generators and transformers shall not be transferred to the busduct system.

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(6) The conductors shall be of single or multi-piece pure aluminium bars (≥99.5%Al) arranged in approved shape with high inertia moment. Construction joints shall be welded at site under inert gas atmosphere.

(7) With the exception of the generator neutral side, the busduct design shall be fully phase segregated, i.e. each phase conductor shall be provided with a concentrically arranged and self-supporting pure aluminium enclosure of adequate dimensions. To ensure perfect tightness, the tubular sections shall be welded together at site. Inspection openings shall be arranged at all locations where inspection and maintenance work shall be carried out.

(8) Bolts, nuts, washers and other fittings for bolted joints shall be of heat-resistant material with guaranteed properties, suitably fixed and not loosening under thermal stresses. The connection surfaces shall be tinned or silver plated. The connections with generator, transformer and switchgear terminals shall be carried out with isolating links and standard type flexible connection pieces (laminated or braided) of appropriate cross-section.

(9) Insulators shall be of cast resin or porcelain type. The strength of insulators shall safely withstand all forces imposed under normal operation and short-circuit conditions. Fixing of the insulators at the conductor and phase enclosure shall consider the thermal expansions due to temperature differences.

(10) The single-phase busducts of one system shall be interconnected with each other and earthed at the generator and transformer end. All supporting points shall be isolated from earth. Measures shall be taken to minimise the losses in the enclosures and conductors.

(11) To avoid the ingress of dust and humidity and to preserve the dielectric strength of the insulating air a pressure of approx. 0.5 to 2 kPa shall be maintained in the busduct enclosures.

For this purpose clean, dry air shall be fed into the enclosures. The air shall be supplied by the station compressed service air system.

Air supply systems comprising air receivers, filters, air dryers, pressure controlled automatic supply valves and pressure monitoring devices shall be installed.

(12) If necessary the generator line and the main transformer LV terminations shall be provided with an overall enclosure to facilitate access and ventilation.

(13) Openings in floors and walls shall be closed after busduct installation. The design of the closure shall be appropriate for the individual location (e. g. fire zone, indoor/outdoor, watertight).

(14) For generator and protection testing an easy to install short circuit bridge shall be provided.

(15) Current transformers:

The current transformers shall be of the ring core type consisting of single ratio measuring and protection cores. The current transformers shall be installed within the

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aluminium enclosure or in separate cubicles. The current transformers shall have the specified lightning impulse and power frequency withstand voltage levels.

(16) Supporting structures

The supporting structures for the busduct systems shall be sturdy aluminium or galvanised steel constructions. The design shall consider all applicable static loads and dynamic forces. Sliding and fixed busduct supports shall be provided as required. Bolts, nuts and related fittings shall be of stainless steel.

The three phase isolated phase busduct assemblies shall be mounted on single supporting structures.

Stray currents in the supporting members due to magnetic fields shall be minimised.

10.3.4 Generator Circuit Breaker Assemblies

General

Each generating unit shall be equipped with a generator circuit breaker assembly (GCB) comprising the following equipment:

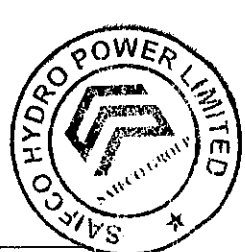
- SF 6 or vacuum type circuit-breaker;
- Service disconnecting switch at main transformer side;
- Earthing switches at both sides of the GCB;
- Braking switch, located according to the manufacturer's standard design;
- Current transformers at both sides of the GCB;
- Voltage transformers at the generator and main transformer side;
- Surge arrester and capacitor at main transformer side;
- Cubicle assembly and busduct terminations.

The three-phase generator circuit-breakers shall be suitable for switching generator circuits under normal and emergency conditions. The arc extinguishing and insulating medium shall be SF6 gas. The generator circuit-breaker assemblies shall be natural air cooled and suitable for indoor installation.

Main Characteristics

(1) General

- Nominal system voltage	11 kV
- Rated voltage	17.5 kV
- Rated frequency	50 Hz
- Power frequency withstand voltages:	
- To earth	38 kV rms
- Across open contacts	45 kV rms
- Lightning impulse withstand voltages:	
- To earth	95 kV peak
- Across open contacts	110 kV peak



- Cooling	AN
- Installation	Indoor
- Protection class	
- Phase enclosure	IP 65
- Control cubicle and operating mechanism	IP 54
- Phase distance	acc. to design

(2) Circuit breaker

- Rated current	4,500 A
- Rated short circuit breaking current	63 kA rms
- Rated short time withstand current (3s)	63 kA rms
- Rated peak withstand current	100 kA peak
- Operating mechanism:	
- Type	Motor or hydraulic-spring
- Operating voltage	220 V DC
- Number of tripping coils	2 Nos.
- Number of closing coils	1 Nos.

(3) Disconnecting switch

- Rated short time withstand current (3s)	63 kA rms
- Rated peak withstand current	100 kA peak
- Motor drive operating voltage	400/230 V AC

(4) Earthing switch

- Rated short time withstand current (3s)	63 kA rms
- Rated peak withstand current	100 kA peak
- Motor drive operating voltage	400/230 V AC

(5) Braking switch

- Rated short time withstand current (3s)	63 kA rms
- Rated peak withstand current	100 kA peak
- Motor drive operating voltage	400/230 V AC
- Rated making current	By Bidder kA rms

(6) Surge arrester

- Type	Metal-oxide
- Rated discharge current, 8/20 ms	20 kA
- Impulse withstand current, 4/10 ms	100 kA

(7) Capacitor

- Type	PCB free
- Capacitance	n F



10.3.5 Generator Voltage Switchgear

General

The generator voltage switchgear shall be type-tested, metal enclosed, utility type switchgear equipped a single busbar and withdraw able SF6 or vacuum circuit breakers for the station service transformer feeders.

The excitation and station service transformers shall be connected to the switchgear with copper bars and single core XLPE type cables respectively.

The generator voltage switchgear and the GCB assembly shall form an integrated arrangement and shall be installed on the generator floor.

Main Characteristics

- Type	Metal-clad, indoor
- Nominal system voltage	11 kV
- Rated voltage	17.5 kV
- Rated frequency	50 Hz
- Rated power frequency withstand voltage:	
- To earth	38 kV rms
- Across open contacts	45 kV rms
- Rated lightning impulse withstand voltage:	
- To earth	95 kV peak
- Across open contacts	110 kV peak
- Rated normal current of bus	400 A
- Rated short-time withstand current (3 s)	31.5 kA rms
- Rated peak withstand current	80 kA peak

Circuit Breakers

The circuit breaker shall be manufactured and tested in accordance with IEC.

The circuit breakers shall have the following main characteristics:

- Type	SF6 or Vacuum, draw - out
- Nominal system voltage	11 kV
- Rated voltage	17.5 kV
- Rated frequency	50 Hz
- Rated power frequency withstand voltage:	
- To earth	38 kV rms
- Across open contacts	45 kV rms
- Rated lightning impulse withstand voltage:	
- To earth	95 kV peak

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- Across open contacts	110 kV peak
- Rated current	400 A
- Rated short-time withstand current (3 s)	31.5 kA rms
- Rated short circuit breaking current	31.5 kA rms
- Rated peak withstand current	80 kA peak

(I) The three-phase circuit breakers (CB) shall be of the SF6-gas or vacuum type equipped with motor charged spring storage operating mechanism. Normal operation shall be carried out by electrical local/ remote control. Manual spring charging and CO control shall be provided.

he charging time for the spring charged mechanisms shall be 25 s approx. The spring shall be automatically re-charged immediately after the switching device has been closed.

Mechanical position indication shall be available.

(II) The CB unit shall be complete with high integrity operating and isolating mechanisms, primary and secondary disconnecting devices, auxiliary contacts, manual tripping facilities, operation counter, mechanical position indicator, control wiring, auxiliary relays and contactors as required. The SF6 type CB shall be fitted with gas pressure monitoring and low pressure alarm.

(III) The duty cycle shall be O - 0.3 s - CO - 180 s - CO

The circuit breakers shall be electrically and mechanically trip-free. Anti-pumping devices shall prevent pumping while the closing circuit remains energised and the breaker fails to latch or be tripped during closing due to the operation of a protection device.

(V) Circuit breaker control circuits shall be fed from the DC auxiliary supply system. All electrical closing and tripping devices shall be suitable for operation at voltages between 110% and 80% of the rated control voltage.

(VI) Circuit breakers shall be of the withdraw able type and have self-aligning fixed contacts for the power circuits and plugs with sockets or other suitable devices of the automatic connection type for the control circuits.

(VII) The CB unit shall be positively locked in the service and in the test position before it is released for complete withdrawal. A mechanical interlock shall be provided to prevent withdrawal of the unit unless the power circuit has been interrupted. The test position shall permit local/remote tripping and local closing of the relevant circuit breaker with the power contacts not energized.

(VIII) The following accessories shall be provided:

- Trip coil supervision
- CO cycle counter
- Auxiliary switches for position and trip indications as required

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- The circuit breakers shall be furnished with all standard accessories, special tools and devices for drawing out and transporting the CB unit.

10.3.6 Generator Neutral Earthing Cubicles

General

The generator neutral points shall be earthed by means of resistor loaded earthing transformers.

All related equipment shall be accommodated in a metal enclosed cubicle, which shall be installed close to the generator pit on the generator floor.

The dimensioning of the equipment shall be based on IEEE Std C37 and 62. A short time withstand rating for 60 s shall be considered.

Main Characteristics

Earthing transformer:

- Type	Dry type cast resin, indoor
- Insulation class	F
- Rating	By Bidder
- Rated short time duty	60 s
- Primary voltage	11 kV
- Rated frequency	50 Hz
- Power frequency withstand voltage	38 kV rms
- Lightning withstand impulse voltage	95 kV peak
- Secondary voltage	By Bidder
- Type of cooling	AN

Earthing resistor:

- Type	Metal grid
- Resistance	By Bidder
- Rated short time duty	60 s

10.4 MAIN TRANSFORMERS

To raise the generator voltage to the grid transmission voltage each generating unit shall be connected to a three - phase main transformer 136/11 kV (MT).

The MT units shall be installed in transformer bays located in the transformer cavern.

The main transformers shall be equipped with DELUGE type fire-fighting systems, provided under "Fire Protection Systems".

The scope of work shall comprise the following:

- Three - phase main transformers;

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- Three sets of related auxiliary plant to provide complete, ready-for-service installations;
- One set of special tools and appliances;
- One set of special spare parts.

10.4.1 Principal Design Features

Main Characteristics

- Number of units	3 Nos.
- Type	3 - phase, oil-immersed, outdoor
- Nominal rating	40 MVA
- Rated voltage:	
- HV	136 kV
- LV	11 kV
- Voltage variation	± 2x2.5 %
- Tap changer	Off circuit
- Rated frequency	50 Hz
- Vector group	YNd11
- Impedance voltage	12 %
- Rated LI withstand voltage	
- HV	650 kV
- LV	95 kV
- Cooling method	ODWF
- Ambient temperature	50 °C
- HV terminations	XLPE cable
- LV terminations	Busducts

10.4.2 PARTICULAR DESIGN AND CONSTRUCTION REQUIREMENTS

Windings

All transformer windings for LI: 350 kV / AC: 140 kV and below shall have uniform insulation. Transformer windings designed for higher insulation levels may have non-uniform insulation. In these cases the rated AC insulation level for neutral points shall be at least 185 kV but not less than required for performance of induced ACSD withstand voltage tests at full test levels as per the table below (whichever is higher).

Due to the possibility of high transferred over-voltages all medium voltage windings for power transformers having HV windings of Um=100 kV and above shall be designed for not less than LI: 125 kV / AC: 50 kV. None of the windings shall be designed for less than LI: 75 kV / AC: 28 kV.

Particular values for insulation and test levels shall be obtained from **Table 10.1** below.

Table 10.1: Particular Values for Insulation and Test Levels

Nominal voltage (Un)	500	220	132	33	13.8	11
Rated short time power frequency withstand voltage (AC)	680	460	275	95	50	38
Rated lightning impulse withstand voltage (FW/CW)	1550/ 1605	1050/ 1155	650/ 715	250/ 275	125/ 138	95/ 105
Rated switching impulse withstand voltage (SI)	1175	850	-	-	-	-

Built-in series reactors, if provided, are only permitted to be connected in-line with the leads to the entrances of delta-connected tertiary windings, and they shall be designed and arranged with particular attention to keep all transferred over-voltages as low as possible and to avoid serious resonances. Built-in neutral earthing reactors will not be accepted.

All windings and their leads shall be designed and arranged to withstand all kinds of transferred over-voltages. Protective capacitors shall not be provided for any of the windings. Non-linear Zn O protective elements in any winding other than regulation windings will not be accepted.

Windings shall be of best modern design with conductors having constant cross-section along the entire winding. Electrolytic copper of a high conductivity and insulation material of high quality shall be used.

The insulation material of windings and connections shall be free from insulation compounds subject to softening, shrinking or collapsing during service. None of the materials shall disintegrate, carbonise or become brittle under the action of hot oil under all specified load conditions. The use of any kind of wood for insulation parts subject to test voltage stresses of LI: 550 kV and/or AC: 230 kV and above across the insulation material is not acceptable, and the Manufacturer is held fully responsible for all selected insulation materials.

The coils shall be capable of withstanding movement and distortion caused by all operating conditions as specified in IEC 60076-7. Adequate barriers shall be provided between windings and core and between the windings. All leads or bars from the windings to the terminal boxes and bushings shall be rigidly supported. Stresses on coils and connections shall be avoided.

To increase the capability of the transformers of withstanding the stresses under short-circuit conditions modern technologies in design and construction shall be applied (e.g. low current densities, pre-drying and pre-compressing of the windings before mounting to the core, etc.)

Unless explicitly agreed otherwise, regulation windings shall consist of a coarse and a fine regulation winding. Regulation windings for delta connected windings shall be provided in mid-winding connection only.

The impedance voltages on extreme tappings shall not deviate from those for principal tappings by a percentage of more than two third of the difference in percentage tapping

factor between the concerned tappings and the principal tappings. The transformers shall have the highest losses at the highest current taps, i.e. lowest voltage taps.

Magnetic Core

The magnetic core shall be of the "core-form type" made of laminations without burrs of non-ageing, cold-rolled, grain-oriented, silicon steel of high permeability (Hi-B-type; W17/50: max. 1.05 W/kg).

The maximum magnetic flux density in the limbs and yokes of the core shall not exceed 1.65 T at rated voltage and frequency, unless specified otherwise in the Technical Data Sheets. Each lamination shall be insulated with high quality insulation coating.

By application of most modern design and construction and the step-lap core-stacking method for the joints of limbs and yokes the no-load losses, the hot spot temperature in the magnetic core and the noise level shall be kept as low as possible.

The core and the clamping plates shall form a rigid unit structure which shall maintain its form and position under the severe stresses encountered during shipment, installation and short circuits. Care shall also be taken to secure uniformly distributed mechanical pressure over all the laminations to prevent setting of the core and to limit noise and vibrations to a minimum.

In order to prevent closed magnetic circuit via the tank, the core top main clamping structure shall not be connected to the tank cover. The magnetic core shall be earthed to the tank cover at one point only by removable links in an appropriate terminal box, installed in an accessible position on the tank cover. The disconnection of the link shall enable the testing of the insulation between the core and transformer tank at voltages up to 2.5 kV for the purpose of checking deteriorations during service.

Magnetic circuits with an insulated sectional construction shall be provided with a separate link for each individual section. Where oil ducts or insulating barriers parallel to the plane of the laminations divide the magnetic circuit into two or more electrically separated parts, the ducts or barriers shall be bridged and the magnetic circuit shall not be regarded as being of sectional construction.

The main earthing connections shall have a cross-section of not less than 70 mm^2 Cu but connections inserted between laminations may have cross-sections reduced to a minimum of 20 mm^2.

Transformer Tank

The transformer tank shall be of the original upper flange type with bolted on reinforced cover. The transformer tank shall have rectangular shape. Any kind of bell type tanks (e.g. modified with upper flange and cover and/or lower flanges welded/bolted to tank bottom etc.) or similar arrangements are not acceptable.

The completely assembled tank shall be fully vacuum proof. The construction shall be of mild steel and shall be of sufficient strength and rigidity to withstand moving, shipping and handling without any de-formation. All seams and joints shall be welded both inside and

outside to secure strong, leak-proof joints. Any kind of laminated tank covers are not acceptable.

Tank stiffeners shall be provided as required, and these shall be designed to avoid water penetration. Tank stiffeners other than used as skid base underneath the tank bottom shall not be of "H"- or "T"- profiles, and they shall not be provided with drillings for any kind of fixing material like bolts etc.

The tank bottom shall be of one plane and shall be a heavy rigid base structure. The four tank walls shall be plane and of one piece each and shall be welded directly to the tank bottom without steps and without any additional welded and/or bolted flanges. In case of self-supporting tank bottom without heavy steel cross beams the bottom plate shall have a minimum thickness of 30 mm for transformers up to 40 MVA per unit and 40 mm for transformers above 40 MVA per unit. Laminated tank bottom will not be accepted.

The completely assembled transformer shall be oil and gas tight and shall be capable of withstanding without damage, under service conditions, the forces arising under pressure conditions of at least 100 KPa and/or exceeding 25% over the maximum operating pressure, resulting from the system of oil preservation used (whatever is higher).

The design of the complete tank shall not show any external pockets in which water can accumulate and no internal pockets in which oil can remain when draining the tank and/or in which air can be trapped when filling the tank.

Wherever possible, the transformer tank and its accessories shall be designed without pockets in which gas may collect. For this purpose the tank cover shall be especially designed. Where pockets cannot be avoided, pipes shall be provided to vent any gas into the main expansion pipe. Vent pipes shall have a minimum inside diameter of 25 mm. Both ends of the tank cover shall be connected to the main expansion pipe.

All connections bolted to the tank shall be fitted with suitable gas and oil resistant gaskets made of such a material that no serious deterioration occurs under service conditions, e.g. heat and oil resistant NITRILE Rubber. All gaskets shall be of closed design (without open ends) and shall be of one piece only. Rubber gaskets used for flange connections of the various oil compartments shall be laid in grooves or in groove-equivalent retainers on both sides of the gaskets throughout their total length. Care shall be taken to secure uniformly distributed mechanical pressure over the gaskets and retainers throughout the total length.

Gaskets of neoprene and/or such material which can be easily damaged by over-pressing (e.g. any kind of impregnated/bonded or other kind of cork) are not acceptable for any of the equipment. Use of hemp as gasket material is also prohibited.

The transformers shall be equipped with manholes and hand-holes of suitable size to facilitate installation and maintenance of tap changers, current transformers, bushings etc. Manholes for tap changers shall be sized minimum 800 mm in height and 350 mm in width, and shall be arranged in a convenient working height (subject to approval). All openings in the cover of the transformer tank for bushings, manholes and terminal boxes shall be provided with adequate flanges. Covers for inspection openings, hand-holes etc. located on the tank cover shall be provided with adequate gas stoppers. All inspection covers etc. shall

be provided with two lifting handles. It shall be possible to completely remove any bushing without removing the tank cover.

The tank cover and all covers for mounting, cleaning, manholes, hand-holes and inspection openings on tank etc. shall be earthed by suitable earthing conductors of the flexible type having a minimum cross section of 95 mm^2. Appropriate earthing studs with nuts and washers made of stainless steel shall be provided.

In order to prevent tank deformation during operation approved spring-loaded pressure relief devices shall be mounted with approved elbow turrets to the tank cover for rapid release of any pressure that might be generated within the tank and cause damage to the equipment. The devices shall operate at a static pressure which shall be less than the test pressure on tank. The nominal operating pressure of the devices shall be 70 kPa. The related elbow turrets shall be connected by vent pipes to the Buchholz relay.

The following moving and handling facilities shall be provided for each transformer:

- Four jacking pads for lifting and lowering the transformers completely filled with oil by means of hydraulic jacks
- Lugs for lifting the complete transformer
- Eyes for lifting the core, coils, tank and/or tank cover
- Bi-directional wheels with blocking facilities for transformers up to 125 MVA per unit. The distance between the wheel-centres shall be 1,505 mm or other approved gauge.
- Skids of rigid construction to allow skidding in any direction for transformers above 125 MVA and for all transformers with busduct and/or GIS terminations. In case of self supporting tank bottom the skids shall be of solid flat mild steel having the same thickness as provided for the tank bottom (plain tank bottom without skids is not acceptable). In case of cross beams being provided as skid-structure their width and height shall be at least 200 mm each.
- Valves for oil sampling (top and bottom) with suitable adapters of R ¾" male thread fitted with screwed cap for direct connection of oil sampling facilities shall be provided and shall be arranged diagonally on one tank wall at a convenient working height.
- Oil filter connection facilities, drain and filter valves, air venting plugs, piping, etc. in accordance with the usual international quantities and design. Drain and filter valves shall have adapters with R 1 ½" male thread fitted with screwed cap.
- Two earthing terminals of adequate size capable of carrying the full LV short circuit current of the transformer for 5 s shall be provided and installed diagonally at the bottom of the transformer tank. Bolts and washers shall be made of stainless steel.
- Eight hydraulic jacks to be used for all transformers.

10.4.3 Cooling

(1) ODWF Cooling

The main transformers shall be equipped with redundant ODWF cooling systems, each capable of meeting the requirements for full load operation.

The transformer cooling systems shall allow the continuous operation within the specified temperature rise limits at full name plate rating with 10 % over- or under-excitation.

The station cooling water system consisting of primary and secondary circuits with an adequate number of circulating pumps is specified with the mechanical equipment. Closed cooling water circuits will be provided at each transformer, ending at motorized valves. The MT cooling water circuits shall be connected to these motorized valves.

The transformer cooling systems shall include the oil circulating pumps, heat exchangers, piping, valves, thermometers, pressure gauges, water flow meter, etc.

(1) 3x100% motor driven oil-circulating pumps of the glandless, submerged type with all ancillary equipment shall be provided. The removal of pump and motor from the oil circuit shall be possible without lowering the oil level or to shutdown of the transformer. Shut-off valves shall be provided in inlet and supply lines.

(2) Upon failure of any service pump the corresponding standby pump shall automatically be started to take over the duty without reducing the load of the transformer.

(3) 3x100% water/oil heat exchangers shall be directly attached to the transformers or installed separately in the transformer bays. The design, selection of the materials and construction of the heat exchangers and related ancillaries shall suit the specified water quality and operating conditions. The heat exchanger gradient shall not exceed 5K.

(4) The design and construction of the water/oil heat exchangers shall safely prevent the penetration of cooling water into the oil circuit at all system pressures. This may be achieved by means of double wall tubes and tube sheets with the intersection used as drain for both the oil and cooling water or by any other equivalent solution.

The oil pressure shall be higher than the water pressure.

The heat exchangers, all related equipment and piping shall be designed for PN10. The general arrangement of the cooling system shall facilitate service and maintenance.

The oil/water heat exchangers shall be fitted with the following:

- Manual shut-off valves shall be provided in all supply and return lines as well as at each point of connection to the transformer tank;
- Removable blanking plates to permit the blanking off of the main oil connection for each heat exchanger;
- A drain valve at the lowest point of each heat exchanger;
- A thermometer pocket fitted with a captive screwed cap on the inlet and outlet oil branches of each separately mounted heat exchanger;
- Oil and water flow indicators with switches and signalling contacts;
- Venting valves.
- Leakage oil shall be collected and released to the oil sump.

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(2) ONAN Cooling

For the ONAN cooling at least two groups of detachable radiators flanged directly to the tank and/or external headers at the transformer tank shall be provided. They shall mainly be arranged in the vicinity of the core-/coil-arrangement at the two long sides of the transformer.

The transformers shall also include a sufficient number of additional radiators to cover continuous operation within specified temperature rise limits at their full self-cooled name plate rating at 10% over- or under-excitation.

Radiators shall be of the DIN type or equivalent provided with min. six cooling channels in each radiator fin. Accumulation of air in the radiator heads shall be avoided. Radiators with upper headers of the elbow type ("swan-neck" type) and radiators of the multi-tube type or similar arrangements are not acceptable.

The cooling fins of the radiators shall have a nominal width of 470 to 520 mm, and their height shall not exceed 3,000 mm. The nominal sheet steel thickness of the radiator walls shall be at least 1.2 mm.

The radiator fins shall be welded with 8 mm round stiffening rods (horizontally and diagonally) to prevent vibration during operation of the transformers. The distance between horizontally arranged bracing straps shall not exceed 1,000 mm. Radiators shall be fully vacuum proof and pressure tested and shall be liquid tight.

The radiators shall be fitted with suitable drain and vent plugs to enable complete draining and venting. Radiators installed underneath air-filled cable boxes shall be of the shortened design (e.g. of the DIN-railway profile style etc. subject to approval). No radiators shall be fitted underneath of air-filled cable boxes containing surge arresters.

The radiators shall be connected to the tank or external headers by butterfly valves in such a manner that each radiator can be removed without taking the transformer out of service, and without draining any oil from the tank and/or common headers (if any). The mechanical tolerance of the arrangement shall be minimised to allow the exchange of all radiators of the same type without additional fitting. The lower radiator headers shall be connected to the transformer tank or common headers in a height of not less than 800 mm but not exceeding 1,500 mm above floor level.

All butterfly valves shall be arranged in vertical position and in such a manner that their position indications are clearly visible and legible from tank cover and from ground level. Valve position indicators shall not be arranged underneath the flange of the tank cover.

Flanged-on common headers shall be connected the tank with gate valves mounted directly to the transformer tank or cover. Common headers shall not be connected to bushing turrets.

Accumulation of air in the radiators and headers shall be avoided. Upper common headers for connection of radiators shall be connected by isolating valves and vent pipes to the main expansion pipe. Separately mounted radiator banks shall not be provided.

The radiators shall be assembled and fitted to the tank to provide mechanical protection to them and to prevent vibrations. Suitable stiffening bars shall be fitted along the radiators on

top and bottom. All parts of the equipment shall be accessible for inspection and cleaning. Hot-dip galvanised radiators shall not be provided.

Where applicable, the following accessories shall be provided:

- One butterfly valve each for inlet and outlet for each radiator, directly accessible from ground level and tank cover
- Two isolating valves for connecting of each common header (if any) with the transformer tank and/or cover
- One drain plug (M12) with screwed cap at the outlets of each lower common header (min. two lower common headers, if provided) suitable for temporary installation of temperature sensors directly in the oil-flow during heat-run tests (subject to approval)
- One air vent plug (M12) with screwed cap at the inlets of each upper common header (min. two upper common headers, if provided) suitable for temporary installation of temperature sensors directly in the oil-flow during heat-run tests (subject to approval)
- One drain plug for each radiator at the outlet of each radiator suitable for temporary installation of temperature sensors directly in the oil-flow during heat-run tests in case of radiators directly flanged to the tank (subject to approval)
- Additional air vent plugs and drain plugs on common headers, if required
- One air vent plugs each at the inlet of each radiator header suitable for temporary installation of temperature sensors directly in the oil-flow during heat-run tests in case of radiators directly flanged to the tank
- Additional miniature thermometer pockets in the oil flow of upper and lower headers at tank inlets and outlets, if required. Those thermometer pockets shall not protrude beyond the outside surface of the concerned headers by more than 12 mm.

ONAF Cooling

The ONAF cooling shall be provided by means of at least six (6) fan units mounted underneath the radiators. The arrangement shall avoid any hot air circulation when the transformer is installed in the transformer bay.

At least 33% additional fans than required for continuous operation at full rated power within specified temperature rise limits shall be installed completely wired with starter units. These fans shall enable the continuous operation at full rated power within specified temperature rise limits with 10% over- or under-excitation including long-time emergency loading within the temperature limits as specified in IEC 60076-7 at 30°C ambient temperature under thermal steady state conditions (to be verified by steady state heat-run tests).

The fan units shall be fitted in an accessible position in a height of not less than 1,000 mm to suitable non-corrosive steel structures rigidly bolted to the radiator groups (subject to approval). The fan units attached to radiator groups shall be mounted in a height not exceeding 1,400 mm above floor level.

The fan units shall preferably be arranged in such a manner as not to protrude beyond the fins of one radiator. In no cases fan units shall protrude beyond the fins of one pair of

radiators. The overall diameter of the fan units shall not exceed 1,000 mm and the weight shall be limited to a maximum of 60 kg. Overlapped arrangement of the fans with any fan(s) of other radiators shall be avoided.

Each fan unit shall be individually removable without dismantling of any structures and without disturbing the operation of other fans. No fan units shall be attached to radiators arranged underneath air-filled cable boxes, unless approved in exceptional cases.

The fan propellers shall be made of sea-water proof aluminium alloy or stainless steel. Propellers or parts of propellers made of any kind of plastics are not acceptable. Mechanical protection against touching of the propellers shall be provided by round wire mesh guards of stainless steel at both sides of the propellers.

The fan motors shall be arranged underneath the propellers and shall be accessible without removing of the guard. A name plate made of stainless steel for each fan motor shall be provided clearly visible and legible on the outer housing of each fan unit at an accessible position.

Starting from the hot condition (100% load at rated excitation) the transformer shall be capable of remaining in operation for at least 60 min without exceeding the winding hot spot temperature of 125 °C at specified maximum ambient temperature, after failure of the forced cooling.

The control equipment for the cooling plant and all auxiliary devices shall be accommodated in a weatherproof cabinet with protection class IP 65, mounted to the transformer.

10.4.4 Control of Cooling Units

The power and control circuits for the cooling system shall be installed in the control cubicles specified in this Section.

The 3x100% redundancy shall also be fully achieved for the power and control circuits.

The systems shall be suitable for local manual and automatic control. Manual/Auto and Local/Remote selector switches shall be provided.

An interface to the CCS shall be provided and all relevant information shall be transmitted to the UCB and CCS.

The following alarms shall be provided:

- Auxiliary supply - auto change-over;
- Auxiliary power supply 1,2 and 3 failure;
- Oil circulating pump failure for each pump.

The following status signals shall be provided:

- Oil circulating pump start for each pump;
- Cooling system in local/remote;
- Cooling system in automatic mode;
- Cooling system in manual mode.

10.4.5 Transformer Oil

The insulation oil shall be new inhibited naphthenic based mineral oil with anti-oxidant (phenol) additives, and shall have properties to avoid formation of copper sulphide under continuous heavy loading conditions even without passivation additives.

It shall be hydro-treated and already laboratory treated, and shall have properties complying with IEC 60296 – 2003, with aging properties meeting Special Applications as specified in this Standard. However, the properties such as the typical kinematic viscosity shall not exceed 10mm²/s at 40°C. The typical dielectric dissipation factor at 90°C shall not exceed 0.001 after laboratory treatment as above. The flash point shall not be less than 140°C. Insulation oil used for all power transformers shall be of the same oil manufacturer and type.

With regard to more efficient detection of corrosive sulphur the oil shall have also passed a test in accordance with ASTM D 1275, method B.

Acceptable oils are all inhibited oil types make NYNAS or equivalent types.

The dissolved gases in oil, the water content in ppm and the dielectric strength of the insulation oil shall also be tested at site during commissioning.

10.4.6 Oil Conservator

The arrangement of the conservator vessels shall not obstruct the electrical connections to the transformer. It shall have sufficient capacity to allow oil expansion from 0°C to 120°C. Conservator vessels shall be sealed against each other and shall not be located directly on (along) the tank cover (subject to approval).

Main tank conservator vessels shall be connected to the tank cover at the end opposite to the OLTC. Magnetic type oil level indicators showing the full level range shall be fitted to all oil vessels, being clearly marked with the normal level at 30°C.

Tap changers shall have their own closed subsections in the conservator. To avoid unnecessary permanent stresses from diverter switch compartment(s) of OLTC to that of the transformer main tank all conservator compartments shall be designed in such a manner that at the same oil temperature all oil levels are nearly equal, and the installation level of the conservator vessel(s) shall not exceed 2.5 m above tap changer head(s) to avoid impermissible stresses at any OLTC compartment when the diverter switches are drawn out for maintenance.

The conservator vessels shall be fully vacuum proof and designed in such a way that they can be completely drained by means of drain valves. Shut-off slide valves shall be provided directly at the conservators for all oil piping connected to the conservators in addition to drain and other valves etc. to be mounted at a convenient working height. Conservator vessels shall be furnished with cleaning openings with covers fitted with two lifting lugs.

A vacuum application valve and vacuum equalising valves for OLTC conservator(s) shall be provided between the air-expansion pipes to the silica gel breathers. The vacuum application

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valve and the vacuum equalising valves between the conservators shall be rigidly fixed at a convenient floor height.

Each conservator vessel shall be fitted with two parallel breathers in which only orange silica gel (transparent clear when wet) has been filled as a dehydrating agent. The containers for the dehydrating agent and the oil trap shall not be of transparent plastics. The parallel breathers shall be connected to the air-expansion pipes via approved two-position three-way valves with captive screwed caps. A universal spanner for removing of the cap and operation of the valve shall be fitted to the tank by a fly-nut on a rigidly fixed bolt of stainless steel at an accessible position in a convenient floor height.

In view of excessive humidity breathers shall be larger in size and shall be provided with oil trap. The silica gel filling capacity of each breather shall be dependent on the size of the transformers (each having a minimum filling capacity of 3 kg for the OLTC conservators and 4.5 kg for transformers up to 40 MVA per unit and minimum 6 kg for transformers above 40 MVA per unit shall be provided).

The silica gel breathers as well as all filling and draining devices shall be rigidly fastened at an accessible position in a convenient working height. All breathers shall be rigidly fixed to the tank by appropriate mounting brackets at their lower ends (subject to approval).

10.5 AUXILIARY TRANSFORMERS

The station auxiliary supply system shall be fed by three station service transformers (SST), each rated for 100% of the auxiliary load. The HV side of the SST1 & 2 shall be connected to the generator voltage switchgear of unit 1 and 2, respectively. The SST 3 shall be connected to the 11 kV switchgear located in the Plant Operation Building. The LV side shall be connected to the relevant feeders of the LV main switchboard.

For the power supply of the Plant and Switchyard Operation Buildings two distribution transformers 11/0.415 kV, 400 kVA shall be provided. For the power supply of the weir site one distribution transformer 11/0.415 kV, 200 kVA shall be provided. The transformers shall be fitted with sheet steel enclosures and installed adjacent to the LV switchboards. The system configuration is shown on the single-line diagrams.

The scope of work shall comprise the following:

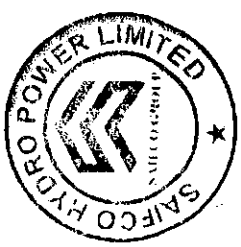
- Three station service transformers 630 kVA;
- Two distribution transformers 400 kVA;
- One distribution transformer 200 kVA;
- Six sets of auxiliary plant to provide complete, ready-for-service installations;
- One set of special spare parts.

10.5.1 Station service transformers

- Number of units	3 Nos.
- Type	3-phase, cast resin
- Location	Indoor, powerhouse
- Rated output	630 kVA
- Voltage ratio	11/0.415 kV
- Rated frequency	50 Hz
- Impulse withstand voltages:	
- Power frequency	38 kV
- Lightning	95 kV
- Impedance voltage	6 %
- Vector group	Dyn11
- Insulation class	HV/LV F/F
- Voltage adjustment	+ 2*2.5 %
- Type of HV termination	Busduct or cable
- Type of LV termination	Cable
- Maximum temperature rise	90 K
- Maximum ambient temperature	50 °C
- Enclosure protection class	IP 23
- Type of cooling	AN

10.5.2 Distribution transformers (Plant, Switchyard and Dam Operation Building)

- Number of units	2 + 1 Nos.
- Type	3-phase, cast resin, indoor
- Location	Plant Operation Building
	Switchyard Operation Building
	Dam Operation Building
- Rated output	400 + 200 kVA
- Voltage ratio	11/0.415 kV
- Rated frequency	50 Hz
- Impulse withstand voltages:	
- Power frequency	38 kV
- Lightning	95 kV
- Impedance voltage	4 %
- Vector group	Dyn11
- Insulation class	HV/LV F/F



-	Voltage adjustment	+ 2*2.5% %
-	Type of HV termination	Cable
-	Type of LV termination	Cable
-	Maximum temperature rise	90 K
-	Maximum ambient temperature	50 °C
-	Enclosure protection class	IP 23
-	Type of cooling	AN

10.6 132 KV CABLE SYSTEMS

The connections between the main transformers (MT) and the Switchyard feeder bays shall be carried out with 132 kV XLPE type single core cable systems. The routing of the cables is shown on the layout drawings.

The scope of work shall comprise the following:

- Three sets of cable systems connecting the MT with the Switchyard MT feeder bays;
- Three sets of transformer cable sealing ends;
- Three sets of outdoor cable sealing ends;
- Three sets of related auxiliary plant to provide complete, ready for service installations;
- One set of special spare parts.

Principal Design Features

(1) The 132 kV cables and accessories shall be the standard product of a reputed manufacturer with a proven track record. The construction of the cables shall be in compliance with the specified requirements and the related ICEA and IEC Standards.

(2) The single core, XLPE insulated cables shall be longitudinal and radial watertight, suitable for installation in air, ground, on cable trays and ladders, in cable ducts and pipes.

(3) The maximum continuous current carrying capacity of each cable system shall be based on the maximum loading at site conditions. The resulting load reduction factors are subject to approval. The conductor cross-sections shall be adequate to carry the fault currents at specified conditions without deterioration of the dielectric properties.

(4) The maximum admissible conductor temperatures for continuous and transient fault conditions shall be as follows:

-	For PVC insulation	70/160 °C
-	For XLPE insulation	90/250 °C

Main Characteristics

The equipment shall have the following main characteristics:

-	Type designation	2XS(FL)2Y

- Nominal system voltage	132 kV
- Rated voltage	145 kV
- Rated frequency	50 Hz
- Rated power frequency withstand voltage	275 kV
- Rated lightning impulse withstand voltage	650 kV peak
- Rated continuous capacity per system	75 MVA
- Rated short time withstand current (1 s)	40 kA rms
- Rated peak withstand current	100 kA peak
- Conductor material	Al or Cu
- Conductor cross section	By Bidder
- Insulation material	XLPE
- Maximum conductor temperature:	
- At rated conditions	90 °C
- During short circuit 1 s	250 °C

10.7 MV INSTALLATIONS 11 KV

The power plant shall be provided with a reliable, easy to operate and maintain AC auxiliary supply system consisting of 11 kV switchgear, station service transformers, LV main switchboard, LV distribution boards, diesel generating units and LV cable systems. In this Chapter mainly the requirements for the MV switchgear and related installations are specified; the requirements for the other equipment are specified in the relevant Sections.

The configuration with the main data and the basic arrangement are shown on the single-line diagrams and layout drawings.

The scope of work shall comprise the following:

- One distribution switchgear 11 kV;
- One lot of pole mounted equipment;
- One set of related auxiliary plant to provide ready for service installations;
- One set of special tools and appliances;
- One set of special spare parts.

10.7.1 Principal Design Features

General Requirements

- The 11 kV distribution switchgear shall be type-tested, metal enclosed utility type switchgear equipped a single busbar and draw-out type SF6 or vacuum circuit breakers.

- The switchgear shall comprise ten feeders equipped as shown on the single line diagram. The switchgear shall be installed in the Switchyard Operation Building.
- The grid transformer, station service transformers SST3 and the overhead line feeders shall be connected to the switchgear with single core XLPE type cables.

Main Characteristics

- Type	Metal-clad, indoor
- Nominal system voltage	11 kV
- Rated voltage	17.5 kV
- Rated frequency	50 Hz
- Rated power frequency withstand voltage:	
- To earth	38 kV rms
- Across open contacts	45 kV rms
- Rated lightning impulse withstand voltage:	
- To earth	95 kV peak
- Across open contacts	110 kV peak
- Rated normal current of bus	400 A
- Rated short-time withstand current (3 s)	31.5 kA rms
- Rated peak withstand current	80 kA peak

Switchboard Design

- The equipment shall be designed to facilitate transport, installation, operation, inspection, maintenance and repairs. Easy access to all components shall be considered;
- The switchgear shall be the type tested standard product of a competent manufacturer;
- Reliability, continuity of supply and safety for the operation personnel shall have the first priority. All operation sequences shall be carried out with switchgear completely closed;
- All equipment shall be suitable for satisfactory operation at the prevailing site conditions;
- The switchboards shall be of the self-supporting free-standing, flush fronted design with the following individual, sheet steel segregated compartments:
  - Circuit breaker compartment provided with shutters to the busbar section,
  - Busbar compartment
  - Cable and measuring transformer compartment;
  - Control and measuring compartment (LV section).

All faults occurring in any of the individual sections shall be restricted to that area, and except for bus faults, shall not cause shut-down of any other unit of the board other than the

faulty unit itself. Insulating barriers, bus supports, moulded covers, etc. shall be of non-hygroscopic, non-inflammable synthetic resin or other approved material. Pressure relief devices shall prevent destruction or deformation of the relevant cubicle. Pressure relief devices shall be provided in such a way as to minimise the risk to personnel. All doors to which this requirement applies shall be fitted with interlocks to prevent the switchgear being operated while they are open and to prevent them being opened while the switchgear is in service.

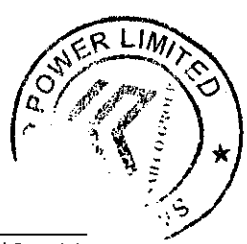
- The switchboards shall have the protection class IP 42. IP 2X is required for internal segregation and IP 4X between cubicles.
- The busbar arrangement shall allow extension at either end. Expansion joints shall be provided as required. Cast resin bushing type partitions shall be provided at each junction between adjacent cubicles.
- Cable termination compartments shall be suitable for cables entering from the bottom or top. They shall also accommodate the measuring transformers and surge arresters.
- The switchboards shall be provided with lockable doors, screens and guards to prevent accidental contact to live parts. All cubicles shall be sufficiently ventilated to ensure an adequate movement of air through the units, particularly when out of service.
- Switchgear shall preferably be designed to maintain appropriate temperature and level of insulation without air conditioning.

Circuit Breakers

The circuit breaker shall be manufactured and tested in accordance with IEC.

The circuit breakers shall have the following main characteristics:

- Type	SF6 or Vacuum, draw - out
- Nominal system voltage	11 kV
- Rated voltage	17.5 kV
- Rated frequency	50 Hz
- Rated power frequency withstand voltage:	
- To earth	38 kV rms
- Across open contacts	45 kV rms
- Rated lightning impulse withstand voltage:	
- To earth	95 kV peak
- Across open contacts	110 kV peak
- Rated current	400 A
- Rated short-time withstand current (3 s)	31.5 kA rms
- Rated short circuit breaking current	31.5 kA rms
- Rated peak withstand current	kA peak 80



(I) The three-phase circuit breakers (CB) shall be of the SF6-gas or vacuum type equipped with motor charged spring storage operating mechanism. Normal operation shall be carried out by electrical local/ remote control. Manual spring charging and CO control shall be provided.

The charging time for the spring charged mechanisms shall be 25 s approx. The spring shall be automatically re-charged immediately after the switching device has been closed.

Mechanical position indication shall be available.

(II) The CB unit shall be complete with high integrity operating and isolating mechanisms, primary and secondary disconnecting devices, auxiliary contacts, manual tripping facilities, operations counter, mechanical position indicator, control wiring, auxiliary relays and contactors as required. The SF6 type CB shall be fitted with gas pressure monitoring and low pressure alarm.

(III) The duty cycle shall be O - 0.3 s - CO - 180 s - CO

(IV) The circuit breakers shall be electrically and mechanically trip-free. Anti-pumping devices shall prevent pumping while the closing circuit remains energised and the breaker fails to latch or be tripped during closing due to the operation of a protection device.

(V) Circuit breaker control circuits shall be fed from the DC auxiliary supply system. All electrical closing and tripping devices shall be suitable for operation at voltages between 110% and 80% of the rated control voltage.

(VI) Circuit breakers shall be of the draw-out type and have self-aligning fixed contacts for the power circuits and plugs with sockets or other suitable devices of the automatic connection type for the control circuits.

(VII) The CB unit shall be positively locked in the service and in the test position before it is released for complete withdrawal. A mechanical interlock shall be provided to prevent withdrawal of the unit unless the power circuit has been interrupted. The test position shall permit local/remote tripping and local closing of the relevant circuit breaker with the power contacts not energized.

(VIII) The following accessories shall be provided:

- Trip coil supervision
- CO cycle counter
- Auxiliary switches for position and trip indications as required
- The circuit breakers shall be furnished with all standard accessories, special tools and devices for drawing out and transporting the CB unit.

Earthing Devices

(I) Earthing switches shall be suitable for earthing cable circuits. They shall be manually operated and interlocked with the circuit breaker in such a manner that they can be

switched on only if the circuit breaker is withdrawn. Inserting the circuit breaker shall not be possible if the earthing switch is closed.

(II) The feeders shall be equipped with earthing switches as shown on the single line diagrams. In the closed position they shall be capable to withstand the maximum fault current.

(III) Busbar earthing shall be preferably by means of earthing switches. If this solution is not feasible the use of portable earthing devices with voltage checking device may be considered.

Current Transformers

The current transformers shall be of the cast resin single phase type, manufactured and tested in accordance with latest revision of the relevant IEC Publications.

Type, number and rating shall comply with actual requirements of the measuring and protection systems.

Voltage Transformers

The voltage transformers shall be of the cast resin single phase type, manufactured and tested in accordance with latest revision of the relevant IEC Publications.

Type, number and rating shall comply with actual requirements of the measuring and protection systems.

Surge limiting devices

Surge arresters and other surge limiting devices shall be installed in the switchgear to ensure reliable protection of the 11 kV equipment connected to the switchgear.

Description and characteristics of proposed arresters and other surge limiting devices shall be submitted with the Bid.

The surge protection of the equipment and surge arrester parameters shall be in accordance with the IEC Publications.

Control, Measuring and Protection

(I) CB units shall be equipped with multipurpose control and protection systems. The systems shall be based on logic, programmable control units with display, HMI and bus interface to the CCS. The equipment shall be readily accessible installed in the LV compartment.

(II) The control of the feeders shall be local or remote from the CCS.

(III) Interlocking shall be programmable according to the requirements of the overall control concept for the station auxiliary supply system.

(IV) All alarms and indications shall be signalised at the individual cubicle. All information shall be available for individual or grouped transmission to the CCS.

(V) The following information shall be considered in the switchgear control concept but not being limited to:

- Remote/Local, Auto/Manual control mode indication;
- Position indication of circuit breaker, disconnecting and earthing switches;
- CB truck service and test position;
- CB trip circuit failure;
- Electrical protection "alarm and trip";
- Bus under-voltage;
- DC auxiliary voltage failure;
- MCB trip.

(VI) The following protection features shall be realised in the control unit:

- Instantaneous over current protection (50/50 N)
- Time delayed over current protection (51/51 N)
- Station service transformer differential protection (87 ST)
- Under voltage protection (27)

(VII) The requirements specified in the Section "Electrical Protection Systems" shall apply.

(VIII) Multifunction measuring devices shall be provided comprising the display of:

- Voltage
- Current
- Frequency
- Active and reactive power
- kWh metering

(IX) Multifunction measuring features can also be integrated in the control units. Due regard shall be given to the CT/VT circuits and the measuring accuracy.

The specified stresses for outdoor equipment like wind, earthquake and thermal expansion due to rated current and sun radiation shall be considered. Appropriate surface treatment for all parts especially when installed outdoor shall be considered. The structures shall be of hot-dipped galvanised steel or aluminium.

Pole-mounted Equipment

(I) Load break and earthing switches shall comply with voltage class 17.5 kV and shall be suitable for pole mounting. The drive mechanisms shall allow the operation from the ground floor.

(II) Pole mounted surge arresters complying with the IEC Standards shall be of the non-linear resistance type for outdoor use and shall have a nominal discharge current of 10 kA. Surge arresters shall include a device to visually indicate the damage of a unit.

(III) All fittings shall be designed to avoid deforming the stranded cable. All fittings shall have suitable locking devices (nuts or splint pin) and shall be hot dip galvanised. Dead end clamps shall be of the bolted type or other approved compression system.

(IV) Warning and designation plates shall be fitted to each support.

10.8 LV AC AUXILIARY SUPPLY SYSTEMS

The power plant shall be provided with a reliable, easy to operate and maintain AC auxiliary supply system consisting of 11 kV switchgear, station service transformers, LV main switchboards, LV distribution boards, diesel generating units and LV cable systems. In this Section mainly the requirements for the LV switchgear are specified; the requirements for the other equipment are specified in the relevant Sections.

The scope of work shall comprise the following:

- One Main switchboard for the Powerhouse;
- Two Unit MCC;
- One MCC for common services;
- One distribution board for the Transformer Cavern;
- One distribution board for the Plant Operation Building;
- One distribution board for the Switchyard Operation Building;
- Two Distribution boards for E&M workshops;
- One Distribution board for the Dam Operation Building;
- One lot of sub-distribution boards;
- One lot of related equipment to provide complete, ready for service installations;
- One set of special spare parts.

10.8.1 Main Characteristics

- Nominal system voltage	400/230 V
- Rated voltage	690 V
- Rated insulation voltage	1,000 V
- Rated frequency	50 Hz
- Power frequency withstand voltage	2,500 V rms
- Rated short time withstand current (1 s)	40 kA rms
- Rated peak withstand current	100 kA peak
- Installation	Indoor
- Protection class	IP 42

10.8.2 Feeder Allocation

For defining the number and type of feeders to be provided in the switchboards the following shall be considered:

(1) Switchboards and feeders for electrical and mechanical equipment shall be provided as specified.

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(2) The following mechanical equipment shall have particular MCC or Local Control Cubicles (LCC), provided by the relevant manufacturer:

- Cooling water system
- Drainage system
- Dewatering system
- High pressure compressed air system
- Low pressure compressed air system
- Oil handling system
- HVAC systems
- Fire protection systems
- Potable water system
- Sewage treatment plant
- Powerhouse crane.

(3) For a.m. MCC and LCC feeders shall be provided from the normal and essential busbar of the main switchboard, as required.

(4) The distribution board for the Dam Control Building shall be equipped with the following feeders:

Power Intake:

- Intake gate	1x24 kW
- Trashrack cleaning equipment	1x25 kW

Spillway:

- Spillway flap gate, hydraulic hoist	1x20 kW
- Spillway gantry crane	1x5 kW

Sluiceway:

- Sluice radial gate, hydraulic hoist (2 gates)	1x37 kW
- Sluice radial gate, hydraulic hoist (1 gate)	1x37 kW
- Sluice gantry crane	1x5 kW

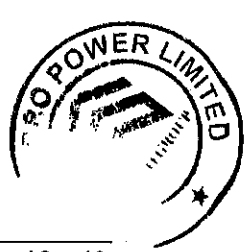
Desander:

- US hydraulic hoist	2x12 kW
- DS hydraulic hoist	2x12 kW

(5) The following Hydraulic Steel Structures shall be supplied by the Main Switchboard:

- Tailrace service gate	1x6 kW

Normal and essential supply shall be provided as required.



(6) An automatic dam monitoring system (ADMS) with data collection terminals in the CCR and in the Dam Operation Building. 230 V AC power supply shall be provided for this equipment.

(7) The Powerhouse Instrumentation System with data collection terminals in the CCR. 230 V AC power supply shall be provided for this equipment.

10.8.3 Main Switchboards, Distribution Boards, MCC

(1) The switchboards shall be of the self-supporting, free-standing, flush fronted design. They shall be the standard, type tested product of a competent manufacturer with proven track record. As far as possible the same type of switchgear shall be used in the power plant.

(2) The switchboards shall be equipped with air circuit breakers (ACB), moulded case circuit breakers (MCCB), miniature circuit breakers (MCB), load break switches (LBS) and motor starters. Equipment with ratings 630 A and above shall be of the draw-out type provided with appropriate sliding supports and trucks for handling the switchgear.

Motor starters shall be mounted on draw-out modules fitted with main and control circuit plug connections.

(3) The individual cubicles shall be divided into compartments fully isolated from each other, comprising:

- Circuit breaker and motor starter compartment;
- Busbar compartment;
- Compartment for control and protection devices;
- Power and control cable compartment.

Special arrangements shall be made for the connection of the LV busducts coming from the SST.

(4) Any fault occurring in the individual compartments shall be limited to that area, and except for busbar faults, shall not cause the shut-down of any other equipment. Insulating barriers, bus supports, moulded covers, etc. shall be of non-hygroscopic, non-inflammable synthetic resin or other approved material. Pressure relief devices shall ensure that over pressures occurring during switching operations do not cause any destruction or deformation of the switchgear.

(5) The busbar systems shall consist of 3 phases (L1/L2/L3), neutral (N) and protective earth (PE). The busbars shall be made of fully insulated copper bars, arranged horizontally or vertically. All busbar connections shall be silver plated, adequately bolted and shrouded with insulation materials.

(6) Shutters shall be provided which automatically cover bus bars, cable terminations and contacts whenever withdrawable units are removed; IP 30 shall be maintained.

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The safety shutters shall be automatically opened and closed by action of the withdraw able unit. A positive drive to the shutters shall be provided in both directions. They shall be lockable in the closed position.

(7) Cable access shall be possible from top or bottom. The connection of control cables to each compartment shall be carried out with terminals or reliable plug-socket combinations positively fixed by springs or screws.

Power cables shall be terminated to terminal blocks or to adequately support auxiliary busbars provided with the ACB, MCCB, etc. to avoid any stress transfer from the cable to the switchgear. No external cable connection boxes shall be permitted.

(8) The switchboards shall be equipped with all necessary power and control elements such as circuit breakers, motor starters, auxiliary switches, contactors, devices for indication, protection, metering, control and interlocking. Manual control elements and local instruments shall be located in the lockable front doors.

(9) Power supply for important switchboards and MCC shall comprise two incoming feeders connected to the normal and essential busbar.

The DC auxiliary supply circuits required in the different locations may be mounted in the related AC switchboards, suitably segregated from the AC circuits.

10.8.4 Controls, Interlocks and Alarms

(1) The switchboards shall comprise hard-and software for the realisation of the electrical interlocks, auto-transfer and manual ON/OFF operations for incoming feeders and tie breakers. Station or cubicle process units with CCS interface shall be provided. The equipment shall be installed in the relevant switchboard compartment.

For motor starters, defined ON/OFF signals comprising all necessary process interlocks shall be received from the CCS or from the programmable, self contained station/cubicle control units and interposing relays.

(2) The basic interlocking and control functions shall be as follows:

- All incoming feeders of a distribution board or a section of such board shall be mechanically or electrically interlocked against each other or against the tie breaker, so that each distribution board or section can be fed by one power source only.
- Paralleling of two feeders or bus sections of the same switchboard, which are fed from the same power source shall be possible for a few seconds. In such case, one of the two feeder breakers or the tie breaker shall subsequently be switched off (manual operation) or the circuit breaker which had not finally carried out parallel operation shall trip after a preset period (automatic operation).
- Wherever dual power supply to a switchboard is provided, arrangements shall be made that at voltage failure detected by the busbar voltage monitoring relay (27) the standby power source will automatically be connected in the shortest possible time unless the reason for the power loss was over current.

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Such auto-transfer function may also be initiated manually in which case break before make operation of the concerned circuit breakers is required if the switchboard is fed from different power sources. Hence, each breaker combination shall be equipped with a key operated selector switch MANUAL/AUTO/OFF.

- At loss of the busbar voltage detected by the voltage monitoring relay (27), a trip signal shall be given to the feeder circuit breaker originally in service. Such signal shall not prevent auto-changeover to a standby power source.

(3) All draw-out units shall be provided with electrical and mechanical interlocks to prevent incorrect operation and to provide safety for the operation personnel. External interlocks specified for operational reasons shall be considered. Opening of cubicle doors and covers shall only be possible after disconnecting of the supply to exposed live parts.

(4) Control circuits shall be protected with MCB and separated for trip, alarm and signalisation circuits.

(5) All alarms relevant to a feeder shall be displayed at the individual panel/ compartment. The alarms of the entire switchgear shall initiate a group alarm displayed on the common local alarm tableau provided with lamp test facilities or with an alarm lamp provided at the upper part of the switchboard front panel. The following group alarms shall be provided:

- CB trip
- Electrical protection alarm/trip
- Control voltage failure
- Bus voltage ON/OFF.

10.8.5 Air Circuit Breakers

(1) The air circuit breakers (ACB) shall be of withdraw able type, equipped with adjustable electromagnetic instantaneous and thermal over current protection. Alternatively the manufacturer shall propose solid state protection devices with CT. The over current trip shall consist of two independent systems with adjustable pick-up current and time.

2) The following standard features shall be provided:

- Safety shutter for primary contacts
- Locking device
- Test jumpers to allow OC test on removed breaker
- Anti-pumping control with OFF preference
- Trip coil supervision
- Operation counter
- Auxiliary switches for position/trip indication
- Operation/service truck.

10.8.6 Switchgear Components

- MCCB
- MCB
- Contactors and thermal over current release
- Motor starters
- Switchboard control elements
- Local push button stations
- Small wiring

10.8.7 Typical Feeders

The switchboard configurations shall be based on the single line diagrams. The number, type and rating of the feeders shall be in accordance with the actual requirements.

The typical feeders shall be equipped as follows:

(1) **Incoming feeders** for main switchboards with ratings according to actual requirements, comprising the following equipment:

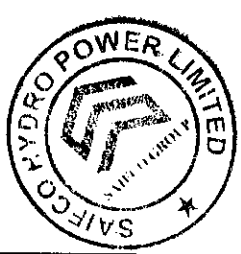
- One ACB for electrical local/remote control
- One automatic transfer device
- Three CT
- Three VT
- One multifunction measuring device
- One measuring transducer
- One set of control and protection devices
- Interface to the CCS

(2) **Tie breakers** with ratings according to actual requirements, comprising the following equipment:

- One ACB for electrical local/remote control
- One set of control and protection devices
- Interface to the CCS

(3) **Incoming feeders** for distribution boards and MCC with ratings according to actual requirements, comprising the following equipment:

- One ACB/MCCB for electrical local/remote control for normal and essential feeder
- Three CT
- Three VT
- One multifunction measuring device
- One change-over device
- One measuring transducer



- One set of control and protection devices
- Interface to the CCS

(4) **Outgoing feeders**, with ratings according to actual requirements, comprising the following equipment:

- One MCCB for manual control.

(5) **Motor starters** with ratings according to IEC utilisation categories and actual requirements, comprising the following equipment:

- One MCCB for manual operation;
- One power contactor and reverse power contactor, as applicable;
- One adjustable thermal overload (49) and phase failure protection (46), thermal over current release, as applicable;
- One CT, ammeter and current transducer, h – meter, as applicable;
- One set of control devices (push buttons, selector switches M/A and L/R);
- Interface to the CCS.

10.9 DIESEL GENERATING UNITS

This Section specifies the requirements for the diesel engine driven generating units complete with all auxiliary equipment. The generating units shall be mounted in enclosed and ventilated purpose-built engine rooms which shall contain the complete installations including the day tank, cooling system, control equipment, starting battery and battery charger.

The Scope of Work shall comprise the following:

- One Diesel Generating Unit, rated 250 kVA, 0.4 kV, 1,500 rpm;
- One Diesel Generating Unit, rated 100 kVA, 0.4 kV, 1,500 rpm;
- Two sets of related auxiliary plant to provide complete, ready for service installations;
- Two sets of special tools and devices;
- Two set of special spare parts.

10.9.1 Principal Design Features

General

(1) The DG units shall mainly serve for the following:

- Black start of one turbine - generating unit;
- Power supply to selected essential feeders during complete black-out and/or complete shutdown of the plant.

(2) The DG units shall be suitable for isolated operation, single or parallel operation of the two units and parallel operation of one or two units with the station auxiliary supply system.

(3) The DG units shall be connected to the LV auxiliary supply systems as shown on the single line diagrams.

(4) The DG units shall be completely self-sufficient, i.e. not depending on any external auxiliary source.

(5) The DG unit rating shall be such, that one DG unit is capable of supplying the essential consumers of the entire plant.

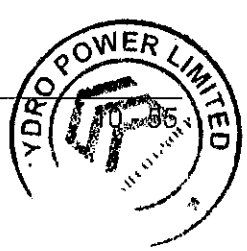
The equipment shall have the following main characteristics:

10.9.2 Diesel Engine

- Type	4-stroke Diesel
- Rated output PH	200 kW
- Rated output Dam Site	80 kW
- Rated speed	272.7 rpm
- Cooling system	Closed water circuit, radiator with motor fan
- Fuel supply	By gravity, fuel supply pump
- Fuel	Commercial diesel
- Starting system	Electric 24 V DC, battery and charger
- Day tank capacity PH	1,000 l approx.
- Day tank capacity Dam Site	500 l approx.
- Storage tank PH	5,000 l approx.
- Storage tank Dam Site	2,500 l approx. (5 days operation)

10.9.3 Generator

- Type	3-phase, synchronous, directly coupled to the diesel engine
- Design	Horizontal
- Cooling	Air-cooled
- Rated output PH	250 kVA
- Rated output Dam Site	100 kVA
- Rated voltage	400 / 230 V
- Rated frequency	50 Hz
- Voltage regulation	± 5 %
- Rated speed	272.7 rpm
- Power Factor	0.8
- Insulation Class	F
- Protection class	IP42
- Excitation System	Brushless with rotating diodes,self-regulating



10.9.4 General Requirements for Design and Construction

- The DG units shall be complete, self-contained, independent units including all auxiliary equipment and controls as specified and required for proper and satisfactory operation.
- The emergency diesel generating units shall be a standard product of a competent manufacturer, factory assembled and tested.
- The offered engine model shall be one from the existing regular production range used by the supplier.
- The auxiliary plant of the units shall include, but not limited to, starting systems, fuel and lubrication systems, cooling systems, exhaust system, air, fuel, oil and exhaust piping, control and protection equipment and cabinets, etc.
- The various components of the DG units shall form a completely self-contained plant.
- The mechanical performance for the complete range of operation of the engine shall be demonstrated in a shop test. Reference list and performance curves of power versus speed, specific fuel consumption, efficiency, etc. shall be submitted with the Bid.
- The unit shall be free from injurious vibrations, dangerous torsions and critical speed.

10.9.5 Base Frame

The diesel engine and direct coupled generator shall be mounted on a robust, stress relieved, fabricated steel base frame. The diesel engine and generator shall be accurately aligned on the base frame before workshop tests and despatch to site.

The bearing arrangement and method of coupling of the engine and of the generator shall be the proven standard design of the manufacturer.

Anti-vibration mountings shall be provided on the fabricated steel base frame. These shall be designed to minimise the transmission of vibrations to the engine room floor slab without excessive amplitude of movement of any part of the generating unit. Mountings containing rubber shall be fully protected against contamination by oil leakage from the engine.

Flexible connections shall be provided for all exhaust, water, air, fuel and oil piping that leave the engine to prevent the transmission of vibration and the fracture of the piping due to movement of the unit. The choice of connections and their installation shall be such as to give long life under normal operating conditions of the unit.

10.9.6 Starting System

The starting system shall consist of electric motor starters and 24 V batteries with battery chargers. Two sets of batteries of the Lead/Acid type with a total capacity sufficient to maintain cranking speed through a 4 minute cycle of 15 s crank followed by 15 s rest for consecutive cycles shall be provided. Each battery set shall have the capacity for 3 consecutive cycles.

One battery with charger shall be provided for control and common auxiliaries. The batteries shall be installed in a heavy gauge sheet steel cabinet with adequate ventilation. The battery cabinets shall be mounted 300 mm above floor or skid. The batteries shall be furnished in a dry condition with electrolyte liquid in separate containers. Electrolyte shall be added at the time the engine is put into service and batteries given a commissioning charge. The battery chargers shall have duplicated infeed from the station auxiliary supply system.

The DG units shall be capable of starting promptly at ambient temperature and shall also be capable of carrying the full rated load within 30 s after receiving a starting signal. The starting systems shall be capable of successive starts without the need to recharge the batteries.

10.9.7 Automatic Start Mode "Service"

The selector switch is in "Automatic/Service" position. The selector switch "Automatic/Manual" and "Service/Test/Off" shall be provided in the LCC.

Following a loss of normal station auxiliary supply, the DG Unit shall start automatically and be brought to nominal speed and voltage on receiving a signal from the mains monitoring devices. All accessories required for starting and completing the sequence of operation for the above purpose shall be provided.

Immediately after the DG unit reached rated speed and rated voltage, voltage and frequency monitoring devices located in the LCC shall send a command for closing the generator circuit breaker. The loading of the DG unit shall be realised with the CCS in the CCR.

10.9.8 Manual Start Mode "Service"

DG Unit in SERVICE

The selector switch is in "Manual/Service" position.

The operation scheme shall be same as the auto mode detailed above except that the starting command shall be given manually with push button/touch screen either from the LCC or the CCR.

10.9.9 Manual Start Mode "Test"

DG Unit in SERVICE

The selector switch is in "Manual/Test" position.

The operation scheme shall be same as that of manual start into service mode, except that the closing command for the generator circuit breaker shall not be given automatically. To allow paralleling of the DG units with the station auxiliary supply system, manual and automatic synchronising equipment shall be provided. The minimum testing load shall be 50% of the nominal load.

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10.10 DC AND UPS SYSTEMS

For the safe and reliable operation of the control, protection and communication systems 220 V DC and 230 V AC UPS systems shall be provided in the Powerhouse, Plant Operation Building and the Dam Operation Building.

10.10.1 Scope of work

The scope of work shall comprise the following:

(1) Powerhouse (PH)
- Three battery chargers 400 V AC/220 V DC for the 220 V DC auxiliary supply system;
- Three lead acid batteries 220 V and 600 Ah approx. for the 220 V DC auxiliary supply system;
- Three DC main switchboards
- One lot of DC sub-distribution boards

(2) Plant Operation Building (POB)
- Three battery chargers 400 V AC/220 V DC for the 220 V DC auxiliary supply system;
- Three lead acid batteries 220 V and 600 Ah approx. for the 220 V DC auxiliary supply system;
- Three DC main switchboards.
- Three UPS systems, 220 V DC/400/230 V AC 50 Hz of approx. 10 kVA output;
- Three UPS switchboards.

(3) Switchyard Operation Building (SOB)
- One DC main switchboard.

(4) Dam Operation Building (DOB)
- One battery charger 400 V AC/220 V DC for the 220 V DC auxiliary supply system;
- One lead acid battery 220 V and 400 Ah approx. for the 220 V DC auxiliary supply system;
- One DC main switchboard.
- One UPS system, 220 V DC/400/230 V AC 50 Hz of approx. 5 kVA output;
- One UPS switchboard.

(5) Common
- One lot of related equipment to provide complete, ready for service installations;
- Two sets of special tools and appliances;
- One set of special spare parts.

10.10.2 General Design Features

(1) The basic system configuration of the DC auxiliary supply systems is shown on the single line diagrams. The systems shall be supplied by battery chargers and batteries,

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each rated for 100% of the total auxiliary load. The DC equipment shall be installed in purpose built equipment rooms. The locations and tentative layouts are shown on the layout drawings.

(2) The ratings of batteries, battery chargers and inverters are not finally selected and shall be adapted in accordance with the approved power balances. These power balance calculations shall be elaborated at the detailed design stage, based on the data of the selected equipment.

(3) Adequate measures shall be taken in the DC auxiliary supply systems to maintain the voltage at the main switchboard busbars between 0.85 and 1.15 p.u. rated voltage at all rectifier and battery operating conditions.

(4) The specified fault levels shall be adapted accordingly and the switchgear selected in accordance with the standard products.

(5) Equipment which requires a voltage other than the system voltage shall be supplied by redundant DC/DC converters.

10.10.3 Storage Batteries

The main characteristics of the storage batteries shall be the following:

- Type	Lead acid
- Rated voltage	220 V DC
- Rated capacity 10 h discharge PH/POB	600 Ah
- Rated capacity 10 h discharge DOB	400 Ah
- Nominal voltage	2.0 V/Cell
- Trickle charging voltage (floating)	2.2 V/Cell
- End voltage after 10h discharge at rated current	1.8 V/Cell
- Maximum self-discharge rate at 40°C	< 5 %/month
- DC system	Isolated, L+/L-/PE

10.10.4 Battery Chargers

The main characteristics of the battery chargers shall be the following:

- Charging mode	I/U constant characteristic
- Nominal input voltage	400/230 V AC
- Rated output voltage	240 approx. V DC
- Rated output current PH/POB/DOB	A DC By Bidder
- Initial and boost charging, adjustable	2.4 V/cell
- Float charging operation	2.23 V/cell
- Recharging from 1.8 V/cell to rated capacity	12 max. h
- Protection class	IP 41

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10.10.5 Inverters

The main characteristics of the inverters shall be the following:

- Rated input/ output voltage	220/230 V DC/V AC
- Rated output POB/DOB	10/5 kVA
- Permissible variation of the input voltage	0.8 - 1.15 p.u.
- AC voltage stability (steady state)	± 1 %
- AC voltage waveform	Sinusoidal
- Harmonic voltage distortion (linear load)	< 5 %
- Voltage recovery time	< 4 ms
- Static switch response time	< 5 ms
- Frequency	50 Hz
- Frequency variation, maximum	± 1 %
- Power factor range, minimum	0.8 - 1.0
- Noise level, minimum	60 dB (A)
- Permissible overload, minimum for 1 /10 min	50/25 %
- Protection class	IP 41

10.10.6 Switchboards

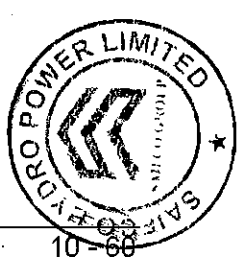
The main characteristics of the DC and UPS switchboards shall be the following:

(1) DC switchboards

- Nominal system voltage	220 V DC
- Rated voltage	690 V
- Rated insulation voltage	1,000 V
- Power frequency withstand voltage	2,500 V rms
- Rated short time withstand current (1 s)	20 kA rms
- Rated peak withstand current	50 kA peak
- Installation	Indoor
- Protection class	IP 42

(2) UPS switchboards

- Nominal system voltage	400/230 V
- Rated voltage	690 V
- Rated insulation voltage	1,000 V
- Power frequency withstand voltage	2,500 V rms



- Rated short time withstand current (1 s) 20 kA rms
- Rated peak withstand current 50 kA peak
- Installation Indoor
- Protection class IP 42

10.10.7 UPS Systems

(1) DC/ AC inverters shall employ fully static elements such as single or three-phase transistor inverters or diodes with pulse width modulation. By suitable bias control signals, the direct current shall be chopped into a series of rectangular pulses passed through a filter (leakage inductance and capacitor) to obtain a sinusoidal voltage with low content of higher harmonics. By varying the pulse width of the chopped DC blocks, the AC output voltage shall be kept constant in a wide range despite varying the DC input voltage on the AC load (pulse-width modulation principle). Other control principles shall also be acceptable if providing the same results; they shall be subject to approval of the Employer/Engineer.

The static inverters shall be of the natural air cooled type. The normal power source to the inverter shall be DC from the DC auxiliary supply system.

(2) Besides the normal DC power source, every inverter shall be equipped with a stand-by feeder connected to the AC mains with a matching and de-coupling transformer and a static bypass switch (SBS) for uninterrupted load transfer. The modes of stand-by feeder operation shall be:

- ***Stand-by Operation***

The load is fed by the AC stand-by feeder. The inverter is neither connected to the DC nor to the AC side.

- ***Test Operation***

The load is fed by the AC stand-by feeder. The inverter is connected to the DC system. It shall be possible to manually initiate automatic load transfer from the stand-by feeder to the inverter and vice versa without AC voltage interruption.

- ***Normal Operation***

The load is fed by the inverter. Upon loss of the inverter output, the AC load shall be automatically transferred by the SBS without AC voltage interruption to the stand-by feeder.

In the event of automatic transfer of the load to the bypass circuit and subsequent restoration of the inverter output quantities within the permissible tolerances, automatic retransfer to the inverter shall be carried out. Manual transfer shall also be possible.

The two UPS systems (2x100%) shall be equipped with all necessary facilities to work in parallel in 50% load-sharing mode.

(3) Dependent on the mode of operation the inverter frequency shall be controlled either by the AC mains or by an oscillator (frequency generator) which shall be part of the inverter. The inverter frequency control shall automatically match frequency and time

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phase of the inverter output voltage to the standby voltage within the permissible limits at any instant prior to load transfer. A lock-out circuit shall be included to prevent automatic transfer to the stand-by AC power supply if alternate source voltage is not available.

(4) The inverter AC output circuit shall be short-circuit proof, i.e. the commutation circuit shall be designed that the thyristor stack fuses are not blowing at short-circuit conditions. After the transient inrush, the short-circuit current shall be limited to a maximum of 4 times the rated AC current. The inverter shall continue to automatically provide reduced voltage during short-circuit or overload condition and to raise it automatically upon its removal.

(5) An input filter shall be provided to avoid noise feedback from the inverter into the DC input. This filter shall also prevent voltage surges from the battery disturbing the inverter.

When de-energised, the inverter as well as the standby source shall withstand without trip the transient inrush current.

(6) The UPS systems shall comprise digital, microprocessor controlled control units providing the following feature:

- Control of the power circuits;
- Control of the thyristors;
- Monitoring and self-diagnostic function;
- Display of AC/ DC voltage and current, frequency;
- Indication of operation mode and alarms;
- Treatment of measuring values, status and alarm signals;
- Interface to CCS.

(7) Cubicles shall be floor mounted, self-supporting type with hinged front and rear doors, protection Class IP 41.

10.11 ELECTRICAL PROTECTION SYSTEMS

Electrical protection systems shall be provided to isolate faulty circuits with speed and certainty, to limit damage and to maintain healthy systems in stable operation.

The protection systems shall be grouped to provide main and back-up protection features.

The scope of work shall include the following protection equipment:

- Three unit protection systems to provide the complete range of electrical protection for the generators, busduct systems, main transformers and HV cable systems;
- Three protection systems to provide the complete range of electrical protection for the 132 kV transmission line feeders;
- One protection system to provide the complete range of electrical protection for the 132 kV busbar systems and the bus coupler;

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- One protection system to provide the complete range of electrical protection for the 10 MVA, 132/11 kV grid transformer;
- One set of special tools and appliances;
- One set of special spare part.

10.11.1 Principal Design Features

(1) The protection systems shall be complete in every respect and include the specified protection devices, the necessary auxiliary relays, interposing transformers and power supply units. The protection devices shall be of the numerical, microprocessor controlled type of a competent manufacturer with a 5 years proven track record.

(2) The relay assemblies shall be grouped in a logical manner to provide a good overview and facilitate the identification. Test plugs for measuring and test injection shall be easily accessible from the front side. For the power supply to each relay or group of devices redundant DC/DC converters shall be provided.

(3) The cubicles accommodating the devices shall facilitate easy access to the wiring inside the cubicle and to the rear side of the devices. Each protection cubicle forming a functional group shall have a door mounted signal lamp indicating the trip of any protection device. After manual resetting of the relay the lamp shall be off. Trip and reset indications, adjustments and functional operations shall be arranged at the front of the protection device or cubicle.

(4) Control circuits including potential and current transformer secondary circuits, AC/DC auxiliary power supply circuits, supervisory alarms and communication circuits associated with the function of the concerned equipment shall be protected against electrostatic and electro-magnetic influences of transients from the neighbouring circuits.

(5) All devices shall have the necessary quantity of output contacts with sufficient make and break capability, suitable for control, monitoring, supervisory and tripping functions related with the equipment. Switching of contacts in AC/ DC control circuits shall not produce harmful over voltages. CT terminals shall be shorted automatically when the relay is withdrawn from its casing.

(6) The software for each device function shall be accessible for setting values and retrieval of events via a special software package. Each relay module shall be equipped with an integrated key pad and display.

A notebook shall be included for adapting values/settings of the protection devices.

(7) After response, the tripping contacts of the protection device shall reset automatically, however, the signalling contacts shall remain in the tripped position until the manual reset by the operator.

(8) All relay setting ranges shall fit with the special requirements of the individual circuits. Generally, time delay modules shall have a definite time characteristic with a continuous adjusting range. Inverse time relays are likewise acceptable provided they cover

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suitably wide adjusting range and ensure sufficient selectivity with other protection devices.

(9) During the detailed design a comprehensive protection study shall be performed to define the required protection parameters, redundancies, selectivity and relay setting ranges based on the maximum and minimum short-circuit capacity of the network.

(10) Back-up protection functions shall be properly co-ordinated with due consideration of short-circuit durations and appropriate time constants of the related network elements.

Auxiliary Power Supply

(1) Auxiliary power for each protection system or individual protection device shall be supplied by redundant DC/DC power units connected to the DC auxiliary supply systems 1,2 and 3, respectively, provided in the Powerhouse and in the Plant Operation Building;

(2) The DC/DC power units shall be natural air cooled;

(3) Adequate voltage monitoring with alarm annunciation shall be provided.

Protection Cubicles

(1) The protection devices, auxiliary power supply units and all related equipment shall be accommodated in freestanding sheet steel cubicles of standard design with adequate space and cooling;

(2) The equipment shall be mounted in convenient working height. The cubicles shall have lockable front and rear doors. The front doors shall be fitted with windows providing a clear view of the interior, especially of the protection device displays;

(3) Protection devices related to the Switchyard may also be accommodated in the LCC of the relevant feeder bay;

(4) Main and back-up protection systems shall be safely separated from each other. Installation in separate cubicles is preferred;

(5) The unit protection cubicles shall be arranged in a common assembly with the UCB;

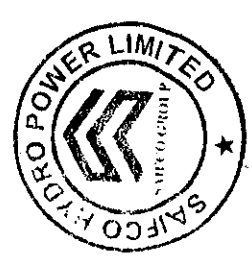
(6) Protection devices for auxiliary supply systems may be accommodated in the instrument compartments of the relevant switchgear.

10.11.2 Particular Design and Construction Requirements

Generator, Main Transformer and HV Cable Protection Systems

(1) The following equipment comprising the generating units with the main circuits up to the 132 kV Switchyard shall be adequately protected:

- Synchronous generator;
- Excitation transformer;
- Generator busduct systems with tie-offs;
- Main transformer;



- Station service transformer;
- Cable system 132 kV between MT and Switchyard.

(2) The protection systems for the above listed equipment shall be installed in cubicles, arranged in a common assembly with the UCB.

Configuration of the protection devices

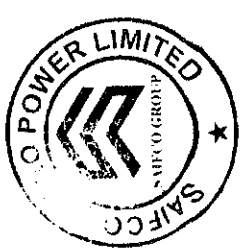
The following protection devices shall be considered as the minimum requirement:

System I:

24G	Generator over excitation protection
24MT	Main transformer over induction protection
32	Generator reverse power protection
40	Loss of excitation protection
46	Negative phase sequence protection
49R	Field winding overload protection
49S	Stator winding overload protection
50BF	Breaker failure protection
50ET	Instantaneous over current protection excitation transformer
51N-MT	Over current earth fault protection MT
51MT	Main transformer stand-by over current protection
51ET	Over current protection excitation transformer
59	Generator overvoltage protection
59N	MT neutral displacement
64R	Rotor earth-fault protection
64S1	100 % Stator earth-fault protection
87C	HV Cable differential protection (MT to Switchyard)
87G	Generator differential protection
87MT	Main transformer differential protection

System II:

21G	Generator back-up distance protection (under impedance)
27	Under voltage protection for synchronous condenser mode
49MT	Main transformer oil and winding temperatures
51	Symmetric overload stator protection
51ET	Over current protection for excitation transformer
59	Generator overvoltage protection
64S2	95% stator earth-fault protection
60	Voltage balance relay, VT circuit failure monitoring
78	Out of step protection
81	Under frequency protection for synchronous condenser mode
87N-MT	Restricted earth-fault protection for Main-transformer
95MT	Main transformer Buchholz



Switchyard and Transmission Line Protection Systems

(1) The following equipment shall be adequately protected:

- Busbar systems and bus-coupler;
- Grid Transformer 132/11 kV 10 MVA;
- The outgoing 132 kV double circuit transmission line.

The protection cubicles shall be installed in the Plant Operation Building together with the Switchyard Local Control Unit (LCU). The protection systems shall communicate with the LCU and CCS by means of bus systems.

Configuration of The Protection Devices

Busbar and bus-coupler protection

System I:

87BB 1-1	Busbar differential protection 132 kV busbar system 1
87BB 2-1	Busbar differential protection 132 kV busbar system 2
25	Synchro-check relay
27/59	U/O voltage protection
50/51	Over current protection
50BF	Breaker Failure Protection

System II:

87BB 1-2	Busbar differential protection 132 kV busbar system 1
87BB 2-2	Busbar differential protection 132 kV busbar system 2

Transmission Line Circuit No. 1 and 2

System I:

21	Distance protection
21N	Distance EF protection
21FL	Distance protection fault locator
25	Synchro-check relay
27/59	U/O voltage protection
50BF	Breaker failure protection
67N	Directional overcurrent protection
68	Power swing blocking
79	Auto reclosing relay

System II:

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21	Distance protection
21N	Distance EF protection
25	Synchro-check relay
50/51	Overcurrent protection
50N/51N	Overcurrent EF protection
59N	Zero sequence overvoltage protection
81	U/O frequency protection

Grid Transformer 10 MVA

System I:

87GT	Transformer differential protection

System II:

50/51	Overcurrent protection
51N	Neutral earth fault protection

Protection Systems for Auxiliary Supply Systems

The following equipment of the station auxiliary supply systems shall be adequately protected. The protection devices shall be accommodated in the unit protection cubicles and the LV compartments of the relevant switchgear respectively.

(1) Station service and distribution transformers

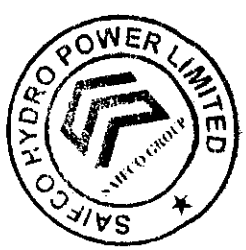
50	Instantaneous overcurrent protection
51	Time-delayed overcurrent protection
51.1	Overload protection
51N	Earth-fault protection at 0.4 kV level

(2) Distribution service transformers

50	Instantaneous overcurrent protection
51	Time-delayed overcurrent protection
51.1	Overload protection
51N	Earth-fault protection at 0.4 kV level

(3) 11 kV Overhead Lines

50	Instantaneous overcurrent protection
51L	Time-delayed overcurrent protection
67N	Directional earth-fault protection



10.11.3 COMPUTERISED CONTROL SYSTEM

The power plant shall be provided with a state of the art control system, comprising:

- One Power Plant Supervisory, Automation and Control System - in the following referred to as 'Computerised Control System - CCS'

The scope of work shall include all required studies, calculations, design, engineering, manufacturing, supply, submission of drawings and documents, shop and site testing, erection, adaptation to related equipment, commissioning and training services for the CCS and its components. The CCS shall be fully developed, debugged, commissioned and tested for manual and fully automatic control of the power plant. The CCS shall principally be composed of the following systems, components and ancillaries not being limited to:

10.11.4 Central Control Room Equipment

- Three operator stations with three monitors and alarm printers;
- One large screen with controller;
- One fire detection and alarm panel;
- One video surveillance system based on IP-technology with 4 monitors;
- One metering station with two monitors and printer;
- One archiving system for long term and spontaneous data archiving;
- One training & simulation station with two monitors and printer;
- One engineering station with two monitors and laser colour printer;
- Two redundant main servers in hot-standby;
- One interface with firewall to Office LAN and Web Client for remote access;
- One GPS master clock system with interface to secondary system;
- One redundant gateway to the National Power Control Centre (NPCC);
- One portable service station;
- One redundant fibre optic main Gigabit bus system according to IEC 60870-5-104;
- One redundant fibre optic process Gigabit bus system according to IEC 60870-5-104;
- One interface to the automatic dam monitoring system;
- One interface to the Powerhouse instrumentation system;
- One set of furniture for the Central Control Room (CCR).

10.11.5 Unit Control Boards (UCB) and Local Control Units (LCU)

- Two redundant unit controllers with field-bus interfaces to sub-controllers and monitors;
- One redundant station auxiliary controller;
- One redundant common services controller;
- One redundant 132 kV Switchyard controller;
- One redundant Dam Site controller with operator station and fully equipped Dam Site Control Room.



The CCS shall include all additionally necessary instruments, sensors, adapters, transmitters, wires, cabling, Ethernet repeater stations, and data bus systems as a fully functioning system complete in every respect. All necessary control processors, input/output (I/O) cards, redundant power supplies, data interfaces, marshalling and termination facilities shall be provided. An overall 10% extension capacity shall be provided to all electronic hardware and associated components.

10.11.6 Principal Design Features

System Concept

The CCS shall be characterised by an innovative system concept, powerful communication capabilities and a scheme-wide unique engineering and configuration tool. The CCS shall consist of state-of-the art equipment and components, applying the latest knowledge and achievements in the industrial process automation technology, such as:

- Client-Server/ Master-Slave concepts;
- Object-oriented processing of data;
- Re-usable automation software objects and program modules;
- High-level of hardware modularity and scalability;
- System-wide data management and data access with single data entry;
- Central engineering system to program and configure all system components;
- Long-term availability of components;
- Expandability;
- Standard-based communication from field to management level;
- Standardised 10/100/1000 BASE FX Gigabit-Ethernet bus system;
- Application of IEC 60870-5-104 protocol;
- Distributed redundant concept;
- Integrated alarming;
- Time correct processing;
- Effective human-machine interfaces;
- Window-based operation system, process diagrams and sequential controls;
- Total plant efficiency optimization modules and diagnosis functions.

Expansion or software updates of the CCS shall be enabled based on an open system architecture concept and by strictly applying international communication standards for the main-, process- and field-bus applications.

System Architecture

The CCS shall be designed in consistent hierarchical and decentralized structure. Dividing the total scheme automation system into autonomous functional areas shall increase the

availability and guarantee all time pre-defined and safe operating modes in case of emergency situations.

The CCS shall be designed to ensure maximum availability by the inclusion of built-in redundancy for both hardware and software. This shall include duplicated control processors, bus systems and power supplies with automatic change-over to the standby device upon detection of a fault or failure. Where appropriate, I/O cards shall also be duplicated.

Simple and safe operation of the power plant and its components shall be enabled by installing touch-panels as human-machine interfaces (HMI) at the UCB/LCU and ergonomically designed graphical user interfaces.

The system shall be designed for industrial use and withstand permanently the climatic and electro-magnetic environmental conditions in a power plant (EMC and ESD).

The CCS shall contain self-monitoring hard- and software functions. Software self-supervisory and fault diagnosis functions and plausibility checks shall lead to an early detection of abnormalities and therefore to a high availability of the plant. Comprehensive system diagnostic facilities shall be incorporated also to assist in maintenance and trouble-shooting.

A failure of any single element shall not affect the operation of any main system of the power plant in operation. In particular, the duplicated controllers shall enable a failure tolerance in order not to affect the plant operation or any control sequences.

All process signals shall be managed without multiple engineering (single data-entry).

The two operator stations with three monitors, keyboards, printers and peripheral devices and their associated control desks shall allow monitoring, control and adjustment of all relevant plant operation tasks with high resolution window-based graphic displays.

The main bus system shall be arranged as a dual fibre optic ring network and realise the data transfer between the redundant main servers, the control room HMI equipment, and all other related controllers according to the system architecture drawing.

The process bus system shall also be arranged as a dual fibre optic ring network and realise the data transfer between the redundant main servers, the unit controllers, and all other related controllers according to the system architecture drawing.

Both bus systems shall apply IEC 60870-5-104 as protocol standard.

Sub-systems like the MIV controller, digital turbine governor, static excitation system, generator circuit breaker and digital protection system shall be interlinked by standard field bus systems, arranged in redundant star shape.

The CCS shall be connected to a GPS master clock system to guarantee synchronisation of all CCS components.

The unit control boards (UCB) shall be equipped with instruments for active and reactive power, stator voltage, stator current, field voltage, field current, turbine discharge, speed measurement, trash-rack differential pressure measurement and wicket gate position indication. The relevant input signals shall be taken directly from the transducers.

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For position indications of the circuit breakers and disconnecting switches, a mimic diagram shall be provided on the unit control board. The signals to the position indicators shall be supplied from interposing relays.

System Main Features

The CCS shall be designed to ensure maximum plant availability and efficiency. In its final configuration, the CCS shall be capable of controlling and monitoring the operation of the entire power scheme, the turbine-generating units, individual sub-systems and auxiliary equipment.

Open system standards and international software protocols shall facilitate interconnectivity to a wide range of optimization and diagnosis applications as well as asset management systems. A high level of modularity and system scalability shall allow optimum process adaptation. The use of standard industrial components shall assure long-term availability and reduce spare part costs.

The following installations and essential equipment shall be monitored and operated by the CCS:

- Weir Site with desander, power intake, spillway and sluiceways;
- Weir Site mini HPP;
- Turbines including governors and ancillary equipment;
- Synchronous generators including ancillary equipment;
- Generator main circuits including generator circuit breakers;
- Main transformers;
- Station auxiliaries (MV switchgear, station service transformers, LV switchgear, DC / UPS systems, DG units);
- Common services (cooling water system, drainage and dewatering system, HVAC, compressed air system, fire protection system, potable water system, and sewage treatment plant);
- 132 kV Switchyard;
- Powerhouse instrumentation system;
- Automatic dam monitoring system.

The CCS shall provide the following functions:

- Fully automatic control and monitoring to provide safe start-up, synchronising, loading, shut-down and emergency tripping of each unit;
- Provision of active and reactive power joint control / joint discharge control;
- Synchronous condenser operation;
- Transmission line charging;
- Plant operation forecast schedule module (daily / 7 days);

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- Plant optimization software module (operation of active units in maximum efficiency point);
- Total discharge calculation module (including spillway and bottom outlet gates);
- Data acquisition from the main transformers and Switchyard;
- Weir site intake gate, spillway and desander gates, control and monitoring;
- Interface to the powerhouse instrumentation and automatic dam monitoring systems;
- Provision of facilities for comprehensive monitoring, storage and presentation of information concerning plant conditions and performance and historical archive;
- Energy metering of scheme output and provision of billing data for invoice purposes;
- GPS master clock systems to generate signals to the secondary clock system;
- Life-beat monitoring;
- Provision for black start capability;
- Interface with the National Power Control Centre.

10.11.7 132 kV Switchyard

The LCC for the generator/transformer bays, the transmission line feeder bays, the bus coupler bay and the 132/11 kV grid transformer bay shall be connected to the CCS with protocol converter units.

The protocol-converters shall be provided by the switchyard supplier. The respective coordination and realisation of the interfaces are part of the present scope.

Weir Site Power Intake

A bus shall be used for the data transfer between the intake and the CCS. The following information shall be exchanged as a minimum:

- Equipment, system status;
- Trash rack losses;
- Level measurement;
- Gate position.

Spillway and Sluiceways

The data transfer between the redundant Dam Site LCU and the gate LCC (spillway and sluiceway gates) shall be processed with protocols converters.

The protocol-converters, if required, shall be provided by the supplier of the Hydraulic Steel Structures (HSS). The respective coordination and realisation of the interfaces are part of the present scope.

Desander

The data transfer between the redundant Dam Site LCU and the gate LCC (US and DS gates) shall be processed with protocols converters.

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The protocol-converters, if required, shall be provided by the HSS supplier. The respective coordination and realisation of the interfaces are part of the present scope.

10.11.8 Powerhouse Instrumentation and Automatic Dam Monitoring Systems

The communication between the CCS and the powerhouse instrumentation/automatic dam monitoring systems shall be realised with protocol-converters.

System Software

The latest version of the manufacturer's systems software packages shall be provided fully developed and tested. All software licenses necessary for the plant operation and maintenance shall be included. This shall lead to unrestricted use of all operator-level applications required for the safe and reliable operation of the plant and its components.

Access to software and application programs at various levels shall be possible by operating or engineering personnel using passwords. This shall protect the software from unauthorised access.

The software and associated displays, reports, databases, etc shall be fully debugged in the shop before testing and commissioning at site. The modification of displays, reports, databases or control strategies shall be possible on-line by the engineering personnel without affecting the plant operation. Modifications to the software shall be done in straightforward and logical steps using, wherever possible, graphic displays.

The HMI software applications shall enable the operator to carry out the necessary actions in a safe and efficient manner. Where process measurement data need to be measured redundantly in the CCS, the values shall be averaged before being processed in control algorithms. For analysis or maintenance purposes the operator shall have the possibility to access either the original or the averaged value.

Control and Supervisory Functions

The control and supervisory functions shall include, but not be limited to the following:

- Mode transition of the units: The mode transition shall be fully automatic; any two-mode combination between stand-still, generating, synchronous condenser mode, including black start shall be possible. The automatic switching of circuit breakers and the operation of the station auxiliary and common services equipment shall be included.
- Realising active power or discharge control with frequency influence either of individual units or of the entire power plant in joint control.
- Realising reactive power regulation or voltage regulation either of individual units or of the entire power plant in joint control.
- Operation of circuit breakers, isolators, earthing switches, electric braking switches.
- Starting/shutdown or raising/lowering operation of unit auxiliary equipment or power plant common equipment, e.g. of the intake gates, etc.

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- On/off of threshold overshoot alarm measuring points: It shall be possible to modify different threshold values on the engineer station. The alarm signals and fault anomaly views shall be re-settable either manually or automatically.
- The emergency shut-down commands generated by mechanical or electrical protection devices shall have the highest priority in all operation modes. The CCS shall have necessary hardware and software measures to ensure permanently the invalidation of erratic commands.

Synchronization

Automatic

(1) Each UCB shall be equipped with an automatic synchronising device. The automatic synchronising devices shall be of digital design, working fully automatic, i.e. once the synchronising command has been issued the turbine speed and generator voltage shall be automatically adjusted to the correct values and the generator circuit breaker closed at the right moment.

(2) The equipment shall be of dual channel, self-monitoring type provided with angle measuring transducers, voltage matcher and frequency matcher unit, as well as with a command generating unit. At least setting of two different breaker closing times shall be possible.

(3) The devices shall be provided with testing facilities to check both channels individually. For periodic checking of set values and functions manual and automatic testing shall be possible.

(4) The adjustments shall feature the following:

- - Sampling frequency;
- - Speed and voltage differential values;
- - Breaker making time;
- - Vector angle mismatch;
- - Overall operation time.

(5) In automatic synchronisation mode, the measuring instruments and synchro-check relay as described for manual operation shall be in service as well.

(6) With the selector switch in TEST position all automatic functions shall be executed without the breaker closing control. The successful breaker closing shall be indicated by LED.

Manual

Each UCB shall be provided with a set of independent manual synchronising equipment comprising the following:

- One double voltmeter;

- One double frequency meter;
- One synchronouscope.

By means of a key operated selector switch MANUAL/TEST/OFF/AUTO set to MANUAL, the reference voltages shall be connected to enable manual adjustment of turbine speed and generator voltage.

Manual closing of the generator circuit breaker shall be supervised by a synchro-check relay to prevent mal-operation. This relay shall compare phase angle, voltage difference and frequency difference with pre-set values.

The relay shall also feature the following operation modes:

- Synchronising check;
- Dead line/live bus check and vice versa;
- By-pass with check function inoperative.

System Configuration

Operator Stations with Relational Database

Two Operator stations, each with three monitors and printers shall be provided for the operation and supervisory functions. The man machine interface shall incorporate the following functions:

- Monitoring and operation of the entire power scheme;
- Event handing and event list;
- Alarm functions and alarm list;
- Trend data logs and trend display;
- Report functions;
- Status list;
- Display printout;
- Communication with controllers;
- Display design and integration.

A relational database shall be used in the operator stations whereby the standards ODBC (Open Data Base Connectivity) and SQL (Structured Query Language) shall be used. The integral OPC server (Object Linking and Embedding for Process Control) shall make available all process data to other office applications. The operator station shall also receive data from other OPC servers. OPC shall permit simple, standardized access to process data.

Large Screen with Controller

A high resolution large screen (LCD or DLP type) shall be installed in the CCR. The screen size shall be approximately 2.00 m x 1.50 m. All relevant displays shall be selectable from the large screen controller.

The large screen shall include the interfaces to the control system. The installation shall include all necessary supports and ancillary equipment, coupling units, software etc.

The large screen shall be operable in parallel to the monitors.

Fire Alarm Panel

The panel shall be an integral part of the fire fighting system. The fire alarm panel shall be suitably integrated in the CCR layout.

The main bus shall link the fire alarm panel with the plant fire protection system in order to display alarm messages on the operator stations.

Video Surveillance System

The video surveillance system is specified in the section 'Security Systems' (CCTV).

Metering Station

The metering system shall be of digital type with accuracy classes suitable for revenue purposes.

The pertaining national specifications for power system/dispatch system interface shall be observed. The gateway protocol shall be in accordance with the national protocol standards.

The metering station shall be capable of receiving energy pulses from the active and reactive energy transducers or the contact signals and capable of counting and saving them, transmitting them periodically or according to the scanning requirement. The pulse counting rate shall not be more than 10 pulses and the register capacity shall be equal or greater than 16 digits of binary code. The accumulated pulses shall be converted with a conversion factor and displayed with the actual kWh and kV Ar h.

Generator Monitoring

Graphical diagram showing the main circuit with auxiliary and excitation T-offs.

Instruments for:

- Generator current;
- Generator voltage;
- Voltage setting;
- MW and Mvar;
- Synchroniser with selector switch;
- Power factor;
- Frequency;

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- Field voltage and current.
- Push buttons, switches and status indications for:
- Voltage raise/ lower;
- Selector switch Local Man/ Local Auto/ Remote;
- Main transformer tap changer control;
- Brake ON/ OFF;
- Circuit breaker ON/ OFF;
- Generator auxiliary systems ON/ OFF;
- Alarm panel.

Turbine Monitoring

Graphical diagram showing the turbine with waterways and the generator Instruments for

- Speed;
- Speed setting;
- Nozzle/needle position;
- Guide vane limiter;
- Jet deflector position;
- Brake jet status;
- Discharge;
- Active power actual / set-point.
- Push buttons, switches and status indications for:
- Speed raise/ lower;
- Opening raise/ lower;
- Power raise/ lower;
- Speed/opening/power control mode;
- Intake gate emergency close;
- Unit emergency shutdown;
- Turbine auxiliary systems.
- Alarm panel.

Redundant Station Auxiliary Controller (LCU - Station Aux. Systems)

The station auxiliary controller shall provide the data transfer from/to the following equipment:

- MV switchgear;
- Station service transformers;
- LV switchgear;
- DC and UPS systems;
- Diesel generating units.



Redundant Common Services Controller (LCU - Common Services)

The station auxiliary controller shall provide the data transfer from/to the following equipment:

- Cooling water system;
- Drainage system;
- Dewatering system;
- HVAC systems;
- Compressed air system;
- Fire protection systems;
- Potable water system;
- Sewage treatment plant;
- Tailrace service gate;
- Level measurement systems.

10.11.9 132 kV Switchyard Controller (LCU – 132 kV SWYD)

The interface and functions shall be according to equipment PTS control and remote command functions.

The individual LCC for the generator/transformer bays, the transmission line feeder bays, the bus coupler bay and the 132/11 kV grid transformer bay shall be connected with a protocol converter unit to the CCS.

Unit Control Boards

Unit Control Boards (UCB) shall be provided with redundant controllers and redundant power supply. The UCB shall be used for manual/automatic control of all functions associated with the MIV, turbine, generator, GCB, main transformer, unit auxiliary systems and digital protection systems.

The scope of functions assigned to the UCB shall comprise the equipment shown on the CCS System Architecture Drawing.

Digital and analogue output signals from the unit automation equipment, resistance temperature detectors, generator excitation system, speed governor etc. shall be connected to the UCB controller. All events shall be time tagged (time-stamp) at the input card to permit easy analysis of events in the MMC system.

The UCB shall be designed to work independently when it is disconnected from the CCS.

The UCB system shall mainly comprise the control/monitoring of the following systems:

- Governing system;
- Excitation system;
- Mechanical protection;

- Electrical protection;
- Main transformer;
- Generator voltage switchgear;
- Interface with the CCS;
- Unit auxiliary equipment LCC.

The UCB shall accommodate all required equipment, instruments and apparatus to perform the following control and supervision of the turbine-generator unit:

- Step by step and/or automatic unit starting and shutdown;
- Interface to the digital turbine governor;
- Interface to the automatic voltage regulation;
- Machine loading with active and reactive power;
- Metering and recording of all characteristics of the turbine, generator and main transformer;
- Indication of normal operation of the auxiliaries essential for secure and reliable operation of the unit;
- Audible and visual warning of inaccurate operation of the unit and the essential auxiliaries;
- Audible and visual alarm and display of dangerous operation of the unit and the essential auxiliaries, or faults that may initiate tripping of the circuit breaker without shutdown the unit;
- Power supply and control of essential auxiliaries of the respective unit.

The process management of the UCB shall be ensured through the local Human-Machine Interface (HMI) mounted on the cubicle's front door with protection class IP 54 or better. The local HMI shall consist of a colour tactile screen.

The following functions shall be available:

- Mimic diagram views;
- Process sequences follow-up for local control;
- Alarm status indication.

10.11.10 Display and Supervision

The UCB/LCC of the unit/system shall have a monitor for display and supervision. On the UCB touch panel with access to various system levels, protected by password, shall be provided.

On the monitoring panel/monitor, it shall be possible to display the data relevant for unit operation, supervision and troubleshooting e.g. electrical quantities, temperature of the unit and main transformer, the status or data of ancillary equipment. Two display patterns shall be possible: a cyclic display and a fixed display.

The contents of display and supervision shall include:

- Supervision of starting conditions prior to unit start-up: check whether the unit fulfil the starting conditions, such as the governor oil pressure, air pressure, states of the main and ancillary equipment. If there is any anomaly, besides local indication the signal shall be sent to CCS for displaying and print-out.
- Sequence supervision of mode transition processes: supervise consecutively the progress of sequence steps of mode transitions; send the main steps to the CCS. Transfer the unit to a safe state or stop it when any impediment happens. Any operating sequence step shall have a local signal sent back to the UCB indicating step with number and clear text.

10.12 COMMUNICATION SYSTEMS

The communication systems for the power plant shall comprise the following:

- One telephone and intercommunication system;
- Communication interface equipment OPGW to existing PLC;
- One radio communication system;
- One set of special spare parts.

10.12.1 Telephone System

System Configuration

(1) The telephone and intercommunication system shall be in compliance with the related standards, the requirements of the Local Authorities and shall be the well proven product of a competent manufacturer.

The telephone system shall comprise the following:

- Digital PABX with software;
- Workstation with monitor;
- Attendant console;
- Main and sub distribution frames;
- Fifty telephone sets for different applications;
- PAX for intercommunication;
- Five multifunctional intercommunication desk sets;
- One digital voice recorder;
- Power supply units;
- Telephone cable system.

(2) The PABX/PAX shall be installed in the telecommunication room in the Plant Operation Building. The workstation and the attendant console shall be located in the entrance hall.

Particular Design and Construction Requirements

Digital Automatic Telephone Exchange (PABX)

(1) The telephone system of the PABX type shall comprise a digital automatic telephone exchange for 100 extensions with direct access for internal telephone users and external telephone connections.

The automatic telephone exchange shall have the following features:

- Flexibility in expansion and increase of its carrying capacity;
- Compatible with ISDN (Integrated Services Network);
- Self-monitoring with protocol print out;
- Open and closed system of numbering with any kind of recording;
- Code dialling with 30 memorised numbers;
- Last number memory and busy call repeat;
- Call forward to another extension;
- Integration with other types of automatic exchanges for all type of links;
- Command signal transmission by all methods;
- Establishing of bypass channels;
- Metering of local and trunk calls;
- Breaking down subscribers into 16 extension categories;
- Connection of pay telephones for local and trunk calls;
- Invoicing of additional services;
- Establishing of communication with the NPCC;
- Connection to fire and security alarm system.

(2) The PABX shall be provided with a workstation and monitor.

(3) The plant shall be equipped with one (1) desk type attendant console. This console shall handle the external traffic to the plant. The console shall contain the following:

- Extension to switch into line;
- Call indicators;
- Internal call indicator;
- Meters for long distance calls.

(4) The following services shall be provided for the telephone subscribers:

- All types of telephone services including trunk and international calls;
- Connection of all types of telephone sets (push-button and frequency dialling);
- Connection of personal computers and facsimile facilities;
- Extension numbers are permanently allocated; they can be moved to other locations;
- Quick dialling;
- Direct calling;

- Conference call service.

(5) Main characteristics

- The automatic exchange shall have the capacity for 100 extensions;
- The automatic telephone exchange shall be provided with stored program control and digital speech channel switching;
- The specific subscriber load shall be up to 0.2 Erlang;
- The specific input power per extension shall not exceed 2.0 W.

Intercommunication System (PAX)

(1) The intercommunication system is intended to provide the station manager and shift engineers direct telephone access to all station areas.

For this purpose the offices of the station manager and shift engineers shall be equipped with multifunctional telephone sets with attachment.

These telephone sets shall have direct access to the telephone subscribers in the Powerhouse, Plant Operation Building, Switchyard Operation Building, DG plant, Dam Site local control rooms and Guard House.

The offices of the heads of department and maintenance engineers shall be equipped with multifunction sets without attachment.

(2) The multifunctional telephone sets shall feature the following:

- Alpha/numeric display;
- Memory for 100 addresses with names, telephone numbers etc.
- Indication of the subscriber's name on the display at internal calls;
- Messages by display;
- Reminding of time and place of meeting;
- Programmed keyboard;
- Programmable keyboard with light emitting diodes;
- Secretary functions;
- Loud speaking communication dialling without lifting up the handset;
- Individual and group calls, interphone;
- Automatic dialling;
- Transfer of calls and interception of calls;
- Internal and external conference coupling;
- Re-dialling;
- Blocking of calls.

(3) Main characteristics

- The multifunctional telephone sets shall be compatible with the digital automatic exchange;

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- The sound brightness shall be at least 80% at noise level of 60 dB;
- Volume of call signal shall be adjustable and not less 70 dB.

Digital Voice Recorder

(1) The intercommunication system shall include digital voice recording equipment for recording the operator communication. The digital type recorder shall be used for continuous automatic recording of the operator communication with high performance reliability.

The voice recorder shall provide the following features:

- Round-the-clock operation in the mode of simultaneous recording of all speech channels;
- Automatic start-up of the recorder when talk starts on any input channel;
- Tagging and display of the date and current time;
- Compatibility of signal and impedance levels with communication;
- Compressed storage of data.

(2) Main characteristics

- The recorder shall have at least 4 recording channels;
- Continuous time of recording shall be at least 52 h;
- Power shall be supplied from the 230 V AC UPS or 220 V DC auxiliary supply systems.

10.12.2 Radio Communication System

System Configuration

(1) The radio communication system shall be in compliance with the related standards and shall be the well proven product of a competent manufacturer.

The compliance with the requirements of the Local Authorities shall be confirmed.

The radio communication system shall comprise the following:

- One repeater station, UHF band;
- One lot UHF antennas with tower;
- One telephone interconnect system for connection to the PABX/PAX;
- Ten portable UHF radio phones;
- One battery charger station suitable for ten UHF portable radio phones;
- Power supply units;
- Communication cable system.

(2) The repeater base unit cabinet and the battery charger station shall be installed in the electronic equipment room adjacent to the CCR.

(3) The equipment ratings and the location of the antenna.

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10.12.3 Security Systems

The security systems for the power plant shall comprise the following:

- One closed circuit television system;
- One access control system;
- One set of special spare parts.

10.12.4 Closed Circuit TV System (CCTV)

System Configuration

(1) The CCTV system shall be in compliance with the related standards and shall be the well proven product of a competent manufacturer.

The CCTV system shall comprise the following:

- One matrix video switcher;
- One colour digital disc recorder;
- One system controller with monitors in the CCR;
- One system controller with monitors in the Guard House;
- Fifteen indoor cameras;
- Twenty outdoor cameras;
- Power supply units;
- CCTV fibre optic cable system.

(2) The matrix video switcher shall be installed in the electronic equipment room adjacent to the CCR. The monitors with control stations shall be located in the CCR and Guard House, respectively.

(3) The equipment ratings and the number of cameras shall be determined, based on the particular features of the proposed system.

(4) The CCTV system shall be based on IP technology.

Particular Design and Construction Requirements

A CCTV system shall be provided for the surveillance of the power plant and the related structures including the Guard House, the main personnel and vehicle entrances to the power plant, the generator and turbine floors, the access to the Plant Operation Building, the Switchyard Operation Building, the Dam Site with Intake Structure, Spillway and Desander.

The manufacturer shall position the cameras at strategic locations, mounted on buildings or using masts as required, to achieve the coverage of the a.m. areas.

The CCTV system shall permit persons to be clearly seen at any position within the coverage area. The CCTV images displayed on the monitors and recorded on video discs shall be of adequate quality to enable clear and unambiguous identification of persons and motor vehicles.

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Central Control and Video Matrix Switching Unit

A microprocessor based central control and video matrix switching unit shall be provided to display selected camera images on manually or automatically selected TV monitors. The equipment may be installed in common cubicles with the communication equipment. Safe power supply shall be provided.

The matrix shall have an interface to the NPCC so that the pictures can be received there. With an NPCC/CCR selector switch at the monitors the camera control shall be transferred.

As a minimum, the following functions shall be provided:

- Keyboard control stations with joy stick, installed in the CCR and the Guard House
- 32 video inputs;
- 6 monitor outputs;
- Superimposing of camera number, time and date on the TV monitor video display;
- Selection of screen format;
- Interface to digital disc recorder and NPCC.

Monitors

Four 15 inch colour TV monitors shall be provided in the CCR and one in the Guard House, suitable to display the images from any of the cameras in the system.

Cameras

Solid state cameras with charge coupled devices (CCD) capable of providing high definition colour video images shall be provided. The image sensor size shall be ½ in format with a horizontal resolution of 460 lines.

Camera lenses shall have a high optical performance to ensure clear images at all positions and distances within the range at day and night.

The focal length of the lens shall be selected for each camera to provide adequate coverage and clarity of the image.

Cameras installed in areas with changing light levels shall have lenses with auto iris control facilities.

The remotely controlled colour TV cameras shall be suitable for indoor and outdoor installation and shall ensure surveillance of stationary and moving objects.

Camera housings shall be sufficiently robust to protect cameras from incidental blows and shall be constructed to facilitate the installation, removal and service/adjustment of the cameras. The fixings shall be appropriate to withstand the extreme weather conditions with very high wind speeds.

Outdoor cameras shall be protected by corrosion and weather proof enclosures with protection class IP 65 fitted with automatically controlled anti condensation heaters.

The cameras shall have the following features:

- Auto-focus with manual override;

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- Optical and digital zoom, manual and automatic;
- Day and night selection command;
- Pan - Tilt - Zoom activity (PTZ);

Colour Digital Disc Recorder

For recording and storing the video surveillance images a colour digital disc recorder with software shall be provided.

The recorder shall feature nine (9) channels. The number of images per second and the image quality shall be selectable for each connected camera.

10.12.5 Access Control System

System Configuration

(1) The access control system shall be in compliance with the related standards and shall be the well proven product of a competent manufacturer.

The access control system shall comprise the following:

- One central access controller with software (including time-management) and printer;
- Two workstations;
- Twenty-five electrical door locks with ID card reader and manual unlock push buttons;
- One lot programmable ID cards;
- Power supply units;
- Power and control cable system;
- One time-registration-terminal in the Plant Operation Building, connected to the central access controller;
- Fifty magnetic switches for door position control, generally to be installed at both the active and the in-active door leafs and connected via the control cable system to the central access controller and the software.

(2) The central access controller shall be installed in the telecommunication room in the Plant Operation Building. One workstation and the printer shall be located at the reception in the entrance hall. The second workstation shall be installed in the Guard House.

(3) The final configuration of the system shall be based on the particular features of the proposed system and the Employer's actual requirements to be defined at the construction design stage.

Systems based on IP technology are also acceptable.

10.13 EARTHING AND LIGHTNING PROTECTION SYSTEMS

Earthing and lightning protection systems shall be provided for the entire power plant with related structures and buildings and the Dam Site.

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The scope of work shall comprise the following:

- Sub-grade earthing systems;
- Above ground indoor and outdoor earthing systems;
- Potential gradient control systems;
- Lightning protection systems.

10.13.1 Principal Design Features

(1) The complete earthing systems shall be designed and constructed in strict compliance with the standards IEEE Std-80-2000 and IEC 60 479-1.

(2) The lightning protection systems shall be designed and constructed in full compliance with the IEC standards.

(3) The design shall be based on the following fault levels:

- 132 kV 31.5 kA/3s
- 11 kV 40 kA/3s
- 0.4 kV 63 kA/3s

It shall be noted that above values are tentative and shall be verified during the construction design.

(4) Necessary measurements to determine the ground and ground water resistivity to be used for the calculations and the design.

(5) The actual cross-sections of the earthing conductors shall be defined in the earthing system calculation.

The minimum cross-section for sub-grade earthing conductors shall be 95 mm² Cu.

(6) The permissible conductor temperatures under fault conditions shall be as follows:

Bare conductors, embedded in concrete or buried °C 300

Bare conductors above grade °C 200

(7) All equipment associated with the plant including reinforcement steel and embedded steelwork shall be bonded to the earthing electrodes by adequately dimensioned conductors.

The various earthing grids shall be interconnected.

(8) Surge arresters and transformer neutrals shall be directly connected to the main earthing conductor and/or particular earthing rods.

(9) The entire earthing system shall have an earthing resistance of approx. 0.5 Ω.

(10) Test links and maintenance earthing points shall be provided.

10.13.2 Particular Design and Construction Requirements

Subgrade Earthing Systems

(1) The sub-grade earthing system shall consist of flexible, bare, electrolytic copper conductors forming an interconnected meshed network.

The complete system shall be buried and/or embedded in concrete with adequately spaced connections to the main earthing bus. To achieve a safe earthing system with the required overall earthing resistance, earthing electrodes of sufficient length and quantity supplemented by driven earthing rods shall be provided.

(2) All embedded earthing materials shall be connected with each other, with earthing electrodes or reinforcement steel bars with standard type thermo-weld joints (CDWELD Process).

(3) Construction and installation of the systems shall be closely coordinated.

The erection staff and materials shall arrive at site in due time according to an agreed schedule.

Above Ground Earthing Systems

(1) The various indoor and outdoor locations shall be provided with earthing systems consisting of common loops with branch connections to the individual equipment. The installations shall be surface-mounted.

(2) All non-current carrying but conductive components shall be bonded with the earthing system.

(3) Switchgear and equipment rooms with electrical installations shall be equipped with an earthing bus of 30 x 4 mm Cu. This bus shall be installed at the circumference of the rooms with connections to the sub-grade earthing systems.

(4) Earthing conductors shall be installed along cable trays and other cable routings.

(5) The earthing conductors for exposed installations shall be tinned, stranded copper conductors of specified minimum cross-sections.

For earthing terminations the conductors shall be fitted with compression type cable lugs.

Earthing conductors shall be connected with compression type straight or T-joints.

(6) Steel constructions shall be earthed at least at both ends. Steel reinforcement in mass concrete, structural steel, pit liners, stay rings and draft tube liners shall be connected to the earthing system at least at two points. Earthing connections shall be protected during concreting to avoid damage or breaking of bonds and connections. Earthing cables embedded in concrete shall have construction joints at right angles to the joint and shall be installed in such a manner that movement will not damage the cable. All connections with the sub-grade earthing systems shall be carried out with standard type, bolted fittings.

All metal structures, such as metal trays, conduits, tanks, gratings, rails, pipes, louvers, staircases, doors, machine housings or enclosures (pumps, fans, compressors, etc.)

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which may become conductive during a fault of an electrical installation by direct contact, arc or via a creepage distance, shall be effectively connected to the protective earthing system. Rails and pipes shall have insulating joints where they leave the protected power plant area.

Oil tanks shall be earthed twice with the earthing conductors taken from two different points of the earthing grid. All piping shall be earthed at all service points in an approved manner.

(7) Metal enclosures and conductive structures of circuit breakers, isolating switches, measuring transformers, busbars, etc., shall be connected to the earthing grid. The housings of the operating mechanism shall be earthed at a point as near to the operating handle as possible.

Power transformer tanks shall be earthed at two points diagonally. These connections shall be brought from the neutral bushing to earth, an additional connection between bushing and tank shall be provided to ensure a straight electrical connection between tank and neutral.

The neutral conductor shall have the same current carrying capacity as the phase conductors and shall be brought directly to an earthing bus.

Surge arresters shall be connected separately to the earthing grid with 150 mm² earthing cable connections.

Electronic equipment rooms shall have a direct connection to the sub-grade earthing system by means of an insulated earthing conductor at lest 50 mm² cross-section.

Potential Gradient Control System

(1) Every building floor or outdoor concrete slab, accommodating HV or MV switchgear, switchboards, transformers or other electrical equipment of 1 kV service voltage or above, shall be provided with a potential gradient control system composed of a mesh of round steel bars of approx. 8 mm diameter. The mesh width shall not exceed 5 m, to be laid in the final concrete slab approximately 50 mm below floor level. This system shall be connected with the main steel structures or the main earthing bus at several points. This system shall by no means be used in lieu of the protective earthing system.

(2) Outdoor potential gradient control systems consisting of bare copper conductors with a cross-section not less than 95 mm² shall be buried in the soil beside or nearby electrical components or metal structures at which a contact or step voltage can exist. Such conductors shall be connected directly to the main earthing bus and laid in approximately 1 m distance from the circumference of said electrical components or metal structures in a depth not exceeding 0.20 m.

(3) Step and touch voltages may be controlled by well-drained gravel surface dressings. Conductive buildings and lightning conductors shall be bonded to the earthing system. The site fences shall be earthed independently from the main earth electrode system.

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Lightning Protection Systems

(1) To protect personnel, electronic and electrical equipment from the effects of lightning strokes the plant shall be equipped with a lightning protection system.

(2) The lightning protection system shall be subdivided into lightning protection zones and consist of roof conductors, air terminals and down conductors.

All materials shall especially be suitable and approved for this type of system.

(3) The lightning protection system shall be connected to the station main earthing electrodes as appropriate.

(4) Due consideration shall be given to EMC and overvoltage requirements.

10.13.3 MV and LV Cable Systems

Power and control cable systems shall be provided for the entire hydropower plant with all related buildings and structures. The cable systems shall comprise all MV and LV power, communication, control and instrumentation cables, the necessary accessories such as cable terminations, cable trays, conduits, supports, fixing and mounting materials to provide complete, ready for service systems.

The scope of work shall comprise the following:

- One lot of 11 kV single core power cable systems;
- One lot of LV power cables for AC and DC systems;
- One lot of communication, control and instrument cables;
- One lot of fibre optic cables for external/internal data transfer systems;
- One lot of the necessary material for supporting, laying and terminating of the cables;
- One set of special spare parts.

Principal Design Features

(1) For the cable systems the following interfaces shall be coordinated:

- Civil works related to the cable systems;
- Electrical consumers of the Hydraulic Steel Structures
- All systems and equipment
- Reference is made to the LV AC and DC auxiliary supply systems.

(2) The equipment will be equipped with MCC, switchboards and control cubicles, as applicable. Power and control cables shall be installed between the auxiliary supply and control systems and the equipment.

(3) At the receiving end the cables shall be terminated and commissioning shall be a coordinated.

(4) The design, permissible continuous rating and the size of cable conductors shall be based on the following:

- Ambient conditions at the different locations but considering 50°C as minimum standard;

- Temperature and grouping correction factors according to cable laying method;
- Cable length with consideration of the permissible voltage drop;
- Permissible short-time withstand current;
- Thermal and dynamic stresses at short circuit conditions.

(5) The maximum permissible conductor temperatures for continuous and fault conditions shall be as follows:

- For PVC insulation	70/160°C
- For XLPE insulation	90/250°C

(6) The following colours shall be used for the cable outer sheaths:

- For MV power cables red colour
- For LV power cables black colour
- For instrument and control cables grey colour

(7) The colour of the PE/N conductors for cables and wires shall be in compliance with the IEC Standards.

(8) Cables shall be insulated and sheathed with materials featuring the following properties:

- Non halogen;
- Inhibition of fire propagation;
- Flame retardant;
- Heat stabilised;
- Not producing corrosive and toxic gases and vapours in case of fire;
- Low smoke generation;
- High dielectric strength and insulation resistance
- Resistant against environmental influences, in particular humidity, fungi, oil and vermin;
- Safe against repeated overloads and short circuits;
- Easy handling.

(9) The design of the cables shall prevent water penetration, radial vapour diffusion and longitudinal water propagation.

10.13.1 Lighting and Small Power Installations

Indoor and outdoor lighting systems with small power service installations shall be provided for the entire power plant and the associated roadways.

The scope of work shall comprise the following:

- One lot of lighting and small power installations for the entire power plant with all pertinent buildings and structures, including the Switchyard and the weir site;
- One lot of lighting and small power installations for the service areas and associated roadways, extending up to 1,000 m from the power plant;

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- Five sets of isolating transformers 230/42 V with power socket outlets for supplying tools;
- Five sets of portable and rechargeable lamps with charging units;
- Five portable, heavy duty maintenance lighting fixtures, fitted with fluorescent lamps;
- One lot of special spare parts.

Principal Design Features

Types of Lighting Systems

The lighting systems shall consist of the following sub-systems:

(1) Normal Lighting System (NLS), fed by the AC auxiliary supply system.

(2) Emergency Lighting System (ELS), fed by the emergency DG units in case of AC auxiliary supply failure. ELS shall be provided for all operational areas to ensure the safe movement of the personnel and to enable essential operations to be carried out at all times. The CCR lighting system shall be fed by the UPS system.

(3) Security Lighting Systems (SLS), fed by the station DC or UPS systems, shall adequately illuminate relevant exits and emergency escape ways.

Self-contained, battery-powered lighting fixtures shall be used in remote areas.

At selected locations portable, automatically recharged lamps, providing 4 h operation, shall be installed.

Illumination Levels

(1) The lighting systems shall illuminate all parts of the power plant at illumination levels in compliance with the DIN and ILE standards; the minimum illumination levels shall be the following:

- Roadways and car parks	15 lx
- Cable floors, galleries, shafts, tunnels, outdoor structures	50 lx
- Corridors, stairways, rest rooms, stores	100 lx
- Machine hall and erection bay, turbine and generator floors, plant rooms, battery rooms, mechanical workshop, transformer bays	250 lx
- Control rooms, electronic equipment rooms, offices, electrical / electronic workshops	500 lx

(2) The lighting calculations shall consider ageing factors 1.25 / 1.67 for indoor and outdoor installations, respectively.

(3) The illumination levels of indoor systems shall be measured horizontally at a height of 0.80 to 1.00 m above the floor; for outdoor lighting systems at the surface. In new condition of the equipment, the ratio of the minimum to the average illumination level

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shall not be higher than 1:3; the ratio of the minimum to the maximum illumination level shall not be higher than 1:6.

Lighting Fixtures

General Requirements

(1) All lighting fixtures complete with lamps and tubes, instantaneous starting control gear, chokes, compensating capacitors, etc. shall be of approved manufacture, constructed of best quality materials and provided with all necessary installations. Special precautions shall be taken to protect the wiring from damage by heat generated by the fixture.

The fixtures shall be wired with 600 V, silicone rubber insulated wires covered with a fibreglass braid.

(2) Incandescent lamps shall be rated at 250 V, inside frosted for "extended service". Incandescent lamps shall be used in exceptional cases only. Compact fluorescent, low energy lamps with a service life of some 9,000 h shall be used instead.

Fluorescent lamps shall be daylight tone, rapid-start with the required ballasts. The service life shall be in the range of 20,000 h.

Mercury-vapour lamps shall be colour corrected deluxe-white type with a minimum service life of 25,000 h.

(3) Outdoor fixtures shall be completely weatherproof. Dispersive reflectors shall be made of vitreous enamelled steel or equivalent.

(4) Poles for outdoor lighting shall be of galvanised seamless tubular steel construction with 3 to 10 m mounting height. In the lower part of the poles, approx. 500 mm above ground, a junction box with terminal blocks suitable for connecting three cables and fitted with individual connectors for the neutral and protective earth shall be provided. Detachable cover plates fixed with screws shall facilitate the access to the junction boxes.

If ballasts shall be mounted inside the pole, they shall be accessible through another detachable cover plate arranged at a convenient height.

(5) Ballasts for fluorescent lamps shall be of the starter less, rapid type with high power factor. Ballasts for high pressure mercury-vapour/metal halide/high pressure sodium lamps shall feature immediate re-striking, high power factor and low line extinguishing voltage and starting current.

Compensation shall be provided to obtain about unity power factor.

Types of Lighting Fixtures

Type 1 Indoor/Outdoor Fluorescent Lighting Fixture IP 65

Fluorescent type fixtures for 36 W or 58 W tubes, surface mounted with diffuser, protection class IP65, shall be provided especially for installation in dusty, wet or damp locations. They shall be of flame retardant material, with white interior reflector, non-ageing gaskets, and

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acrylic or otherwise approved diffuser. They shall enable versatile, individual or row mounting either directly on ceiling or wall, or suspension with rods or chains.

Application: All locations.

Type 2 Indoor Fluorescent Lighting Fixture IP 20

Fluorescent type fixtures for 36 W or 58 W tubes, protection class IP20 shall be suitable for surface and pendant mounting, with or without reflectors as required.

Application: Control room, switchgear rooms, electronic rooms, etc.

Type 3 Indoor Fluorescent Lighting Fixture for Hazardous Areas

Fluorescent type fixtures for 36 W or 58 W tubes, surface mounted with diffuser shall be used in explosive atmospheres, protection class IP65.

Application: Battery rooms and other hazardous locations.

Type 4 Indoor High-bay Lighting Fixture with Mercury Vapour Lamp

High-bay ceiling or pendant mounted luminary with protection class IP23. According to actual requirements, the luminary shall be equipped with one or two mercury vapour lamps 250 W or 400 W.

Application: Machine hall, rooms and areas with ceiling heights of approx. 6 m and above.

Type 5 Recessed Indoor Fluorescent Lighting Fixture IP 20

Recessed fluorescent luminary shall be fitted with injection-moulded prismatic low-brightness acrylic lens mounted in a recessed aluminium frame, rapid-start ballast and lamp, protection class IP20. According to actual requirements the luminary shall be equipped with one, two, three or four fluorescent lamps 18/36/58 W.

Application: Administration areas, offices, residential areas, etc.

Type 6 Lighting Fixture for Roadways

Pole-mounted luminary with pole of rugged construction shall be suitable for the illumination of all kinds of roadways, car-parks and service areas. The luminary shall consist of a seawater resistant canopy of die-cast aluminium silicon alloy, a prismatic or diffusing bowl of acrylic glass, attached by stainless steel clips. The reflector shall be of polished and anodised aluminium.

The optical elements such as reflector and lamp sockets shall easily be adjustable for optimum intensity and distribution. The luminary shall have protection class IP 65. The complete unit shall consist of the luminary and an approx. 10 m high pole with ballast and junction box mounted inside the pole. According to actual requirements the luminary shall be equipped with one or two mercury vapour lamps 125/250/400 W.

Application: All roadways, car-parks, service areas, etc.



Type 7 Recessed Indoor Luminary for Low Energy Lamps

Luminary for one or two low energy lamps 13/18/26 W, suitable for recessed mounting in suspended ceilings, with cast aluminium trim ring, low-brightness reflector and concave Fresnel lens. All visible metal parts shall be white enamel. Protection class IP 20.

Application: Meeting rooms, offices, control room, etc.

Type 8 High Capacity Outdoor Floodlight

High capacity floodlight fixtures shall be suitable for 1 x 1,000 W or 1 x 400 W tungsten metal halogen lamps. The housing shall be of corrosion resistant die-cast Al provided with cooling fins, protection class IP 65. The lamp compartment shall be sealed by a clear glass cover resistant to thermal shocks and fitted with an anodised Al reflector. As required for the individual application the lighting fixtures shall be mounted on steel structures/brackets or on approx.10 m high galvanised steel poles.

Application: Switchyard, take off structures, transformer bays, etc.

Type 9 Indoor/Outdoor Bulkhead Lighting Fixture IP 65

Bulk head fixture shall comprise poly-carbonate housing, antiglare diffuser and polished Al reflector with gasket, protection class IP 65, suitable for wall/ceiling mounting. According to actual requirements the luminary shall be equipped with compact fluorescent lamps of suitable rating.

Application: Small cable rooms and galleries, small equipment rooms, etc.

Type 10 Indoor Security Lighting Fixture

Plastic sealed security lighting fixtures provided with labels "EXIT" and "ESCAPE DIRECTION", equipped with compact fluorescent lamp of adequate rating. The fixture type shall be certified by the relevant authorities.

Location: Escape routes and stairways, etc.

Type 11 Battery Powered Portable Lamp

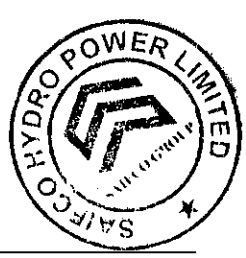
The NiCd battery powered, rechargeable portable lamps shall consist of:

- Spotlight with handle and battery;
- Twin or triple unit charging rectifier, fixed mounted at approved locations.

The charging shall be initiated automatically by putting the lamps on the lamp holder of the charging unit. The spotlight shall be adjustable by 90 degrees.

The service time without recharging shall be approx. 4 h.

Application: Emergency lighting, inspection and maintenance.



Type 12 Portable Fluorescent Lighting Fixture

Portable heavy duty lighting fixtures shall be rubber moulded IP 65 type, equipped with fluorescent lamp, shutter proof tubular glass, fixing device, built-in ballast and approx. 20 m integrated, flexible, heavy duty extension cable with moulded plug.

Application: Inspection, repairs, maintenance, etc.

Cabling and Installation

(1) All installations shall be carried out in compliance with best construction practice. Cables and wires shall be enclosed in conduits, boxes or raceways as applicable.

(2) Cables and wires shall be of 600/1,000 V grade, PVC insulated, PVC sheathed with copper conductors for phases, neutral and protective earth. The minimum cross section shall be 1.5 mm² for lighting circuits and 2.5 mm² for socket outlets.

(3) Exposed cabling shall be laid in surface mounted heavy duty plastic conduits with open bends.

In areas prone to mechanical damages the cables shall be laid in closed galvanized steel conduit systems.

Cabling in plaster or concrete finished rooms shall be installed in embedded plastic or metallic conduits.

Where applicable (e.g. offices, meeting rooms, etc.) floor or wall mounted cable raceways of suitable design shall be provided.

Communication networks (e.g. telephone, LAN, etc.) shall also be installed in these raceways.

(4) The mounting height of switches, socket outlets shall be as follows:

- Socket outlets flush mounted in walls of closed rooms such as offices and control room areas shall be mounted 300 mm above finished floor.
- Switches or switch/socket outlet combinations flush mounted in walls shall be installed 1,200 mm above finished floor.
- 400 V power socket outlets shall be mounted 1,200 mm above finished floor.

(5) The loading of any single-phase lighting circuit shall be limited to 2,500 W or 20 fluorescent or low energy lighting fixtures.

The permissible voltage drop between the sub-distribution board and the remotest fixture shall not exceed 3 %.

Switches and Socket Outlets

(1) Switches

Lighting fixtures in self-contained rooms such as offices, switchgear rooms, battery rooms, etc., shall be switched locally. Where more than two switching points are required (stairways, large rooms with several entrances, etc.) push-button switches shall be used to control

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impulse-operated relays and contactors arranged in the associated sub-distribution boards. All other circuits shall directly be controlled from the relevant distribution boards.

Switches installed in rooms with embedded wiring shall be designed for flush-mounting in moulded plastic wall boxes. In all other cases, surface installation of heavy duty industrial type switches with adequate enclosures shall be provided.

(2) Power Socket Outlets

The socket outlets shall be of the CEE type, weather-proof, heavy duty industrial type with shock-proof plastic housings. The following types of socket outlets shall be provided at approved locations:

- Single-phase socket-outlets 230 V 16 A or higher ratings as required;
- Three-phase socket-outlets 400 V 63 A or higher ratings as required;
- The type, rating, quantity and locations shall be defined during the detailed design;
- Socket outlets shall not be interchangeable for different voltages;
- Each unit shall be effectively earthed and provided with appropriate plugs.

10.14 ELECTRICAL WORKSHOP

Electrical Workshop is the essential part in Hydro Power Project. Electrical workshop is proposed with following measures and equipment's.

Hazard Identification

Identify all the hazards; evaluate the risks (low / medium / high); describe all existing control measures and identify any further measures required. Specific hazards should be assessed on a separate risk assessment form and cross-referenced with this document. Specific assessments are available for hazardous substances.

Contact Injuries (abrasions, cuts, burns)

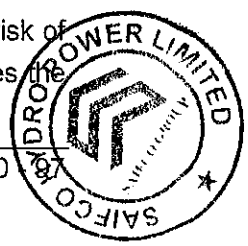
Access to the workshops is strictly restricted to authorized personnel only. No one may operate workshop equipment unless they have received a sufficient training and permission from the technician-in-charge. Specific risk assessments for machinery and the generic risk assessment for power hand tools have been completed and safe systems of work issued to operatives. All workshop equipment must be regularly maintained and serviced.

Electrical equipment (electric shocks or burns from using faulty electrical equipment)

All portable electrical equipment must be tested at for electrical safety at correct intervals and labelled with the date of the test. Electrical cables and plugs should be regularly visually inspected by the user for damage. Any defective equipment should be reported to the technician-in-charge and taken out of use until the repair has been affected. Electrical equipment must always be operated in accordance with manufacturers' instructions.

Manual handling of heavy/bulky objects (back injuries)

A risk assessment must be completed for lifting heavy and bulky loads that present a risk of injury. Training in lifting techniques must be provided for workshop staff who undertakes the



lifting of heavy loads. Appropriate PPE for lifting operations must be worn. Lifting equipment must be registered with the University's Engineering Insurers and annual inspections carried out. Records of the inspections must be kept in the safety file.

Hazardous Substances (e.g. irritating vapors, skin sensitization, dermatitis)

A COSHH risk assessment must be completed for using substances that may present a hazard to health. A Material Safety Data Sheet (MSDS) must be kept together with a risk assessment in the Workshop Safety File for future reference. All containers used for storage of hazardous and non-hazardous substances must be suitably labeled indicating their contents.

Slips and trips

Workshop working areas must be kept clear of obstructions. Any spillages should be cleaned up immediately. Any hazards such as trailing cables, defects to floor coverings and faulty lighting etc. should be reported immediately to the technician-in-charge. All areas well lit.

Fire

Users must be familiar with the risk assessment and safe system of work for using stepladders. A stepladder should have a visual inspection by the user prior to use for damage. Stepladders must be individually identified and formal inspections must be carried out and records of inspection kept. Any defective stepladder should be clearly labelled and taken out of use until the repair has been affected.

Lone / Out of Hours (LOOH) Working

LOOH working in the Workshops is strictly prohibited unless permission from the Health and Safety or Sub Engineer in charge is given and a specific lone working risk assessment is carried out. Safety glasses/goggles, safety shoes, gloves, barrier creams, hearing protection, dust masks and respirators are to be used as the work dictates.

Identify any additional relevant information to the activity, including supervision, training requirements, special emergency procedures, and requirement for health surveillance.

Transmission System for Shigo HPP

Shigo Kas Power dispersal is proposed by 132KV transmission line from Shigo kas Power station and 132 KV Timergara Grid Substation with a distance of 13 KM.

Towers

WAPDA standard towers for 132 kV double circuit lines are recommended as in **Table 10.2.**

Table 10.2: Tower Types and Weights

Description	Suspension ZM-1 in [t]	Angle tower 30° ZM-30 in [t]	Angle tower 60° ZM-60 in [t]
Basic body	4.142	6.5	8.207
3 meter leg extension	0.696	1.237	1.7
6 meter body/leg extension	1.379	-	-

Conductor and Optical Ground Wire (OPGW)

Conductors and Optical Overhead Ground Wire (OPGW) to be used are shown in **Tables 10.3 & 10.4.** The additional loading due to ice will be taken care by adjustment of span lengths. Reference is made to design aspects for loading conductors in excess of those given in regulation Annexure-I (Overhead line practice 3rd edition and author John McCombe & F.R. Haigh, year of publication 1966).

Table 10.3: Conductor as Per WAPDA Specification P-50:88

Code Word	Aluminum Conductor	Steel Core	Diameter		Cross area of Aluminum	Area of Complete Conductor	Rated Ultimate Strength	D.C Resistance at 200C	Weight
			Complete Conductor	Steel Core					
	No/mm	No/mm	mm	mm	mm^2	mm^2	kg	ohm/km	kg/km
Lynx	30/2.79	7/2.79	19.53	8.37	183.41	266.20	8192	0.158	842

In order to protect the transmission line and grid station equipment from lightening and to transmit the protection, communication signal, an optical ground wire will be provided.

The main feature of cable shall be as under.

Table 10.4: Optical Ground Wire (OPGW)

OPGW SIZE	Outer Diameter	DC Resistance at 200C	No of Fibers	Breaking Load	Nominal Weight
mm^2	mm	Ω/km	No	Kg	Kg/km
70	11.4	1.02	12	8000	458

Insulator:

Standard fog type porcelain insulators as per WAPDA specification P-8:96 will be provided as follow:

Normal Location 8 Nos.

Angle / Dead end Location 9 Nos.

For location having extra pollution, additional insulators will be provided as per requirements. The characteristics of insulator are shown in **Table 10.5.**

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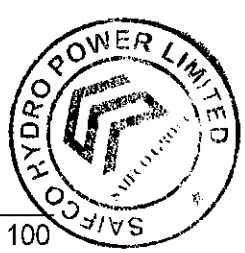
Table 10.5: Insulator as per WAPDA Specification P - 8:96

Type Designation	Normal Type				Fog Type			
	U70BL	U80BL	U100BL	U160BS	U70BLF	U80BLF	U100BLF	U160BSF
Dimensions								
Disc Diameter (D), mm	255	255	255	280	255	255	255	292
Disc Spacing (P), mm	146	146	146	146	146	146	146	146
Minimum Creepage Distance, mm	290	290	290	300	430	430	430	470
Standard Coupling dia (dl), mm	16	16	16	20	16	16	16	20
Mechanical Values								
Short time Electro Mechanical Breaking load, KN	70	80	100	160	70	80	100	160
Mechanical Routine Test Load, KN	28	32	40	64	28	32	40	64
Mechanical Impact Strength, Nm	6.2	6.2	11.3	11.3	6.2	6.2	11.3	11.3
Electrical Values								
Power Frequency with stand voltage, KV	70	70	70	70	85	85	85	85
Wet power frequency withstand voltage, KV	40	40	40	40	50	50	50	50
Impulse withstand voltage, KV	110	110	110	110	110	110	110	110
Low frequency puncture voltage, KV	110	110	110	110	130	130	130	130
Radio Noise								
Max. radio influence voltage at 1000 KHz, micro volts	50	50	50	50	50	50	50	50
Test voltage to ground, KV	10	10	10	10	10	10	10	10
Colour of glaze	Brown	While	Grey	Brown	Brown	White	Grey	Brown

Hardware:

WAPDA standard hardware for conductor, insulator and optical overhead ground wire (OPGW) will be used.



Vibration Dampers:

In order to avoid damages on line conductors and on earth wire, due to vibrations, also considering the heavy every-day stress for sagging, vibration dampers will be used both on suspension and tension towers.

The dampers are of Stockbridge type and their number at each end of the span depends from the span, varying from one to three.

Foundation:

Normal concrete spread footing with pad/column will be provided which shall be designed for uplift/compression loading by wind imposed on tower, conductor and conductor broken condition, ice loading etc.

Earthing:

Effective earthing is to be provided for steel towers.

Environmental aspects

In high voltage range, the conductor selection is based on

(a) Corona losses

(b) Radio interference

(c) Television interference

(d) Audible noise

Corona Loss

The effect of increasing the operating voltage of a line, as its critical surface gradient (21.2 kV/cm) is approached, is to produce power losses in the lines and to cause the conductor to generate and emanate higher frequencies causing radio and television inference.

The condition of absence of corona loss in fair weather can be written in the form

$Vph = V\sqrt{3} \leq = 21.2 * 0.8 * 6.5 = 110 r_0$

r_0 = radius of conductor in cm d min = 1.15*10-2Vn

d = diameter of conductor in cm Vph= Phase Voltage in kV

Where d min / r0 are expressed in cm and Vn is in kV. For 110, 220 and 440 kV line, minimum permissible diameters are equal to 1.25, 2.5 and 4.6 cm respectively. For KB Hydropower Project, Transmission line, the conductor diameter is 1.952 cm which is much higher than the permissible limit. In view of the Lynx Conductor, there will be no problem of corona, Radio interference and Television interference.

Audible Noise (AN)

Up to 500 kV level, the audible noise generated by transmission lines is usually no concern. The level of a generation with conductor design which satisfies the RI requirements is sufficiently low.

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Conductor	Lynx
Area	226.19 mm^2
Diameter	19.56 mm
Weight	0.83 kg/m
Aluminum	30/2.89 mm
Steel	7/2.89 mm

Surface Gradient

The clearance between overhead transmission lines and nearest objects are set primarily to avoid any possibility of flash over. With the clearance prescribed there will be no problem of surface gradients causing charging current through this human body or passing vehicle.

(Electrical) Minimum Clearances of 132 kV Overhead Line

		Meter
i)	132 kV lines across country	6.7
ii)	Over roads and highway	7.9
iii)	Over Rivers and major canals measured from highest flood level	9.15
iv)	Minimum clearance from building	
	o Vertical	3.7
	o Horizontal	6.1

10.15 CONNECTION TO THE GRID

In order to meet the increasing power requirement, the transmission of power from national grid to the Project, one of the alternatives would be to interconnect the grid system with the local area at 132 kV line. But this interconnection will not be technically as well as financially possible solution. This will be possible only when major Hydro power project is built in the area. The nearest point of the national grid is located in Timergarah, which is almost 13 km from Project.

10.15.1 Load Flow Study

Besides for interconnecting the Area network with regional/national network, it is advisable to have a proper load flow study system study by the planning power to arrive at optimal solution with regard to voltage level and point of interconnection and year when it should be available.

ANNEX

10A

ELECTRICAL DRAWINGS

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CHAPTER

10

ELECTRICAL EQUIPMENT STUDIES

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ANNEXURE – 11A

STAKEHOLDER'S CONSULTATION

The following stakeholders were identified to contact for preparing IEE report for Shigo-kas hydropower project.

1- Forest Department
2- Irrigation Department
3- Fisheries Department
4- Water Management
5- Communication & Works
6- Wildlife Department
7- EPA Regional Office

Forest Department Timmergra

Forests play an important part in sustainability of waters flowing into our rivers. It also controls sedimentation flowing into reservoir so enhancing the life span of the project. As this project has no such reservoir which needs clearance of a large number of trees so this project has minimal affect on vegetation and forestry, DFO explained during project briefing by the expert in his office. Forest department is ready "to take any initiative in collaboration to make project successful" he further added during discussion for scaling of negative impacts and their mitigations. SDO, Mr. Pervaiz Mannan also contributed during discussion by adding "although these projects are not major threats for forestry however, local species must be protected and a watershed development programme must be initiated by involving local community as KPK has good track record in social forestry to alleviate poverty from the project area".

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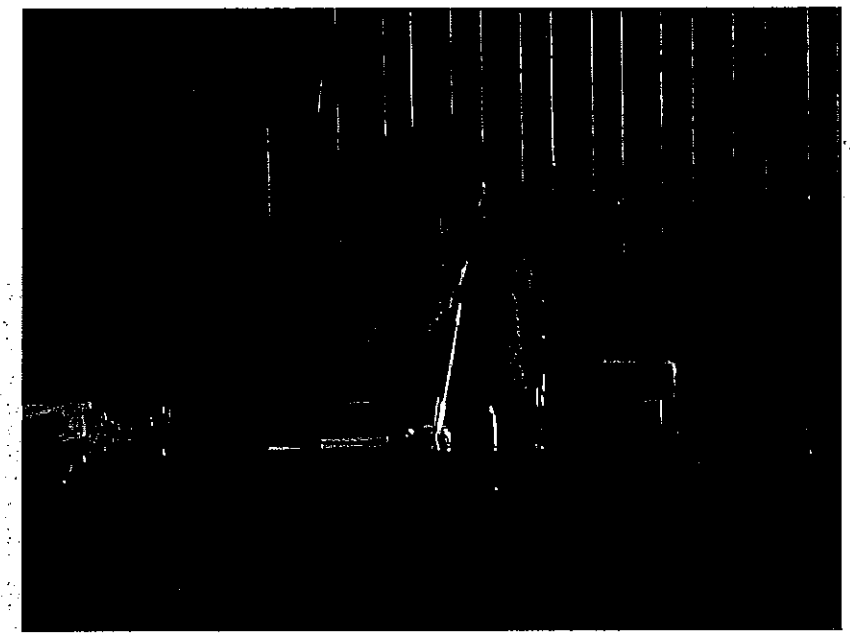

DFO Mr. Abdul Rashid during Information Session with Environmental Expert in His Office



Discussion with Mr. Mannan SDO Forest Timergara

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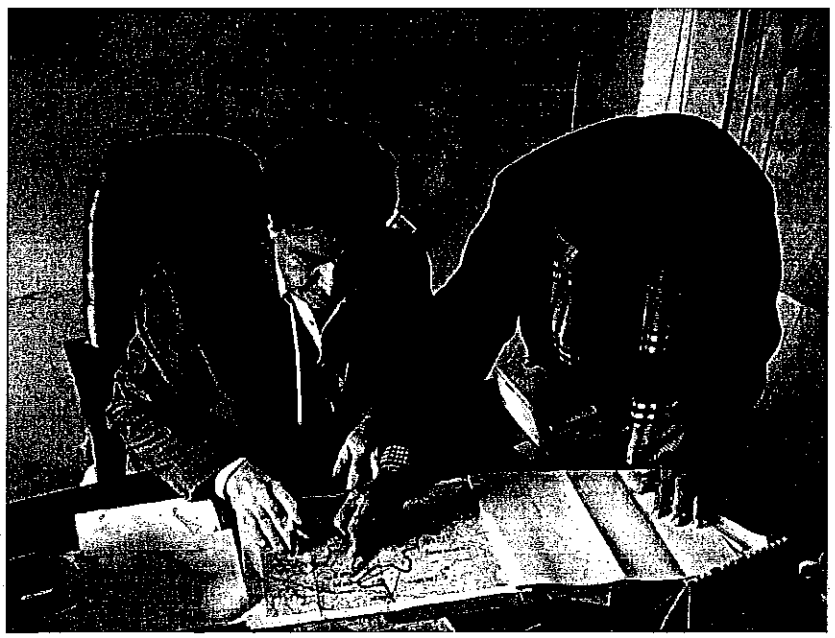
Irrigation Department Timergara

"There is absolutely no negative impacts as for as irrigation department is concerned, if for other stakeholders it has some concerns must have soft corner due to desperate need of electricity in the country" Akhunzada Tahir Saeed, SDO Timergara commented during project discussion in his office. "Small negative impacts will be supported by the positive gains environmentally and economically" he further added. We fully support towards successful implementation of this project, he concluded. There is no question of downstream water user's rights in this project as irrigation has no irrigation channel in this reach so it has no impacts. However, blasting during tunnel excavations or road construction may have negative effect on wildlife as he himself is very fond of hunting and have an eye in this area in this respect. These threats should properly address in formulating environmental management plan, he advised.



Discussion with Mr. Tahir Akhunzada SDO Irrigation Timmergra

Fisheries Department

There is no inventory of fish stock carried out till to date in Panjkora River. Only people caught fish for their personal consumption or as a recreational activity and not for commercial use" AD fisheries responded the question regarding fish inventory in Panjkora River. There are some projects in pipeline, he added to preserve and for inventory initiatives, he further told. More focused is on private fish farms which are on an increasing trend government offer different schemes time to time for private fish farm development. People also show greater interests in

this because of a profitable business. He suggested that although , there is little fish stock in the river so we must not destroy and must provide safe passage by providing fish ladder or any other suitable design option.

Water transfer may also result in translocation of aquatic species and may have negative effect on aquatic eco-system in affected areas. Unfortunately, we cannot scale out these negative impacts as having no such record/database. Environmental flow reserve must be maintained to protect aquatic life in the river reach, he concluded finally.

Water Management

DFO WMG, Mr. Jamil Khan commented on the project" "although these projects are for electricity generation not for irrigation purposes so we are not directly affected. But its positive effect on economy can easily be envisaged". Downstream water rights must be protected if such problem arises in this project, he advised to make project a success and sustainable and conflict free. Soil erosion which is a normal feature must be control through biological or engineering solutions. "Submergence of community assets" should be avoided, he concluded the discussion.

Communication and Works Department

Mr. Mohamamd Yar, SDO commented Hydropower construction is not simply an electricity generation project but brings a complete development package of the area. Present road conditions are not satisfactory to accommodate project traffic, he raised question it will need re-alignment and widening of roads. So during construction public will greatly suffer if these activities are not properly managed which includes Dust control, traffic management, blasting schedule etc, he concluded on mitigation measures of problems raised. All this have major negative affect during construction which needs proper attention by giving his comments while supporting the project.

Wildlife Department

A detailed meeting was held with Mr. Mohammad Hussain, DFO Wildlife in his office. "Although these projects have some negative affects because of destroying natural habitat and disturbing ecological balance in the project area for wildlife but have positive effects in the long run by providing altered habitats and new ecological zones better for migratory species" responded by explaining the impacts of projects. He also added watershed management is very necessary for controlling siltation in the river and for sustainability of the project.



Information Sharing with Mr. Mohammad Hussain DFO Wildlife Timmergra

EPA Regional Office Swat

Unfortunately, a planned meeting was not scheduled by AD EPA regional Office Mangora due to immediate and urgent meeting with the local administration. However, on telephone he gave his input by giving suggestions that it is the volume of project which determine whether an EIA or IEE is required. Anyway, at all cost all environmental statuary requirements must fulfill in these projects.

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ANNEXURE – 11 B

ADDRESSES OF CONCERNED AGENCIES

Officers Meeting Record during Scoping Session Held from 18-21 December, 2012 and 16 to 19 -9-13.

Name	Designation	Office Address	Contact No
Mr.Jamil Khan	DFO WMNG	Timergrah District Complex	0945-9250109
Akhunzada Tahir Saeed	SDO Irrigation Lower Dir	Timergrah District Complex	03135779500
Mr. Abdul Rashid	DFO Forest Department Lower Dir	Timergrah District Complex	0945-9250105
Mr. Pervaiz Mannan.	SDO Forest Department	Timergrah District Complex	09459250105
Mr. Bakhat Zaman	Assistant Director Fishiries	Timergrah District Complex	03439194840
Mr. Muhammad Yar	SDO C&W	Timergrah District Complex	09459250078
Mr. Muhmmad Hussain	DFO Wildlife	Timergrah District Complex	09459250145

ANNEXURE – 11 C

WATER QUALITY TEST REPORT

Shigo Kas

Government of Pakistan
Ministry of Science and Technology
Pakistan Council of Scientific and Industrial
Research Laboratories Complex
Jamrud Road, Peshawar
TEST REPORT

PLC/ILO/5.10/01
Issue #: 01
Issue date: 14.02.2013
Rev. #: 00

Page 01 of 01

Test Report #: 1010-A Lab. Code No. PLC/FTC/2567/2013 Dated: 30-07-2013
Case #: ILS/ATR/1010-A/2013

1. Name and Address of Client: ENGR. MUHAMMAD HAROON FARUQI TEAM LEADER FEASIBILITY STUDIES OF THREE HYDROPOWER PROJECTS IN DISTT. DIR REGION

Ref. #: dIR3HPP/PCSIR/13/02 Client Request Date: 22-07-2013 Date of Receipt: 23-07-2013

2. Description of the Sample (s):
Item: Chemical Analysis of River Water Sample(s) Mark if any: N.A. Shigo Kas
Condition found on receipt: 1.5 Liter Pet Bottle (s)

3. Sampling Plan / Procedure Used: Sample provided by client
(Where Applicable)

4. Environmental Conditions: Temp: 34 °C Humidity: 56 %
(Where applicable)

5. Method Used/Statement of Compliance: Standard Methods for Examination of Water & Wastewater 21st Edition (2005)

6. Measurement & Results:

Parameters	Method No.	Units	PANJKORA RIVER Wastewater Sample (Patrak)	Wastewater Sample (Shigo Kas)	NEQS
pH	4500-H+.B	-	7.95	8.16	6.50 - 8.50
Biochemical Oxygen Demand (BOD)	5210.B, 4500-O C	mg/L	14.00	16.00	80.00
Chemical Oxygen Demand (COD)	5220-C	mg/L	33.00	31.00	150.00
Total Dissolved Solids(TDS)	2540. C	mg/l	43.00	91.00	3000.00
Total Suspended Solid(TSS)	2540. D	mg/l	8.00	11.00	150.00
Oil & Grease	5220-B	mg/L	0.71	0.84	10.00
Chloride as Cl	4500-Cl. B	mg/l	14.99	22.99	1000.00
Sulphate as SO_4	4500-SO_4.E	mg/l	4.39	3.49	600.00
Cobalt as Co	3500-Co	mg/L	ND	ND	-
Copper as Cu	3500-Cu	mg/L	ND	ND	1.00
Lead as Pb	3500-Pb	mg/L	ND	ND	0.50

7. Remarks/Comments (where required):
N.A.

Tested by:
Tufail Ahmad (Tech)

Checked / Verified by:
Inayat ur Rehman (SO)

HRC/OIC

DIRECTOR (P&D)
End of report

Director (P&D)
PCSIR Laboratories Complex
Peshawar

P.T.O.

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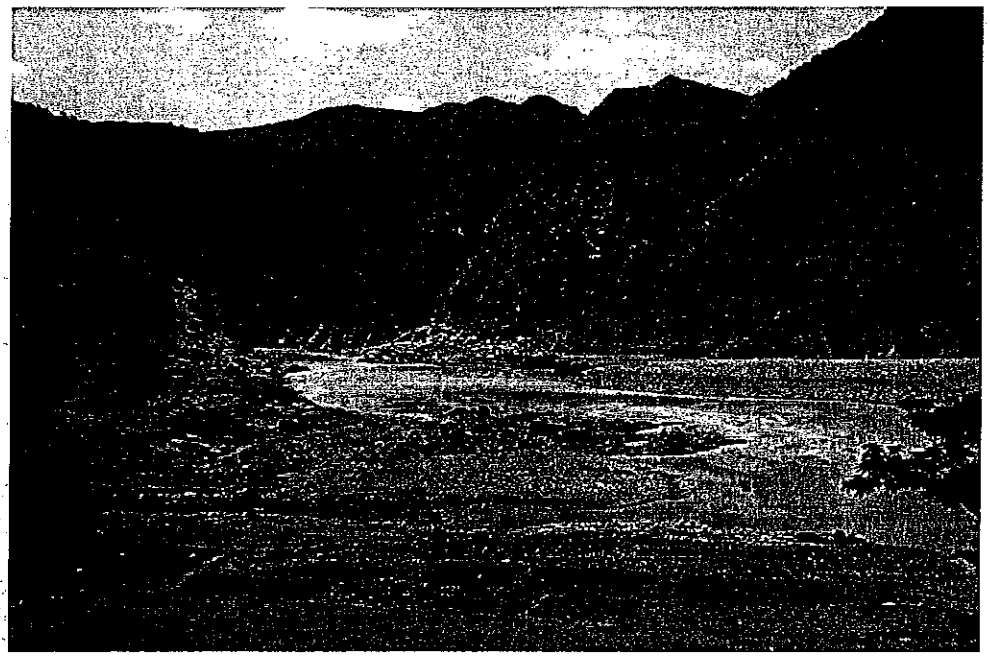
PHOTO GALLERY



Vegetation under Threat in Reservoir Area



Downstream View of Impounding Area



A View of Impounding Area



Locating Weir Site Axis on Main Timergara Road before Approaching the Weir Site

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Agricultural Fields near Powerhouse Site



Powerhouse Site with Some Agri-Terraces and Vegetation

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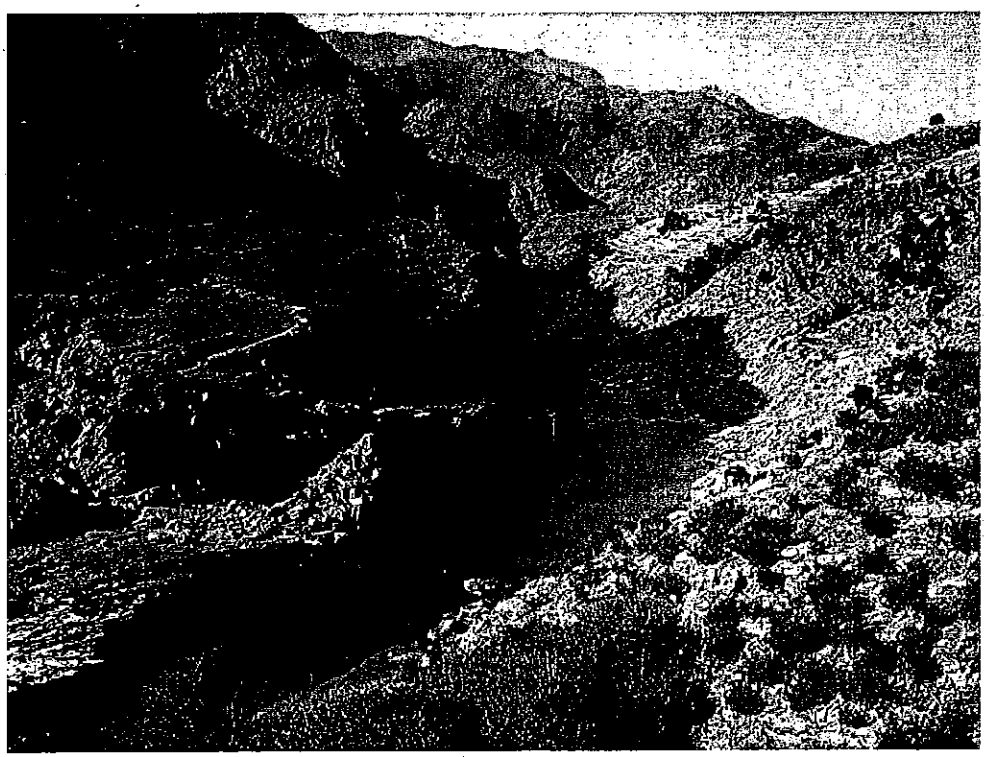
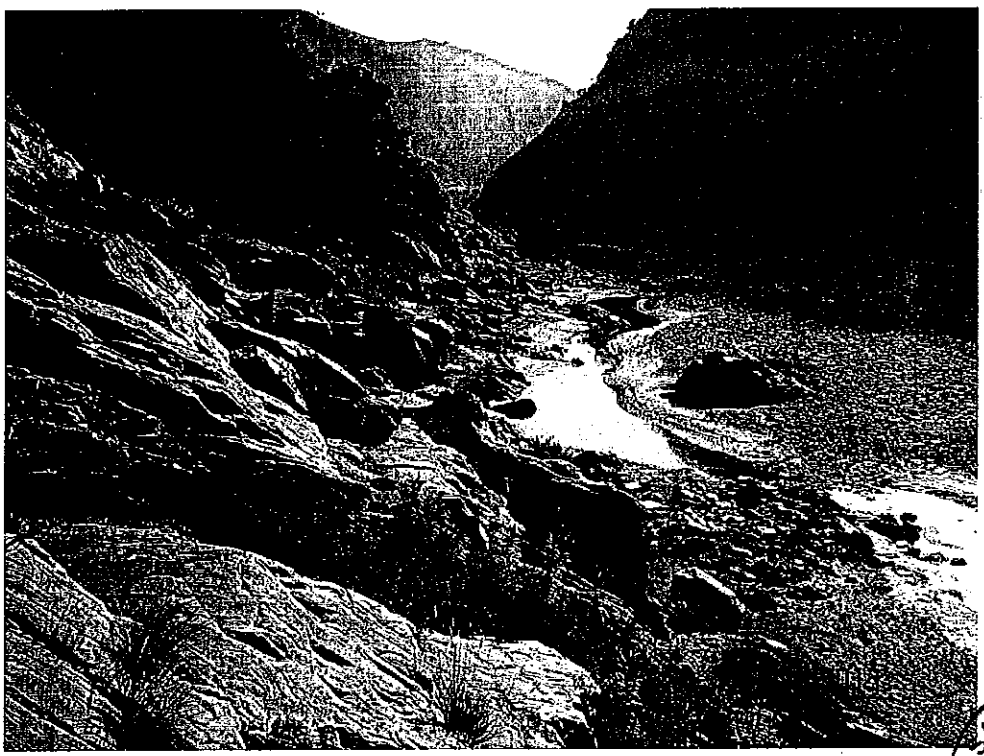


Powerhouse Site Looking Upstream



Powerhouse Site Looking Downstream

CHAPTER 11

ENVIRONMENTAL IMPACT ASSESSMENT

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LIST OF ABBREVIATIONS:

Assistant director (AD)
Communication and works (C&W)
Deutsche Gesellschaft fur Techniche Zusammenarbeit (GTZ)
DFO
Environmental Impact Assessment (EIA)
Government of Pakistan (GoP)
International Labour Organization (ILO)
Material Safety Data Sheets (MSDS)
National Environmental Quality Standards (NEQS)
Non-Government Organizations (NGOs)
Pakhtunkhwa Energy Development Organization (PEDO)
Pakistan Environment Protection Agency (Pak-EPA)
Statutory Regulatory Order (S.R.O)
Sub-divisional officer (SDO)
Water and Power Development Authority (WAPDA)
World Health organization (WHO)

ENVIRONMENTAL IMPACT ASSESSMENT

11.0 GENERAL INTRODUCTION OF THE PROJECT

Pakistan is endowed with a hydel potential of more than 40,000 MW, most of which lies in the Khyber Pakhtunkhwa Province. However, an abundant hydel potential is still untapped which needs to be harness. The total installed capacity of the hydropower stations in the country is about 6700 MW, out of which 3850 MW is in Khyber Pakhtunkhwa Province, 1699 MW in Punjab, 1039 MW in Azad Jammu & Kashmir (AJK) and 117 MW in the Gilgit Baltistan.

Energy is critical for the developing countries not only for social development and human welfare but also as a catalyst for overall development in the New Millennium. Energy in the form of electricity provides the basic infrastructural input to the national economic growth per capital electric consumption is considered as an index of a nation's progress and development.

Pakistan has been facing a chronic shortage of energy. With the passage of time, the gap between demand and deliverable capacity from the national power stations is widening. Power Development Authorities have been endeavoring hard to narrow the gap, through installation of thermal power stations with steam and gas turbines as well as combined cycle units. The power generation through these stations is not only expensive but also is not convenient to rely upon, due to ever increasing cost of oil and depleting resources. Water is the primary source of energy in Pakistan. The shortage of energy can minimize by exploring small and medium hydel projects in Khyber Pakhtunkhwa Province.

11.0.1 Background of the Study and Project Description

The German Technical Cooperation (GTZ) originally studied many hydropower projects over the whole country as a part of water resources development in the early 1990's and a local consulting company (Jafri and Associates) reviewed in 2005 after many years. However, the studies stopped at preliminary stage or at 'desk-level study' and on-site survey was not actually conducted in detail. The statistical data of the GTZ report and its review report are very limited accordingly. In addition, nearly 20 years have passed since the original study was done and it is believed that the project area has been changed now because of agriculture and other socio-economic activities.

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ENVIRONMENTAL IMPACT ASSESSMENT

11.0 GENERAL INTRODUCTION OF THE PROJECT

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Pakhtunkhwa Energy Development Organization (PEDO) and Deutsche Gesellschaft fur Techniche Zusammenarbeit (GTZ), a German Government Agency for Technical Co-operation, carried out extensive studies in Dir Kohistan of Pakistan for the identification of potential sites for the generation of hydropower.

Government of Khyber Pakhtunkhwa has included in their development program the feasibility studies of hydropower sites located in Dir Kohistan of Khyber Pakhtunkhwa Province. In this regard PEDO has entered into an agreement with M/s ELECTRA in association with M/s INTGERATION to provide consultancy services for conducting feasibility study of Shigo kas with installed capacity of 102 MW.

11.1 RATIONALE OF THE EIA STUDY

This report on the Environment Assessment-Baseline Survey of the proposed Shigo Kas Hydropower Development Project has been prepared by M/S ELECTRA (the Project Consultants).The study has been carried out to determine the principle existing activities and environmental facilities, which could be affected by each project component in as quantified manner as possible.

11.2 NEED FOR THE ENVIRONMENTAL STUDY

The law makes it mandatory to carry out Initial Environmental Examination (IEE) or detailed Environmental Impact Assessment (EIA) of the development projects depending upon the nature and magnitude of the impacts. Pakistan Environmental Protection Agency (Pakistan-EPA) regulatory guidelines (Pakistan Environmental Assessment Procedure; 1997; Policy and Procedures for filling, review and approval of environmental assessment exempt a hydropower and dam project from being put to EIA only when:

- The dams and reservoir have a water storage volume more than 50 million m^3 or the surface area is more than 8 km^2.
- Hydropower generation capacity is more than 50 MW.

The Shigo kas Hydropower power generation capacity is more than 50 MW and falls in Schedule A projects requiring EIA by projects categorization in the light of PEPA 1997. So the project qualify for Environmental Impact Assessment (EIA), rather an Initial Environmental Examination (IEE). As the Project falls in the jurisdiction of Pak-EPA, for that matter Environmental Protection Agency of Khyber Pakhtunkhwa, it desirable that regulatory requirements for environmental protection and social safeguards of both Government of Pakistan and Provincial are adhered to.

All Asian Development Bank (ADB) projects are assigned one of four categories (A, B, C, or FI) for environmental assessment. The category is assigned based on the project's potential for environmental impact. The proposed Project is classified by the Asian Development Bank (ADB) criteria as categories A; which qualify for Environmental Impact Assessment EIA. So, this chapter has been prepared keeping in view the regulatory requirements of both Pak-EPA and ADB.

11.3 OBJECTIVES OF THE EIA STUDY

The environmental assessment of the Project has been carried out to achieve the following:

(i) Review the baseline conditions of the biophysical and socio-economic environments in the project area through data review, site inspections and meetings with related organizations and local people.

(ii) Undertake an examination of the potential impacts of the Project on the biophysical and socio-economic environment to determine the type and magnitude of such impacts and to determine the required level of environmental impact assessment to fulfill the requirements of the Government of Pakistan and International Guidelines.

(iii) To develop an Environmental Management and Monitoring Plan for implementing during the preconstruction, construction and operation phases of the Project.

11.4 PROJECT DESCRIPTION

11.4.1 Project location and Accessibility

The Project is located on the left bank of Panjkora River and is accessible through black top road from Chakdara to Timergara. Panjkora River is the main artery of the area which joins the Swat River some 40 km downstream of Timergara. Chakdara - Timergara road provides the access to the left bank of the Project area. Roads and communication are necessary for the development of infrastructures and these play a vital role in the socio-economic development of any area. Shigo Kas HPP area is accessible from Peshawar via Dir road. The project area is located 10 km downstream from Timergara Town, where Panjkora River becomes narrow again and passes a bottleneck. This bottleneck is located 13 km upstream the Junction of Panjkora River with Swat River.

11.4.2 Proposed Scheme of Shigokas HPP

The project area is located on left side of Panjkora River. The coordinates of start of the intake and powerhouse are as follows:

Site	Latitude	Longitude
Weir Intake site	34°-45'-33.3"	71°-48'-18.2"
Powerhouse	34°-45'-12.2"	71°-47'-58.6"

There will be a diversion weir, Intake structure, sand trap, tunnel, surge tank and surge shaft, penstock, and powerhouse and tailrace canal. Weir & powerhouse site is shown in **Figures 11.1 to 11.3.**

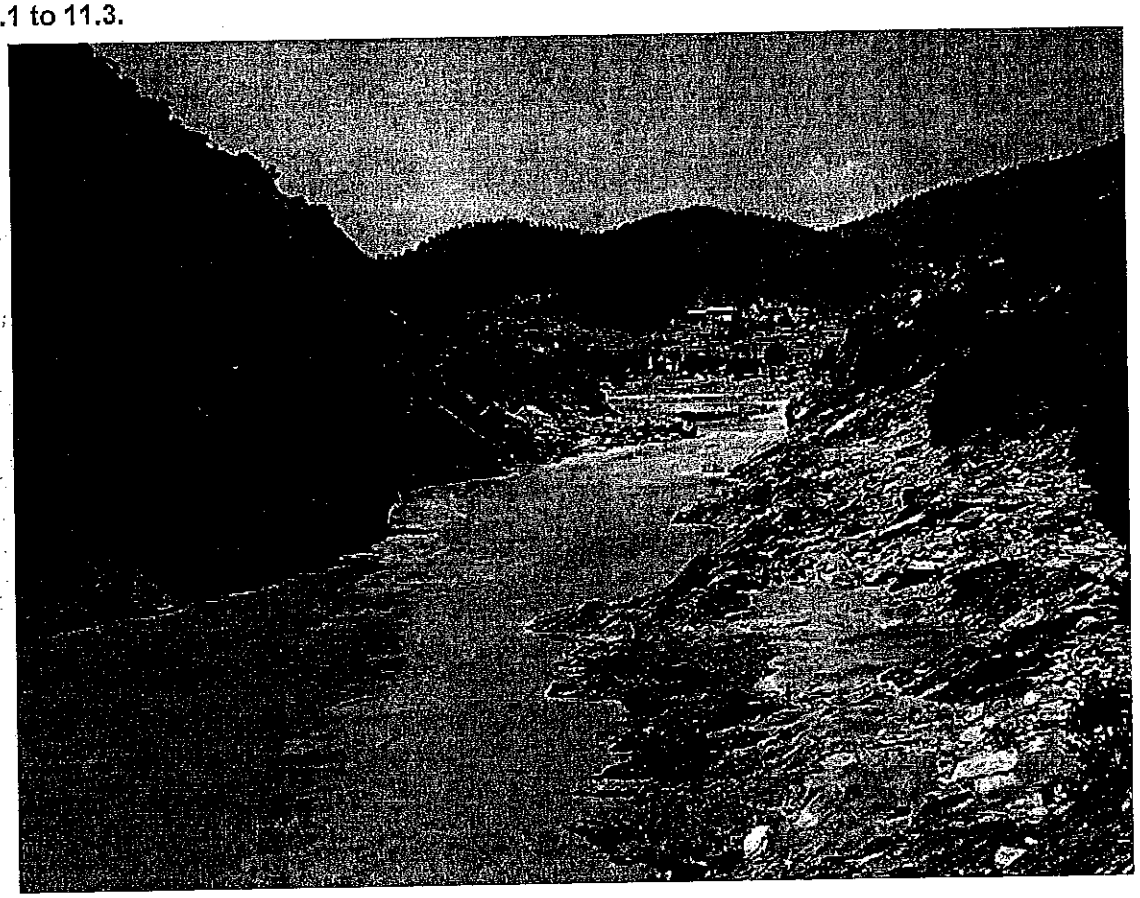

Figure 11.1: Weir Site Looking Upstream



Figure 11.2: Powerhouse Site Looking Up Stream



Figure 11.3: A View of Powerhouse Site

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11.4.3 Project Components

The project will utilize the flows of Panjkora River to generate 102 MW (3 x 34MW) with average energy output of 520 GWh per. The rated discharge and rated net head for the project have been revised at 150 m^3/s and 78.5 m respectively.

Project consists of following major components;

- Diversion weir
- Intake structure
- Connecting channel
- Sand trap
- Headrace tunnel
- Surge tank
- Penstocks with valve chamber
- Surface powerhouse
- Tailrace channel
- Switchyard
- Transmission line

11.4.4 Project Specific Information

- **Location**

River	Panjkora River
Site	Shigo Kas
District	Lower Dir

- **Power Potential**

Installed capacity	102 MW
Average annual energy	520 GWh
Plant factor	58.2 %
Turbine efficiency	93 %
Design Discharge	150 cumecs
Net head	78.5 m

- **Weir**

Crest El. of overflow section	El. 650.0 m
Bed level at weir	El. 639.0 m
Flood water level at weir	El. 654.0 m (1 in 10,000 return period)
Width of river at weir site	118.5m
Width of overflow section	25 m
Design flood	5600 cumecs
(1 in 10,000years return period)	

- **Connecting Channel**

Type	Rectangular
Length	65m
Design discharge	150 cumecs
Connecting channel width	18 m
Connecting channel depth	8 m

- **Sandtrap**

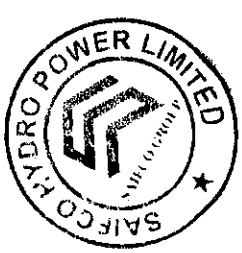
Nos. of chambers	3 Nos.
Sand trap length	115 m
Max. Effective sand trap depth	9.0m
Chamber Width	15m
Max. Operating level	650 m
Flushing channel	2.5m x 1.5m
Flushing channel length	2 Nos Length = 33m

- **Pressure Tunnel**

Tunnel length	10.22 km
Tunnel Dia	7m
Water Depth	7m
Flow velocity	3.5 m/s
Slope of connecting Tunnel	1:500

- **Surge Tank**

Surge Height	42m



Surge Tank Diameter	20m

- **Penstock**

Pressure Shaft Diameter	5.5m
Pressure Shaft Length	220 m
Penstock manifold	3m Dia 3 Penstock Branches

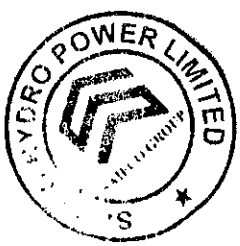
- **Powerhouse**

Powerhouse length	73m
Powerhouse width	35m
No. of units	3 Units
Type of units	Francis vertical
Generator Capacity	40 MVA
Generation Voltage	11 KV
Dispatch Voltage	11 KV

- **Tailrace Channel**

TYPE	Stepped Floor Type
Channel width	20
Channel depth	9.5m
Channel length	31m
Channel capacity	150 cumecs

• **Facility**	**Access**
Access from main Timergrah_Dir Road	Distance Km
Weir	500m
Connecting channel	500m
Surge Tank	25km
Penstock	25km
Powerhouse	25km
Colony	25km



11.5 DATA REQUIREMENT AND STUDY METHODOLOGY

Both primary and secondary data have been used to prepare this EIA report. Field visit were conducted to collect primary data, whereas all required secondary data were gathered through the review of literature adopting desk study method.

11.5.1 Desk study and literature review

Project relevant documents were reviewed to collect necessary data.

- Existing plans, policies, acts, rules and regulations related to Environment and hydropower of GoP;
- EIA report of Sharmai Hydropower Project approved in 1998 and other approved EIA reports of hydropower sectors.
- EIA report of Koto Hydropower project
- IEE report of Machai Hydropower project approved by ADB
- EIA report of 209 MW-Asrit-kedam hydroelectric power plant on Swat River

11.5.2 Field Visits

To collect and update baseline information and likely impacts on the existing environment, series of field visits were conducted in the project-affected area. EIA expert has visited the field several times over the last 9 months to update the physical, biological, socio-economic and cultural baseline data, as well as to ensure that the stakeholder's concerns were reflected in the design of the project, and to provide any new or required information to all stakeholders.

Secondary information in terms of physical, biological, socio-cultural aspects relevant to the proposal was collected from various sources.

11.5.3 Scoping Sessions with Stakeholders

This summarizes the consultation process undertaken as a part of the EIA (Environmental Impact Assessment) for the project Shigokas with installed capacity 102 MW in Lower Dir District. Scoping is critical, early steps in the preparation of EIA which identifies the issues that are likely to be of most importance during EIA process and eliminates that are of little concern. Initial consultations were undertaken by the expert with the technical experts in design sections working on this project, key government departments which are directly and or indirectly have interests or may likely to affect in this project and most importantly initiating

public consultation (see details in social assessment report). Stakeholder consultations were undertaken during EIA process lead by the environmental expert with the following objectives

- To facilitate onsite discussion with the design team to see in more depth environmental aspects during field visit to finalize the viable design.
- To share project information with a wide range of stakeholders, discuss and address potential issues and to voice their concerns.
- To gather baseline environmental data/information held by stakeholders and provided an opportunity to disseminate more detailed information about the purpose, nature, capacity, location and duration of various project activities.
- To aid project planning and development of mitigation measures and monitoring plans to address issues raised.

An output from the consultation was the base of issues tracking and gauges their severity which helped in finalizing the designs and in preparing this EIA report and formulating environmental management and monitoring plan.

Details of Stakeholders Consultation are in Annexure-11A

11.6 POLICY, LEGAL AND INSTITUTIONAL FRAMEWORK

11.6.1 Environmental Legislation and Pollution Control

The Constitution of Islamic Republic of Pakistan itself contains no statement of principles and policy about the rights and obligations of the state and its citizen with respect to the environment. It does however; confer concurrent legislative power on the Federation and the Provinces to legislate in respect of the environmental pollution and ecology. Prior to promulgation of the Pakistan Environmental Protection Ordinance (PEPO) of 1983 and the passage of the Pakistan Environmental Protection Act (PEPA), 1997, Pakistan had laws that contain provision for environmental protection, these laws dealt with land use, water quality, air quality, noise, toxic and hazardous substances, solid waste and effluents, marine and fisheries, forest conservation, mineral development, energy, public health etc. The laws include;

- The Pakistan Penal Code,1860
- The Canal Drainage Act, 1873
- The Motor Vehicle Ordinance, 1965: and the Motor Vehicle Rules, 1969
- The Factories Act, 1934
- The West Pakistan Fisheries Ordinance, 1961



- The Forest Act, 1927
- The Boilers Act, 1923
- The Pakistan Petroleum (exploration and production) Rules, 1986
- The Antiquities Act, 1975
- The West Pakistan Epidemic Diseases Act, 1959
- The Explosive Act, 1884

11.6.2 Pakistan Environmental Protection Ordinance, (PEPO) 1983

The Pakistan Environmental Protection Ordinance 1983 was the first piece of legislation specifically established to tackle the issue of environment. This ordinance provided for the establishment of a council to frame policies on standards for the environment, and the establishment of an agency to implement the policies and enforce the standards.

As a result the Federal Government of Pakistan established the Pakistan Environmental Protection Council and the Pakistan Federal Environmental Protection Agency (FEPA). The Ordinance permitted FEPA to delegate powers to any Government agency and it is understood that under this power the NWFP EPA and Punjab EPA were set-up in 1989. One particular task of the FEPA was to set national policy and standards.

Under the provisions of the 1983 Ordinance, the FEPA established the National Environmental Quality Standards (NEQS) that were gazetted as a Statutory Notification on 29 August 1993. These standards are to be applied to any project development through all phases of construction and operation. NEQS have been issued for liquid effluents and for industrial gaseous emissions. The former intends to restrict disposal of liquids from flushing of pipelines or tunnels; the latter maybe relevant to pumping or generating plant. NEQS also cover municipal effluents, motor vehicle exhausts and noise.

11.6.3 Pakistan Environmental Protection Act (1997)

Pakistan Environmental Protection Act, 1997 (PEPA) is the basic Environmental Legislation in the country. PEPA 1997 was enacted on 6 December 1997 with the objective of "protection, conservation, rehabilitation and improvement of environment for the prevention and control of pollution, and promotion of sustainable development". Other than PEPA 1997 environmental protection or resource conservation is partially covered under various laws such as the Pakistan Penal Code (1860), the forest act etc. The following major steps have been taken after the passage of PEPA 1997:

- The Pakistan Environmental Protection Council (PEPC) was reconstituted to give

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more representation to Provinces, trade and industry, and NGOs.

- Two Environmental Tribunals were set up, one in Lahore and the other in Karachi.
- The Lahore Tribunal has jurisdiction over the Provinces of Punjab, Khyber Pakhtunkhwa and the Federal Capital Territory while the Karachi Tribunal has its jurisdiction in the Provinces of Sindh and Baluchistan.
- Three of the four Provinces have designated Environmental Magistrates under the provision of Section 24 of the PEPA 1997.
- The Federal Government has delegated powers to the Provincial Governments for implementation of the Act.
- A system for self-monitoring and reporting for industry has been developed, which includes a Self-Monitoring and Reporting Tool (SMART). SMART is a software and information package to streamline data reporting. This would facilitate monitoring and networking with industries and Federal and Provincial EPAs.
- A National Coordination Committee headed by the Director General, Pakistan Environmental Protection Agency has been constituted under Section 7(k) of the PEPA, 1997 to supervise implementation of the environmental policies and enhance inter Provincial coordination.
- Analytical methods and sampling procedures have been formulated.

The Act includes the following additional clauses that are pertinent to assessment of environmental impact of projects:

S.R.O. 339 (1)/2001 – In case of the powers referred by Section 33 of the PEPA 1997 (XXXIV of 1997), Pak – EPA, with the approval of the Federal Government has introduced "Pak-EPA (Review of IEE and EIA) Regulations, 2000.

Clause 14 - Handling of Hazardous Waste: requires anyone who generates, collects, consigns, transports, treats, disposes of stores, handles or impacts any hazardous waste to have a permit to do so from FEPA.

Clause 16 - Environmental Protection order: permits FEPA to enforce protection measures and remediation where contamination of the environment has taken place. Where an order is not carried out, FEPA have the authority to carry out the required works and to recover the costs from the person responsible for the source of environmental contamination.

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11.6.4 Pak-EPA Review of IEE and EIA Regulations 2000

The Pakistan Environmental Protection Agency Review of IEE and EIA Regulations, (The 2000 Regulations) promulgated under PEPA 1997 was enforced in June 2000. These Regulations define the applicability and procedures for preparation, submission and review of IEE and EIA. These Regulations also give legal status to the Pakistan Environmental Assessment Procedures prepared by the Federal EPA in 1997.

The KPK-EPA is bound to conduct a preliminary scrutiny and reply within 10 days of the submittal of the report. It is required in these regulations that a monitoring report be submitted to the KPK-EPA after completion of the construction, followed by annual monitoring reports during operations. The contents of the monitoring report are not described in the regulations.

11.6.5 National Environmental Quality Standards (NEQS)

One of the functions of the Pak EPA under the provision of PEPO of 1983 was to issue NEQS for municipal and liquid industrial effluent, industrial gaseous emissions and motor vehicle exhaust and noise. The Pak EPA issued a statutory regulatory order (S.R.O) in 1994. It required all units coming into production after 1st July 1994 to comply immediately with the new standards. Those already in production at the time of S.R.O were required to comply starting 1st July 1996. The Pak EPA was not able to implement the NEQS effectively for many reasons, including lack of implementation capacity and resistance from industry.

With the PEPA, 1997 the Pak EPA revised the NEQS with full consultation of the private sector, industrialist, trade and business associations and NGOs. The municipal and liquid industrial effluent standards cover 32 parameters. The standards for industrial gaseous emissions specify limits for 16 parameters, and the standards for motor vehicles prescribe maximum permissible limits for smoke, carbon monoxide and noise. Revised standards cover discharges limits of effluents into inland water, sewage treatment plant and the sea. The NEQS are primarily concentration based. Unfortunately, the limits on industrial effluents are neither industry specific nor do they have any relationship with the quantum of production. The NEQS prohibit dilution, but this can be easily circumvented.

11.6.6 Self-Monitoring and Reporting System (SMART)

A system for self-monitoring and reporting for industry has been developed, which include a self-monitoring and reporting tool (SMART). SMART is a software and information package to streamline data reporting. This would facilitate monitoring and networking with the industrial and the Federal Provincial EPAs. A national coordination committee headed by the

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Director General, Pakistan Environmental Protection Agency has been constituted under section 7(K) of the PEPA, 1997 to supervise implementation of the environmental policies and enhance inter provincial coordination. Analytical methods and sampling procedures have been formulated.

The self-monitoring and reporting system (SMRS) of the Pak-EPA takes into account the resources and interests of both the EPA and industry. It classifies industries into categories A, B, and C, each corresponding to a specified reporting frequency. Category A) industry will report their effluents and emission levels every month, Category B) industry quarterly and Category C) industry biannually. The industries must have their effluents tested by a Pak-EPA certified/accredited laboratory and enter the results in the electronic forms included in the software package. The data must be sent to the respective Provincial EPA via email or on a floppy disk. Sampling and analysis requirements and procedures and the reporting format are also prescribed.

SMRS makes the country's industry owners and operators responsible for systematic monitoring and reporting of their environmental performance, saving EPA's expense, time and effort, as well as enabling industry to make long-term provisions for environmentally friendly production.

11.6.7 Pollution Charges

The modalities for the implementation of the pollution charges have been evolved through the process of coordination among representatives of industry, government, environmental NGOs and academic researchers. The consensus of all stakeholders has been to adopt a market based approach, i.e. a pollution charge or tax combined with fiscal incentives to industries, rather than a command and control approach through regulations to ensure compliance with NEQS. Appreciable progress has been made towards operational zing the process. Unfortunately, the January 1999 date set for implementation of the pollution charges programme met procedural and departmental hurdles.

The pollution charge payable by an industrial unit will be determined in accordance with guidelines to be prepared by the Pak-EPA. Industrial units liable to pay the pollution charge will themselves be responsible for ensuring the correct calculation, reporting and payment.

11.6.8 Pakistan Environmental Assessment Procedures

Pursuant to the provisions of the PEPA of 1997, all Government Ministries, Departments, Agencies and Establishments and private sector project sponsors are required to prepare the Initial Environmental Examination (IEE) and/or Environmental Impact Assessment (EIA)

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prior to the approval of their proposals for the projects. The primary purpose of the environmental assessment process is to provide proponents and decision makers, as well as members of the public, an understanding of the potential environmental effects of the proposed action, so as to avoid or minimize adverse effects, bearing in mind the costs and benefits of using the environmental resource in the individual project wherever possible. The Pak-EPA has developed a complete package of Environmental Assessment Procedures.

11.6.9 National Environmental Action Plan (NEAP)

Environmental issues are high on the Government of Pakistan's national Agenda. Government priorities and strategies are to be found to this affect the in the recently adopted National Environmental Action Plan (NEAP). The primary objective of NEAP is to initiate actions and programs for achieving a state of environment that safeguard public health, promote sustainable livelihood, and enhance the quality of life of the people in Pakistan. The NEAP has identified four primary areas, (1) Clean air (2) Clean water (3) Management of solid waste, and (4) Ecosystem management. The plan also presents five additional areas of concern (i) Management of fresh water concerns, (ii) Marine pollution, (iii) Toxic and hazardous substances, (iv) Energy conservation as well as management, and (v) Compliance with international treaties and protocol.

11.6.10 International Treaties and Conventions

Pakistan is a signatory/member to various international treaties and conventions on the conservation of the environment and wildlife protection. The country is obliged to adhere to the commitments specified in these treaties. The United Nations Conference on Environment and Development (UNCED), 1992 emphasize on Protection, rational use and development of resources; further prevention of degradation and reducing the risk of long term irreversible effects and conservation of biodiversity, and the sustainable use of genetic resources.

The World Heritage Convention makes it mandatory on signatory/member states to ensure identification, protection and transmission of the natural heritage to future generations. A world heritage site is a site (natural or cultural) recognized by the international community (in the shape of the World Heritage Convention founded by the General Conference of UNESCO in 1972) as possessing universal value, and coming under a collective responsibility.Other international conventions and programmes to which Pakistan is a party relate to biodiversity conservation, for all of which there is a national legislation. Three conventions dealing with species are:

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- Convention on Conservation of Migratory Species of Wildlife Animals, adopted in Bonn, Germany in 1979 which Pakistan ratified in 1987;
- Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES), signed in Washington in 1973 of which Pakistan became a party in 1976;
- Convention on Biodiversity (CBD), singed in Rio de Janiero in 1992 which Pakistan ratified in 1994;
- Convention on Wetlands of International Importance especially as Waterfowl Habitat, signed in Ramsar in Iran in 1971, to which Pakistan became a party in 1978; and
- Convention Concerning the Protection of the World Culture and Natural Heritage, signed at United Nations Educational, Scientific and Cultural Organization (UNESCO), Paris in 1972.

11.6.11 Administrative and Regulatory Framework

The FEPA is not concerned with environmental protection activities within individual provinces. This responsibility has been delegated to the Provincial EPAs, in this case the KPK EPA.

The KPK Wildlife Department is responsible for protection of wildlife in the Province. The concerns of the Department are limited to areas designated as game reserves, national parks or wildlife sanctuaries and to protecting species afforded protection under KPK Wildlife Act

1975. So long as the law is not being contravened they have no official interest in activities carried outside game reserves, national parks and wildlife sanctuaries. However, they have the power to halt illegal activities outside the protected areas.

Wildlife legislation in both pre- and post independent days was voluminous but in each case it was concerned almost entirely with the hunting and shooting of game species. The extermination of predators was encouraged and there was a lucrative trade in skins and other animal products in the mountain areas. Legislative needs arose due to international commitments. The present legislation mainly consists of provincial acts and ordinances in the mountain areas. They are: a) The KPK Province Wildlife (Protection, Preservation, Conservation and Management Act 1975); and b) The Northern Areas Wildlife Protection Act 1975.

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The laws on hunting in the protected, reserved and other categories of forests declared under Forest Act 1927 and Hazara Forest Act 1936 were not changed by the wildlife laws of NWFP. Two Federal Acts are applicable in all the provinces, namely Pakistan Forest Act 1927 and Pakistan Environmental Protection Act 1997.

The Forestry Departments manage official forestry reserves and has time and again expressed concern about the level of woodcutting, which has taken place as a result of the construction of access roads, construction of tunnels for the railways and roads and for oil and gas exploration.

Existing forest laws in KPK and the Northern Areas are largely reflective of outdated scientific knowledge and priorities and are not geared to current conservation needs. The reasons are numerous but a few deserve special mention. Human and livestock populations in the mountain areas have increased dramatically, rights and concessions of individuals have multiplied, and the timber prices have been greatly appreciated since the laws were enacted. Forests have

been victims of exploitation by timber mafia comprising those in authority even at the highest level of hierarchy that has little respect for the law and no concern for the principles of sustainable use. The various Forest Acts do not account for wildlife and their habitat, nor do they protect the interests of forest-edge communities.

In 1993, the Federal Government adopted a 25 year Forestry Sector Master Plan, which sets out policy guidelines for the future development and management of forestry sector. The Plan includes an Ecosystem and Biodiversity Action Programme, including schemes for rehabilitating the mangrove forest of the Indus Delta, protecting the Juniper chilgoza pine forests in Balochistan and all endemic and endangered species of flora and fauna and important ecosystem through the designation of conservation areas. The Plan also recommended that provincial forest legislation be updated to provide, among others, for the conservation of natural forest ecosystems and suggests a model law for the purpose.

The KPK Forest Ordinance 2001 stresses on the involvement of local communities and other stakeholders in the formulation and implementation of forest management plans and operational policies. This law seems to be in the interest of the mountain communities in terms of effective protection, conservation, management and sustainable development of forests and consolidation and updating of existing laws with a view to enacting a

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comprehensive law, which adopts modern concepts and promotes present day objectives of forest management. Its effective implementation is still awaited, however.

11.6.12 Policies and guidelines

A number of guidelines on the environmental protection are in use in Pakistan over the last ten years. An important document is the "Guidelines for Operating Safety, Health and Environmental Management in Pakistan Petroleum Exploration and Production Sector" produced by the Director General of Petroleum Concessions (DGPC).

The FEPA guidelines classify Power Production and Transmission systems exceeding 50MW as projects likely to require only an EIA.

The set of comprehensive "Sectoral Guidelines for Environmental Reports" were prepared by FEPA in 1997. They have not been formally published, although draft copies dated December 1997 are available for consultation. There is no specific Sectoral guideline pertaining to Hydroelectric Power Generation but some important environmental aspects like drilling and

disposal of mining wastes are covered by the "Guidelines on Oil and Gas Exploration and Production". The Guideline provides an overview of oil and gas exploration activities describes the associated potential impacts and suggests mitigation measures in general, along with monitoring and reporting parameters. Other relevant FEPA guidelines include:

- Policy and protection for filing, review and approval of environmental assessment.
- Guidelines for preparation and review of environmental reports.
- Guidelines for public participation.
- Guidelines for sensitive and critical areas.

The Ministry of Housing and works (Environmental and Urban Affairs Division) prepared EIA guidelines for selected industrial and power related projects with the assistance of the Asian Development Bank (ADB) in 1986. These guidelines have been endorsed by the FEPA, but usually only has significant relevance when ADB loans are involved, along with the various ADB Environmental Guidelines for Selected Development Works.

11.7 ENVIORNMENTAL BASELINE CONDTIONS

The environmental baseline data/information was collected from primary and secondary sources, field visits and scoping sessions with the officials of various departments including departments of forestry, wildlife, fisheries and water management.

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11.8 PHYSICAL ENVIRONMENT

The information on the physical environment was collected both from primary and secondary sources.

11.8.1 Climate

The summer season is hot and winter is extremely cold. A steep rise of temperature occurs from May to June, and then very hot during July to the end of August but during September weather turn in normal especially at nights. A rapid fall of temperature occurs from October onwards. The coldest months are December and January. The minimum temperature is -2.5 C° in the month of January while the maximum temperature is 32.4 C° in the month of June. Most of the rainfall occurs in the months of July, August, December, January and February. Towards the end of cold weather there are occasional thunderstorms and hail storms.

The annual rainfall over the area can be taken as similar to the surrounding areas. **Table 11.1** given below shows the rainfall pattern relevant to the area.

Table 11.1: Long Term Areal Monthly Precipitation

Long Term Areal Monthly Precipitation, Kalkot Barik				
Month	Station			
	Dir	Kalam	Drosh	Areal Barikot
	(mm)			
Jan	115.7	76.7	64.1	84.0
Feb	165.2	121.6	72.0	117.3
Mar	238.9	194.0	123.9	182.9
Apr	169.4	153.5	112.7	144.0
May	89.4	82.9	66.9	79.2
Jun	53.9	30.1	20.4	33.8
Jul	144.8	36.0	22.6	63.9
Aug	145.3	36.5	23.3	64.5
Sep	82.0	35.7	24.8	45.8
Oct	66.7	47.5	32.6	48.0
Nov	51.8	53.0	27.3	43.6
Dec	78.5	50.8	42.0	56.1
Annual	1401.7	918.4	632.5	963.3

11.8.2 Description of the Catchment

Proposed Gated weir site is located on Shigo Kas. The Panjkora River is the main tributary of Swat River. It rises high in the Hindu Kush at lat. 35.45, flows south through Upper Dir and

Lower Dir Districts and joins the Swat River near Chakdara, Malakand, Khyber Pakhtunkhwa. The project is located in Dir region. The gated weir site lies at latitudes 34° 45' 30.15 E and longitude 71° 48' 12.19" N. The catchment lies in Digital Elevation Model (DEM) in srtm_51_05 and srtm_51_06.

11.8.3 The Catchment

As given before, the drainage area of Panjkora River upto proposed gated weir site is about 5816 km^2, several streams drain into the Panjkora River upstream of proposed site and contribute appreciable amount of water for hydropower shown in Figure 11.4. The valley of Dir descends from an elevation of 5563 meters above mean sea level (masl) at weir site the bed level of river 639. The average slope in the watershed is about 1.2 %. The length of the main stream is 160 km.

Maximum area of Dir Lower surrounds River Panjkora which gushes out in the Hindukush and joins the Swat River at Tehsil Adenzai. Lower Dir is rugged and mountainous except from its lower parts round Chakdara (Tehsil Adenzai) and Munda area in the south west. River Panjkora is one of the rivers in the country contribute and facilitate water sources for cultivation and power generation. Dir lower is a hilly area and there is a net of small streams that ultimately joins the River Panjkora at one point or the other ("Punj" means 5 in Urdu and "Kora" means streams. Mainly River Panjkora is consist of two main streams i.e. one flows from Kohistan area and other from Ushairai Dara. Beside this there is net of relatively small streams that joins it in different places like, Toormang stream, Rabat stream, Shalfalam Stream, Kunai Stream (emerges from Maidan), and River Bajaur (Rodh) joins it from Bajaur. These streams in common routine remain dry but in summer (Moon Soon) April-August, it flooded high when it rains and brought huge destruction and gated weirage to the cultivated lands and commercial properties. River Panjkora and River Swat join each other at Chakdara and ultimately fall into River Indus. River Panjkora flows through nine Union Council which include Toormang, Shalfalam, Khall, Munjai, Timergara, Koto, Khungai, Balambat, and Bandagai. The people of these union councils have dependency on the river for drinking water and water for cultivation. A substantial piece of land lies on the bank of this river which it facilitates for watering the crops. The major crop which is the identification of this part of land is Mota Rice. This crop is the main source of food for these people.

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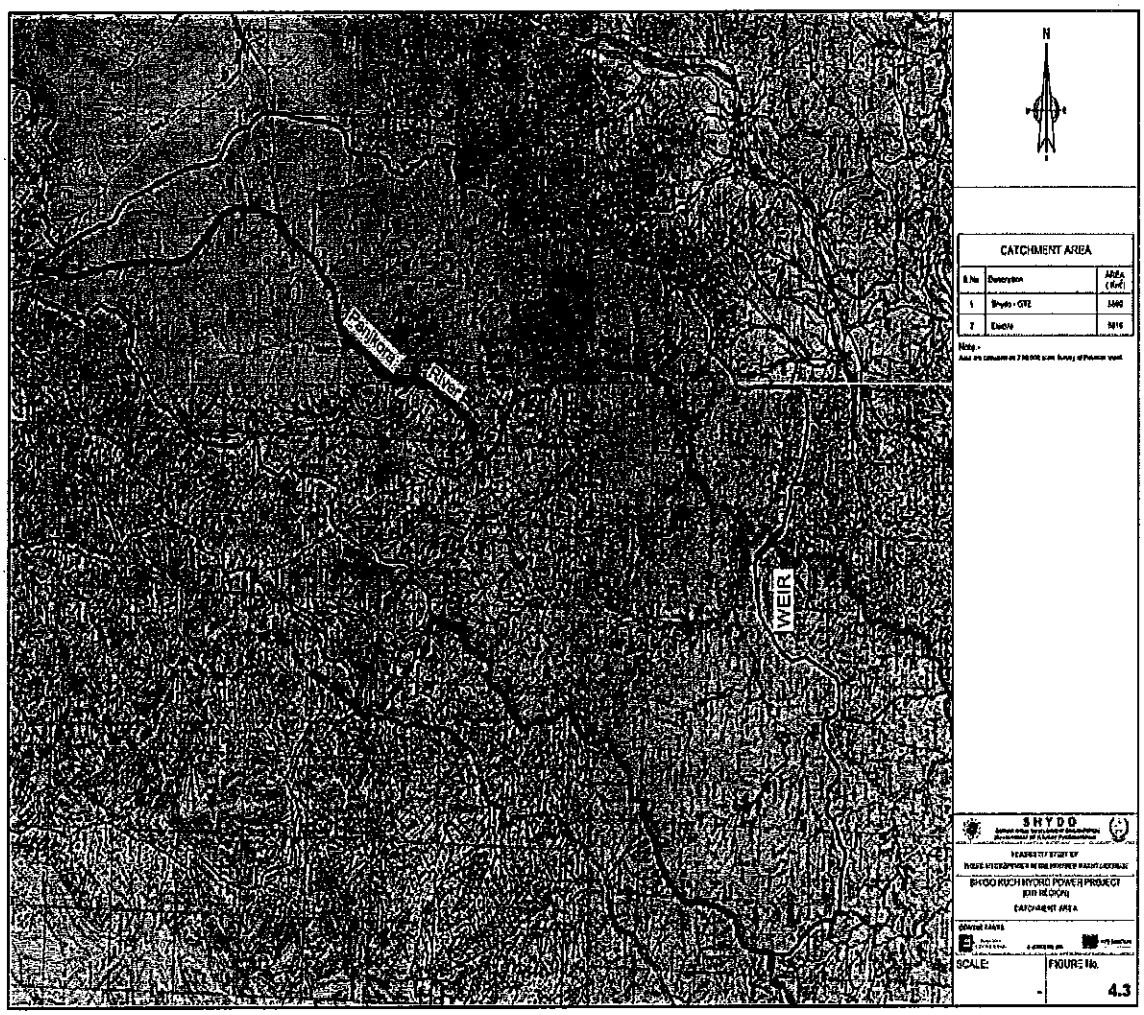

Figure 11.4: Catchment Area of the Proposed Hydropower Project

11.8.4 General Geology

The project area lies at the margin of Kohistan island arc and Higher Himalaya near the Main Mantle Thrust, MMT. The southern part of project area is comprised of Higher Himalayan rocks while the northern part comprised of rock of Kohistan sequence.

Higher Himalayan rocks are comprised of granite gneisses and its cover metamorphosed amphibolites and locally upper amphibolites facies (Chaudhry et al., 1994; Spencer, 1994). Chaudhry et al., (1994) assigned the nomenclature to these gneisses of basement and cover sequence as Kel group and Shardra group in upper Neelum valley, Purbinar group and Burawai group in upper Kaghan valley, Alpurai group and Slampur Formation in upper Swat valley. These units further extended westward to Dir, Bajaur and Afghanistan (Chaudhry et al., 1994). Two distinct varieties of gneisses can be characterized in the project area

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Rocks of Kohistan sequences are found in the north of MMT and it is comprised of ultramafics-mafic rocks of ophiolites and Kamila amphibolites and volcanics.

Scree

It is comprised of fallen materials by gravitational force, rock chips angular to sub angular usually found at the foot of vertical to sub vertical cliff or fur. It contains soil, clay, silt material drown/flown by weathering agent.

Alluvium

It comprises of sand grain, clay soil particles, organic materials and silt with gravels and boulders.

Major rock group of the project area are Granitic gneiss and widely spread along weir, Intake area, Sand trap, intake of tunnel, along the tunnel and power house areas. Poorly to well outcropped in and around Tunnel and outlet portal, In most of the reaches along Tunnel, rock of the area is well exposed and widely distributed under thin to thick cover of Secree/Colluviums and terrace deposits, details are described in geological report.

Soil types

Mostly the mountains are covered with primary soils, except along the river and nullahs where the beds are almost devoid of soil material either for steep slopes of for the scouring action of the river/nullah flows. Within the flood plains where slopes are milder to nearly level deposits of secondary soils are met with. Such areas include Munjai, Rani, Danwah and Baroon villages of Lower Dir District, which are used for agricultural purposes. Virtually, the land on both banks of the river is under agriculture.

11.8.5 Air and Noise Quality

No air quality monitoring data is available for the project area. The air quality of the project area and its vicinity is generally fresh and clear under normal condition. There is no major source of air pollution as there is no major vehicular movement or industrial setup in its vicinity. The vegetation cover in the area is thick and the level of ambient (suspended) dust increases during windy conditions and major traffic movement which is an occasional occurrence.

The air quality of the project area and its vicinity is generally good in natural conditions. The major reason is there is no industrial setup in the project vicinity and level of traffic is also very limited. However, the level of ambient (suspended) dust may increases during windy conditions and by more traffic movement which may occur during construction activities

Noise

The project area is located in the valleys surrounded by steep slopes having vegetation. There are some houses located near the sites of project component. Though the roads are available in the project area but the intensity of traffic is very low and the level of noise is assumed to be low. Generally, the ambient noise level in the project area is less than the permissible limits of 85 dB A as fixed by Pak – EPA, NEQS, 2000 or the WHO noise guidelines that prescribe a limit of 55 dB A with respect to receptors in outdoor areas.

11.8.6 Water Quality

Water samples of Panjkora River were collected. Laboratory results are shown in the Annexure-11B which shows water from Panjkora River is assumed to be good for drinking as well as for irrigation purposes. There is no industries exist in project area which discharge their effluent in Panjkora River so water from Nala/river and springs are also supposed to be safe for consumption. No water quality test is taken from these Nalas or springs

11.8.7 Rare or Endangered Species

There is no rare or endanger species is the vicinity of Shigo kas hydropower project.

11.9 BIOLOGICAL ENVIRONMENT

11.9.1 Natural Flora

The forests in the project area are the largest and most important resource and play a vital role in the economy of the area as a source of supply of timber, fuel wood, forage and grazing. Their other benefits in terms of watershed value, source of water supply for the rivers, aesthetic value, wild life habitat and grazing grounds are also important. The coniferous forests are largely protected forests burdened with all types of rights of extraction of timber and firewood, grass cutting and grazing for local use, unless specifically disallowed in certain areas. In commercial sale of conifer forests, 60% of the sale price is the community's share and the rest 40% is received by the provincial Government.

Lower Dir District is rich in natural vegetation. Besides the scattered vegetation in almost entire area, the hills are covered with forests of broad leaf and pine trees depending on the altitude. Fruit trees are also exist. These are generally found in the courtyards of the farming communities. Most common trees are Deodar, Shisham, Pine, Drake, Beri, Kahu and Bakain. Trees of Apricot, Pear, Persimmon, Peaches, and Walnut also exist in the district. Detail of flora in the District shown in **Table 11.2.**

Table 11.2: Details of Flora in District Lower Dir

Sr.No.	Scientific Name	Vernacular Name
1	Pinus roxberghii	Pine
2	Dalbergia sisso	Shisham
3	Cedrus deodara	Deodar
4	Melea azedarie	Bakain
5	Punica granatum	Drake
6	Zyziphus jajuba	Beri
7	Olea cuspidate	Kahu
8	Melia azedarach	Bakain
9	Robinia pseudoacacia	Rubania
10	Liriodendron tulipifera	Poplar
11	Diospyros digyna	Persimmon
12	Malus domestica	Apple
13	Prunus persica	Peaches
14	Pyrus boissieriana	Pear
15	Prunus armeniaca	Apricot
16	Sect. Juglans.	Walnut
17	Acacia nilotica	Kikar

Source: Feasibility of Koto Hydropower Project

11.9.2 Fauna of Dir-Kohistan

Dir Kohistan consists of the following habitat types:

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Most of the fauna in the project area are local / domestic. Owing to winter severity and moderately pleasant and short summers, no significant reptiles have been reported from the project area. Reptilian and amphibian fauna of the area is not well documented. However, local people have reported some snakes. Rock lizards are common in the region. The project area is also devoid of any habitat for the migratory species. Some species however, use local water resources as resting and feeding ground. **Table 11.3 and Table 11.4** enlist the wildlife occurring in the mountains of the District and domestic fauna in project area, respectively.

Table 11.3: List of Wild Fauna in District Lower Dir

Sr. No.	Scientific Name	Local Name
1.	Capre falconeri	Markhur
2.	Porous impejanus	Monal
3.	Ovis Orientalis	Urial
4.	Selenaretos, thibetanus	Himalyan bear
5.	Panthera pardus	Leopard
6.	Canis lupus pallipes	Wolf
7.	Vulpes bengalensis	Fox
8.	Maaca mulatta	Monkey

Source: Feasibility of Koto Hydropower Project

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Table 11.4: Detail of Fauna in Project Area

1.	S.senegalensis	Little brown dove
2.	Canis spp	Dog
3.	Streptopelia chinensis	Spotted dove
4.	Coraciiformes	King fisher
5.	Felis silvestris	Wild cat
6.	Sylvilagus brasiliensis	Rabbit
7.	Anoa spp	Buffalo
8.	Caprahircus	Goat
9.	Equus asinus	Donkey
10.	Equus Cahallus	Horse
11.	Equus spp	Mule

Source: Feasibility of Koto Hydropower Project

Avifauna

Bird life is scanty. The birds such as crow, kite and common sparrow, King Fisher, Monal, Little brown dove can be seen. The bird population is thin in project area. Besides common birds, some significant species of the upper and lower Dir Districts are Himalayan Snow Cock (Tetragallus himalayensis), Koklas Pheasant (Pucrasia macrolopha) and Snow Partridge (Lerwa lerwa

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Table 11.5: Status of General Wild life in the Panjkora Valley

S. No.	Species	Remarks
A. Mammals		
I	Rhesus Monkey	Common
ii	Markhor	At Risk
iii	Himalayan Ibex	Threatened
iv	Musk Deer	Rare
v	Black Bear	Occasional
vi	Brown Bear	Occasional
vii	Wolf	Common
B. Birds		
I	Snow Patridge	Protected
ii	Monal Pheasent	Protected
iii	Koklas Pheasent	Protected
iv	Chukar	Protected

Reference: Shermai Feasibility

11.9.3 Aquatic Fauna and Flora

The temperature of Panjkora River is extremely low, throughout the year. Secondly the flow of stream is very fast, so the conditions are not favorable for aquatic fauna and flora, and only that fish can sustain its adhesive organs to attach itself to the rock bed and those fish that rely for their good on that flora or fauna which are present in this rive.

11.9.4 Fish

Few species of fish are found in this river including brown trout and swati's trout (schizothdax), swati fish are also present on stream banks, masher and rainbow trout are also found in some seasons due to migrations. Site specific data on aquatic culture is lacking. Only recreational fishing is undertaken and there are no commercial fishermen in the area. No study has been done on the indirect economic benefit of trout fishing. According to Assistant Director (AD) Kalkot Fish hatchery, Serai to Kumrat, is a favorite trout area while Bala to Barikot is a Swati fish area. Trout includes both Rainbow and brown while others are

Katsary along with some other species etc; sufficient environmental flows are kept for the fish and other aquatic life survival. For free movement of fish and to avoid negative impacts on fish movement, provision of fish ladder is also suggested in this project.

11.10 SOCIO-ECONOMIC AND CULTURAL ENVIRONMENT

Social-economic baseline survey of the project area was undertaken to know the pre-project situation and status of households in order to establish a basis for developing the economic targets and livelihood rehabilitation plans for the PAPs, who will pass through the experience of project impacts i.e. loss of land, loss of production and other assets.

A socio-economic baseline survey was conducted in the project area and in the Indirect Impacts Zone through Focus Group Discussions and interviews with the key informants, Village Profile Information and related Secondary Data. Various components covered in this section include Demography, administration, dwellings, occupation, and household incomes, socio-cultural scenario, traditions, conflicts, ethnic condition, languages, religion, civic amenities, health, education, communication, drinking water facilities, electricity & other facilities.

11.10.1 Demography

Population and development are closely related and interdependent. Demographic patterns, population control and welfare measures may be integrated into comprehensive social and economic plans and development plans.

A brief account of demographic trends in Lower Dir district including the project area has been considered for this section according to the Censes Report 1998 and Development Statistics of KPK 2010, Salient features are depicted below in the **Table 11.6**.

Table 11.6: Population Status of Lower Dir District

S. No	Name of the Area	Population 1998	Estimated population 2010-11	Cumulative increase during 1998-2010/11
	Lower Dir Distt: (Timergara)	718000	1105000	53.81%
	Timargara Tehsil	74274	114233	
	Bagh Dushkhel UC	22875	35182	
	Bagh Dushkhel Village	2781	4277	
	Dogal	752	1156	
	Uttala Dushkhel	1072	1649	
	Banadgai	930	1430	
	Shamshi Khan	1905	2930	
	Zulam	329	506	
	Shigo	404	621	

11.10.2 Administration

Lower Dir was declared as a separate district of Malakand division on the 13th Aug 1996, the Deputy Commissioner is the Executive Head of the district. The district is divided into two sub-division. The sub-division have been further divided into six tehsils namely Samarbagh, Munda, Lal Qila, Balambat, Timergara and Adezai. The Deputy Commissioner is assisted by the Assistant Commissioners and Tehsildars for Revenue and maintance of law and order. Judiciary, Police Excise and Taxation, Education, Health, Irrigation, Agriculture, Forest, Public Health Engineering, C&W and other departments are available on district level to provide services to the population in the Timergara urban and rural areas.

11.10.3 Dwellings

Normally houses are constructed of bricks cement, mud and stones. Timber is extensively used in house construction. Joint family system is encouraged and is very common.

11.10.4 Occupations

Farming and trade are the main occupations in the district. A small population seeks employment in Govt, NGO and private institutions. Due to lack of employment opportunities people earn livelihood within and outside the country. Foreign remittances have improved living condition of some of the households. They usually invest this money in business.

11.10.5 Ethnicity /Tribes

Mashwani, Sadat, Shah-khel, Mastkhel, Shinwari, Yousafzai, Umarkhel, Osa Khel, Dushkhel, Mayar, Anikhel, Sultankhel, Lal Khan Khel, Akakhel and Atrafi are the major tribes in the district.

11.10.6 Culture, Customs and Traditions

People of Timergara district love traditions, culture and customs of Pakhtunwali. They are strict in following these traditions. They are simple, hardworking, religious people and conservative in approach Honour and dignity are the qualities of these people Hospitality is widespread and they prefer resolve their problems through Jirga.

11.10.7 Food

Maize, Wheat and rice are their staple foods. Beef, mutton, poultry and fish are used widely especially in well-off families. Guests are entertained with open heart. Special dishes are prepared for guest's entertainment, religious and on other festivals.

11.10.8 Dress

Dress is simple. Both men and women wear shalwar kameez. Males like caps and waster coat and chaddar. Females take chaddar, dopatta and burqa for observing strict parda, Western dress is discouraged by them.

11.10.9 Marriages and Deaths

These festivals are strictly managed by the family members, which are attended by all the family members, relatives and friends. Food is served at both the occasions with full monetary freedom.

11.10.10Health

Economic development and social progress are closely linked with the state of health of the population. Health facilities are essential not only to provide clean and disease free atmosphere to live but also to enhance the efficiency and productivity. The state of health of

an area and its population rests on availability of clean drinking water, sanitation facilities and number of doctors available in the medical units. It is essential to keep people not only free from communicable diseases but also to make sure quality of life and reduction in mortality rate.

People of the project area are facilitated with the rural level facilities like Dispensaries, Rural Health Centre, and Basic Health Units etc. The main medical facilities are available in the Lower Dir Medical Centers. Development Statistics of medical facilities is shown in the following **Table 11.7**.

Table 11.7: Medical Facilities in Lower Dir District in 2010-11

Sr. #.	Name of Insinuations	Nos.
1.	Hospitals	3
2.	Dispensaries	19
3.	Rural Health Centers	4
4.	Sub-Health Centers	2
5.	Basic Health Units	33
6.	Leprosy Centre	2

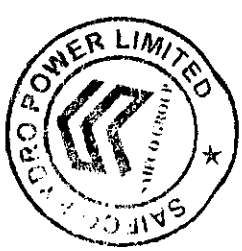
Source: KPK Development Statistics 2011

11.10.11 Education

Education is key to development Efforts have been made by the Government and private investors to boost up literacy rate in Lower Dir district. **Table 11.8** shows the number of educational Institutions in District Lower Dir:

Table 11.8: Educational Institutions in Lower Dir in the Year 2010-11

Sr. #	Institutions	M	F	Total
1.	Primary Schools	831	418	1249
2.	Middle Schools	92	61	153
3.	High Schools	62	38	100
4.	Higher Secondary	14	8	22



5.	Degree Colleges	2	1	3
6.	Govt. Colleges of Management Sciences	-	-	2
7.	Technical Vocational Centers	-	-	3
8.	Govt. Universities	-	-	1
9.	Private Primary Schools	-	-	157
10.	Private Secondary Schools	-	-	80
11.	Maktab Schools	-	-	175

The increased Number of Educational Institution has raised the literacy rate of the district and encouraged female education especially in rural areas.

11.10.12Communication, Roads and Transport Facilities

The district is equipped with land line, wireless loop and mobile telephone systems up to village levels. There are 34 telephone exchanges and 67 post offices in the district providing coverage to both urban and rural areas.

The district rural areas are well connected with black-topped roads and shingle roads. The weir site of the project is situated on Timergara – Chakdara road while the power house site has Katcha and Pakka mixed road approach.

Transport Facilities are available in plenty both for passengers and goods transportation.

11.10.13Civic Amenities

A number of civic amenities are available in the district like drinking water, electricity, sanitation and drainage, roads, streets & street lights etc. Street lights are restricted to the urban localities only.

Drinking Water: Drinking Water is mostly fetched from the rivers and springs which is of good quality. Public Health Engineering Department is responsible for water schemes. For domestic use water is uplifted or brought form the river.

Electricity: Mostly the area is electrified though WAPDA connections.

Drainage & Sanitation: Project area has good slopes which helps quick disposal of waste water and run-off during rainy season. The outlet is river Panjkora or its tributaries. In populated areas waste water is drained out to the river which creates pollution problems.

11.10.14Agricultural Services & Institutions

Agricultural Extension, Animal husbandry and other related departments are available in the area and provide services to the local farmers through district headquarter and sub-offices. Loan facilities are available from the commercial banks. Marketing of produce is done easily through trucks and small vehicles.

Crops: December, January and February are cold and June, July and August are the hot months. Maximum rainfall month is March with average 240 mm. Cropping pattern suited to the climate of Lower Dir includes maize, rice, wheat, barley, mustard, onion and vegetables. Fruits include walnut, persimmon, apple, pears, plums, apricot, fig, loquat and mulberry. The blood red variety of sweet oranges (Malta) of Rabat area is well known in the country and abroad.

Goats, sheep, buffaloes and cows are common livestock reared in the project area. The animal products are utilized domestically as well as for marketing. Agricultural produce is usually utilized for domestic use because landholdings are small. Irrigation is done through government as well as private canal systems. Tub wells, open wells, tanks and lift pumps are also used for irrigation.

11.10.15Industry Trade & Trade Centres

The district is famous for the trade of food-grains. Major trade centers are at Timergara, Mayar, Samar Bagh, Monda, uch, Chakdara, Talash, Ziarat and Rabat. Most of daily use commodities and other amenities are brought from big cities including Peshawar, Rawalpindi, Lahore, Faisalabad, Gujranwala and Karachi. The nearest main trading center is Batkhela, Malakand District.

Flour mills, furniture, cement based industries, marble and chips industries and rice mills exist in the district. Cottage industry is restricted to caps and knives making.

11.10.16Gender Roles

The district reflects male dominated society where gender roles and responsibilities are well defined. Male population works outside for livelihood earnings while women shoulder the responsibility of household activities. Some agricultural activities are also shared by women.

Improving trends in education have provided employment opportunities for females in education and medical sectors. Women decision making role is confined to the domestic sphere. Women are strict parda observers and their interaction with the outsiders is not allowed. Information regarding female roles are provided by the male family members only if they desire.

11.10.17Poverty and Vulnerability and House Hold Income

People of the project area are not well off generally. Some people who have business, income from the family members living aboard forest ownership or regular employment run their domestic affairs properly but majority of people hardly earn their livelihood. Poor people are living without fundamental freedom of action and choice. They often lack food, shelter, education and health.

11.11 CONSIDERATION OF ALTERNATIVES

11.11.1 Alternatives Analysis

This section comprises of alternative layouts that were considered during the selection of the final project layout.

The design discharge of 135 cumecs (as per regional power development study by PEDO and GTZ) has been used for the design of various components of project and installed capacity for comparison and screening of various alternatives. For the seventh alternative a discharge of 150 cumecs is used. The project involves a concrete weir, sand trap, connecting channel headrace tunnel, surge shaft, penstock, powerhouse, tailrace canal and housing area.

For comparison of different alternatives, the tentative cost estimates of various components of project layouts have been work out based on available Norwegian standard charts and curves for costing.

For the selection of more viable site of the project, seven different alternatives were considered and analyzed to go for the most suitable layout of the project for further studies.

Other details are given in relevant section of the Feasibility Report.

The basic data of Alternative #.7 is given in **Table 11.9 to 11.11,** which is used for further study.

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Table 11.9: Basic data of Alternative No. 7

Gross Head	91 m
Design Discharge	150 cumecs
Installed Capacity	102 MW
Weir Type	Ogee and Gated
Sand Trap Structure	Yes
Gravel Spill Structure	Yes
Headrace Tunnel Length	10.22 km
Connecting Channel Length	65 m
Surge Shaft	42 m high & 20 m diameter
Pressure shaft Length	220 m
Access Road	25.5 km
Environmental/Social Issues	Minimum
Energy Cost (Rs/kWh)	6.28

Table 11.10: Comparison of Alternatives Layouts

S.No	Feature	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
1	Gross Head (m)	35	20	18	48	48	48	91
2	Design Discharge (m3/sec)	135	135	135	135	135	135	150
3	Installed Capacity (MW)	39.3	20.6	18.1	46.8	51.7	54.4	102
4	Weir Type	High Dam with spillway, bottom outlets	Overflow Weir with under-sluices and stilling basin	Overflow Weir with under-sluices and stilling basin	Overflow Weir with under-sluices and stilling basin	Weir with spillway, bottom outlets & stilling basin	Dam with spillway, bottom outlets	Overflow Weir with under-sluices and stilling basin
5	Turbine	Francis	Kaplan	Kaplan	Francis	Francis	Francis	Francis vertical
6	Sand Trap	Yes	Yes	Yes	Yes	Yes	Yes	Yes
7	Gravel Spill Structure	No	No	No	No	No	No	No
8	Headrace Tunnel Length (km)	0	1.30	1.40	6.3	2.3	0	10.22

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S.No	Feature	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Alt. 6	Alt. 7
9	Surge Shaft	No	Yes	Yes	Yes	Yes	No	Yes
10	Penstock Length (m)	140	170	160	170	170	140	
11	Inspection Road (km)	No	No	No	No	No	No	No
12	Access Road	4.5	5.0	4.5	12.5	12.5	12.5	25.5
13	Environmental/ Social issues	Severe	Minimum	Minimum	Minimum	Minimum	Minimum	Minimum
14	Energy Cost (Rs / kWh)	9.63	8.58	10.64	7.31	6.46	7.77	6.28

Table 11.11: Financial Comparison

Alt. No.	Capacity	Energy	Cost			NPV		Tariff
			Civil	Equipment	Total	Economic	Financial	
	(MW)	(GWh/year)	(Million Rs.)			(Million Rs.)		(Rs./KWh)
1	39.3	182.09	9119.87	2098.46	11218.34	4776.96	626.57	6.93
2	20.6	95.43	3924.98	1303.95	5228.93	3554.32	1092.01	8.58
3	18.1	73.13	3867.97	1102.64	4970.61	1920.62	-330.93	10.64
4	46.8	216.42	7599.71	2469.00	10095.71	8851.88	4637.09	7.31
5	51.7	239.40	7145.35	2714.69	9860.04	11050.96	9705.80	6.46
6	54.4	251.71	9685.18	2818.65	12503.82	9381.57	4484.79	7.77
7	102.0	566.70	11109.55	4823.89	15933.43	12833.60	9052.18	6.28

11.12 ENVIRONMENTAL FLOWS

A river is the only ecosystem that connects other ecosystems, carries water, transports dissolved minerals, sediments and nutrients to maximum places before emptying into its natural outlet. How much water would flow through a river channel and the sediment and nutrient load carried by a river is decided by the nature of the catchment and the rainfall or snow fall pattern. Flowing rivers connect different ecosystems like glaciers, forests, riparian zones, flood plains, mangroves, etc. on their way. Flowing rivers also create flood plains, sand deposits, deltas, etc. Rivers while draining the land carry out groundwater recharge by

percolating into deeper aquifers. All rivers do not necessarily flow directly to the seas or open oceans.

High flows of different frequency are important for channel maintenance, bird breeding, algae control, wetland flooding and maintenance of riparian vegetation. Moderate flows may be critical for cycling of organic matter from river banks and for fish migration, while low flows of different magnitudes are necessary for fish spawning, water quality maintenance, the use of the river by local people, etc.

It is hence imperative to understand the inextricable linkages between flowing rivers and dependencies of communities, which is at the core of the 'environmental flows' concept. . Considering this reality, devising ways for mainstreaming community concerns and efforts in water management within a river basin in general and e-flows in particular is a challenging task. The term environmental flow refers to the quantity, quality, and timing of water flow needed to sustain ecosystems and the services they provide to humans (Dyson et al. 2003; Poff et al. 2010). A distinction should be made between the natural flow regime of a river that would maintain ecosystems in a pristine state and an environmental flow. An environmental flow has the goal of allocating sufficient water to ecosystems to maintain.

Since the concept emerged in the mid-20th century, more than 200 methods for estimating environmental flows have been developed globally. These methods can be classified into four approaches (Tharme 2003). Hydrology-based methodologies use historical discharge records to make environmental flow recommendations, usually expressed as a fixed proportion of flow intended to sustain river health (e.g., 10% of average annual discharge). Hydraulic-rating methodologies rely on basic hydraulic parameters (e.g., depth, wetted perimeter) that relate to habitat for aquatic biota; environmental flow recommendations are made by plotting acceptable levels of reduction in these parameters against discharge. Hydraulic-rating methodologies preceded more sophisticated habitat simulation methodologies that employ hydrological hydraulic and biological response data to quantify suitable in stream physical habitat available to target species, usually fish, under different flow regimes. Habitat-discharge curves depicting the range of habitat for biota as a function of flow are then used to determine environmental flow recommendations. Holistic methodologies aim to approximate the natural flow regime, and often employ some of the tools of hydrology-based, hydraulic rating, and habitat-simulation approaches.

Reference: A Primer on Environmental Flows Latha Anantha & Parineeta Dandekar, 2012

In the absence of a specific guideline or recommendations in Pakistan for the amount of water (residual water) to be retained in a water reach as an environmental flow when water

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is diverted for hydropower purposes, following two different methods were considered to evaluate ecological flow:

1. USA (Montana) Method

Hydrology-based Tennant (Montana) Method (Tennant 1976) This Provides guidelines for flow management based on the percentage of average flow that would maintain biological attributes of a river as optimum (>60%), outstanding (40%), excellent (30%), good (20%), fair, poor, minimum, or degrading (10%).

This method is known as Tennant or Montana method. The Panjkora River downstream reach has low biological productivity. Commercial fishery is not being practiced in the reach.

2. CEMAGREF Model:

For the determination of ecological flow, a formula representing a function of the available mean monthly discharges and the mean annual discharges, was used as presented below,

$Qe = \{(0.0651 \times Qm+2) /100\} \times Qa$

Where Qe = Mean monthly ecological flow (m^3/s)

Qm= Mean monthly flow (m^3/s)

Qa = Mean annual flow (m^3/s)

The formula was also used for feasibility study for Madian HPP, Koto hydropower feasibility and feasibility study of the Gabral-Kalam HPP and was developed by CEMAGREF which is an Agricultural and Environmental Engineering Research Organization of (Antony) France. The model is also recommended by the International Association of Small Hydropower.

The CEMAGREF Model is also used as a reference to calculate the mean monthly ecological or residual flows as this method was used in Koto hydropower project feasibility study to calculate environmental flows.

The available discharge of 150 cumecs was optimized for getting maximum benefits by generating average annual energy of 520 Gwh after leaving 3.0 cumecs in low flow seasons as environmental flows for maintaining river ecology. Although, recommended environmental flows falls under category of poor or low biological attributes of a river by using USA (Montana) method. As there is no irrigation requirement and just to accommodate fish culture in this reach, availability of 3.0 cumecs is sufficient in prevailing conditions as environmental flows, shown in Table 11.12.

Table 11.12: Showing Mean Monthly Flows with Ecological Flows

Months	Mean Monthly Flows	Ecological Flows Calculated by CEMAGREF Model	10% Calculated by USA (Montana) Method
Jan	40.22	6.94	4.02
Feb	41.69	7.08	4.17
Mar	59.34	8.81	5.93
Apr	116.45	14.40	11.65
May	231.39	25.64	23.14
Jun	362.39	38.46	36.24
Jul	368.50	39.06	36.85
Aug	261.46	28.58	26.15
Sep	144.58	17.15	14.46
Oct	76.67	10.51	7.67
Nov	55.29	8.41	5.53
Dec	45.31	7.44	4.53

Note: Flows are in cumecs

11.13 IMPACT PREDICTION AND DETERMINATION

11.13.1 Screening of Anticipated Environmental Impacts

Assessment Procedure

Assessment of the significance of impacts identified (assessment of effects) enables identification of necessary mitigation and a determination of environmental and social costs associated with the project. Environmental or social impacts can either be beneficial or adverse and are assessed by making a comparison between the quality of the existing environment and the predicted quality of the environment once the project is in operation.

In order to describe the significance of an impact, it is important to distinguish between two concepts, sensitivity and magnitude. As far as possible impact magnitude and sensitivity are described with reference to legal requirements, accepted scientific standards or accepted

impact assessment practice, and / or social acceptability. Where no known published 'standard' criteria exist for determining the magnitude of effects, established professional criteria and best practice techniques are used and clearly described.

This EIA identifies the impacts likely to arise as a result of construction and operational activities associated with Shigo Kas Hydropower Project and assess the likely magnitude of impacts in order to provide some indication as to which impacts are likely to be most significant. Impact assessment is based on baseline information collected during technical studies, desk review, site surveys, environmental studies and field visits to the project area.

A full determination of the significance of the identified impacts, based on an assessment of magnitude in relation to the sensitivity of the receiving environment, has been made as part of the EIA. A description of the methodology for determining significance is provided below.

Sensitivity

Sensitivity is generally site specific and criteria are developed from baseline information gathered. The sensitivity of a receptor is determined based on review of population (proximity/numbers/vulnerability), presence of biological features of the site or the surrounding area, soil, agricultural suitability, geology and geomorphology, proximity of aquifers, watercourses, existing air quality, presence of architectural and historic heritage, landscape etc.

Sensitivity, relates to the value, importance and tolerance of an environmental resource or receptor and should take into account where possible stakeholders views and public acceptability. Sensitivity can be categorized as high, medium, low, and negligible to the assessment of receptor sensitivity.

Magnitude

The assessment of magnitude is undertaken in two steps. Firstly the key issues associated with the project are categorized as being either adverse or beneficial.

Secondly, beneficial and adverse impacts are then further subdivided into major, moderate, minor or negligible based on consideration of the parameters listed below:

- Duration of the impact.
- Spatial extent of the impact.
- Reversibility.
- Likelihood.
- Legal standards and established professional criteria.

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This report aims to categorize the magnitude of impacts identified according to categories outlined in **Table 11.13.**

Table 11.13: Parameters and Examples of Criteria used to Determine Magnitude of Impacts

Parameters	Major	Moderate	Minor	Negligible
Duration of the impact	Long-term (more than 35 yrs)	Lifespan of the project Medium term (5 to 15 yrs)	Less than the project lifespan (i.e. construction) Short-term (0-5 yrs)	Temporary with no detectable impact
Spatial extent of the impact	Widespread far beyond project component site boundaries (e.g. powerhouse site, dam site, borrow pit area, etc. as applicable) boundary Regional / national / international	Beyond immediate project component site boundaries Local area	Within project component site boundaries	Specific location within project component site boundaries with no detectable impact
Reversibility of impacts	Impact is effectively permanent, requiring considerable intervention to return to baseline	Baseline requires a year or so, or with some intervention, to return to baseline	Baseline returns naturally or with limited intervention within a few months	Baseline remains consistent
Legal standards and established professional criteria	Breaches national standard limits and / or international guidelines	Complies with national standard limits but breeches international / Lender guidelines in one or more parameters	Meets minimum national standard limits and / or international guidelines	N/A

Parameters	Major	Moderate	Minor	Negligible
Likelihood of impact occurring	Occurs under typical operating / construction conditions	Occurs under worst case (negative impact) or best case (positive impact) operating conditions	Occurs under abnormal / exceptional / emergency conditions	Unlikely to occur

Assigning Significance

The significance of an impact is determined by the interaction of magnitude and sensitivity as depicted in the significance matrix shown in **Figure 11.5** and **Table 11.14**.

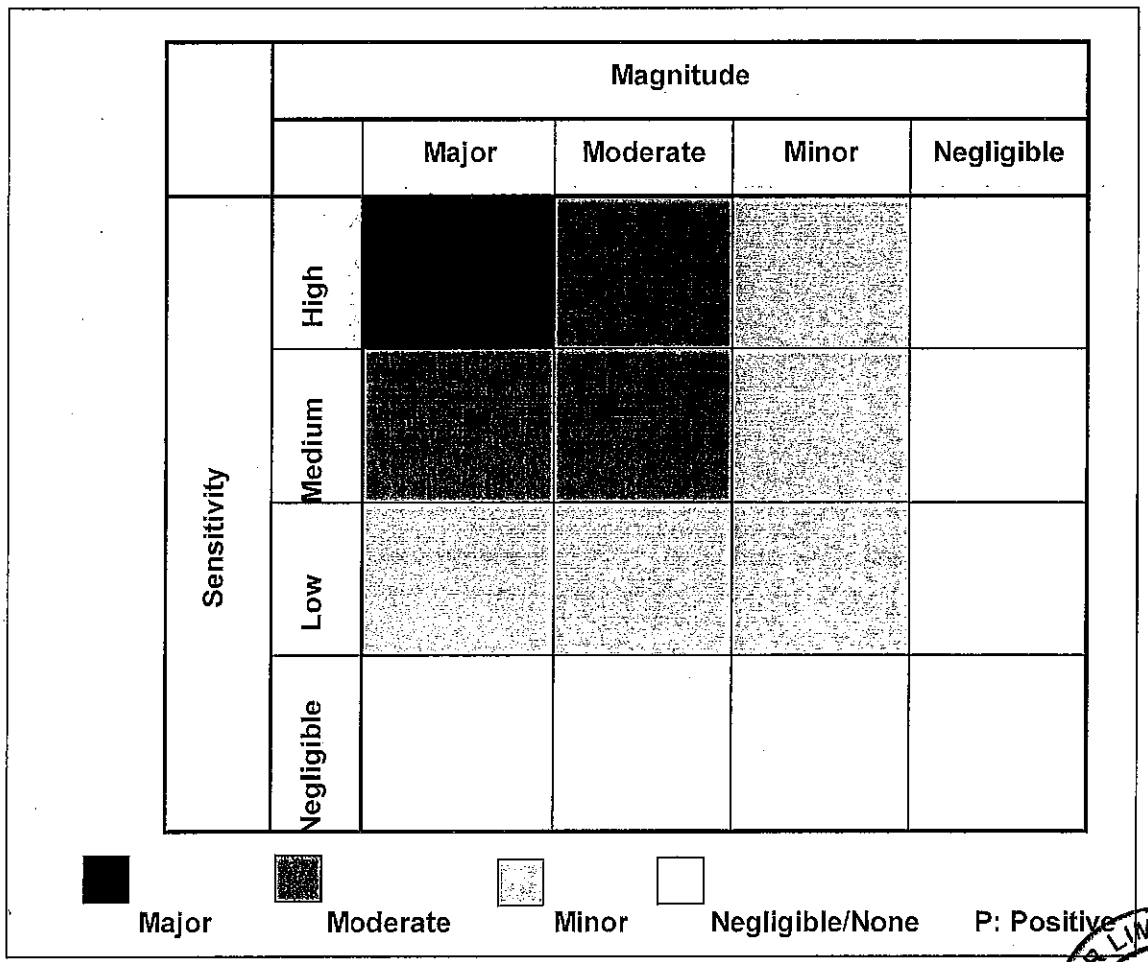

Figure 11.5: Significance Matrix

Table 11.14: Significance Matrix

Significance	
Negligible	No detectable impact - i.e. effects are within the range of normal natural variations in the system. No additional mitigation is required.
Slight	Short time scale of the activity or event. Area over which the activity or event may occur is <5 of the area occupied by the resource of concern. Affects a specific group or localized receptors / population. Activity does not exceed statutory limits. No mitigation is required.
Moderate	Time scale of the activity or event is 5-10% of the regeneration time of the resource of concern or a critical sensitive period. Area over which the activity or event may occur is 5-10% of the area occupied by the resource of concern. Affects a portion of a population and impact may bring about a change in abundance and/or distribution over one or more generations, but does not threaten the integrity of that population or any population dependent on it. Affects users of natural resources, but only in the short term, or resources used by a minority of local people (<10%). Some mitigation will help minimize impacts.
Substantial	Time scale of the activity or event is >10% of the regeneration time of the resource of concern or a critical sensitive period. Area over which the activity or event may occur is >10% of the area occupied by the resource of concern. Causes a decline in abundance/distribution of an entire population or species, beyond which natural recruitment would not return that population or species, or any population or species dependent upon it, to its former level within several generations without mitigation. Users of natural subsistence or commercial resources (on which more than 10% of local people depend) are affected to the degree that their well being is affected over a long term, if mitigation not applied. Activity occasionally exceeds statutory/regulatory limits, and mitigation is required.
Critical	Event or activity is considered significant and not amenable to mitigation. Affects an entire population or species to cause a decline in abundance and /or change in distribution beyond which natural recruitment would not return that population or species, or any population or species dependent upon it, to its former level. May affect a subsistence or commercial resource (on which more than 10% of local people depend) use to the degree that the activity is no longer viable. Activity regularly exceeds statutory/regulatory limits, and changes to project design may be required.

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Assessment of the significance of identified impacts is essentials and enables identification of necessary mitigation associated with the project. Environmental impacts can either be beneficial or adverse. In order to describe the significance of an impact, As far as possible impact magnitude and sensitivity are described with reference to legal requirements, accepted scientific standards or accepted impact assessment practice. The assessment of magnitude is undertaken in two steps. Firstly the key issues associated with the project are categorized as being either adverse or beneficial.

Secondly, beneficial and adverse impacts are then further subdivided into major, moderate, minor or negligible based on consideration of the parameters listed below:

- Duration of the impact.
- Spatial extent of the impact.
- Reversibility.
- Likelihood.

Project Activities / Environmental Impacts	Access Roads	Construction Machinery	Const. of Camps / Workshops/Colony	Blasting Operation	Tunnel Construction	Dam/Weir Construction
Physical Impacts						
Air Quality						
Noise and vibration						
Soils						
Water use / quality						
Hydrology						
Erosion / sedimentation						
biological Impacts						
Forestry / vegetation						
Birds						
Fisheries						
Other wildlife / land animals						
Aquatic flora						
Health, safety and security						
Community disturbances						

	Moderate	Minor	Negligible / None

Figure 11.6: Environmental Impacts of Project Activities

11.14 PHYSICAL AND BIOLOGICAL ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

A summary of the impacts and mitigation measures regarding the project during construction and regular operation of the project is given here under. For a comprehensive treatment reference has been made to the Environmental Management Plan preceding this write-up.

11.14.1 Air Impacts

Impacts during Construction

The major impact on air quality during construction will be due to enhanced dust levels from construction machinery, shock waves and dust during rock blasting, tunneling, excavations, cement mixing, road construction and other civil construction and smoke from construction machinery and vehicles. Dust from transport and wind generated dust from project activity may impact upon vegetation, trees, plants, crops, animals, houses located nearby and human health in terms of lungs and eyes irritation and reduced visibility. Deposition of dust on plant leaves may impact photosynthetic activity and result in increased incidence of plant pests and diseases and reduced crop productivity.

Sensitive receptors likely to be susceptible to air emissions are villages/schools adjacent to the road as well as those near the weir or powerhouse sites and workers at site. The impacts will be limited and localized to the project sites and for a short period.

Impacts associated with air quality during the construction phase are considered to be of be moderately negative significance, given the extent of the area to be affected, duration of construction, and presence of sensitive receptors.

Mitigation Measures

The unpaved parts of the road leading to the construction sites and the construction sites will be regularly sprayed with water; at least twice a day during hot and dry period and the maintenance of vehicles will be properly managed and monitored. This will mitigate the problems.

Minimizing dust from open area sources, including storage piles, by using control measures such as installing enclosures and covers, and increasing the moisture content.

Avoid open burning of solids.

Minimizing dust from material handling sources, such as conveyors and bins, by using covers and /or control equipment.

Impacts during Operation

During operation, air pollution is expected to be very limited, and the main sources will be from vehicle emissions / dust from maintenance traffic on unpaved roads and increased traffic due to movement of workforce. In addition, there may be some dust from construction quarries and sites before they are fully rehabilitated.

Impacts on air quality during operation are not considered to be significant.

Mitigation Measures

Few mitigation measures such as proper vehicle tuning and road maintenance etc. are available to limit influx of traffic movements resulting from improved road infrastructure.

11.14.2 Noise and Vibration Impacts

Impacts during Construction

During the construction phase, the noise and vibration will generally be generated from vehicular movement, sand and aggregate processing, tunnel construction, concrete mixing, excavation machinery, 'mucking out' of excavated material, construction noise and blasting.

Construction activities will begin with the road enhancements to enable access to the powerhouse and weir sites, followed by other structures and headrace tunnels. Noise will be concentrated at powerhouse and weir sites; however, increased traffic to and from construction material sources and workers will result in noise impacts.

Further, the increased access as a consequence of the road improvements may generate some additional traffic which could also impact on the existing noise levels in the project area. Therefore, appropriate noise reduction measures will be taken to reduce the generation of any noise levels.

Noise levels in the construction area from machinery and vehicles are estimated to remain between 70 to 80 dBA. Noise and vibration disturbance will be experienced by the people living very near to the construction sites. The phase is temporary and short term. Construction workers will be the main potential target of high noise levels.

Impacts associated with construction noise are considered to be of moderate negative significance, considering the size and extent of the project area affected.

Mitigation Measures

Mitigation measures for noise impacts on construction workers will include standard occupational health and safety practices such as ear protection and enforcement of exposure duration restrictions.

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Blasting activity should be limited or restricted during night time, if noise levels are unacceptable for people living in the vicinity and to reduce impacts on wildlife.

Using noise control devices, such as temporary noise barriers and deflectors for impact and blasting activities, and exhaust muffling for combustion engines.

Avoiding or minimizing project transport through community areas.

The Contractor as well as the resident Project Manager will be responsible for compliance with the health and safety requirements regarding blasting activity including (i) proper storage and safety of the explosives, (ii) restriction of the blasts to daytime, and (iii) proper siren system to warn the workers and evacuate the grounds before the blast etc;

Impacts during Operation

Power station will be the major source of noise during operation. The noise will mainly be generated in the power station only through the operation of the electrical and mechanical equipment.

Noise impacts during operational phase are considered to be of minor significance.

Mitigation Measures

The proper noise control measure will be taken in powerhouse operation for noise reduction, therefore, the noise levels will not exceed the limiting value as desired by the national and international Standards.

Mitigation measures for noise impacts on workers will include standard occupational health and safety practices such as wearing of ear plugs in noisy area.

11.14.3 Solid Waste

Solid waste during the construction phase will consists primarily of tunnel muck along with excessive concrete and cement, rejected components and materials, packing and domestic garbage. Such waste can contaminate the soil, surface water, air quality. Other non-hazardous solid wastes include office, kitchen, and workers camp waste. Hazardous solid waste includes contaminated soils, or small amount of machinery maintenance materials, such as oily rags, used filters, and used oil as well as spill cleanup materials from oil and fuel spills.

Impacts associated with this activity are considered to be moderate and are of medium term in duration in surrounding areas.

Mitigations

Muck disposal be made at approved sites by the client and Consultants.

Construction places, storage houses, and camps should be kept clean, and waste should not be burnt or abandoned. Solid waste should be deposited in temporary waste sites such waste sites should be situated more than 50 meters from any residential areas and drainage lines and then all waste should be disposed-off properly at approved sites.

Concrete and cement excess and left-over not usable should be broken down in small pieces and deposited in proper waste disposal sites. Packages made of bio degradable material such as paper, cardboard and wood should be deposited in waste disposal sites and for reuse purposes. A team must be responsible to maintain working site clean, collecting all solid waste produced by the workers involved in the project.

All workers must receive induction training with respect to not polluting environment, waste management procedures and penalties for polluting environment, such as, providing adequate secondary containment for fuel storage tanks and for the temporary storage of other fluids such as lubricating oils and hydraulic fluids, using impervious surfaces for refueling areas and other fluid transfer areas, training workers on the correct transfer and handling of fuels and chemical band responses to spills, providing portable spill containment and cleanup equipment on site and training in the equipment deployment.

11.14.4 Impacts on Hydrology

Water flow will be minimized from intake at weir site to the powerhouse out fall. According to site survey and interviews with the local people it was revealed that downstream section of Panjkora River below the weir, there is very little human consumption of river water along with aquatic life requiring water in Panjkora River for its survival.

Therefore, under these circumstances a certain quantity of compensation water should be released to sustain and survival of any human activity and aquatic life in the section of the Panjkora River under discussion.

Impacts on hydrology during operation are considered to be of moderate negative significance.

Compensation flow has been estimated based on the average monthly flows to maintain the ecology of Panjkora River. The weir site has flow values from which about 20% of minimum monthly flow will be released in Panjkora River as compensation flow. This flow is in addition to the flows of streams / tributaries joining the river downstream the weir.

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Mitigation Measures

To mitigate the hydrological impacts, the following measures are recommended:

A recommended compensation water flow should be released in the river during construction for the survival of any aquatic life in the Panjkora River.

An Operation Support System will be established for the powerhouse; based on observations of hydro meteorological data, better knowledge of the hydrology in the river system and downstream conditions.

11.14.5 Soil Impacts

Impacts during Construction

During the construction phase there are large risks for heavy soil erosion that may create considerable stress for the river biota, as well as may create problems for human use of the water. Consequently, erosion abatement measures need to be adopted at all construction sites.

Soil will be impacted due to:

- loss of topsoil
- failure to refill and re-vegetate borrowed areas and temporarily used land
- erosion
- soil contamination by products used for the project
- Failure to re-utilize displaced earth during the construction period.

11.14.6 Soil Rehabilitation

Soil rehabilitation in all cases can be minimized by regular rehabilitation of areas not in use for project activities during construction. Some of the measures to be taken are listed hereunder:

- The soil and rock pits (quarry) will be filled and appropriately planted with trees, shrubs and grasses.
- Disposal areas will be well marked and monitored so that appropriate procedures for disposal of different agents and waste materials are followed to minimize soil contamination.
- Re-grading and immediate re-vegetation (using fast-growing species and different functional groups of plants for keeping soil in place) of slopes to minimize erosion.
- Use of top soil removed and stockpiled from project area.

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- Installation of sediment runoff control devices.
- Soil erosion and siltation will be minimized by preventive measures and appropriately engineered storm water diversion, on a case-by-case basis.
- All unpaved areas will be greened by planting of trees and grasses to reduce erosion during the construction period.
- Soil erosion due to road construction will be minimized by suitable road engineering techniques and road edge buffer re-planting.
- All excavated rock and aggregate will be used in construction where possible, while the spoil will be deposited in an area with minimum landslide potential, multilayered and covered with soil, and planted with trees, shrubs and grasses.
- Machine parking areas and roads should be paved to the extent possible.

Impacts during Operation

During project operation, potential impact to soil may occur from spillage of hazardous materials and wastes including hydrocarbons and from localized scour at the water outlet.

Mitigation Measures

To mitigate the adverse impacts, the following measures are recommended:

- Soil contamination will be prevented by installing oil separators at wash down and refueling areas, and by installing secondary containment at fuel storage sites.
- All hazardous wastes and hazardous materials will be stored in properly designed storage facilities.

11.14.7 Water Quality Impacts

Impacts during Construction

During the construction phase, the following activities can adversely affect water quality:

- Erosion due to road building, construction work in the weir and powerhouse area, machines park area, construction workers living camps area, spoil rock deposit area, soil deposits, clear logged areas, and accidental water releases.
- Run off from crushed and ground rock material from drilling, blasting and stone crushing plant (quarry).
- Sewage (black water) from the construction worker's camps.
- Oil, grease and chemical spills from machinery and vehicles during greasing and oil change.
- Leaching of ammonia and nitrogen from the tunnel blasting and spoil rock deposits.

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Impacts during Operation

Downstream of the Weir Site

During the early years, at weir site soil erosion will take place and the silt and clay fraction of this erosion material will also impact the river water downstream.

Impacts on water quality are not considered to be significant.

Measures against Oil, Greases and Chemical Spills

The presence and operation of heavy machinery in close proximity to the river, along with the storage and use of chemicals, fuels etc, can result in localized contamination and decrease in water quality. construction machinery at workshops and maintenance areas will involve large scale use of fuels, oils, hydraulic fluid, battery acids, etc. At this place there could be a lot of spills of these materials.

Therefore, all these activities should be gathered at one area that should be paved and equipped with a controllable drainage so that all diffuse spills and accidental spills could be collected at all times.

All such storage areas, including those for fuels and chemicals should be situated away from river as for as possible and should be properly signposted.

All workers involved in use of such materials must use protection equipment (gloves, mask uniform etc,)

Measures against Blasting Chemicals

Explosives shall have to be inducted into the project area, and without proper handling and explosive management pose a safety risk to workers and residents alike.

Details of the hazardous and toxic materials to be used on site are not currently available and should be taken care during construction stage providing indicative quantities and the impacts arising from their use and disposal. The different materials need to be managed in different ways according to their potential environmental impacts.

Mitigation Measures

Mitigation measures including adequate monitoring and standard health and safety procedures will need to be included to avoid potential impacts.

The runoff from the tunnel should be monitored and passed through a sedimentation basin where neutralization could be performed if extremely high pH values are observed.

All chemical must be used, stored and transport according to instruction provided as MSD (Material safety data sheet).

Aquatic Ecology

During the construction activities, water will be channelized to pass through the weir construction area so that it could not affect the construction activities and during the operation phase the water will flow over the crest of weir as weir is overflow type and the gates of under sluices will be opened when the flushing is required or flood to be passed without causing significant head over the crest.

This will significantly impact the aquatic life of the area but the Panjkora River, upstream and downstream of project has no fish or any other aquatic life except green algae.

It is expected that there will no significant impact on the existing environment.

Monitoring

A monitoring program should be launched both in the construction phase, and also in the operational phase.

The monitoring should include the water quality especially:

- Measures against sewage from workers camp should be taken for treatment.
- Sewage should not be allowed to be discharged into the river to avoid health hazards for those living downstream.
- The grey water (washing and kitchen water) should be infiltrated at the site before discharging into the river.

11.14.8 Socio-Economic Impacts

Impacts are identified taking into account all phases of the project's life cycle, including the planning phase, the construction phase, operation phase and decommissioning phase. Unlike many other impacts identified in this EIA, social impacts begin the day the project is proposed and behavior and effects may alter in anticipation of the impacts.

Employment Generation during Construction Phase

During construction phase most of the labor will be employed from the project area.

The beneficial impact in terms of employment and the indirect positive effects it has on household income is considered to be of minor magnitude despite the large number of employees required, because of the relatively short timescale involved.

Employment generation impacts during the construction phase are considered to be positive impact of moderate magnitude.

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The well-being and working conditions of the labor force is an important issue for this project due to the large number of employees.

It is recognized that some poor labor management practices, for instance frequent and long overtime use and lack of legally required minimum wages, combined with a lack of adequate occupational health and safety focus has led to accidents and in some cases strikes in the State. Providing satisfactory and safe work conditions will promote the labor force's ability to achieve tasks without undue delays and discontentment which can have financial ramifications.

Part of the Contractor's responsibilities will be to implement adequate health and safety provisions for laborers. In order to address labor management and working condition issues, the contract should include clauses for the following issues:

- Adoption of a human resource policy that sets out the Contractor's approach to managing employees which is compliant with the national labor law and ILO conventions.
- Implementation of a recruitment policy which reflects equal opportunity, fair treatment, and compliance with the national labor law. Information that adequately describes working conditions and grievance procedures will be provided to workers at the time of hire along with their contracts. Efforts need to be made to use local labor, for instance by consulting with local administration as well as NGOs. Efforts also need to be made to identify appropriate positions that can be considered for female applicant.
- Treatment of employees and working conditions will be compliant with the Labor Law, for instance in regards to overtime payment (double the hourly wage) and working hours (under the Factories Act, 1934 no adult employee, defined as a worker who has completed his or her 18th year of age, can be required or permitted to work in any establishment in excess of nine hours a day and 48 hours a week.
- No use of child or forced labor. It is recommended that the Contractor does not contract anyone under the age of 18 to work on the project.
- Payment of all salaries will be on a timely basis as per conditions of employment. Specify maximum number of late payment days before the Contractor should be required to pay compensation on wages.
- Provision of employment certificates and a training register to workers contracted.

over six months on completion of contracts.

- Establishment of a grievance mechanism for workers to raise reasonable workplace concerns.
- The Contractor will be expected to produce a Labor Force Management Plan. It should contain the commitments in relation to human resource management, working conditions, use of resource by itself, its employees as well as subcontractors' employees and use of a local work force (including and especially PAPs) to the largest extent possible.
- A labor camp will be established for the construction labor force.

It is recognized that in the manner the labor camps are designed and managed affect the health, safety and well being of employees. The labor camp or camps will provide essential services, including electricity, potable safe drinking water, adequate cooking and bathing facilities to ensure safe and hygienic conditions.

The labor camps will be addressed in the following plans which the Contractor will produce in the construction phase:

- Environmental and Social management and Monitoring Plan (ESMMP).
- The Labor Force Management Plan.
- The Health and Safety Plan.

The camps will be administered and supervised to ensure health, safety and environmental management taking into account cultural and social sensitivities among the workforce. The plans need to address the following issues related to the labor camps:

- Fencing, boundaries and access processes.
- Infrastructure servicing (electricity, sewage and garbage, water).
- Recreation and religious facilities.
- Access to supplies and services for daily living.
- Waste management based on reduces, reuse, and recycle.
- Medical facility for all workers at site
- Conservation of natural resources.
- Safety devices, for instance against fire, lightening and exposure to contaminants.
- Safe travel planning for delivery of goods and staff.

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- The Contractor will recruit an Environment, Health & Safety Inspector, of appropriate level, who will verify continuously during the works the respect of all relevant standards, rules & operating procedures. This inspector will establish monthly reports which will be annexed to the Contractor's monthly progress report.
- For working conditions, safety and health requirements, the Contractor will apply and respect the ILO Convention No.62 as for as applicable to the project contract signed and ratified by The Islamic Republic of Pakistan
- The Contractor will give preference to local communities for recruitment, especially (but not only) for non-qualified workers. Outsiders will be recruited only if it is not possible to find proper skills locally.
- Warning to local communities prior to blasting and to enhance blasting safety the contractor will use protective devices, including wire containment, displaying warning signs along the work site, blowing sirens etc

11.14.9 Community Health, Safety and Security

There is a potential for social impacts resulting from activities as well as the presence of job seekers and construction workers on the site. As a result of construction an influx and congestion of people may contribute to deterioration of community health, safety and security due to people's interactions and behaviors. For instance, incidents of accidents, social conflicts, property theft and spread of communicable diseases can occur. Impact magnitude is likely to be minor. However, the social receptors are considered medium sensitive community members who may potentially lack literacy skills to read signs, be young or old, may lack resources and power to prevent crime and / or bullying. There are mitigation measures available and these issues should be addressed early in the construction schedule.

Impacts relating to deterioration of community health, safety and security are considered to be negative and of minor magnitude.

There is a tendency for the construction sector to be unregulated with regards to occupational health and safety, especially in areas hard to access. Additionally unskilled and some skilled construction workers may be illiterate and not necessarily informed or familiar with what the protective measures should be. The Shigokas Hydropower Project should be operated under the auspices of an Occupational Health and Safety Management System with OHSAS 18001:1999 certification.

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The Contractor will need to carry out a risk assessment and then develop a site and project specific Health and Safety Management Plan aimed at preventing accidents, injuries and work-related diseases for both construction and operation and addressing occupational health and safety as well as community health, safety and security. It will be based on the Environmental and Social Management and Monitoring Plan (ESMMP) provided in this document which identifies activities and monitoring indicators associated with good occupational health and safety.

- Developing emergency prevention, preparedness and response arrangements. Place signs around the construction areas to facilitate traffic movement, provide directions to various components of the works, and provide safety advice and warning. All signs shall be in Urdu and Pashto language and be constructed according to established specifications;
- Materials, including hazardous substances, for both construction and operation will be managed safely, for instance their transport and storage will be arranged to prevent community and personnel exposure.
- Care should be exercised for the safe transport of raw materials and the transport and disposal of waste.
- Safety processes will be put in place to promote a safe environment and structural elements of the project will be designed, constructed and operated to meet good international industry practice. Project vehicles and equipment will be maintained and project related traffic will be requested, at a minimum, to travel no more than the speed limit. The EMMP includes processes to address both occupational health and community health, including emergency preparedness measures.

Among others, the measures need to be focused on:

- Preventing or minimizing the potential for community exposure to hazardous materials.
- Prevent or minimize the potential for community exposure to water-borne, water-based, water-related vector-borne diseases and other communicable diseases that could result from the project.
- Assess significant potential hazards and assist in the preparation to respond effectively to emergency situations.

11.15 ENRONMENTAL MANAGEMENT AND MONITORING PLAN

An Environmental Management and Monitoring Plan (EMMP) contain instruction allowing the Client to integrate the environmental issues that arise from the environmental assessment, in the project implementation process. The Client is responsible for accomplishment of these instructions. Subsequently, in all phases of project life cycle, the Client will delegate responsibilities to other companies involved in project implementation, namely the Contractor and sub-contractors and Consulting engineers to ensure that the guidelines and instructions are fulfilled.

Although this outlines EMMP comprises a range of general and specific recommendations, which collectively act as basis for environmental management and control during construction and operation. However, a more comprehensive and targeted EMMP will be produced during detail design stage of the project and during construction implementation a site specific EMMP will be prepared by the contractor. This will allow for design changes and other changed circumstances to be taken into account.

The EMMP is a dynamic document and can be reviewed and updated as necessary throughout the construction and operation phases of the project.

The objective of the EMMP is to provide environmental standards for the construction, operation and routine maintenance of the Shigokas hydro power project. Through this EMMP impacts can easily be monitored as long as the project makes a provision for regular inspection and monitoring.

The environmental management plan and its institutional requirements have been described in tabular form at Table given below. The Table identifies the effects of the construction of different project components on various environmental parameters. It also spells out mitigation/enhancement actions. The Table also defines the responsibilities of various actors, viz. Proponent, Contractor and the Consultants in the implementation and monitoring of the mitigation actions. The Environmental Management & Monitoring Plan (EMMP) will help PEDO to address the adverse environmental impact of the project, enhance project benefits and introduce standards of good environmental practice.

The Contractors are legally required to comply with the EMP. the Contractor is solely and exclusively fully responsible for the non-compliance of the standards laid down in this document.



Table 11.15: Environmental Management and Monitoring Plan

Impacts	Description	Receptors	Mitigation	Responsibilities	
				Implementation	Supervision
Land Acquisition	The process of required land acquisition be started immediately with the owners/tribe for land clearing to start project activities.	Land Owner/ Local tribe	Consultation with local authorities and land owners Cash compensation for acquired land at replacement value.	Deputy Director (DD) in charge of the land acquisition /(Supervisory Consultant) Land Revenue Department (LAC)	(Supervisory Consultant) PEDO
Site Clearance and cutting of trees	Social conflict within the tribe	Vegetation Local community	Marking of vegetation to be removed prior to clearance. Clearance Strictly limited to target vegetation.	Forest Department And DD Incharge	PEDO
Construction Phase					
Soil Erosion and Land Sliding	Due to natural weathering hill slopes become increasingly prone to soil erosion and land sliding. Soil erosion may also occur at quarry areas due to unmanaged blasting.	Local Communities	Erosion control by applying good engineering practices at construction sites and in borrow and dumping areas and on long haul tracks.	Contractor	Supervision Consultant, PEDO
	The reduction in vegetative cover will reduce the binding capacity of soil and enhanced erosion.		Slope protection will be strengthened by fast growing indigenous trees with deep roots. Work should be avoided in heavy rainfall periods. Leveling and grading will be carried out in a manner to minimize soil erosion. Install erosion control measures mentioned	Contractor	Supervisory Consultant, PEDO

Impacts	Description	Receptors	Mitigation	Responsibilities	
				Implementation	Supervision
			in the detail designs. Guidelines for road construction and maintenance should be followed.		
Soil Contamination	Land may be contaminated by the spillage of chemicals like fuels, solvents, oils, paints and other construction chemicals and concrete.	Construction sites and workshops	Training of workforce in the storage and handling of hazardous material should be arranged on regular basis Soil contamination should be prevented by installing oil separators at refueling and wash down areas and further by installing secondary containment at fuel storage sites	Contractor	Supervisory Consultant, and PEDO
Depletion of the river flow	Reduction in available water for existing uses and river ecology may suffer	Local Community and Farmers along river channel.	Mean monthly ecological or residual flow as recommended should be maintained in the river reach.	Contractor	Supervisory Consultant, and PEDO
Spoil /Tunnel Muck disposal	Pose severe environmental threat if not disposed-off properly	Local ecology and community	Tunnel muck shall be disposed off at places approved by PEDO	Contractor	Supervisory Consultant, and PEDO
Solid Waste Management(debris and Domestic refuse from construction camps)	Health hazards	Workers and community	Re-use spoil where appropriate Any extra spoil generated by the construction activities should be disposed of at an Approved location. Avoid any inconvenience to the daily activities of the community in temporary storage. Choose the location	Contractor	Consultant and PEDO

Impacts	Description	Receptors	Mitigation	Responsibilities	
				Implementation	Supervision
			for stockpiles or spoil heaps to avoid blocking surface run-off or drainage lines. If the spoil heap or stockpile containing fine sediments remained bare for longer period in a high rainfall area, cover it to prevent sediment run-off. Littering should be prevented by providing adequate number of containers, which shall be emptied on a regular basis. Domestic waste should be collected and disposed of in an appropriate manner. After completion of construction the site shall be properly cleaned of any Construction waste, litter, etc. and properly rehabilitated and vegetated. Small amount of discarded material during maintenance work should be disposed of as per the workplace guidelines		
Explosives/chemicals	Health hazards	Workforce and local community	These must be stored as per safety standards in secure areas. The storage sites should be placed under armed guards.	Contractor	Supervisory Consultant and PEDO

Impacts	Description	Receptors	Mitigation	Responsibilities	
				Implementation	Supervision
			Chemicals must be handled according to MSDS as provided with all locally applicable laws and regulations regarding the transport, storage and use of explosives or hazardous material should be followed strictly		
Contamination of Surface Water Resources	If waste material is not properly disposed of, it is a danger to pollute the river water quality.	Local Peoples, Aquatic flora/ Fauna	Sewage from contractors' workshops/worker's camp should be treated through septic tanks or similar facility to the NEQS levels before discharging in to river. Raw sewage should not be discharged into any surface water bodies. Waste oil from trucks and vehicles maintenance should not be discharged into the river or any other surface water body. Treated sewage should be strictly monitored for its level of treatment as required by the NEQS.	Contractor	Supervisory Consultant, and PEDO
Dust Smoke and other Pollutants from Plants & Equipments	The emission or dust from the batching plant or construction machinery can be very harmful for the site workers especially and the local community in general.	All Biological receptor	Regular spraying of water should be undertaken to minimize the dust pollution All vehicles, machinery, equipment and generators used during construction activities will be kept	Contractor	Monitoring Consultant, and PEDO

Impacts	Description	Receptors	Mitigation	Responsibilities	
				Implementation	Supervision
			in good working condition to minimize the exhaust emissions. Proper PPE should be issued to the site worker and make sure the worker wears the PPE properly during working on site. Regular monitoring of air quality for dust, CO, CO2, NOx, SOx and Oxygen should be carried out at least at all sites where extensive construction is going on.		
Smoke from Burning of Waste Material or Burning Firewood	Smoke from Burning of Waste Material or Burning Firewood	Workers/ Nearby communities	Cutting and burning trees or shrubs for fuel shall be prohibited. Gas Cylinders should be used in the workers camp /field offices for cooking purposes.	Contractor	Monitoring Consultant, and PEDO
Noise pollution	Construction activities particularly blasting site could generate noise and disturb the natural habitat.	Adjacent communities and domestic Fauna	All working activities should be restricted within the day time particularly blasting. Construction equipment and vehicles shall have exhaust mufflers (silencers) to minimize noise generation. To the extent possible, maintain noise levels associated with all machinery. Maintenance of	Contractor	Monitoring Consultant / and PEDO

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Impacts	Description	Receptors	Mitigation	Responsibilities	
				Implementation	Supervision
			vehicles should be done according to their manuals. Workers shall be provided with PPEs to minimize noise effect. Avoid unnecessary horns in the project area During construction, noise, standards of occupational health & safety practices should be observed. Follow Pak-EPA and WHO guideline values for community noise in specific environment.		
Impact on Flora	During construction activities the Contractor's workers may damage the vegetation and trees.	Flora and owner of trees	Cutting of trees keep minimum, if unavoidable then with consultations of with owners be made prior or starting activity to avoid conflicts. Compensation plantation should be carried out as per agreement with the help of local forest department or with concerned community Relevant contract clauses will be included to control cutting of trees/vegetation.	Contractor	Forest Department, PEDO
Impacts on Fauna	Unmanaged blasting activities may harm birds and Mammals such as jungle cat, jackal, fox, etc. in the project area.	Domestic Fauna	Blasting and other noise generating activities will not be carried out during the night. Hunting, poaching	Contractor	Supervisory Consultant, PEDO

Impacts	Description	Receptors	Mitigation	Responsibilities	
				Implementation	Supervision
			and harassing of wild animals will be strictly prohibited and Contractor shall be required to warn its labor accordingly.		
	There is no definite record about fish is available however diversion will impact on aquatic ecosystem.	Down Stream Ecosystem	Ensured the prescribed ecological flow always be maintained in the Panjkora River for aquatic eco system and for down steam users.	Contractor	Supervisory Consultant, and PEDO
Impacts on Local Communities/ Work force	Effect on general mobility Accessibility of the local population to the valley access road.	Local people	The contractor shall ensure mobility of the local communities and their livestock is not hindered. The contractor shall provide crossing points at appropriate places.	Contractor	Supervisory Consultant, and PEDO
	Community will have to face the noise and dust hazards.	Local Communities	The contractor shall ensure controlled blasting near vicinity of the settlements.	Contractor	Supervisory Consultant, and PEDO
	The presence of outside construction workers inevitably causes some degree of social disruption.	All social Components	The Contractor shall maintain close liaison with the local communities to avoid and resolve conflicts.	Contractor	Supervisory Consultant, and PEDO
	The night time working will be having intrinsic problems relating to safety and noise hazards for the communities.	Social or Biological Components	Night-time working should be avoided, if necessary take approval from Supervision Consultant	Contractor	Supervisory Consultant, and PEDO
Traffic Management	Mobility problems for the community	Construction sites	Avoid existing routes blockage as far as possible Ensured arrangements for clearing road immediately for	Contractor	Supervisory Consultant, and PEDO

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Impacts	Description	Receptors	Mitigation	Responsibilities	
				Implementation	Supervision
			smooth traffic flow during blasting. Fix maximum permissible vehicular speed 30Km/hr or as volume of traffic permits during construction period Place signs around the construction areas to facilitate traffic movement and provide directions to various components of the works. Provide safety advice and warning signs. All signs shall be in Urdu /Pashto and be prepared according to development specifications. Signs should be erected at appropriate places.		
Health and Safety	Occurrence of accidents/incidents during the construction activities.	Construction Crew and general public	Complying safety precautions for construction workers as per International Labor Organization (ILO) Convention No. 62, ISO 8000 for social compliance should be observed. Ensured provision of adequate healthcare and first-aid with rescue facilities at construction site Fire extinguish equipment and other emergency facilities (ambulance,	Contractor	Supervisory Consultant, and PEDO

Impacts	Description	Receptors	Mitigation	Responsibilities	
				Implementation	Supervision
			stretchers etc) should be provided at site PPE be provided at site		
Training of Workers	Occurrence of accidents/incidents during construction activities	Construction crew	Training modules, spillage control, explosive handling and safe transportation, health and safety at work place etc list of all participants and keep record	Contractor	Supervisory Consultant, and PEDO
Rehabilitation of borrow Areas and temporarily acquired land	Occurrence of accidents Danger of damping site	Local	Rehabilitation of borrow areas and temporarily acquired land should be carried out through: 1. Immediate re-vegetation and / or planting fast-growing species and different functional groups of plants. 2. Use of top-soil removed and stockpiled from project area	Contractor	Supervisory Consultant, and PEDO

11.16 INSTITUTIONAL ARRANGEMENTS FOR IMPLEMENTATION OF EMMP

Supervision and implementation of the EMMP will be undertaken by the PEDO management in conjunction with the Management and supervision consultants.

For mitigation of these impacts a position for environmental expert should be created to ensure compliance with the Site Specific Environmental Management and Monitoring (SSEMMP) as legal requirement under the Pakistan Environmental Protection Act 1997 with the supervision consultant who will be responsible for the entire environmental compliance during construction phases.

He will also be responsible to report on progress and the status of the compliance at each stage of construction. Wherever required, he will be assisted by some expertise of the Forest Department, Fisheries, Wildlife, etc. and EPA of Government of KPK. Necessary

budget on regular basis should be provided to keep the capabilities of this unit for enabling it to effectively manage its responsibilities/activities.

PEDO will also be responsible for ensuring that conditions are included in the project construction contract documents. It will also ensure that during the construction phase, environmental mitigation measures, as per the SSEMMP, are effective and are implemented by contractor. The SSEMMP implementation will be coordinated with the help of all stakeholders and especially the concerned community

The Environmental Expert will ensure implementation of the environmental management plan and the environmental monitoring plan during construction period of the Project. Implementation of the mitigation of impacts of works during construction phase will be the responsibility of the head Contractor. Sub contractor if any will also be responsible to comply with Environmental Management and Monitoring Plan (EMM) .PEDO will also be responsible for compensation / resettlement costs and for environmental compliance during operation phase

PEDO will also obtain approvals from Khyber Pakhtunkhwa- EPA and then monitor the project and forward monitoring reports on a regular basis to the Provincial EPA as per the requirements of the Federal EPA regulations.

The Contractor will recruit an Environment, Health & Safety Inspector, of appropriate level, who will verify continuously during the works the respect of all relevant standards, rules & operating procedures. This inspector will establish monthly reports which will be annexed to the Contractor's monthly progress report. The Implementing Agency shall procure that the international conventions and due diligences are fully implemented and respected during the construction and the operation phases of the project: the implementation by the EPC contractor of the needed mitigation measures during construction;

At the plant level, all the monitored data will be reviewed and scrutinized at the level of Shift Engineer and on monthly basis at the General Manager level. The data will be documented according to appropriate format and discrepancies will be duly addressed for presentation of the data to the concerned agencies, i.e., the Environmental Protection Agency, Government of KPK, and the Environmental Protection Agency, Government of Pakistan, Islamabad.

11.16.1 Budget for EMP Implementation

Environmental estimated costs are based on the expenditures required to neutralize the impacts, due to the construction of the project, and maintained ecology of the surrounding area. Monitoring cost consists of staff and equipment required for checking and testing of

water quality, air quality and noise levels during construction phase of the project as with Rs.4 million.

Watershed Development and erosion control cost measures are also included.

11.17 CONCLUSION AND RECOMMENDATIONS

11.17.1 Conclusions

The present EIA reveals that some moderate to significant negative environmental impacts are likely to occur due to the construction activities with few minor impacts during operations after the proposed construction. Recommendations are made to mitigate expected negative impacts. Implementation of appropriate mitigation measures during the construction, and operation phases will minimize the negative impacts of the Project to acceptable levels.

The Project will have an overall beneficial impact and any negative environmental impacts will be carefully monitored and mitigated. Therefore, the completion of this EIA fully meets both the ADB and EPA standards.

The construction of the project will open job opportunities for the local people. This will help in raising their livelihood.

11.17.2 Recommendations

- To ensure that mitigation measures are implemented, the measures shall be included in the contract specification of the Project.
- Site specific environmental management/monitoring plan shall be prepared by the Contractor using feasibility EMMP guidelines for better environmental compliance during construction.
- Site specific health and safety with emergency preparedness and response plan shall be prepared by the contractor to cover risk assessment at site.
- During construction, a close consultation with the local stakeholders i.e. community is highly recommended for their cooperation and to resolve issues if come under consideration during construction.
- A fish ladder is recommended for passage to fish in the river.
- Watershed development in the up-land with the help of the NGO's and the community focusing on sustainable development approach and to enhance their

livelihood is highly recommended.

There should be a proper supervision for the environmental management, maintain health and safety with monitoring plans to enhance the project benefits.

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ANNEX

11 A

DETAILS OF STAKEHOLDER'S CONSULTATION



ANNEX

11 B

ADDRESSES OF CONCERNED AGENCIES



ANNEX

11 C

WATER QUALITY TEST REPORT

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CHAPTER

11

ENVIRONMENTAL IMPACT ASSESSMENT



ANNEXURE – 12A

Scoping / Consultation meeting 3HPPs Dir Region

Place of meeting:	Shigo kas Lower Dir, Timergara
Date & Time:	09/04/2013 5:30 PM
Venue:	Project Office Shigo kas
Facilitators:	Engr. Sahibzada Siyaf and Mr. Muhammad Rafiq enumerator

S. No	Name	S.No	Name
1	Ajab Khan	34	Zahir Badshah
2	Haji Muhammad Nageen Khan	35	Muhammad Nawaz
3	Karem Ullah	36	Bakht Zamin
4	Gul Hakeem Khan	37	Gul Zamin
5	Bacha Muhammad	38	Muhammad Shah
6	Raz Muhammad	39	Muhammad Zamin
7	Sajjad Haidar	40	Sayad Mateen Khan
8	Zar Muhammad	41	Abdul Mateen
9	Zara Khan	42	Masaud Shah
10	Haji Fazal Urehman	43	Abdul Qayum Khan
11	Haji Azeem Ullah	44	Parvaiz Akhtar
12	Sheer Hakim Khan	45	Muhammad Ismail
13	Nawab Gul	46	Muhammad Naeem
14	Muhammad Rehman	47	Nazir Zada
15	Shakeer Khan	48	Zaid Muhammad Khan
16	Amjad S/O Ghazi Khan	49	Mauhammad Zamin
17	Amjad S/O Gul Zaman	50	Muhammad Zada
18	Shafe Ullah	51	Shah Zada
19	Amir Zaman Khan	52	Anwar Badshah
20	Shahab Uddin	53	Gul Badshah
21	Kashar Khan 1	54	Amir Badshah
22	Kashar Khan 2	55	Gul Hameed Jan
23	Rafi Ullah	56	Shah Nazir Khan
24	Gul Zareen Khan	57	Khan Layaq
25	Umara Khan	58	Gul Nawaz Khan
26	Yousaf Khan	59	Usman
27	Waheed Ullah	60	Islam Uddin
28	Abdul Qasim	61	Nizam Uddin

29	Amir Sher Ali Khan	62	Akbar Zada
30	Shah Wazir	63	Asghar Khan
31	Wara Khan	64	Hayat Zada
32	Suhail Khan	65	Islam Badshah
33	Ahmad Sultan	66	Husain Khan



The stakeholders of Shigo kas Weir site expressing their views about the project



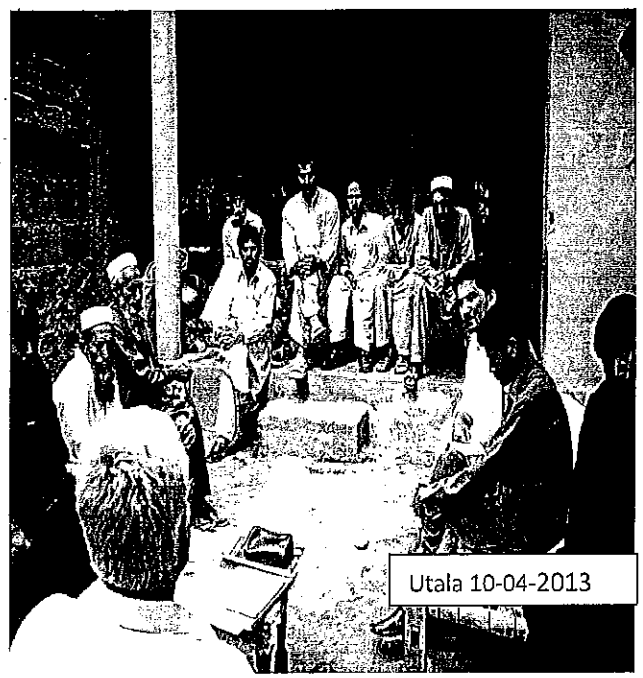
The Sociologist explaining salient features of the project with the meeting participants

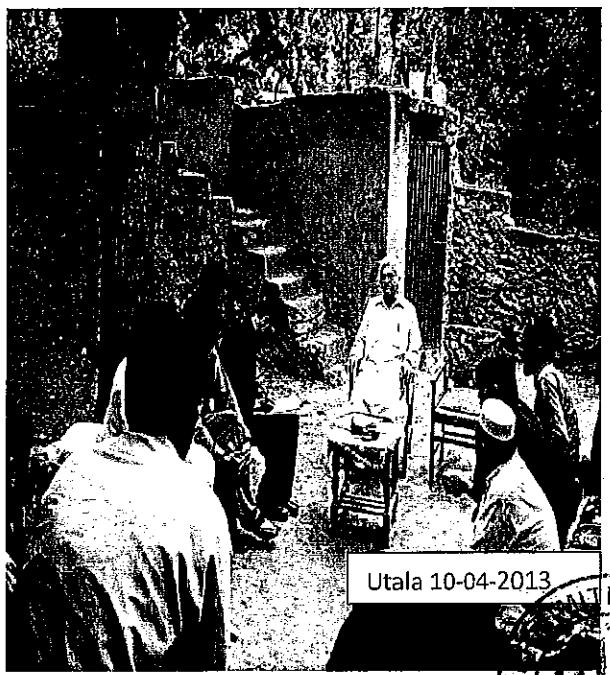
Scoping / Consultation meeting 3HPPs Dir Region

Place of meeting: Village UTALA Manzai, Timergara
Date & Time: 10/04/2013 11:00 AM
Venue: Hujra Mati-Ur-Rahamn S/O Salih Rahman
Facilitators: Engr. Sahibzada Siyaf and Mr. Muhammad Rafiq (Enumerator)

Meeting Conducted by : Ameer-Ul-Hasan Zaidi (Socialogist)

S.No	Name	S.No	Name
1	Abdul Qadir	10	Sayed Zaman
2	Mati-Ur-Rahman	11	Ajab Khan
3	Waqar Younas	12	Arif Khan
4	Deedar Khan	13	Shams-Ur-Rahman
5	Hayat Ullah	14	Anwar Khan
6	Kiramat Khan	15	Gul Khaliq
7	Shafi-Ur-Rahman	16	Rahman Uddin
8	Aqil Muhammad	17	Nizam Uddin
9	Hizbullah		





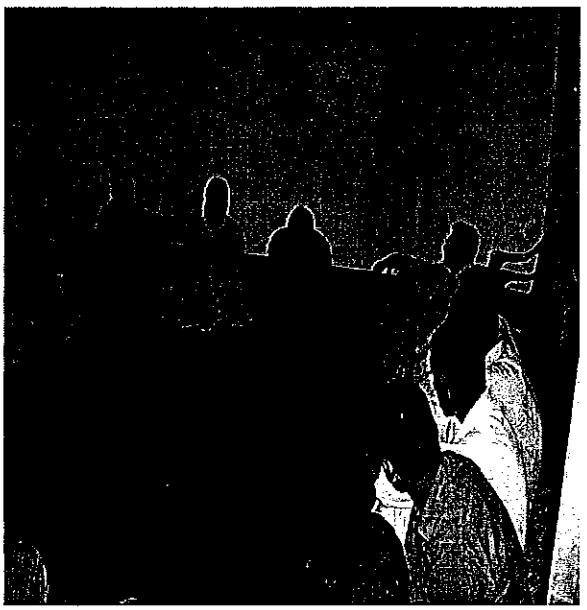
View of Utala Meeting at the proposed power house site Shigo kas Project HPP

Place of meeting:	Shigo kas Lower Dir
Date & Time:	29/04/2013 02:30 PM
Venue:	Project Office
Facilitators:	Muhammad Rafique enumerator
Meeting Conducted by:	Ameer-Ul-Hasan Zaidi (Sociologist)

Sr. No.	Name	Sr. No	Name
1	Bakht Badshah (Shigokas)	14	Naseeb Badshah
2	Gul Badshah	15	Akhtar Khan
3	Hayat Zada	16	Bakht Zada
4	Shah Wazir	17	Bahadur Said
5	Waheed Ullah	18	Muhib Zada
6	Ismail	19	Javid
7	Shakir Zada	20	Rahim Zada
8	Mushtaq	21	Badshah Zada
9	Sahib Zada	22	Ikram
10	Bakht Rawan (Zolam)	23	NAwshad Khan
11	Said Rahman	24	Naseeb Zada
12	Bahadur Khan	25	Zakir Khan
13	Nisar Ul Haq		







A delegation from Shigukas, Zulam and near villages are briefed by the sociologist at site office about the proposed project.

Provisional List of owners of property at Shigokas weir (Left site) Timargara (lower Dir) whose property may be acquired for the project.

S.No	Name	S.No	Name
1	Kashar Khan	21	Wara Khan
2	Azim Ullah	22	Bakht Badshah
3	Said Badshah	23	Faquir Muhammad
4	Gul Zamin	24	Zara Khan
5	Bakht Zamin	25	Gul Nawaz Khan
6	Boner Gul	26	Haq Nawaz
7	Abdul Qayyum	27	Muhammad Nasim Khan
8	Abdul Mateen	28	Muhammad Rahman
9	Said Mateen	29	Sadiq
10	Pervaiz Akhtar	30	Nizam Uddin
11	Bashar Khan	31	Ali Jan
12	Umara Khan	32	Anwar Badshah
13	Gul Hameed Jan	33	Shah Zada
14	Rahim Said	34	Sahib Zada

15	Gul Muhammad Khan	35	Shah Nazai
16	Sher Muhammad Khan	36	Muhammad Zada
17	Waheed Ullah	37	Ghazi Rahman
18	Zahir Badshah		
19	Amir Sher Ali Khan		
20	Shahab Uddin		

Scoping / Consultation meeting 3HPPs Dir Region

Place of meeting: Shigo kas Lower Dir
Date & Time: 02/11/2013 02:00 PM
Venue: Project Office Shigokas
Facilitators: Mr. Muhammad Rafiq Enumerator
Meeting Conducted by : Ameer-Ul-Hasan Zaidi Socialogist

S.No	Name	S.No	Name
1	Bakht Zamin Khan	6	Peer Muhammad Khan
2	Saltanat Khan	7	Bashir Ahmad
3	Sherin Zada	8	Muhammad Zamin Khan
4	Bakht Zarin Khan	9	Muhammad Shah
5	M. Saleem Khan		

The above named participants hold ownership of land on the right bank of Panjkora River in the project area where ponding for weir site is expected. This area comes under the administrative control of the Political Agent Bajaur Agency, Tehsil Qazzaffi, Uttmankhel.

Upstream Infrastructure / Buildings available near weir site

1 Govt. Primary School for Boys
2 Jamia Masjid Abubakkar Shigo kas
3 Graveyard
4 Check Post Police

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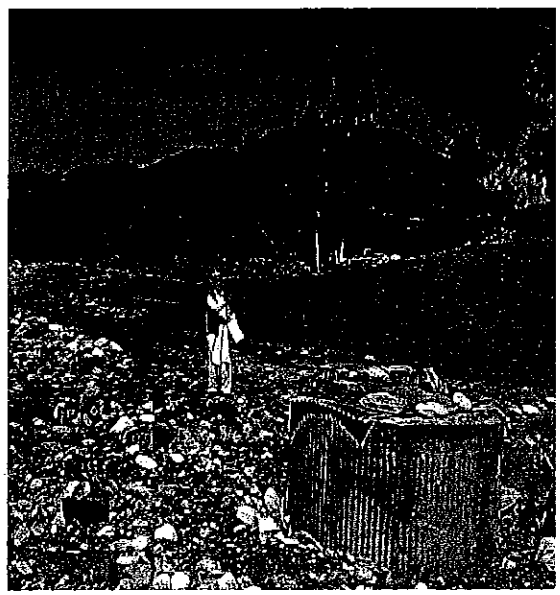



The private property expected to be submerged at Shigo kas weir site



The damaged boundary wall of a school in the vicinity of proposed weir site at Shigo Kas

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ANNEXURE – 12B

EPA, KHYBER PAKHTUNKHWA CHECK LIST QUESTIONS FOR SOCIAL ASSESSMENT & THEIR RESPONSES

Socio-economic and Livelihood Impacts

1. **What are the existing social livelihood system and common property resource management system of the communities?**

Dir region as a whole reflects traditional Pakhtoon culture where joint family system is in practice. Male member of the family earn livelihood within the district, other cities of the country and even abroad. Family heads manage the domestic and outside affairs of the family. The tribes and sub-tribes have communal land as well as communal plantation which is owned by them and its further distribution is done by the elders, Jirga and when necessary Revenue Department is also involved where land settlement work has been completed.

2. **Access to government facilities for health and education, and to drinking water**

The Nation Building Departments which include Health, Education, Public Health Engineering and Agriculture provide basic civic amenities to the people of the district in urban as well as rural areas. People have easy access to these facilities. River Panjkora along-with its tributaries and springs are the main source of water. Public Health Engineering Department provides and manages drinking water facilities.

3. **What are the pattern of existing conflicts, and existing mechanism of conflict resolution for areas under cultivation and grazing lands? Are there any potential conflicts between the upstream and down stream communities?**

Intra tribes and inter tribe conflicts exist in the society which are either resolved through Jirga of Elders of the concerned tribes or by the law and order enforcing agencies i.e Police and Judiciary. No mentionable conflicts were reported in the project area which may impede the proposed project work. River Panjkora has sufficient run off which is sufficient to meet out the needs of communities for agricultural and domestic needs. At present no conflicts were observed between the upstream and downstream comminutes. However, downstream communities were conscious about low discharges in their localities due to construction of weir. They were assured that appropriate allowance of water would be available in the river to meet out their requirements.

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4. **What are the benefits perceived by communities of Hydropower Project (please consult men and women separately)**

People lauded the efforts of the Government for initiating Hydropower Projects. They were optimistic about the job opportunities in the proposed project and expected some electric power share in the electric generation to meet out their local requirements. Women were not interviewed due to traditional and cultural bars.

5. **What role local institutions and communities will have in management and operation of the Hydropower Project:**

Since the project will be owned by the PHYDO the community's role will be restricted only to the advisory matters and consultations during conflicts or odd striations.

6. **Assessment of the potential conflicts between lower and upper riparian communities if any (history of conflicts in the area, claims on lands, disputes etc.):**

Traditional conflicts among the families and communities exist but they have no concern with the proposed project activities. If some conflicts or problems would be seen, they will be resolved by the Grievance Redress and Settlement Committee (GRSC) duly represented by the local people and government officials.

7. **How was the process of consultation carried out, conducted and documented - with communities above and below the proposed project:**

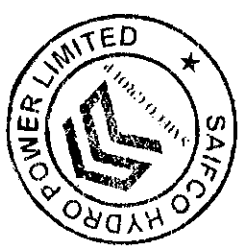
People were informed through personal messengers as well as area elites and public representatives to attend meetings with the project professionals. Focus Group Discussions were arranged in the project areas.

8. **Cultural and religious sites of community significance in the area to be affected /demolished**

No such sites have been identified during survey or social assessment.

9. **Gender Analysis and Impacts; What level of consultation with men and women for the project was carried out?**

Being male dominated society, only men including elders and young attended the meetings. Women are not allowed for interaction with the outsiders; however, female experts are allowed to meet area women in their houses for taking interviews holding meetings.



10. Who is the target (both direct and indirect) of the proposed project? Who will benefit? Who will lose?

In general whole of the population in the project area will be benefitted from the project through employment opportunities and increased income generation sources. The affected persons are those residents who will lose their land and assets for the project.

11. How marginalized communities will benefit by this project?

It is expected that due to project activities existing income generation sources will increase manifold which will help reducing misery of the marginalized communities.

12. Cultural, social and religious constrains to community participation (men and women) if any

No such bottlenecks were observed. People were cooperative and responsive. They took active part in the discussion; however, women are always excluded from such meetings. Women are allowed only when female experts call such meetings.



CHAPTER 12

SOCIAL ASSESSMENT

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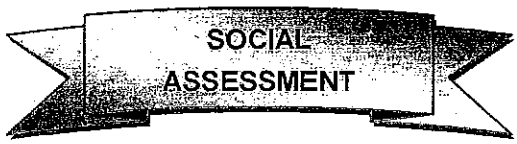

12.0 INTRODUCTION

Social assessment is sine qua non to the environmental assessment. Economic development project bring innumerable benefits but also have innumerable detrimental effects on project and natural resources. Human activities more often result in the disruption of social and communal harmony, the loss of livelihood and the destruction of renewable resources. These and other consequence can negate the positive benefits of economic development.

While significant benefits flow in from different actions, there is also a need to identify and evaluate the negative externalities associated with them. Such impact not only need to be identified and measured but also need to be managed in such a way that the positive results are maximized and the negative impacts are minimized.

It is in this context that the Social Impact Assessment of Shigo kas HPP has been undertaken through consultation with the expected Project Beneficiaries and Project Affected Persons (PAPs). For this purpose Focus Group Discussions were held at both weir and powerhouse sites.

12.1 OBJECTIVE OF THE SOCIAL ASSESSMENT

Keeping in view importance of social assessment for the proposed project, the main objective of the social study was focused on gaining insight into certain social characterization of the area and to obtain feedback from the stakeholders to be used during detailed designing of the proposed project.

12.2 THE PROJECT AREA

Village Shigo kas and Mitha Tehsil of District Lower Dir are the locations for the project weir and powerhouse sites respectively. These sites are short of about 10 km and 33 km respectively from Timergara city. From Peshawar the sites are accessible through Malakand & Chakdara via Mardan.

12.3 METHODOLOGY

Methodology applied for the social assessment included both desk review of secondary data and field visits for collecting primary data.

The Secondary Data was collected from different sources which included:

- District Census Report 1998 for Lower Dir District, Published in 2000 by the Population Census Organization Government of Pakistan, Islamabad.



- District-based Multiple Indicators Cluster Survey, 2001; Planning and Development Department (2002) KPK.

- Identification of Hydropower Development Potential in Dir Kohistan Report PEDO-GTZ (April 1993).

- Social Safeguard Guidelines ADB (2009).

- Social Assessment Modules – The World Bank (1995).

- The Process of Social Impact Assessment: Centre for Good Governance and ICH /NORPLAN.

- Khyber Pakhtunkhwa Development Statistics 2010: Bureau of Statistics Govt. of Khyber Pakhtunkhwa.

- Crops Statistics 2010-2011 Department of Agricultural Khyber Pakhtunkhwa.

12.4 PRIMARY DATA COLLECTION

Several site visits were conducted by the sociologist alone as well as with the multidisciplinary team including reconnaissance for acquaintance with the area & people, holding scoping sessions and conducting consultation meetings with the stakeholders. For this purpose village profile Performa, Focus Group Discussion Questionnaire and other related documentation was utilized.

For these documents a questionnaire checklist and plan of work were prepared. Some common question for social assessment included:

a) Who are the legitimate stakeholders of the property / proposed action?
b) Are project objectives consistent with their needs, interests and capacity?
c) What social and cultural factors affect the ability of stakeholders to participate or benefit from the proposed project?
d) What will be the impact of the project on various stakeholders including women and vulnerable section of people?
e) How can adverse impacts, if any, would be mitigated?
f) What social risk might affect project success?
g) What institutional or capacity building endeavors can be planned for the success of the project?

Pre-testing of this question yielded positive result.

12.5 IDENTIFICATION OF STAKEHOLDERS

Stakeholders are those persons and institutions who have their interests, roles, responsibilities, benefits or losses from the proposed project. The Stakeholders play an important role in the success or failure of a project.

Under this project the following Stakeholders have been identified with whom interaction at various levels and times was held in order to obtain their views and share relevant information with them:

- Primary Stakeholders were the direct users of the water resources from the Panjkora River. They have their lands, houses, buildings and business in the project area and earn their livelihood from there.

- Secondary Stakeholders include providers of services to the primary Stakeholders including public and private sector organizations i.e. Forest, Agriculture, Health, Education Departments & NGO's.

- Vulnerable Stakeholders include Zakat recipients, old age people having no family, widows, orphans and landless persons having no regular source of income.

- Indigenous people who have unique traditions, culture and livelihood patterns quite distinct from the general population. Governments and International donors give special attention to this category of Stakeholders for preserving their identity and culture. No indigenous people are found in the project area.

12.5.1 Sampling Frame.

Village Shigo kas for weir site and village Mitha for powerhouse site were included in the sample frame. In addition Government Departments and NGOs who are expected to play a role as stakeholder during designing and implementation stage of the proposed project were interviewed including agriculture, irrigation, forest, revenue, health and education departments. No NGO having activities related with hydropower could be located.

12.5.2 Study Tools

Tools were selected to maximize stakeholders' participation. These included Village Profiles, Focus Group Discussions, Key informants interviews and Secondary Data. Participatory Rapid Appraised (PRA) technique was also used when necessary. During

this exercise various techniques including transect walks of the area and others were utilized for maximum feedback from the participants.

12.5.3 Baseline Data and Impact on Livelihood

For obtaining baseline data it is necessary that the inundation zone at weir site, proposed resettlement area for colony and transportation corridor are identified during the planning stage. It this connection categorization of the Direct Impact zone (DIZ) and Indirect Impact Zone (INDIZ) should be well distinguished during the feasibility planning stages.

The Direct Impact Zone for the proposed HPP is weir site Shigo kas where ponding will take place inundating some agriculture land, wells for pumping water, crops and private plantation which would be affected as a result of construction of the HPP. It also includes forest trees and walking paths near the tunnel area, both at weir and powerhouse sites.

Indirect Impact Zone includes area that is not affected by project construction and operation activities. In a physical sense it is impacted by a number of secondary activities that are caused by the project i.e. influx of labors, their camps, movements, degradation of environment due to sanitation, diseases, conflict with local population and temporary shifting of routine routes of the residents and school going children.

The indirect impact will have to be taken into account in the mitigation plans.

12.5.4 Socio-economic Baseline

Social-economic baseline survey of the project area was undertaken to know the pre-project situation and status of households in order to establish a basis for developing the economic targets and livelihood rehabilitation plans for the PAPs, who will pass through the experience of project impacts i.e loss of land, loss of production and other assets.

A socio-economic baseline survey was conducted in the project area and in the Indirect Impacts Zone through Focus Group Discussions and interviews with the key informants, Village Profile Information and related Secondary Data. Various components covered in this section include Demography, administration, dwellings, occupation, and household incomes, socio-cultural scenario, traditions, conflicts, ethnic condition, languages, religion, civic amenities, health, education, communication, drinking water facilities, electricity & other facilities.



12.5.5 Demography

Population and development are closely related and interdependent. Demographic patterns, population control and welfare measures may be integrated into comprehensive social and economic plans and development plans.

A brief account of demographic trends in Lower Dir district including the project area has been considered for this section according to the Censes Report 1998 and Development Statistics of KPK 2010, Salient features are depicted below in the **Table 12.1.**

TABLE 12.1: Population Status of Lower Dir District

S. No	Name of the Area	Population 1998	Estimated population 2010-11	Cumulative increase during 1998-2010/11
1	Lower Dir Distt: (Timergara)	718000	1105000	53.81
2	Timargara Tehsil	74274	114233	
3	Bagh Dushkhel UC	22875	35182	
4	Bagh Dushkhel Village	2781	4277	
5	Dogal	752	1156	
6	Uttala Dushkhel	1072	1649	
7	Banadgai	930	1430	
8	Shamshi Khan	1905	2930	
9	Zulam	329	506	
10	Shigo	404	621	

12.5.6 Administration

Lower Dir was declared as a separate district of Malakand division on the 13th Aug 1996, the Deputy Commissioner is the Executive Head of the district. The district is divided into two sub-division. The sub-divisions have been further divided into six tehsils namely Samarbagh, Munda, Lal Qila, Balambat, Timergara and Adezai. The Deputy Commissioner is assisted by the Assistant Commissioners and Tehsildars for Revenue and maintance of law and order. Judiciary, Police Excise and Taxation, Education, Health, Irrigation, Agriculture, Forest, Public Health Engineering, C&W and other departments are available on district level to provide services to the population in the Timergara urban and rural areas.

- Dwellings

Normally houses are constructed of bricks cement, mud and stones Timber is extensively used in house construction. Joint family system is encouraged and is very common.

- Occupations

  Farming and trade are the main occupations in the district. A small population seeks employment in Govt, NGO and private institutions. Due to lack of employment opportunities people earn livelihood within and outside the country. Foreign remittances have improved living condition of some of the households. They usually invest this money in business.

- Ethnicity /Tribes

  Mashwani, Sadat, Shah-khel, Mastkhel, Shinwari, Yousafzai, Umarkhel, Osa Khel, Dushkhel, Mayar, Anikhel, Sultankhel, Lal Khan Khel, Akakhel and Atrafi are the major tribes in the district.

- Culture, Customs and Traditions

  People of Timergara district love traditions, culture and customs of Pakhtunwali. They are strict in following these traditions. They are simple, hardworking, religious people and conservative in approach Honour and dignity are the qualities of these people Hospitality is widespread and they prefer resolve their problems through Jirga.

- Food

  Maize, Wheat and rice are their staple foods. Beef, mutton, poultry and fish are used widely especially in well-off families. Guests are entertained with open heart. Special dishes are prepared for guest's entertainment, religious and on other festivals.

- Dress

  Dress is simple. Both men and women wear shalwar kameez. Males like caps and waster coat and chaddar. Females take chaddar, dopatta and burqa for observing strict parda. Western dress is discouraged by them.

- Marriages and Deaths

  These festivals are strictly managed by the family members which are attended by all the family members relatives and friends. Food is served at both the occasions with full monetary freedom.

- Health

  Economic development and social progress are closely linked with the state of health of the population. Health facilities are essential not only to provide clean and disease free atmosphere to live but also to enhance the

efficiency and productivity. The state of health of an area and its population rests on availability of clean drinking water, sanitation facilities and number of doctors available in the medical units. It is essential to keep people not only free from communicable diseases but also to make sure quality of life and reduction in mortality rate.

People of the project area are facilitated with the rural level facilities like Dispensaries, Rural Health Centre, Basic Health Units etc. The main medical facilities are available in the Lower Dir Medical Centers. Development Statistics of medical facilities is shown in the following **Table 12.2.**

Table 12.2: Medical Facilities in Lower Dir District in 2010-11

Sr. No.	Name of Insinuations	Nos.
1.	Hospitals	3
2.	Dispensaries	19
3.	Rural Health Centers	4
4.	Sub-Health Centers	2
5.	Basic Health Units	33
6.	Leprosy Centre	2

Source: KPK Development Statistics 2011

- Education

Education is key to development Efforts have been made by the Government and private investors to boost up literacy rate in Lower Dir district. The following **Table 12.3** shows the number of educational Institutions in District Lower Dir.

TABLE 12.3: NO. OF EDUCATIONAL INSTITUTIONS IN LOWER DIR IN THE YEAR 2010-11

Sr. #.	Institutions	M	F	Total
1.	Primary Schools	831	418	1249
2.	Middle Schools	92	61	153
3.	High Schools	62	38	100
4.	Higher Secondary	14	8	22
5.	Degree Colleges	2	1	3

Sr. #.	Institutions	M	F	Total
6.	Govt. Colleges of Management Sciences	-	-	2
7.	Technical Vocational Centers	-	-	3
8.	Govt. Universities	-	-	1
9.	Private Primary Schools	-	-	157
10.	Private Secondary Schools	-	-	80
11.	Maktab Schools	-	-	175

The increased Number of Educational Institution has raised the literacy rate of the district and encouraged female education especially in rural areas.

12.6 Communication, Roads and Transport Facilities

The district is equipped with land line, wireless loop and mobile telephone systems up to village levels. There are 34 telephone exchanges and 67 post offices in the district providing coverage to both urban and rural areas. The district rural areas are well connected with black-topped roads and shingle roads. The weir site of the project is situated on Timergara – Chakdara road while the power house site has Katcha and Pakka mixed road approach. Transport Facilities are available in plenty both for passengers and goods transportation.

12.7 Civic Amenities

A number of civic amenities are available in the district like drinking water, electricity, sanitation and drainage, roads, streets & street lights etc. Street lights are restricted to the urban localities only.

- **Drinking Water:**

  Drinking Water is mostly fetched from the rivers and springs which is of good quality. Public Health Engineering Department is responsible for water schemes. For domestic use water is uplifted or brought form the river.

- **Electricity:**

  Mostly the area is electrified though WAPDA connections.

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- **Drainage & Sanitation:**

  Project area has good slopes which helps quick disposal of waste water and run-off during rainy season. The outlet is river Panjkora or its tributaries. In populated areas waste water is drained out to the river which creates pollution problems.

12.8 Agricultural Services & Institutions

Agricultural Extension, Animal husbandry and other related departments are available in the area and provide services to the local farmers through district headquarter and sub-offices. Loan facilities are available from the commercial banks. Marketing of produce is done easily through trucks and small vehicles.

Crops:

December, January and February are cold and June, July and August are the hot months. Maximum rainfall month is March with average 240 mm. Cropping pattern suited to the climate of Lower Dir includes maize, rice, wheat, barley, mustard, onion and vegetables. Fruits include walnut, persimmon, apple, pears, plums, apricot, fig, loquat and mulberry. The blood red variety of sweet oranges (Malta) of Rabat area is well known in the country and abroad.

Livestock:

Goats, sheep, buffaloes and cows are common livestock reared in the project area. The animal products are utilized domestically as well as for marketing. Agricultural produce is usually utilized for domestic use because landholdings are small. Irrigation is done through government as well as private canal systems. Tub wells, open wells, tanks and lift pumps are also used for irrigation.

12.9 Industry Trade & Trade Centres

The district is famous for the trade of food-grains. Major trade centers are at Timergara, Mayar, Samar Bagh, Monda, uch, Chakdara, Talash, Ziarat and Rabat. Most of daily use commodities and other amenities are brought from big cities including Peshawar, Rawalpindi, Lahore, Faisalabad, Gujranwala and Karachi. The nearest main trading center is Batkhela, Malakand District.

Flour mills, furniture, cement based industries, marble and chips industries and rice mills exist in the district. Cottage industry is restricted to caps and knives making.

12.10 Gender Roles

The district reflects male dominated society where gender roles and responsibilities are well defined. Male population works outside for livelihood earnings while women shoulder the responsibility of household activities. Some agricultural activities are also shared by women. Improving trends in education have provided employment

opportunities for females in education and medical sectors. Women decision making role is confined to the domestic sphere. Women are strict parda observers and their interaction with the outsiders is not allowed. Information regarding female roles are provided by the male family members only if they desire.

12.11 Poverty and Vulnerability and House Hold Income

People of the project area are not well off generally. Some people who have business, income from the family members living aboard forest ownership or regular employment run their domestic affairs properly but majority of people hardly earn their livelihood. Poor people are living without fundamental freedom of action and choice. They often lack food, shelter, education and health. They also face extreme vulnerability to ill health, economic dislocation and natural disasters.

It is observed that the Project Affected Persons (PAPs) are safe from the poverty bottom line and vulnerability. They have agricultural lands, houses, transport and sufficient income to run their Kitchens. A poverty assessment exercise in Shigo kas proposed project area is indicative and taken in general from 12 well off persons having per month income more than Rs. 25000, 40 better off with income between 12000 to 25000 per month; 60 families having poor earning less than Rs. 10000 per month; 12 poorest families earn less than Rs. 5000 per month while 10 destitute families are vulnerable, zakat recipients widows, old aged persons and orphans. As analyzed the poverty dimensions include malnutrition, poor heath, poor living, insecurity and asset deprivation.

12.12 Consultation Meetings with the Stakeholders

Focus Group Discussions with the Stakeholders and administering village profile questionnaire in the project area was undertaken by the sociologist for gathering both qualitative and quantitative input for social assessment. The base-line information has been collected from the primary stakeholders as well as from the secondary data available in various reports.

Public consultations in the project area constituted an important activity in the overall field work conducted for social assessment study.

Irrigation, Forest, Agriculture, District Administration and local government functionaries were contacted for discussing the proposed projects who assured their support as and when needed.

The primary goal of the public consultations has been to explain the objectives and salient futures of the project to the local population and also to highlight importance of conducting social assessment. The task also entailed to document the social concerns identified by the local residents with regard to the proposed project which the consultants aimed to design a forum where all the stakeholders participate in the assessment process by way of voicing their concerns in public and to streamline the study, by way of including public opinion in the assessment process to increase the applicability of the proposals.

The objectives of these consultations and scoping sessions were:

- To disseminate overall aim and objectives of the proposed Hydropower Project and facilitate the stakeholders to participate in the pre-project preparation.

- To ascertain opinion on likely adverse social impacts due to implementation of the proposed project and

- To create awareness on the importance of safeguarding social concerns during construction and implementation of the proposed HPP.

- **Process of Consultation**

  The aim of the public consultation was to ensure that there is good representation from various interested groups institutions and government officials as well as NGOs involved in such activities and have concerns about the proposed project.

- **Identification of Social Impacts**

  This section discusses how a proposed sub-project can affect the people or any interested group and influence the social position directly or indirectly. Particular attention has been given to community perceptions and cross sectional issues in identifying the impacts.

- **Social Impacts**

  Sub-projects undertaken for development purposes and to overcome infrastructure problems in the project areas, necessitates forcible relocation of some residents causing severe adverse social and economic impacts. The problem becomes exacerbated when the rights and entitlements of these affected people are not recognized by the concerned authorities. In such case it becomes the responsibility

of the project implementation authorities to see that the proposed project plan takes into consideration the potential social impacts on the local residents before considering the project for implementation. In this connection it is essential that the proposed project adopt the motto of "Pareto Optimality" which means making one person better off without making any other worse off. Hence the living standards of the displaced persons may be increased as far as possible. It should not be decreased in any case. The fruit of development must be shared with the local people especially the Project Affected Persons (PAPs).

Some of the social and Economic Impacts associated with the proposed HPP include:

a. Loss of agricultural land, crops
b. Loss of lease and tenancy
c. Loss of traditional land rights and subsistence income which may force PAPs to a weaker economic condition, than the existing status.

- Loss of Built up property.

Some pathways may be lost. Loss of productive assets, trees loss of livelihood from the existing place, loss of utility lines i.e. telephone electricity poles, road passing through the area may also be affected.

12.13 Findings of FGDs

For getting feedback from the stakeholders a village profile and questioners for Focus Group Discussions were designed which were pretested. The responses are given below:

12.13.1 Identification of stakeholders

During reconnaissance survey of the weir and proposed powerhouse site local residence and officials who have direct or indirect stake in the proposed project were consulted. A total number of 4 meetings were organized in the project villages which were attended by 117 persons including those stakeholders whose property is expected to be affected for the project.

12.13.2 Awareness about the proposed project:

Responding to this question about 90% of the stakeholders showed their ignorance about the proposed project. During discussion they appreciated the efforts of the government's team for starting project awareness campaign well before starting other investigations in the area, which may otherwise, creates problems. They appreciated this approach and requested that in future before visiting the area at early stages by any investigating or survey team, the local

people should be taken into confidence and assistance should be sought from the area elders in order to avoid any confusion.

12.13.3 Information Sharing:

The participants of the meetings were briefed about the salient features of the project. They welcomed the information and shared their ideas with the sociologist.

12.13.4 Views of the Stakeholders about the project:

They welcomed the efforts of Government for promoting hydropower projects in their area. However, they requested that their pressure property should be saved as for as possible. They demanded that proper justice should be done while making compensation to the affected persons and the payments should be made only to the actual owners only prevailing market rates. They also demanded that the electricity generated through this project may also be provided to the area if possible.

12.13.5 Indications of Vulnerable Groups

Some indirect stakeholders were identified who were in vulnerable conditions including widows, orphans, aged persons and land less people. During and after completion of the project this section of peoples is expected to be benefited as indicated by the participants.

12.13.6 Social Conflicts

The participants indicated no conflicts in the area which may affect the proposed project. They pointed out that in case of conflicts they prefer Jirga system for resolving their problems.

12.13.7 Suggestions

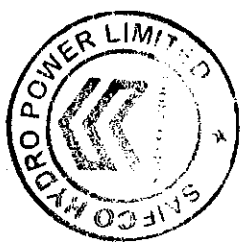
The participants of the meetings demanded that they should be given preference in employment and entry of outsiders may be kept at minimum level keeping in view the misery of the area. They also demanded that due to project construction their routine life should not be disturbed.

12.14 Conclusion and Recommendations

The people were found cooperative and with positive thinking towards the proposed project. They requested that the elders of the project area should be consulted by the visiting specialists time and again in order to avoid misconception and confusion amongst the local people. A Grievance Resolving and Settlement Committee (GRSC) may be constituted by the Client which will be helpful in streamlining the activities of the project.

ANNEX
12A

SCOPING / CONSULTATION MEETING
3HPPS DIR REGION



ANNEX

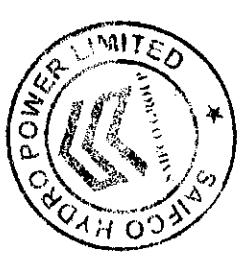
12B

EPA, KHYBER PAKHTUNKHWA CHECKLIST QUESTIONS FOR SOCIAL ASSESSMENT & THEIR RESPONSES



CHAPTER
12

SOCIAL ASSESSMENT



CHAPTER
13

TRANSPORTATION AND ACCESS ROADS



CHAPTER 13

TRANSPORTATION & ACCESS ROADS

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Transportation and Access Roads

13.1 Local Transportation Situation

The Project area belongs administratively to the KPK, which is located in the northwest of Pakistan and covers an extensive area stretching from the southern plain facing the Province of Punjab to the northern mountain area. The Panjkora River with the Project site takes its rise in the highland and the mountainous area in the north. The Panjkora River is not a navigable river for shipment and the province has no port where large ship can be moored. Since it is impossible to be use as a loading port for heavy equipment such as turbines and generators needed for the Project, the only available transportation for heavy cargo to Peshawar is land transportation using the road network accordingly. The transportation network in Pakistan is shown in **Figure 13.1**.

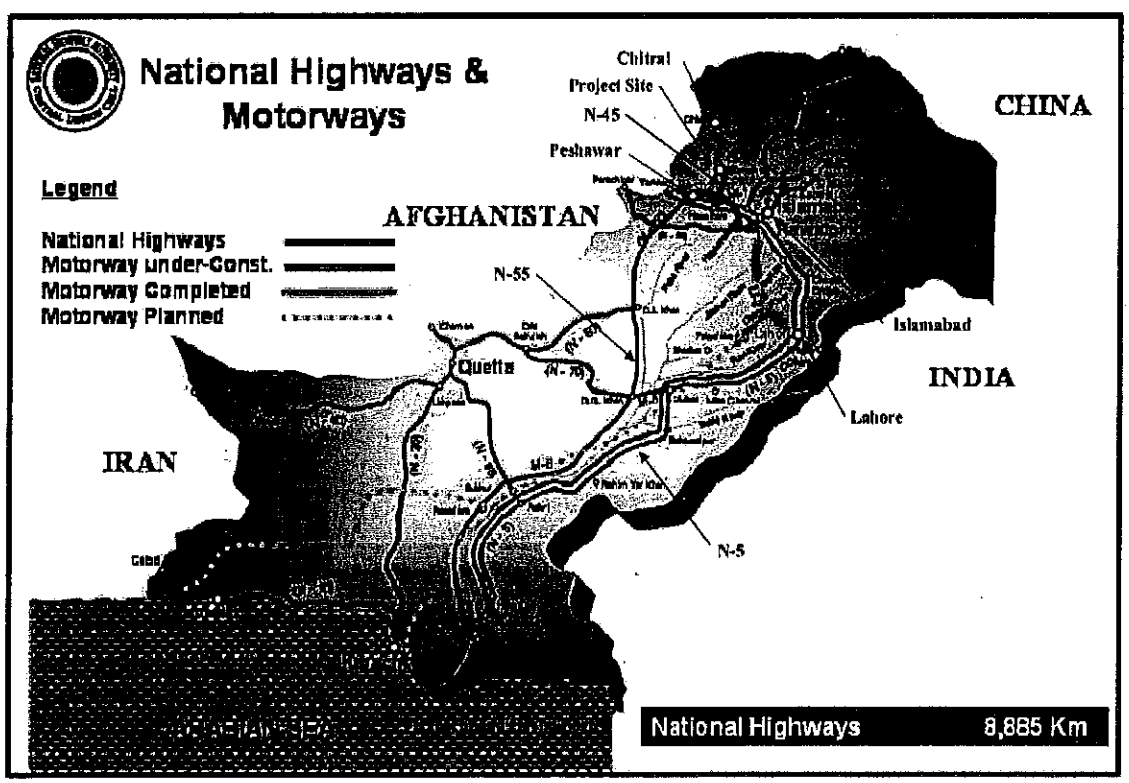

Fig 13.1: Transportation Network

13.2 Loading and Unloading Sea Port

Pakistan has about 1,062 km long coastline facing the Arabian Sea spreading from the Indian to Iranian border. In the past, Pakistan had one deep sea port at Karachi, which was provided transit trade facilities for inland area. However its cargo handling has rapidly increased in the recent year and the necessity for other ports was felt strongly. The federal

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government has attempted to alleviate the increased congestion by constructing a second port in Qasim about 30 km east of Karachi and third port in Gwadar about 650 km west of Karachi. Karachi or Qasim Ports are expected for the unloading seaport of the heavy equipment such as turbines and generators due to the port facilities, the connection for the road network, etc. The summary of each port is shown as follows.

13.2.1 Karachi Port

Karachi port is Pakistan's largest seaport, handling about 60 % of nation's cargo, 25 million tons per annum. The port is located close to the main business district of Karachi and several industrial areas. The geographic position of Karachi places the port in close proximity to major shipping routes such as the Straits of Hormuz. The administration of the port is carried out by the Karachi Port Trust, which established in the nineteenth century.

The port comprises a deep natural harbor with an 11 km long approach channel which provides safe navigation for vessels up to 75,000 DWT. The main areas of port activity are two wharves, East Wharf with seventeen vessel berths and West Wharf with thirteen vessel berths. The Maximum depth alongside the berths is currently 11.3 m. The two wharves extend in opposite Directions along upper harbor, the West Wharf southwest from Saddar town and the East Wharf Final Northeast from Kiamari Island.

West Wharf berth has a handling capacity of 300,000 TEUs per annual and handles container ship up to 11 m draught. The total quay length is 600 m divided into two container berths. The Terminal is equipped with three Panamax cranes and one post-Panamax crane. East Wharf has a Handling capacity of 350,000 TEUs per annual and handles container ships up to 11.5 m draught. The total quay length is 600 meters divided into two container berths. The terminal is equipped with two Panamax cranes. In addition, further deepening of the port has been planned by the Karachi Port Trust in order to enhance facilities. The channel is being dredged initially to 13.5 m deep to cater for 12 m Draught vessels at all tides. At Kiamari Groyne, located at the outer tip of the harbor, dredging will be to 16.5 m to enable vessels up to 300 m long to dock. The Karachi Port Trust also plans to develop a trans-shipment terminal at Kiamari Groyne, which should minimize turnaround time for large vessels.

13.2.2 Qasim Port:

Qasim port is located nearby Karachi and constructed in the late 1970s to relieve congestion at Karachi port. Qasim port is managed by Port Qasim Authority and is handling about 35 % of the nation's cargo of 17 million tons per annual. It is located in an old channel of Indus River at a distance of 35 kilometers east of Karachi city center. The approach to the port is along a 45 km long navigation channel which provides safe navigation for vessels up to 75,000 DWT.

Location of its major advantage is the proximity to national transport facilities, 15 km from the Pakistan National Highway, 14 km from the National Railway network through six railway tracks located immediately behind the berths and 22 km from Jinnah International Airport. The port has nine cargo-handling berths, multipurpose terminal with four berths each of 200 m length and Qasim International Container Terminal with two berths each of 300 m length and other berths such as chemical and oil terminal. And also, future expansion of the port included the deepening and widening of the navigation channel and the establishment of several terminals such as a liquefied petroleum gas terminal, grain handling and storage facilities, etc. is planned.

13.2.3 Gwadar Port:

Gwadar port is located at Gwadar city at the entrance of the Persian Gulf on Arabian Sea and about 460 km west of Karachi in Baluchistan, Pakistan. Gwadar port, a deep-sea water port has been constructed in two phases with heavy investment from China. The Gwadar port project started in 2002 and the first phase of the project was to be completed in 2005.Phase 1 includes construction of three berths with a depth of 12.5 m and approach channels. Three berths were constructed for loading and unloading of general cargo. And about 700 m long quay will handle up to 50,000 DWT container carriers. And phase 2 will be developed through private sector on BOT and BOO basis, and includes 9 berths, two container terminals, dry bulk terminals, two oil terminals, one roll on roll terminal, one bulk cargo terminal, one general terminal and channel dredging from 15.6 to 20.0 m deep.

13.2.4 Inland Transportation

The inland transportation system in Pakistan mainly depends on north-south links because the Ports shown on the above section are located in the southern coastal area whereas the populous Provinces of Punjab and KPK are in the northern plain area. The two existing major North-south links are National Highway 55 called N-55 on the western bank of the Indus River and National Highway 5 called N-5 on the eastern bank. National Highway 5 and 45 (N-5 and N-45) to the Project site are expected for the transportation route of the heavy equipment. The Summary of the inland transportation is as follows. National highway 5 (N-5) connected from Karachi and Qasim port to Peshawar passes through the western bank of the Indus River via the capital Islamabad and the main city such as Rawalpindi, Lahore and Hyderabad. And it is the main route for the inland transportation of the whole country which has the longest highway having 1,756 km length. The bulk of the Commercial and industrial activity is concentrated along the N-5 corridor and 60 % of entire traffic of the country is carried. N-5 has sufficient width and grade to get heavy transportation vehicles through except the road maintenance partly. National highway 55 (N-55) connected from Hyderabad to Peshawar passes through the Eastern bank of the

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Indus River via Ratodero, Shikarpur, Dera Ismail Khan. N-55 is also available for the inland transportation from Karachi and Qasim Port to Peshawar. However the road condition is poor compared with N-5. In addition, for the transportation from Gwadar port to Peshawar, the federal government has planned the construction of Motorway 8 (M-8) between Gwadar Port and Ratodero that is connected to N-55. After the completion of the construction of M-8, the transportation of the heavy equipment from Gwadar Port would be available to pass through M-8 and N-55 to Peshawar.

From Peshawar to Timergara near the Project site, N-45 as shown in Figure 1.2 is available for the transportation of the heavy equipment such as turbines and generators. N-45 branches from N-5 in Nowshera located 30km east from Peshawar and goes through Mardan, Chakdara and Dir along Swat and Panjkora River toward the north. N-45 is also

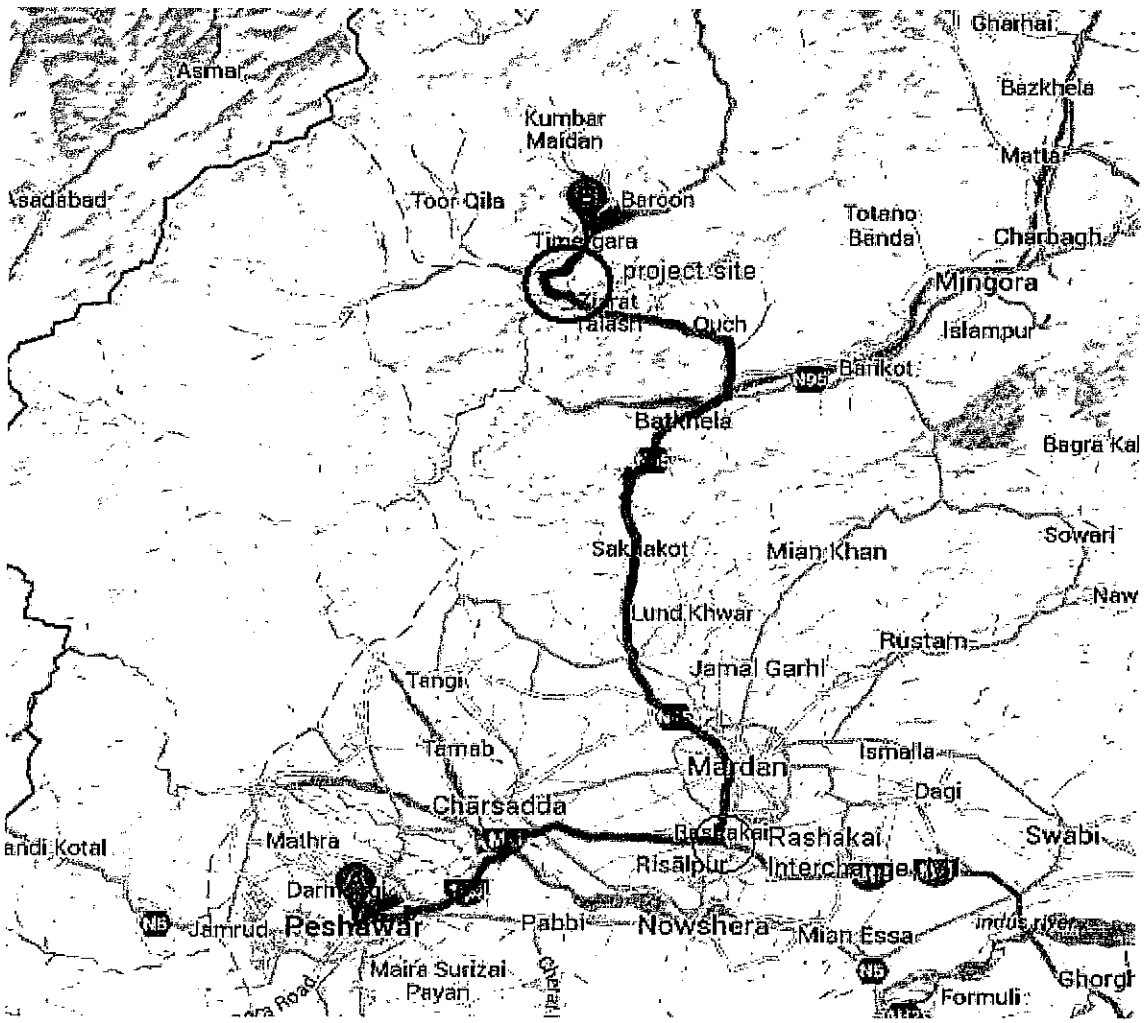

Fig 13.2: Access road from Peshawar to project site

Linked at Rashakai interchange with motorway, M-1.N-45 leads from Nowshera to Timergara and is the most important traffic line for the transportation of the supplies to Timergara, shown in Figure **13.2**. However N-45 is partly in poor condition especially in

rainy season and currently it takes about 4 hours to reach Timergara, which is a town near the project site. The improvement construction of the road is now being conducted and will be much improved in future, which make easily transport goods including heavy equipment from Peshawar to Timergara.

13.3 Access Routes to Main Civil Structure Sites

The heavy equipment, machinery and construction material will be transported through the National Highway N-45 from Islamabad or Peshawar to Timergara.

The outlines of the routes are as mentioned below.

13.3.1 Access road to Weir Site

The weir site is about at 500m distance right side of the National Highway N-45. The access road to the weir site starts from a branch with National Highway N-45 at Shigo kas, shown in Figure 13.3. The branch road does not give full access to the weir site, so construction of about 500m road is required.

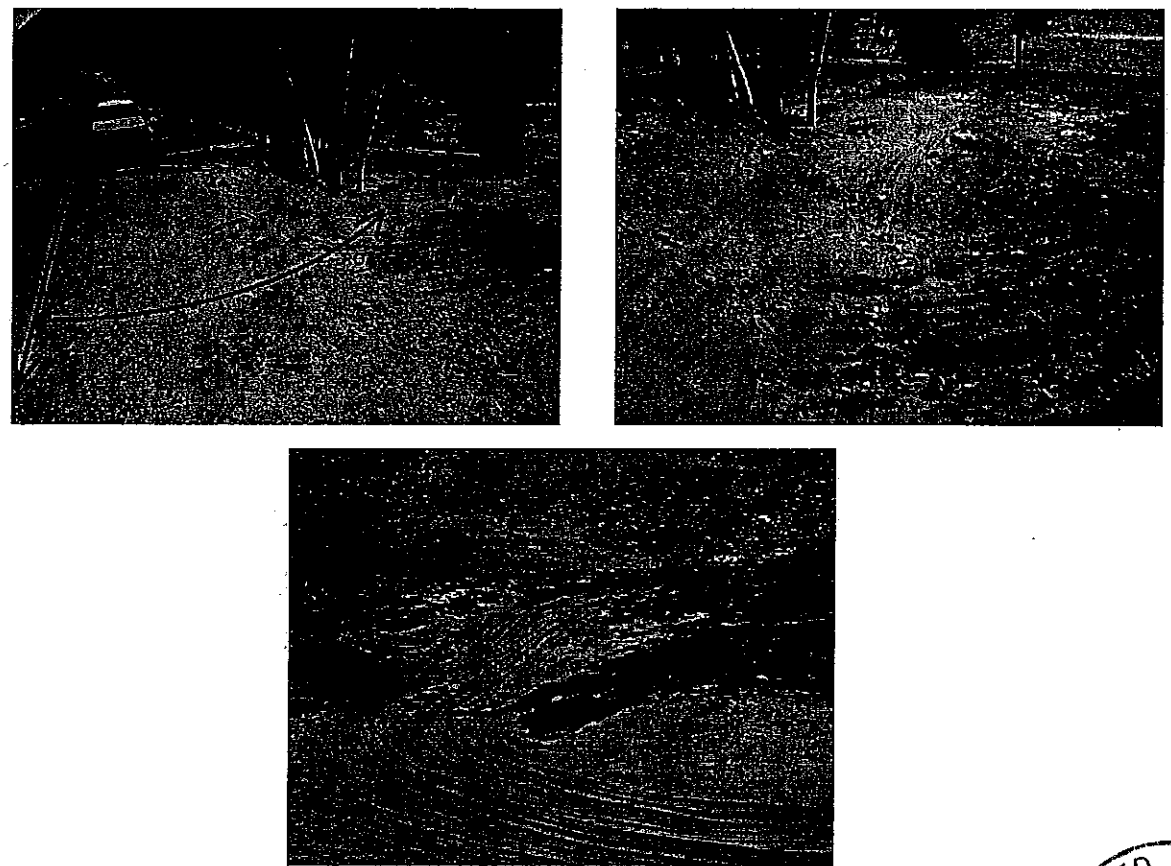

Figure 13.3: Existing Road to Weir

13.3.2 Access road to Powerhouse Site

Powerhouse is located downstream the Bagh-Doshkhel village. Access road to powerhouse branches the National Highway N-45 at Bandagai near Talash. From Bandagai Up to Pingal Kandao police post the road is about 17 km, shown in **Figure 13.4** and its condition is:

- The road is blacktopped
- Sharp curves
- Steep slopes
- Width: Insufficient for heavy vehicles

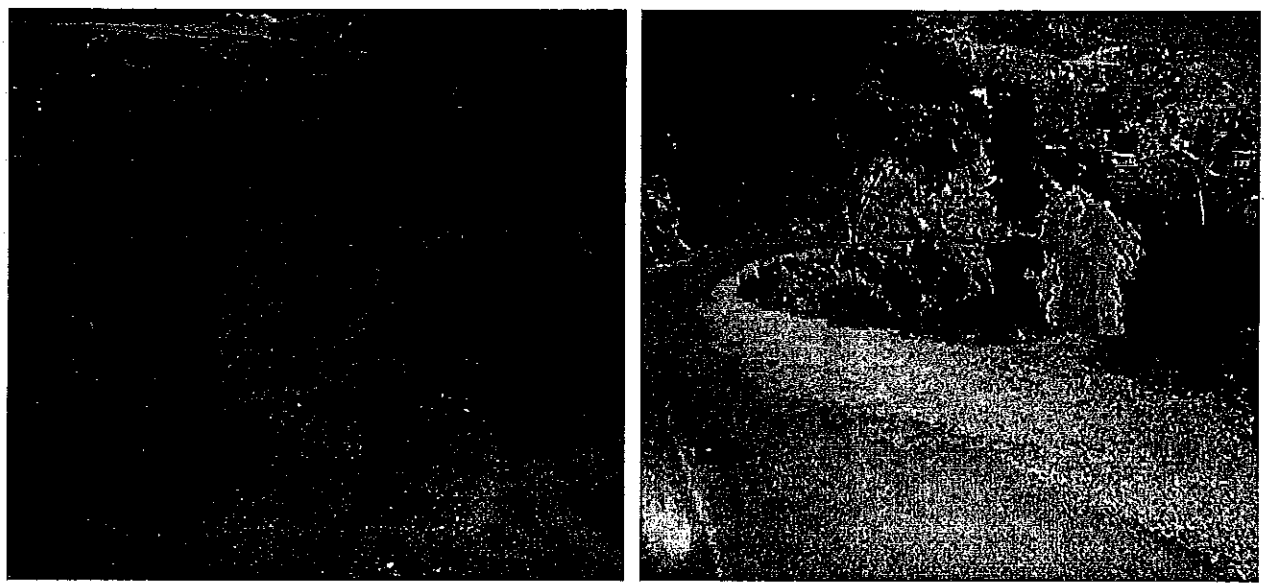

Figure 13.4: Road to Powerhouse

A branch road about 7-8 km at Pingal Kandao police post leads to powerhouse site shown in **Figure 13.5 & 13.6**. Condition of road is:

- Kacha road (worst condition)
- Width: only one vehicle can pass
- Steep slopes
- Sharp curves
- No Retaining walls

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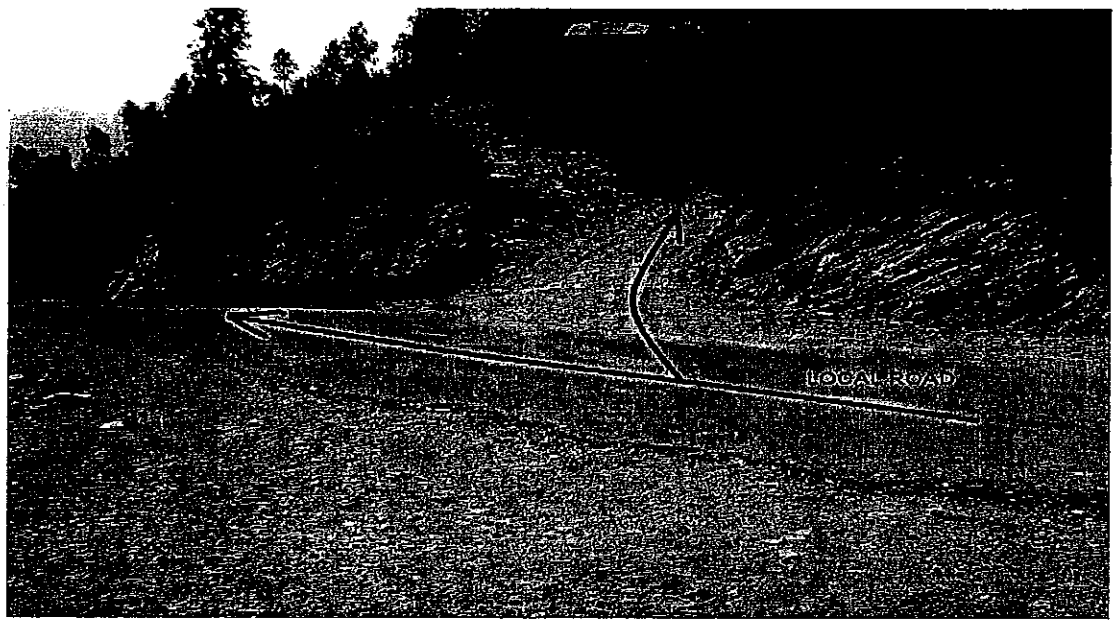

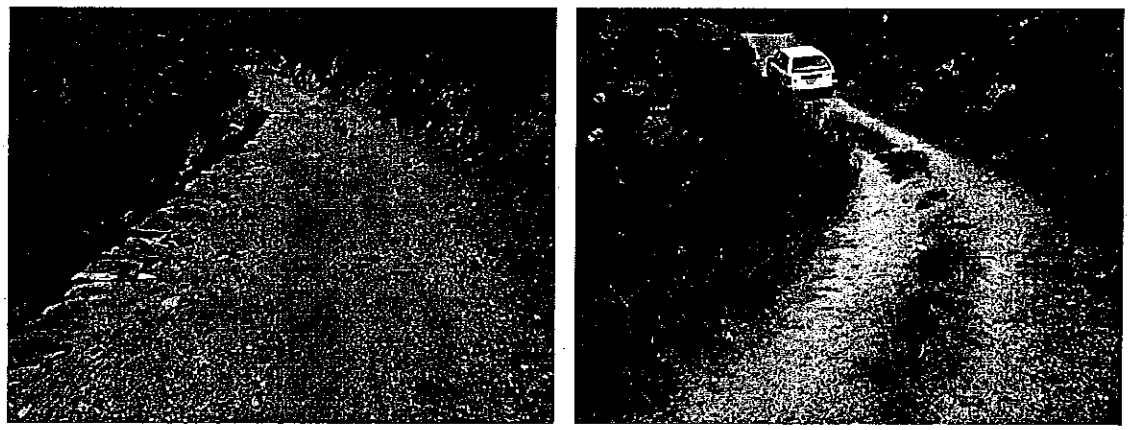

Figure 13.5: Connecting Junction to power house, Branches at police post

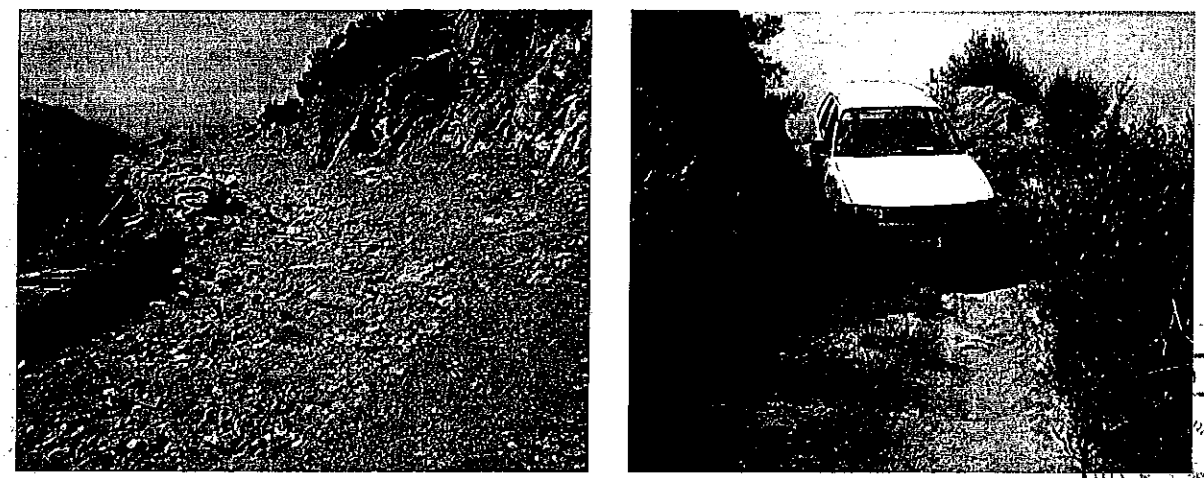

Figure 13.6: Kacha Road to Powerhouse Site

13.3.3 Access Road to Sand trap Site

As the sand trap is near to the weir site so the existing road to weir site will onward leads to sandtrap site and therefore further extension of road weir site is required to access sandtrap and connecting channel site.

13.4 Condition of bridges, culverts and causeways

- **Bridges**

The bridge on Goru Khwar located on the local road to powerhouse from N-45 is in good condition, Shown in **Figure 13.7.**

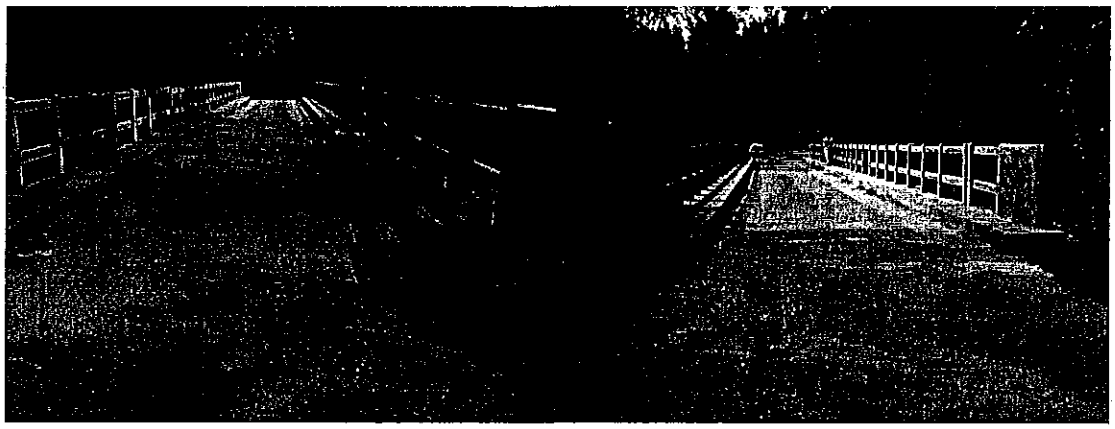

Figure 13.7: Bridge on Goru Khwar

- **Culverts:**

Mostly the culverts are pipe culverts and these are functional and in good condition.
In some places new culverts are to be constructed, detail given in **Table 13.1.**

- **Causeways:**

There are small causeways on different Nallas on branch roads especially to powerhouse which are not in good condition.

13.5 Road and Its Cost

The access road distances to be improved and newly constructed and their construction costs are summarized in **Table 13.1.**

Table 13.1: Road and Its Cost

S.No	Description	Unit	Quantity	Cost (Pak Rupees)
1	Permanent Road work	km	16	207,700,000
2	Temporary Road work	km	9	52,200,000
3	Culverts (1.5 m x 1.5 m)	No	10	30,500,000
4	Culverts (1 m x 1 m)	No	8	9,600,000

CHAPTER

14

CONSTRUCTION PLANNING & COST ESTIMATE



Annex

14A

Detailed Cost Estimate



CHAPTER 14

CONSTRUCTION PLANNING & COST ESTIMATE

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14.1 CONSTRUCTION PLANNING

14.1.1 General

The construction planning for 102 MW Shigokas hydropower project is mainly dependent on the following major factors:

- Construction of weir, power tunnel, penstock and powerhouse, are on the critical path
- 10.2 Km Long power tunnel
- High and low flow periods in the Panjkora river
- Excavation in hard strata of powerhouse and power tunnel
- Transmission line of 13 km length
- Manpower, equipment and other resources available with the contractor

The main components of the project are:

- Weir
- Power tunnel
- Sand Trap
- Surge Tank and penstock
- Powerhouse
- Transmission line

In order to complete the project in the shortest possible time, the schedule has been prepared so that the work can be taken up simultaneously on various activities independently at sites. The construction work of cofferdams will complete in two stages. Stage-I will starts by the 7th month & Stage-II by the 19th month of construction phase respectively as indicated in the Implementation schedule. The civil works will be taking about 48 months, whereas the erection of electromechanical works will take about 34 months. These works will start by the 7th month and 26th month respectively of construction period. Accordingly the first unit will be available for wet testing and commissioning by first week of 52nd month of Construction phase as per construction schedule.



It is anticipated that, the construction of the entire project will be completed in about 60 month period. The sequence, in which the construction of various components of the project will be taken up, has been shown in Figure-14.1 and described in the following paragraphs.

14.1.2 Land Acquisition

No major problem is envisaged in acquisition of land. It is anticipated that land required for the project will be acquired/purchased in 7 months. To streamline the project implementation and to avoid delays, it is desirable that the land acquisition process is accomplished and possession of the land is taken at least one month before start of construction work. Regarding the land acquisition, priority must be given to the land required for construction of access roads.

It is envisaged that the land required for the establishment of camps, stores and workshops and access roads to adits would be acquired on temporary basis by direct negotiation and agreement with the owners. Temporary acquisition will principally be the responsibility of the contractor and the cost should be reflected in the bid.

14.1.3 Mobilization and Preparatory Works

It is foreseen that the contractor will mobilize to the site within 30 days after signing of contract agreement. A period of about 14 months has been allocated for this activity including mobilization, project data collection, and establishment of contractor's camp, detail design of civil & electromechanical works and construction of employer's residential colony. Within the first two months, the Contractor will procure the land to establish camping and other facilities i.e. camps, stores and workshops including the construction of temporary access roads.

The main activities in this period, to be undertaken by the contractor, are briefly outlined below:

- The construction of access roads, to weir site and powerhouse location. Temporary/permanent access in the project area i.e. to power house, colonies, power tunnel, surge shaft, sand trap, intake and weir etc will be made by the contractor according to this work program. A period of 11 months has been provided for the contractor to complete this activity.

- Simultaneously, the contractor is required to construct residential and storage facilities for his manpower, equipment, material and erection of concrete batching plant.

- As the contractor will need power supply to run his equipment and to provide electricity for his camp, he has to arrange proper power supply facility within one month.

- In addition, the EPC contractor will start work on investigations, detailed designing of the project components and demarcating the layout of the project.

14.1.4 Exploration for Borrow Areas and Construction Materials

In the light of feasibility/design studies, the contractor has to confirm, further explore and test materials to check their suitability for use in construction. It is envisaged that this activity will be completed during the mobilization period.

14.1.5 Weir and Intake Structure

Construction of weir includes intake structure for water conveyance and power generation. As the work has to be carried out across the river, it is proposed that this work should be taken up in two stages as described below:

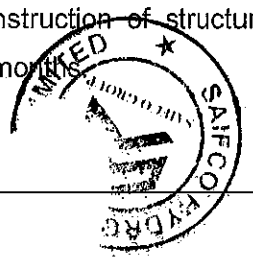
The project envisages two stage diversion of the river flow. The construction of first stage cofferdam is planned to be started by the 7th month of construction phase and will be completed in about 3 month period. It is proposed that a coffer dam should be constructed in the river to isolate the left side of weir for construction. This will facilitate construction of intake structure and the stage I weir structure. The construction of intake and stage I weir will take about 8 months to complete.

The removal of stage I cofferdam and construction of stage II cofferdam will be started from the 18th month and 19th month respectively after the completion of intake and stage I weir structure. This will facilitate construction of the remaining part of the weir structure (Stage II). The leftover part of the weir are expected to be completed in about 10.5 month's time. As indicated in the construction schedule, the diversion arrangement and construction of civil works at the weir and intake sections will take about 26 months during this period the contractor will remain engaged in care and handling of water (including dewatering).

By the end of 32nd month of construction phase the structure will be ready to control/ regulate the river flow.

14.1.6 Sandtrap

Keeping in view, the quantum of material to be excavated the Consultant's planning is to initiate work on this activity from the 26th month of construction period after the construction of access road to Sandtrap area. The sand trap is located just downstream of intake structure. Excavation for sandtrap will be completed in about 5 months, while the construction of structures and installation of lift gates and fixing of trash racks will take another 13 months.



14.1.7 Connecting Channel

For connecting Sand-trap with Power Tunnel, an RCC open gravity channel is to be constructed, for carrying out this task a period of 5 months has been provided. Though the activity is not on critical path but in view of the quantum of excavation, it is proposed that this activity will be 2 months, while the Construction of the channel will take about 3 months.

14.1.8 Power Tunnel

Power tunnel is the major component of the project which is about 10.2 Km long. This activity is on critical path and in view of the quantum of excavation; it is proposed that separate/ independent crew shall be deployed for carrying out this activity / part of the work. A period of about 45.5 months is foreseen for completion of power tunnel. It is proposed that this activity should be started by the contractor immediately after the mobilization and completion of access road by 4th month of construction phase so that the tunnel should be ready by the time other components are completed. As a result water will be available for testing and commissioning. Power tunnel will be completed by the end of 48th month of construction stage.

14.1.9 Surge Tank

For completion of Surge shaft, which is also one of the major structures of the project, a period of 8 months has been provided. As this work is not on the critical path, therefore, it is proposed to be taken up by the 13th month of construction phase, simultaneously with the weir first stage construction. The excavation for the surge shaft will take about 3 months. The surge shaft will be ready by the end of 20th month of the construction phase.

14.1.10 Penstock

Penstock is one of the main activities. Aligning, fabrication and erection of the penstock will take about 11 months. Fabrication of the penstock would be started from 37th month and would take 8 months to complete by the end of 44th month of the construction period along with installation of trash rack and gates of penstock pipe. The concrete work of anchor blocks will take about 3 months to complete.

14.1.11 Powerhouse

Civil works for powerhouse are also on the critical path. Installation work of electromechanical equipment, embedded parts of the turbines and generators and construction of the superstructure, are part of this activity. Construction of the powerhouse has been planned in such a manner that it should be ready by the time other structures are completed. The powerhouse is to be constructed on the left bank of the river. It is proposed that this activity

should be started by the contractor immediately after the mobilization and completion of access roads. Excavation will be started on the 13th month of construction phase. The completion of excavation including treatment for foundations is proposed to take about 9 months. The construction of different floors of powerhouse activity i.e. Civil works will be started in the start of 22th month and construction of the powerhouse is expected to be completed by the end of 44th month of construction period. Fabrication of steel and aluminum doors and windows and architectural work will also be completed by this time.

14.1.12 Tailrace

Excavation of tailrace will commence in the 3rd week of 38th month of construction period. The excavated material will be utilized to make access paths in and around the powerhouse and tailrace area. Tailrace activity would take about 6.5 months and is expected to be completed by the end of 44th month of construction period.

14.1.13 Installation of E & M Equipment

Full manufacturing and installation of electro-mechanical equipment along with embedded parts is expected to take 34 months. The manufacturing of E & M equipment particularly the turbines and generators are again on the critical path and as such the work for these has to be awarded at the time of award of civil works. It is also essential for the equipment to be delivered in stages starting with the embedded parts. Placement of embedded parts will start with second stage concrete. The installation of units has been proposed to be carried out in stages. As soon as curing of concrete around embedded parts is complete the generator and turbine for the first unit will be installed by the end of 42th month of construction period. The installations of all power units including dry and wet tests are proposed to be completed by the 60th month of construction phase.

14.1.14 Switchyard and Transmission Line

The deck for the switchyard would be simultaneously completed with power house construction and erection for switchyard equipment, transformers, gantries, isolators and switchgear will be initiated. Bus bars will be strung and droppers connected up. Powerhouse and switchyard lighting will also be taken up during this period. Installation of panels' connection will start at the 3rd week of 23rd month and will be completed by the end of 47th month of construction phase.

Work on 13 km long 132 kV double circuit transmission line will start by 23rd month and shall be completed by 47th month of construction phase. Total construction time for this activity will be 23 months.

14.1.15 Testing and Commissioning

The work on commissioning of the units will be taken up in stages starting by the end of 52nd month and will include dehydration of the transformers and testing of switchgear. All relays will be calibrated by secondary injection tests. Primary current injection tests will be applied to all CT's and their ratios verified. Relay wiring will be checked and breakers tripped by manual operation of each relay. The turbines will be given no-load mechanical runs to ensure vibration free operation and to check temperature rise of all bearings. Generators will be dried out using standard procedure. After dry out, voltage will be built up and phase sequence checked, and if correct, each machine will be synchronized with the system.

Load runs will be executed to ascertain smooth operation and normal temperature rise of all bearings and windings. If possible, response of each unit to stepped changes of load and voltage will be checked. Full load rejection will be compared with predicted values. If all the above tests and observations give satisfactory results, the station would be certified as fully commissioned. The activity is expected to be completed in three months period. All the three units will be fully commissioned at the end of 60th month of construction period.

14.2 COST ESTIMATE

14.2.1 General

This section describes the assumptions and results relating to the construction cost estimate of the Shigokas hydropower project. The total project construction cost of civil works has been estimated on the basis of rates of various items of work as provided in the Market Rate System 2013 (CSR 2013) Government of Khyber Pakhtunkhwa for 3rd quarter of year 2013. Prices of items not covered under CSR-2013 have been obtained from recently completed hydropower projects of similar nature in the northern areas of Khyber Pakhtunkhwa. Proper price escalation has also been applied for preparing realistic cost estimates and to bring the unit rates used at par with the current market rates 2014.

In the case of cost of E&M equipment, due considerations have been given to recession in the market and low prices being quoted by Chinese manufacturers. Equipment which can be manufactured in Pakistan has also been priced accordingly.

14.2.2 Recapitulation of the Project Base Cost

The estimated project base cost is summarized in **Table 14.1**.



Table 14.1: Estimated Project Base Cost

Sr. No.	Description	Local Pak. Rs. (Million)	Foreign Pak. Rs. (Million)	Total Pak. Rs. (Million)
1	**Direct Cost**			
	Civil Works	18502.45	0.00	18502.45
	Permanent Equipment			
	Electro-Mechanical Works	121.70	973.59	1095.29
	Hydro-Mechanical Works	356.66	3331.61	3688.27
	Transmission Line	105.00	245.00	350.00
2	**Indirect Cost**			
	Physical Contingencies (Unforeseen)	572.58	136.5	709.08
	Preliminary Works	600.20	0.00	600.20
	Environment & Resettlement Costs	560.17	0.00	560.17
	Survey, Geotechnical investigation and Detail Design of Civil and E&M Works	472.72	0.00	472.72
	Transportation and Erection Charges of E&M Equipments	131.48	0.00	131.48
3	**Management Consultancy Costs**	727.08	0.00	727.08
	Base Cost of Project	22150.04	4686.70	26836.74
4	**Client Expenses, Administration and Legal Costs**	268.37	0.00	268.37
5	**Duties & Taxes Costs**	227.51	0.00	227.51

14.2.3 Price Level and Rate of Exchange

The estimate is based on current price level and in converting US dollars to Pak. Rupees, the prevailing exchange rate as on **January 2014** has been adopted **viz., US$ 1 = Rs. 99.**

14.2.4 Scope of the Cost Estimates

The cost of all work required to complete the project has been included in the estimate. However, the following expenditures have been excluded from the Project Base Cost, although covered in the Capital Cost:

- Expenditure incurred before the issuance of notice for the Contractor to proceed.
- Escalation of price and currency fluctuations after one year of commencement (construction stage) of the project.
- Interest during construction (IDC).

14.2.5 Project Base Cost Components

The project base cost estimate includes both the direct and the indirect costs associated with the project.

14.2.6 Project Direct Costs

The project direct costs are those directly associated with the main project features and include the cost of all structures, power generation and transmission facilities. The project direct costs are subdivided into the following main headings:

- Civil Works
- Permanent Equipment
- Electro-mechanical Works
- Hydro-mechanical Works
- Switchyards and Transmission Line

14.2.7 Project Indirect Costs

The project indirect costs include all other expenditures required to complete the project and include those costs that cannot readily be allocated to any specific project feature including:

- Temporary camps and other facilities.
- Roads, bridges and other access facilities.
- Environmental and resettlement
- Engineering and project management.



- Owners' administration expenses.

14.2.8 Currency Breakdown

The costs are divided into their local and foreign currency components. This breakdown is based on the source / origin of the labor, materials, equipment or services involved.

14.2.9 Basic Assumptions and Limitations

The cost estimate is based on the following assumptions:

- Construction of the project is envisaged to be completed in 60 months.
- The economic conditions, both in Pakistan and worldwide, will remain essentially stable.
- The project layout and work quantities as defined in the Feasibility Report will not significantly change during the final design stage (minor variations are covered by price contingency allowance).
- Specifications and general contract conditions will be in accordance with international standards and will not be unduly restrictive. These will include an equitable distribution of risk, mobilization charges, contract price adjustment formulae and adequate provisions to maintain positive cash flows by the contractor.
- The project will be offered for bidding under international competitive tendering conditions, and an adequate number of firms will be invited to ensure a fair degree of competition.
- Work permits and visas will be issued for all foreign expatriate/supervisory personnel required for execution of specialized civil and electromechanical works.
- All necessary permits for the right-of-way and use of access to the site will be guaranteed and secured by the owner.
- Resettlement and other preliminary activities will be completed by the owner without affecting the scheduled key milestone dates.
- The construction of main access roads will be completed by the contractor without causing delays to the scheduled key milestone dates.

The capital cost for developing 102 MW Shigo Kas hydropower project is worked out /formulated under three distinct heads.

- The civil works which covers preliminary/preparatory works at intake system, sediment removal, water conveyance system, powerhouse and switchyard, offices, residential colony, communications and other items of civil works.

- Supply, transportation, erection and commissioning of electromechanical equipment

- Development cost, corporate overheads, project management, construction insurance and interest during construction, land and financing charges.

Working conditions in the area are expected to be fairly good. The country has a fair stock of machinery operators. Conventional method of excavation is intended to be used for all components. Good quality construction material is available in the vicinity and/or in the adjoining areas of Shigo Kas. The above conditions were kept in mind while working out the cost estimate. It is assumed that a main contractor would himself execute the job requiring heavy machinery and specialized knowledge. However, simple jobs like colony building, supply of materials and other small nature jobs not can be sublet to local contractors.

14.3 DEVELOPMENT OF COST ESTIMATE FOR CIVIL WORK

14.3.1 Civil Work Quantities

Quantities of civil work items for Shigo Kas hydropower project have been calculated from the feasibility-level design drawings. Where possible the quantities have been worked out using AutoCAD techniques; while the remaining quantities have been derived through manual computations.

Quantities for civil work have been computed on the basis of Layout Plan developed for the scheme and actual topography of the area. The quantities of excavation are obtained from the cross sections drawn at suitable intervals. Quantities for structures have been calculated from the plans and sections of various components. The quantities of electrical and mechanical equipment have been computed on the basis of selected size and type of generating units and preliminary design.

14.3.2 Selection of Construction Methods

Conventional and proven construction methods that can be realistically applied in Pakistan for the execution of the project have been recommended.



14.3.3 Open Cut Excavation

The cost estimate assumes that all open cut excavation will be executed by use of medium (5 to 8 m^3 capacity) to large (9 to 12 m^3 capacity) excavators and matching off-highway dump trucks. Drilling and blasting operations are assumed to be performed using medium size hydraulic track drills and conventional explosives. Production rates for open cut excavation are based on past experience on similar projects.

14.3.4 Underground Excavation

Excavation for the tunnel is assumed to be performed using conventional drilling and blasting techniques and equipment. Underground advance work is assumed to be based on tunneling rates experienced on similar work. The construction program allows sufficient time for crossing foreseeable faults and difficult geology.

14.3.5 Processing of Construction Material

The cost estimate of Construction Material is based on the assumption that all processed materials for both coarse and fine concrete aggregates and filters would be obtained from required excavations and / or from a quarry. For estimation purposes it is assumed that a crushing and screening plant of at least 20 ton per hour capacity would be required to provide aggregates for the conventional concrete.

14.3.6 Conventional Concrete

It has been assumed that the conventional concrete would be manufactured using a 20 m^3 per hour capacity batch and mix plant having aggregate pre-cooling and ice manufacturing facilities.

14.3.7 Material and Supplies

Most of the required material is supposed to be available from sources in Pakistan. The only significant items that will have to be imported are bits, rods and other drilling consumables. Rates of these items therefore include custom duties and taxes. The cost of these materials and supplies also covers the delivery of these supplies to the site. These materials include local as well as foreign currency purchases. The supply of cement, reinforcing steel, structural steel etc is included in the local currency purchase whereas mechanical rebar joints etc are included as a foreign currency purchase. Cost of small tools and supplies such as safety clothing, hand tools, small power tools, hardware, ladders and welding plant have been covered under the main item cost.

14.3.8 Construction Program

Construction schedule, developed on critical path planning, is shown on Figure-14.1. This schedule comprises the total project split into its main components. Schedule activity sequence and durations are based on production rates that can be reasonably achieved by use of plant and equipment that was selected for the purposes of developing the cost estimate. The schedule shows that the project would be completed in 60 months.

14.3.9 Analysis of Unit Rates

Rates for different items of Civil Work for Shigo Kas Hydropower Project have been based on:

- The rates of various items of civil works taken from the Market Rate System 2013 (CSR 2013) Government of Khyber Pakhtunkhwa for 3rd quarter of year 2013.
- Prices of items not covered under CSR-2013 have been obtained from recently completed hydropower projects of similar nature in the northern areas of Khyber Pakhtunkhwa. Proper price escalation has also been applied for preparing realistic cost estimates and to bring the unit rates used at par with the current market rates 2014.
- Rates of E&M works such as turbines, generators, transformers and other related equipment adopted in view of the following considerations:

  a) Rates from on-going similar projects.

  b) Using engineering judgment to review the prevailing local market rates of different items of works.

  c) Current recession in market and low rates being quoted by Chinese manufacturers.

14.3.10 Historical Costs

Unit costs for minor civil work items were derived from properly adjusted historical records. For comparison purposes, historical in-house data from previous projects, formulae and experience curves were also used to check estimated costs for major civil works. Where necessary, adjustments for escalation, (to June 2011 price levels) and for local conditions were applied.

14.3.11 Miscellaneous Item Costs

The estimate includes an allowance for unquantifiable and unforeseen miscellaneous items such as excavation over break, water stoppers, lean concrete, bedding mortar, grouting,

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instrumentation to observe rock movements, anchor bolts, steel ribs, special finishes, miscellaneous steel work, minor equipment/tools and contact grouting etc.

All such unquantifiable, unforeseen and miscellaneous items have been labeled and accounted globally as "Other Items". Depending on the type of work, the allowances for these items vary from 0 to 10 percent of the corresponding section subtotal.

14.4 DEVELOPMENT OF COST ESTIMATE FOR PERMANENT EQUIPMENT

14.4.1 Turbines, Generators and Transformers

The cost for supply and installation of turbines, generators and transformers was determined from international manufacturer's budgetary prices. These prices were compared with in-house historical data and experience curves and were found reasonable.

14.4.2 Hydro-mechanical Equipment

Costs of gates, hoists, trash racks, and other miscellaneous hydro-mechanical equipments were estimated on the basis of component weight or adjusted data from previous projects.

14.4.3 Permanent Miscellaneous Electromechanical Equipment

The cost of the "balance of plant" and the miscellaneous electromechanical equipment was estimated in detail on the basis of preliminary specifications and in-house historical data that was available from similar projects.

14.4.4 132 kV Transmission Line and Substations

Transmission line from bus bar will be connected to Timergara grid station. The length of transmission line is estimated as 13 km. The cost of 132 kV transmission line and the substation costs were estimated on the basis of contract prices of existing PHYDO/WAPDA projects and prices obtained from the manufacturers. The construction costs have been estimated considering the difficult terrain and access involved. Cost of towers and foundations were based on conductor loadings.

14.4.5 Transport and Communication Equipment

Provision has also been made for vehicles and communication equipment.

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14.4.6 Erection and Transportation Charges

Erection and transportation charges associated with the electrical and mechanical equipment are taken as 3% of the total cost of E & M works.

14.5 DEVELOPMENT OF COST ESTIMATE FOR THE PROJECT INDIRECT COST

14.5.1 Temporary Camps and Other Facilities

The staff needed for operation and maintenance will stay at site and will need accommodation. About 9,000 square meter covered area has been proposed for residential colony. Temporary camps and offices required for the project were priced based upon information on local housing costs obtained in Lower Dir, Timergara town and villages falling in the project area. The prices were adjusted for the type and quality of buildings required for the project.

It was assumed that at the end of the construction period some of the temporary camps will be converted to permanent colonies to be used for the operation and maintenance staff. An allowance for renovation of these facilities has been included in the estimate.

14.5.2 Project Access Facilities

A road network of approximately 15.5 km access roads will be needed for approach to weir, surge tank and powerhouse. A new concrete bridge and 18 No. culverts will also be required for approach to these sites. Costs have been estimated based on a feasibility level design of the road, bridge and culverts.

14.5.3 Environmental and Resettlement

The cost for mitigation of the environmental impact and resettlement was estimated as follows:

- The cost for land compensation has been estimated based on current market rates.
- The cost of trees such as mulberry tree and the cost of firewood is estimated on the lump sum basis for mulberry and firewood trees.
- The cost for electric power supply lines and telephone lines is estimated based on current prices.



14.5.4 Survey ,geotech investigation and Detailed Design and Tender Documents

Cost for detailed design and tender documents has been charged to the Shigo Kas hydropower project @ 2% of the sum of civil, electrical, mechanical costs, transmission and preliminary work costs.

14.5.5 Client Expenses

Client expenses i.e. cost for administration and legal matters has been charged to the Shigokas Hydropower project @1% of the sum of civil, electrical, mechanical costs, transmission and preliminary work costs.

14.5.6 Management Consultancy Cost

An allowance of @3% of the total estimated construction cost (sum of civil, electrical, mechanical costs, transmission and preliminary work costs) has been included to cover the following engineering and administration expenses:

- Prequalification of contractors
- Evaluation of tenders
- Review of contractor's submittals
- Construction management including construction supervision, contract administration and processing of contractor's claims.
- Owner's administration and coordination costs
- Other costs incurred by the Owner and the Engineer

14.5.7 Duties and Taxes

Costs relating to duties and taxes on imported construction equipment and installed plant are included in the project and worked our @5% of the cost of foreign equipment.

14.5.8 Cash Flow

The capital cost estimate for the project was based on the construction program. It is anticipated that all power generating units will be in commercial operation in 72 months. The resulting cash flow was also prepared keeping in view the construction of the entire project. This has been discussed in the chapter 15 (Economic & Financial Analysis).

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14.5.9 Cost Estimate

Summary of Cost Estimated and Detailed Cost Estimate of the project are given in **Annexure-14A.**

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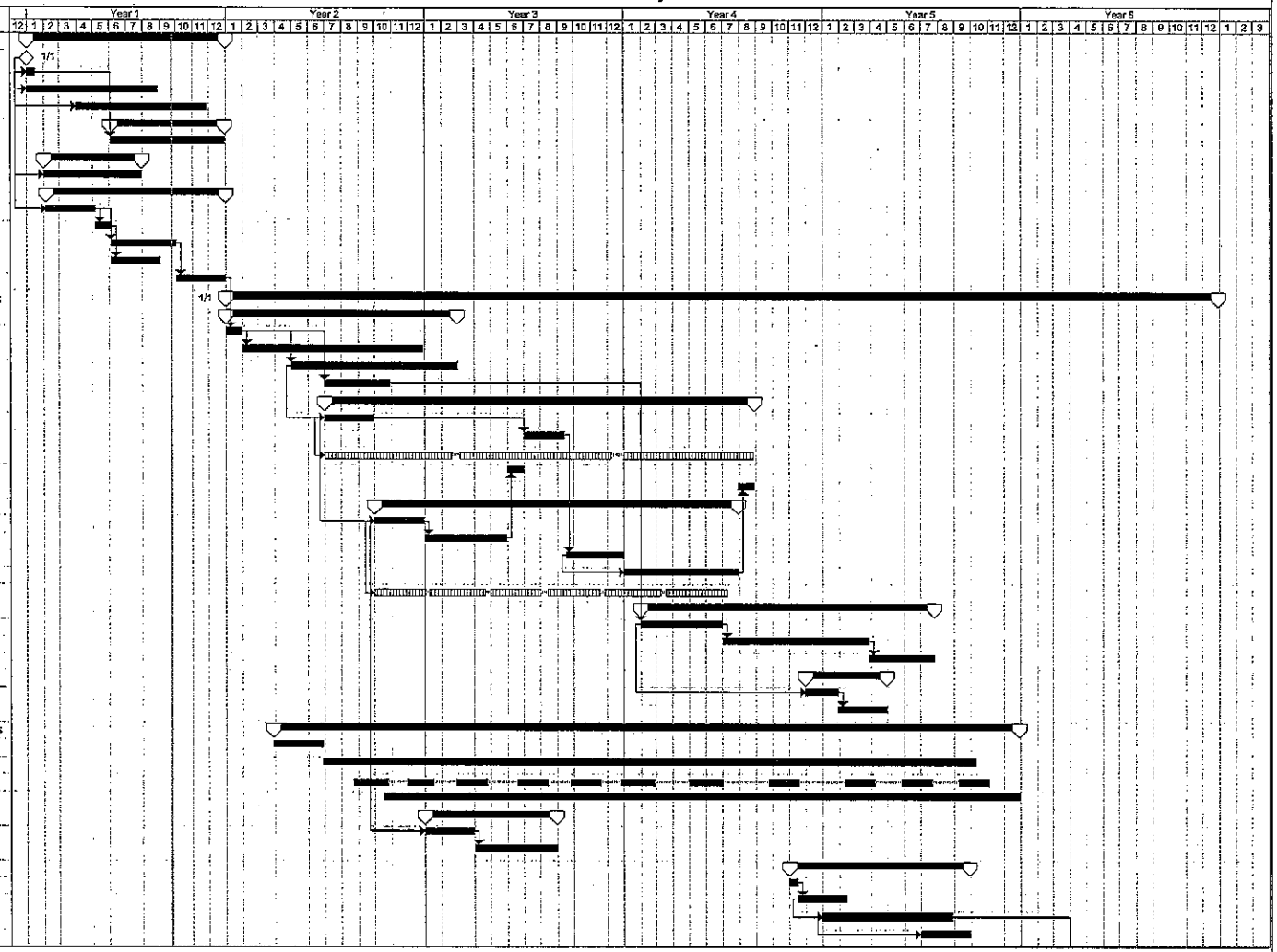
FIGURE 14.1

SHIGO KAS HYDROPOWER PROJECT DISTRICT DIR
(OVER ALL IMPLEMENTATION SCHEDULE)

ID	Task Name	Duration
1	**1 Pre-Construction Stage**	**365 days**
2	1.1 Feasibility Study	0 days
3	1.2 PC - I	15 days
4	1.3 Tariff, Power Sales Terms & NEPRA Approval, Misc.Legal Issues & Approvals	240 days
5	1.4 Power Purchase Agreement & Water Use Agreement	240 days
6	**1.5 Land Acquisition**	**210 days**
7	1.5.1 Program Set-up & Land Acquisition	210 days
8	**1.6 Permits and Approvals**	**180 days**
9	1.6.1 Environmental Clearance & Generation License	180 days
10	**1.7 Consultancy and Tendering**	**330 days**
11	1.7.1 Appointment of Consultant	90 days
12	1.7.2 Additional Investigation and surveys	30 days
13	1.7.3 Tender Design & Tender Documents, Tendering and Receiving Bids	120 days
14	1.7.4 Prequalification of EPC Contractor	90 days
15	1.7.5 Tender Evaluation and Selection of Contractor & Negotiation and Awards	90 days
16	**2 Construction Stage**	**1824 days**
17	**2.1 Preparatory Works**	**425 days**
18	2.1.1 Notice to Proceed + Mobilization	30 days
19	2.1.2 Detail Design of Civil other Works, Offices, Camps, Colony & Other Site Facilities	330 days
20	2.1.3 Access Road in working area I/c Power House & Colony	305 days
21	2.1.4 Concrete Plant and Equipment	120 days
22	**2.2 River Diversion**	**790 days**
23	2.2.1 Construction of Embankment for Stage-I Cofferdam	90 days
24	2.2.2 Construction of Embankment for Stage-II Cofferdam	75 days
25	2.2.3 Care and Handling of Water & Dewatering	750 days
26	2.2.4 Removal of Cofferdam Stage-I	30 days
27	2.2.5 Removal of Cofferdam Stage-II	30 days
28	**2.3 Construction of Weir and Intake**	**668 days**
29	2.3.1 Excavation Stage-I and backfilling	90 days
30	2.3.2 Foundation Treatment, RCC in (Weir, Intake), Installations of (Trash racks, Conti	150 days
31	2.3.3 Excavation Stage-II and backfilling	105 days
32	2.3.4 Foundation Treatment, RCC in (Weir, Intake), Installations of (Trash racks, Conti	210 days
33	2.3.5 Care and Handling of Water & Dewatering	600 days
34	**2.4 Sand Trap**	**540 days**
35	2.4.1 Excavation and backfilling	150 days
36	2.4.2 Reinforced Concrete in Sand Trap Chambers / Forebay	270 days
37	2.4.3 Installations of (Mechanical Embedded Parts, Trash racks, Control Gates, S.Guar	120 days
38	**2.5 Connecting Channel**	**150 days**
39	2.5.1 Surface Excavation	60 days
40	2.5.2 Lean Concrete, RCC in Channel Walls / bed , instalation of (Guardrail + security f	90 days
41	**2.6 Power Tunnel**	**1372 days**
42	2.6.1 Portal Excavations	90 days
43	2.6.2 Underground Excavations,	1200 days
44	2.6.3 Rock Bolting and Shortcrete,	630 days
45	2.6.4 Reinforced Concrete in Power Tunnel Lining	1169 days
46	**2.7 Surge Shaft**	**243 days**
47	2.7.1 Portal & Underground Excavations	90 days
48	2.7.2 Concreting and Rock Bolting, Reinforced Concrete in Portals & in Surge Shaft & T	150 days
49	**2.8 Penstock / Pressure Shaft**	**332 days**
50	2.8.1 Alignment for Penstock	15 days
51	2.8.2 Excavations	90 days
52	2.8.3 Fabrication & Erection of Steel Liner / Gate / Trashrack	240 days
53	2.8.4 Reinforced Concrete in Anchor Blocks for Penstock	90 days



Task
Mile Stone
Task Summary
Split

Care & Handeling of Water
Comercial Operation
Takeover Certificate

Project: Shigo Kas HPP
Location: District Lower Kur

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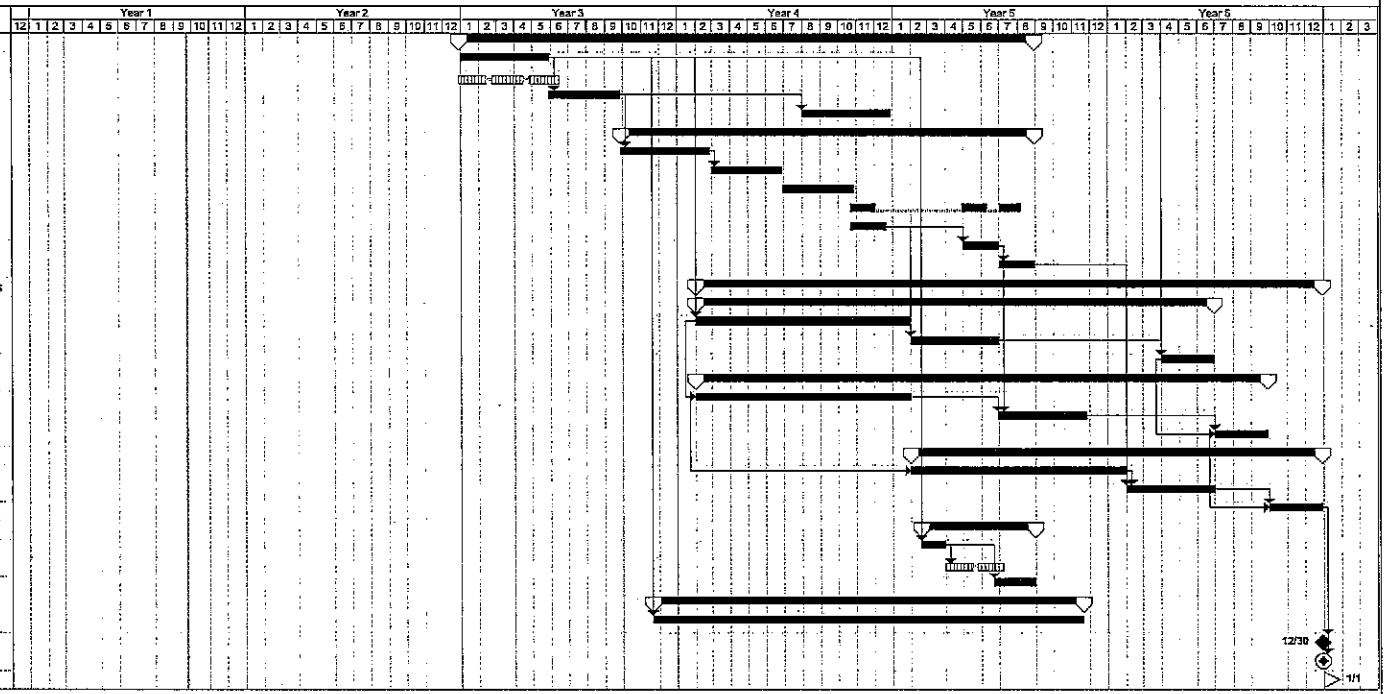
FIGURE 14.1

SHIGO KAS HYDROPOWER PROJECT DISTRICT DIR
(OVER ALL IMPLEMENTATION SCHEDULE)

ID	Task Name	Duration
54	**2.9 Power House**	**975 days**
55	2.9.1 Excavation	150 days
56	2.9.2 Dewatering	150 days
57	2.9.3 Foundation Treatment	120 days
58	2.9.4 Fabrication and Fixing of Doors & Windows & Architectural Works	150 days
59	**2.9.5 Concrete**	**701 days**
60	2.9.5.1 Concrete in Foundations	150 days
61	2.9.5.2 RCC in (Draft tubes , Turbine Floor and Walls)	120 days
62	2.9.5.3 Reinforced Concrete in Superstructure	120 days
63	2.9.5.4 Second Stage Conrete	120 days
64	2.9.5.5 Installation of Embedded Parts of Unit -1	60 days
65	2.9.5.6 Installation of Embedded Parts of Unit -2	60 days
66	2.9.5.7 Installation of Embedded Parts of Unit -3	60 days
67	**2.10 Electrical and Mechanical Works**	**1062 days**
68	**2.10.1 Unit-1**	**879 days**
69	2.10.1.1 Fabrication and Delivery of Embedded Parts, E & M Equipment	365 days
70	2.10.1.2 Erection of (Turbine, Generator and other Equipment)	150 days
71	2.10.1.3 Wet testing and Commissioning	90 days
72	**2.10.2 Unit-2**	**970 days**
73	2.10.2.1 Fabrication and Delivery of Embedded Parts, E & M Equipment	365 days
74	2.10.2.2 Erection of (Turbine, Generator and other Equipment)	150 days
75	2.10.2.3 Wet testing and Commissioning	90 days
76	**2.10.3 Unit-3**	**697 days**
77	2.10.3.1 Fabrication and Delivery of Embedded Parts, E & M Equipment	365 days
78	2.10.3.2 Erection of (Turbine, Generator and other Equipment)	150 days
79	2.10.3.3 Wet testing and Commissioning	90 days
80	**2.11 Tailrace**	**193 days**
81	2.11.1 Excavation	40 days
82	2.11.2 Dewatering	90 days
83	2.11.3 Reinforced Concrete in Tailrace, Installations of Mechanical Embedded Parts and	70 days
84	**2.12 Transmission Interconnection**	**730 days**
85	2.12.1 Construction of Powerhouse Switchyard, Transmission Line	730 days
86	**3 Start of Commercial Operation**	0 days
87	**4 Taking over Certificate**	1 day
88	**5 Deffect Liability Period (As per Client Requirement)**	0 days



Project: Shigo Kas HPP
Location: District Lower Dir

SAIFCO HYDRO POWER LIMITED

Task
Mile Stone
Task Summary
Split

Care & Handeling of Water
Comercial Operation
Takeover Certificate

Table – 15.1

FEASIBILITY STUDY OF SHIGO KAS HYDROPOWER PROJECT

DERIVATION OF STANDARD CONVERSION FACTOR

(Rs.Million)

	Description/Years	2007-08	2008-09	2009-10	2010-11	2011-12	Average
1	Total Imports *	2512072	2723570	2910975	3455287	4009093	3122199
2	Total Exports *	1196638	1383718	1617458	2120847	2112140	1686160
3	Import Duties **	159923	155153	161504	187695	219589	176773
4	Sales Tax on Imports **	196034	203715	247246	308648	430399	277208
5	Subsidies on Imports ***	69705	29300	37725	20200	49198	41226
6	Export Duties **	3148	3815	4551	5685	5762	4592
7	Export Rebates **	12408	7646	5783	8527	8453	8563

$$\text{Standard Conversion Factor} = \frac{M + X}{(M+Tm) + (X-Tx)} = \frac{4808359}{5307537}$$

$$= 0.906$$

Where M = CIF value of imports
X = FOB value of exports
Tm = Net value of taxes on imports
Tx = Net value of taxes on exports

* Economic Survey 2011-12
** FBR Islamabad
*** Ministry of Finance Islamabad.

SAIFCO HYDRO POWER LIMITED

Table -15.3
FEASIBILITY STUDY OF SHIGO KAS HYDROPOWER PROJECT
PHASING OF CAPITAL COST

(Amount in Million Rs.)

Sr. No.	Component	1st YEAR			2nd YEAR			3rd YEAR			4th YEAR			5th YEAR			Total Cost		
		Local	FEC	Total	Local	FEC	Total	Local	FEC	Total	Local	FEC	Total	Local	FEC	Total	Local	FEC	Total
A	Preliminary Works	480.16	0.00	480.16	120.04	0.00	120.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	600.20	0.00	600.20
B	Environment & Resettlement Costs(Land Acquisition)	560.17	0.00	560.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	560.17	0.00	560.17
C	Civil Works	2175.89	0.00	2175.89	5273.20	0.00	5273.20	5828.27	0.00	5828.27	5225.09	0.00	5225.09	0.00	0.00	0.00	18502.45	0.00	18502.45
D	Electrical & Mechanical	0.00	0.00	0.00	71.75	645.78	717.53	133.94	1205.46	1339.40	148.29	1334.61	1482.90	124.38	1119.35	1243.73	478.36	4305.20	4783.56
	Transmission Line	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	69.99	163.32	233.31	35.01	81.68	116.69	105.00	245.00	350.00
	Total Works Cost	**3216.22**	**0.00**	**3216.22**	**5464.99**	**645.78**	**6110.77**	**5962.21**	**1205.46**	**7167.67**	**5443.37**	**1497.93**	**6941.30**	**159.39**	**1201.03**	**1360.42**	**20246.18**	**4550.20**	**24796.38**
E	Physical Contingencies (Unforeseen) @3% of	65.28	0.00	65.28	160.35	19.37	179.72	178.87	36.16	215.03	163.30	44.94	208.24	4.78	36.03	40.81	572.58	138.50	709.08
F	Transportation and Erection Charges of E&M Equipments @3% of D (Foreign Cost)	0.00	0.00	0.00	14.35	0.00	14.35	36.16	0.00	36.16	44.94	0.00	44.94	36.03	0.00	36.03	131.48	0.00	131.48
G	Survey ,geotech investigation and Detail Design of Civil and E&M Works @ 2% of (C + D)	43.52	0.00	43.52	119.81	0.00	119.81	143.35	0.00	143.35	138.83	0.00	138.83	27.21	0.00	27.21	472.72	0.00	472.72
H	Management Consultancy Cost @ 3% of (A + C + D)	79.68	0.00	79.68	183.32	0.00	183.32	215.03	0.00	215.03	208.24	0.00	208.24	40.81	0.00	40.81	727.08	0.00	727.08
	Total Base Cost	**3404.70**	**0.00**	**3404.70**	**5942.82**	**665.15**	**6607.97**	**6535.62**	**1241.62**	**7777.24**	**5998.68**	**1542.87**	**7541.55**	**268.22**	**1237.06**	**1505.28**	**22150.04**	**4686.70**	**26836.74**
I	Client Expenses, Administration and Legal Costs @1% Base Cost	34.05	0.00	34.05	66.08	0.00	66.08	77.77	0.00	77.77	75.42	0.00	75.42	15.05	0.00	15.05	268.37	0.00	268.37
J	Custom Duty@ 5% of D (on FEC)	0.00	0.00	0.00	32.29	0.00	32.29	60.27	0.00	60.27	74.90	0.00	74.90	60.05	0.00	60.05	227.51	0.00	227.51
K	Escalation @ 6.50% on Local cost & 1.3% on FEC	0.00	0.00	0.00	355.22	0.00	355.22	800.28	15.67	815.95	1131.95	38.95	1170.90	42.79	47.44	90.23	2330.24	102.06	2432.30
L	Interest during Construction (IDC) @10.65% of Base Cost	362.60	0.00	362.60	703.75	0.00	703.75	828.28	0.00	828.28	603.18	0.00	603.18	160.31	0.00	160.31	2658.12	0.00	2658.12
	Total Project Cost	**3801.35**	**0.00**	**3801.35**	**7100.16**	**665.15**	**7765.31**	**8302.22**	**1257.29**	**9559.51**	**8084.13**	**1581.82**	**9665.95**	**546.42**	**1284.50**	**1830.92**	**27834.28**	**4788.76**	**32623.04**

SAIF POWER LIMITED
ARIF HABIB GROUP

Table -15.2

FEASIBILITY STUDY OF SHIGO KAS HYDROPOWER PROJECT

SUMMARY OF PROJECT CAPITAL COST

(Amount in Million Rs.)

Sr. No.	Component	Estimated Cost		
		Local	FEC	Total
A	Preliminary Works	600.20	0.00	600.20
B	Environment & Resettlement Costs(Land Acquisition)	560.17	0.00	560.17
C	Civil Works	18502.45	0.00	18502.45
D	Electrical & Mechanical Works	478.36	4305.20	4783.56
	Transmission Line	105.00	245.00	350.00
	Total Works Cost	**20246.18**	**4550.20**	**24796.38**
E	Physical Contingencies (Unforeseen) @ 3% of C+D	572.58	136.50	709.08
F	Transportation and Erection Charges of E&M Equipments @3% of D	131.48	0.00	131.48
G	Survey ,geotech investigation and Detail Design of Civil and E&M Works @ 2% of (C + D)	472.72	0.00	472.72
H	Management Consultancy Cost @ 3% of (A + C + D)	727.08	0.00	727.08
	Total Base Cost	**22150.04**	**4686.70**	**26836.74**
I	Client Expenses, Administration and Legal Costs @1% Base Cost	268.37	0.00	268.37
J	Custom Duty@ 5% of D (on FEC)	227.51	0.00	227.51
K	Escalation @ 6.50% on Local cost & 1.3% on FEC	2330.24	102.06	2432.30
L	Interest during Construction (IDC) @10.65% of Base Cost	2858.12	0.00	2858.12
	Total Project Cost	**27834.28**	**4788.76**	**32623.04**

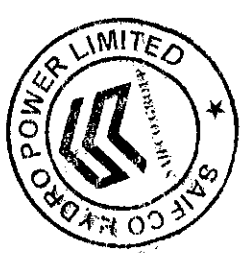


TABLE 15.4
FEASIBILITY STUDY OF SHIGO KAS HYDROPOWER PROJECT
ECONOMIC ANALYSIS USING SIMPLE CYCLE PLANT AS THERMAL EQUIVALENT

YEAR	YEAR OF OPERATION	PROJECT COSTS			COSTS OF EQ. THERMAL PLANTS					
		CAPITAL COST	O & M COST	TOTAL	CAPITAL COST	REFURB. COST	O & M COST	FUEL COST	TOTAL	NET BENEFITS
1		3094.875		3094.875					0.000	-3094.875
2		6355.404		6355.404					0.000	-6355.404
3		7858.107		7858.107	3441.40				3441.398	-4416.709
4		7976.493		7976.493	3871.57				3871.573	-4104.920
5		1503.55		1503.549	1290.52		335.599	3083.395	4709.518	3205.969
6	1		483.061	483.061			671.199	6166.789	6837.988	6354.926
7	2		483.061	483.061			671.199	6166.789	6837.988	6354.926
8	3		483.061	483.061			671.199	6166.789	6837.988	6354.926
9	4		483.061	483.061			671.199	6166.789	6837.988	6354.926
10	5		483.061	483.061			671.199	6166.789	6837.988	6354.926
11	6		483.061	483.061			671.199	6166.789	6837.988	6354.926
12	7		483.061	483.061			671.199	6166.789	6837.988	6354.926
13	8		483.061	483.061			671.199	6166.789	6837.988	6354.926
14	9		483.061	483.061			671.199	6166.789	6837.988	6354.926
15	10		483.061	483.061			671.199	6166.789	6837.988	6354.926
16	11		483.061	483.061			671.199	6166.789	6837.988	6354.926
17	12		483.061	483.061			671.199	6166.789	6837.988	6354.926
18	13		483.061	483.061			671.199	6166.789	6837.988	6354.926
19	14		483.061	483.061			671.199	6166.789	6837.988	6354.926
20	15		483.061	483.061			671.199	6166.789	6837.988	6354.926
21	16		483.061	483.061			671.199	6166.789	6837.988	6354.926
22	17		483.061	483.061			671.199	6166.789	6837.988	6354.926
23	18		483.061	483.061			671.199	6166.789	6837.988	6354.926
24	19		483.061	483.061			671.199	6166.789	6837.988	6354.926
25	20		483.061	483.061			671.199	6166.789	6837.988	6354.926
26	21		483.061	483.061			671.199	6166.789	6837.988	6354.926
27	22		483.061	483.061			671.199	6166.789	6837.988	6354.926
28	23		483.061	483.061			671.199	6166.789	6837.988	6354.926
29	24		483.061	483.061		2753.1187	671.199	6166.789	9591.107	9108.045
30	25		483.061	483.061		3097.2586	671.199	6166.789	9935.246	9452.185
31	26		483.061	483.061		1032.4195	671.199	6166.789	7870.407	7387.346
32	27		483.061	483.061			671.199	6166.789	6837.988	6354.926
33	28		483.061	483.061			671.199	6166.789	6837.988	6354.926
34	29		483.061	483.061			671.199	6166.789	6837.988	6354.926
35	30		483.061	483.061			671.199	6166.789	6837.988	6354.926
36	31		483.061	483.061			671.199	6166.789	6837.988	6354.926
37	32		483.061	483.061			671.199	6166.789	6837.988	6354.926
38	33		483.061	483.061			671.199	6166.789	6837.988	6354.926
39	34		483.061	483.061			671.199	6166.789	6837.988	6354.926
40	35		483.061	483.061			671.199	6166.789	6837.988	6354.926
41	36		483.061	483.061			671.199	6166.789	6837.988	6354.926
42	37		483.061	483.061			671.199	6166.789	6837.988	6354.926
43	38		483.061	483.061			671.199	6166.789	6837.988	6354.926
44	39		483.061	483.061			671.199	6166.789	6837.988	6354.926
45	40		483.061	483.061			671.199	6166.789	6837.988	6354.926
46	41		483.061	483.061			671.199	6166.789	6837.988	6354.926
47	42		483.061	483.061			671.199	6166.789	6837.988	6354.926
48	43		483.061	483.061			671.199	6166.789	6837.988	6354.926
49	44		483.061	483.061			671.199	6166.789	6837.988	6354.926
50	45		483.061	483.061			671.199	6166.789	6837.988	6354.926
51	46		483.061	483.061			671.199	6166.789	6837.988	6354.926
52	47		483.061	483.061			671.199	6166.789	6837.988	3083.395
53	48		483.061	483.061			671.199	6166.789	6837.988	3083.395
54	49		483.061	483.061			671.199	6166.789	6837.988	6354.926
55	50		483.061	483.061			671.199	6166.789	6837.988	6354.926
TOTAL		26788.428	24153.066	50941.494	8603.496	6882.797	33895.530	311422.855	360804.678	303320.120

SUMMARY OF ECONOMIC INDICES

Benefits / Cost Ratio @ 12% discount rate	1.85
EIRR	23.13%
Present Worth of Cost (Rs. Million)	21621.655
Present Worth of Benefits (Rs. Million)	40041.285
NPV (Rs. Million)	18419.630

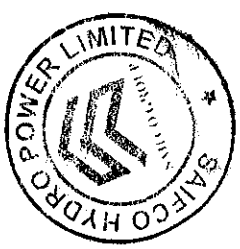


TABLE 15.5
FEASIBILITY STUDY OF SHIGO KAS HYDROPOWER PROJECT
ECONOMIC ANALYSIS USING COMBINED CYCLE PLANT AS THERMAL EQUIVALENT

YEAR	YEAR OF OPERATION	PROJECT COSTS			COSTS OF EQ. THERMAL PLANTS					
		CAPITAL COST	O & M COST	TOTAL	CAPITAL COST	REFURB. COST	O & M COST	FUEL COST	TOTAL	NET BENEFITS
1		3094.875		3094.875					0.000	-3094.875
2		6355.404		6355.404					0.000	-6355.404
3		7858.107		7858.107	4968.22				4968.216	-2889.891
4		7976.493		7976.493	5589.24				5589.243	-2387.250
5		1503.55		1503.549	1863.08		476.776	2167.720	4507.577	3004.028
6	1		483.061	483.061			953.552	4335.440	5288.992	4805.931
7	2		483.061	483.061			953.552	4335.440	5288.992	4805.931
8	3		483.061	483.061			953.552	4335.440	5288.992	4805.931
9	4		483.061	483.061			953.552	4335.440	5288.992	4805.931
10	5		483.061	483.061			953.552	4335.440	5288.992	4805.931
11	6		483.061	483.061			953.552	4335.440	5288.992	4805.931
12	7		483.061	483.061			953.552	4335.440	5288.992	4805.931
13	8		483.061	483.061			953.552	4335.440	5288.992	4805.931
14	9		483.061	483.061			953.552	4335.440	5288.992	4805.931
15	10		483.061	483.061			953.552	4335.440	5288.992	4805.931
16	11		483.061	483.061			953.552	4335.440	5288.992	4805.931
17	12		483.061	483.061			953.552	4335.440	5288.992	4805.931
18	13		483.061	483.061			953.552	4335.440	5288.992	4805.931
19	14		483.061	483.061			953.552	4335.440	5288.992	4805.931
20	15		483.061	483.061			953.552	4335.440	5288.992	4805.931
21	16		483.061	483.061			953.552	4335.440	5288.992	4805.931
22	17		483.061	483.061			953.552	4335.440	5288.992	4805.931
23	18		483.061	483.061			953.552	4335.440	5288.992	4805.931
24	19		483.061	483.061			953.552	4335.440	5288.992	4805.931
25	20		483.061	483.061			953.552	4335.440	5288.992	4805.931
26	21		483.061	483.061			953.552	4335.440	5288.992	4805.931
27	22		483.061	483.061			953.552	4335.440	5288.992	4805.931
28	23		483.061	483.061			953.552	4335.440	5288.992	4805.931
29	24		483.061	483.061		3974.5728	953.552	4335.440	9263.565	8780.503
30	25		483.061	483.061		4471.3944	953.552	4335.440	9760.386	9277.325
31	26		483.061	483.061		1490.4648	953.552	4335.440	6779.457	6296.395
32	27		483.061	483.061			953.552	4335.440	5288.992	4805.931
33	28		483.061	483.061			953.552	4335.440	5288.992	4805.931
34	29		483.061	483.061			953.552	4335.440	5288.992	4805.931
35	30		483.061	483.061			953.552	4335.440	5288.992	4805.931
36	31		483.061	483.061			953.552	4335.440	5288.992	4805.931
37	32		483.061	483.061			953.552	4335.440	5288.992	4805.931
38	33		483.061	483.061			953.552	4335.440	5288.992	4805.931
39	34		483.061	483.061			953.552	4335.440	5288.992	4805.931
40	35		483.061	483.061			953.552	4335.440	5288.992	4805.931
41	36		483.061	483.061			953.552	4335.440	5288.992	4805.931
42	37		483.061	483.061			953.552	4335.440	5288.992	4805.931
43	38		483.061	483.061			953.552	4335.440	5288.992	4805.931
44	39		483.061	483.061			953.552	4335.440	5288.992	4805.931
45	40		483.061	483.061			953.552	4335.440	5288.992	4805.931
46	41		483.061	483.061			953.552	4335.440	5288.992	4805.931
47	42		483.061	483.061			953.552	4335.440	5288.992	4805.931
48	43		483.061	483.061			953.552	4335.440	5288.992	4805.931
49	44		483.061	483.061			953.552	4335.440	5288.992	4805.931
50	45		483.061	483.061			953.552	4335.440	5288.992	4805.931
51	46		483.061	483.061			953.552	4335.440	5288.992	4805.931
52	47		483.061	483.061			953.552	4335.440	5288.992	4805.931
53	48		483.061	483.061			953.552	4335.440	5288.992	4805.931
54	49		483.061	483.061			953.552	4335.440	5288.992	4805.931
55	50		483.061	483.061			953.552	4335.440	5288.992	4805.931
TOTAL		26788.428	24153.066	50941.494	12420.540	9936.432	48154.384	218939.704	289451.060	238509.566

SUMMARY OF ECONOMIC INDICES

Benefits / Cost Ratio @ 12% discount rate	1.61
EIRR	21.58%
Present Worth of Cost (Rs. Million)	21621.655
Present Worth of Benefits (Rs. Million)	34911.073
NPV (Rs. Million)	13289.419

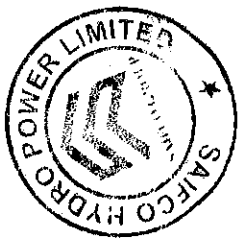


TABLE 15.6
FEASIBILITY STUDY OF SHIGO KAS HYDROPOWER PROJECT
ECONOMIC ANALYSIS USING DIESEL PLANT AS THERMAL EQUIVALENT

YEAR	YEAR OF OPERATION	PROJECT COSTS			COSTS OF EQ, THERMAL PLANTS					
		CAPITAL COST	O & M COST	TOTAL	CAPITAL COST	REFURB. COST	O & M COST	FUEL COST	TOTAL	NET BENEFITS
1		3094.875		3094.875					0.000	-3094.875
2		6355.404		6355.404					0.000	-6355.404
3		7858.107		7858.107	3821.08				3821.083	-4037.024
4		7976.493		7976.493	4298.72				4298.719	-3677.774
5		1503.55		1503.549	1432.91		762.094	3033.613	5228.614	3725.065
6	1		483.061	483.061			1524.188	6067.227	7591.415	7108.354
7	2		483.061	483.061			1524.188	6067.227	7591.415	7108.354
8	3		483.061	483.061			1524.188	6067.227	7591.415	7108.354
9	4		483.061	483.061			1524.188	6067.227	7591.415	7108.354
10	5		483.061	483.061			1524.188	6067.227	7591.415	7108.354
11	6		483.061	483.061			1524.188	6067.227	7591.415	7108.354
12	7		483.061	483.061			1524.188	6067.227	7591.415	7108.354
13	8		483.061	483.061			1524.188	6067.227	7591.415	7108.354
14	9		483.061	483.061			1524.188	6067.227	7591.415	7108.354
15	10		483.061	483.061			1524.188	6067.227	7591.415	7108.354
16	11		483.061	483.061			1524.188	6067.227	7591.415	7108.354
17	12		483.061	483.061			1524.188	6067.227	7591.415	7108.354
18	13		483.061	483.061			1524.188	6067.227	7591.415	7108.354
19	14		483.061	483.061			1524.188	6067.227	7591.415	7108.354
20	15		483.061	483.061			1524.188	6067.227	7591.415	7108.354
21	16		483.061	483.061			1524.188	6067.227	7591.415	7108.354
22	17		483.061	483.061			1524.188	6067.227	7591.415	7108.354
23	18		483.061	483.061			1524.188	6067.227	7591.415	7108.354
24	19		483.061	483.061			1524.188	6067.227	7591.415	7108.354
25	20		483.061	483.061			1524.188	6067.227	7591.415	7108.354
26	21		483.061	483.061			1524.188	6067.227	7591.415	7108.354
27	22		483.061	483.061			1524.188	6067.227	7591.415	7108.354
28	23		483.061	483.061			1524.188	6067.227	7591.415	7108.354
29	24		483.061	483.061		3056.8666	1524.188	6067.227	10648.282	10165.220
30	25		483.061	483.061		3438.9749	1524.188	6067.227	11030.390	10547.329
31	26		483.061	483.061		1146.325	1524.188	6067.227	8737.740	8254.679
32	27		483.061	483.061			1524.188	6067.227	7591.415	7108.354
33	28		483.061	483.061			1524.188	6067.227	7591.415	7108.354
34	29		483.061	483.061			1524.188	6067.227	7591.415	7108.354
35	30		483.061	483.061			1524.188	6067.227	7591.415	7108.354
36	31		483.061	483.061			1524.188	6067.227	7591.415	7108.354
37	32		483.061	483.061			1524.188	6067.227	7591.415	7108.354
38	33		483.061	483.061			1524.188	6067.227	7591.415	7108.354
39	34		483.061	483.061			1524.188	6067.227	7591.415	7108.354
40	35		483.061	483.061			1524.188	6067.227	7591.415	7108.354
41	36		483.061	483.061			1524.188	6067.227	7591.415	7108.354
42	37		483.061	483.061			1524.188	6067.227	7591.415	7108.354
43	38		483.061	483.061			1524.188	6067.227	7591.415	7108.354
44	39		483.061	483.061			1524.188	6067.227	7591.415	7108.354
45	40		483.061	483.061			1524.188	6067.227	7591.415	7108.354
46	41		483.061	483.061			1524.188	6067.227	7591.415	7108.354
47	42		483.061	483.061			1524.188	6067.227	7591.415	7108.354
48	43		483.061	483.061			1524.188	6067.227	7591.415	7108.354
49	44		483.061	483.061			1524.188	6067.227	7591.415	7108.354
50	45		483.061	483.061			1524.188	6067.227	7591.415	7108.354
51	46		483.061	483.061			1524.188	6067.227	7591.415	7108.354
52	47		483.061	483.061			1524.188	6067.227	7591.415	7108.354
53	48		483.061	483.061			1524.188	6067.227	7591.415	7108.354
54	49		483.061	483.061			1524.188	6067.227	7591.415	7108.354
55	50		483.061	483.061			1524.188	6067.227	7591.415	7108.354
TOTAL		26788.428	24153.066	50941.494	9552.708	7642.166	76971.502	306394.957	400561.334	349619.840

SUMMARY OF ECONOMIC INDICES

Benefits / Cost Ratio @ 12% discount rate	2.06
EIRR	25.73%
Present Worth of Cost (Rs. Million)	21621.655
Present Worth of Benefits (Rs. Million)	44453.996
NPV (Rs. Million)	22832.342



TABLE 15.7

FEASIBILITY STUDY OF SHIGO KAS HYDROPOWER PROJECT

SENSITIVITY ANALYSIS USING COMBINED CYCLE PLANT AS THERMAL EQUIVALENT

YEAR	YEAR OF OPERATION	Base Case			Cost Overrun by 10 %		1 Year Benefits Delay		Combination		
		Total Cost	Total Benefits	Net Benefits	Total Cost	Net Benefits	Total Benefits	Net Benefits	Total Cost	Total Benefits	Net Benefits
1		3094.875	0	-3094.875	3404.363	-3404.363	0	-3094.875	3404.363	0	-3404.363
2		6355.404	0	-6355.404	6990.944	-6990.944	0	-6355.404	6990.944	0	-6990.944
3		7858.107	4968.216	-2889.891	8643.918	-3675.702	0	-7858.107	8643.918	0	-8643.918
4		7976.493	5589.243	-2387.25	8774.142	-3184.899	4968.216	-3008.277	8774.142	4968.216	-3805.926
5	1	1503.549	4507.577	3004.028	1653.904	2853.673	5589.243	4085.694	1653.904	5589.243	3935.339
6	2	483.061	5288.992	4805.931	531.367	4757.625	4507.577	4024.516	531.367	4507.5769	3976.21
7	3	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
8	4	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
9	5	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
10	6	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
11	7	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
12	8	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
13	9	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
14	10	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
15	11	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
16	12	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
17	13	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
18	14	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
19	15	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
20	16	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
21	17	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
22	18	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
23	19	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
24	20	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
25	21	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
26	22	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
27	23	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
28	24	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
29	25	483.061	9263.565	8780.503	531.367	8732.198	5288.992	4805.931	531.367	5288.9918	4757.625
30	26	483.061	9760.386	9277.325	531.367	9229.019	9263.565	8780.503	531.367	9263.5646	8732.198
31	27	483.061	6779.457	6296.395	531.367	6248.09	9760.386	9277.325	531.367	9760.3862	9229.019
32	28	483.061	5288.992	4805.931	531.367	4757.625	6779.457	6296.395	531.367	6779.4566	6248.09
33	29	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
34	30	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
35	31	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
36	32	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
37	33	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
38	34	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
39	35	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
40	36	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
41	37	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
42	38	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
43	39	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
44	40	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
45	41	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
46	42	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
47	43	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
48	44	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
49	45	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
50	46	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
51	47	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
52	48	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
53	49	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
54	50	483.061	5288.992	4805.931	531.367	4757.625	5288.992	4805.931	531.367	5288.9918	4757.625
TOTAL		50458.433	284162.068	233703.657	55504.254	228657.822	278873.076	228414.665	55504.254	278873.076	223368.830

SUMMARY OF ECONOMIC INDICES

Economic Indices	Base Case	Cost Overrun 10 %	1 Yr. Benefits Delay	Combination
Benefits / Cost Ratio @ 12% discount rate	1.61	1.47	1.44	1.31
EIRR	21.58%	19.21%	17.69%	16.03%
Present Worth of Cost (Rs. Million)	21620.706	23782.775	21620.706	23782.775
Present Worth of Benefits (Rs. Million)	34900.689	34900.689	31150.945	31150.945
NPV (Rs. Million)	13279.983	11117.914	9530.239	7368.170



Table - 15.8
FEASIBILITY STUDY OF SHIGO KAS HYDROPOWER PROJECT
FINANCIAL ANALYSIS

(Million Rs.)

YEAR	COST			ENERGY	ENERGY	RATE/KWh	TOTAL	NET BENEFITS
	CAPITAL	O&M	TOTAL	GENTD(M.KWh)	SOLD(M.KWh)	SOLD(Rs.)	REVENUE	
	3438.750		3438.750	0.00	0.00		0.000	-3438.750
	6674.050		6674.050	0.00	0.00		0.000	-6674.050
	7855.010		7855.010	0.00	0.00		0.000	-7855.010
	7616.970		7616.970	0.00	0.00		0.000	-7616.970
	1520.330	536.735	2057.065	260.00	254.80	11.10	2828.280	771.215
1		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
2		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
3		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
4		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
5		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
6		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
7		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
8		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
9		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
10		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
11		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
12		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
13		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
14		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
15		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
16		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
17		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
18		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
19		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
20		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
21		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
22		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
23		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
24		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
25		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
26		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
27		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
28		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
29		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
30		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
31		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
32		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
33		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
34		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
35		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
36		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
37		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
38		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
39		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
40		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
41		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
42		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
43		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
44		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
45		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
46		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
47		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
48		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
49		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
50		536.735	536.735	520.00	509.60	11.10	5656.560	5119.825
51	-2710.511	0.000	-2710.511			0	0.000	2710.511
TOTAL	**27105.110**	**27373.475**	**54478.585**				**285656.280**	**233888.206**

B / C Ratio @ 12% discount rate = 1.25
Present Worth of Cost (RS. Million) = 22519.024
Present Worth of Benefits (RS. Million) = 28259.662
NPV (RS. Million) = 5740.638
Financial Internal Rate of Return (F.I.R.R) = 14.85%



Table - 15.9
FEASIBILITY STUDY OF SHIGO KAS HYDROPOWER PROJECT
FINANCIAL ANALYSIS (With CDM)

(Million Rs.)

YEAR	COST			ENERGY	ENERGY	RATE/KWh	TOTAL	CDM	TOTAL	NET BENEFITS
	CAPITAL	O&M	TOTAL	GENTD(M.KWh)	SOLD(M.KWh)	SOLD(Rs.)	REVENUE	BENEFITS	BENEFITS	
	3438.750		3438.750	0.00	0.00		0.000		0.000	-3438.750
	6674.050		6674.050	0.00	0.00		0.000		0.000	-6674.050
	7855.010		7855.010	0.00	0.00		0.000		0.000	-7855.010
	7616.970		7616.970	0.00	0.00		0.000		0.000	-7616.970
	1520.330	536.735	2057.065	260.00	254.80	11.10	2828.280		2828.280	771.215
1		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
2		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
3		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
4		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
5		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
6		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
7		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
8		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
9		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
10		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
11		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
12		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
13		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
14		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
15		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
16		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
17		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
18		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
19		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
20		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
21		536.735	536.735	520.00	509.60	11.10	5656.560	356.134	6012.694	5475.959
22		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
23		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
24		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
25		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
26		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
27		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
28		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
29		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
30		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
31		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
32		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
33		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
34		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
35		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
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39		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
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41		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
42		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
43		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
44		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
45		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
46		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
47		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
48		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
49		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
50		536.735	536.735	520.00	509.60	11.10	5656.560		5656.560	5119.825
51	-2710.511	0.000	-2710.511			0	0.000			2710.511
TOTAL	27105.110	27373.475	54478.585				285656.280			241367.020

B / C Ratio @ 12% discount rate = 1.32
Present Worth of Cost (RS. Million) = 22519.024
Present Worth of Benefits (RS. Million) = 29787.791
NPV (RS. Million) = 7268.767
Financial Internal Rate of Return (F.I.R.R) = **15.60%**

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Table -15.10

FEASIBILITY STUDY OF SHIGO KAS HYDROPOWER PROJECT

Cost per KWh & MW

Sr. No.	Description	Million Rs.
1	Total base cost	26836.740
2	Overhead Expenses	268.370
3	Import Duties	227.510
4	Price escalation	2432.300
5	Interest During Construction	2858.120
6	Financial cost	32623.040
7	Amortization of capital cost @ 10.65% for 30years.	3649.637
8	Operation & Maintenance Cost @ 2 % ofBase Cost	536.735
9	Annual Recurring Cost	4186.372
10	Annual Energy generated (GWh)	520
11	Annual Energy available for sale GWh	509.6
12	Cost per unit generated in Rs.	**8.05**
13	Cost per unit generated- US Cent	**8.13**
16	Installed capacity (MW)	102
17	Installed Cost per MW in M.Rs	319.83
18	Installed Cost per MW in M.US$	3.23

NOTE:- EXCHANGE RATE : 1 US$ = Rs. 99

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Table -15.11
FEASIBILITY STUDY OF SHIGO KAS HYDROPOWER PROJECT
PROFIT & LOSS STATEMENT

(Amount in Million Rs.)

YEAR	EXPECTED INCOME	EXPECTED EXPENDITURE				PROFIT (+) / LOSS (-)
		INTEREST DURING OPERATION	O&M COST	DEPRECIATION	TOTAL	
1	2828.280	3474.354	536.735	978.691	4989.780	-2161.500
2	5656.560	3418.024	536.735	978.691	4933.450	723.110
3	5656.560	3355.695	536.735	978.691	4871.121	785.439
4	5656.560	3286.728	536.735	978.691	4802.154	854.406
5	5656.560	3210.417	536.735	978.691	4725.843	930.717
6	5656.560	3125.978	536.735	978.691	4641.404	1015.156
7	5656.560	3032.546	536.735	978.691	4547.972	1108.588
8	5656.560	2929.164	536.735	978.691	4444.590	1211.970
9	5656.560	2814.771	536.735	978.691	4330.197	1326.363
10	5656.560	2688.196	536.735	978.691	4203.622	1452.938
11	5656.560	2548.141	536.735	978.691	4063.567	1592.993
12	5656.560	2393.169	536.735	978.691	3908.595	1747.965
13	5656.560	2221.693	536.735	978.691	3737.119	1919.441
14	5656.560	2031.955	536.735	978.691	3547.381	2109.179
15	5656.560	1822.010	536.735	978.691	3337.436	2319.124
16	5656.560	1589.706	536.735	978.691	3105.132	2551.428
17	5656.560	1332.661	536.735	978.691	2848.087	2808.473
18	5656.560	1048.241	536.735	978.691	2563.667	3092.893
19	5656.560	733.531	536.735	978.691	2248.957	3407.603
20	5656.560	385.303	536.735	978.691	1900.729	3755.831
21	5656.560	0.000	536.735	978.691	1515.426	4141.134
22	5656.560	0.000	536.735	978.691	1515.426	4141.134
23	5656.560	0.000	536.735	978.691	1515.426	4141.134
24	5656.560	0.000	536.735	978.691	1515.426	4141.134
25	5656.560	0.000	536.735	978.691	1515.426	4141.134
26	5656.560	0.000	536.735	978.691	1515.426	4141.134
27	5656.560	0.000	536.735	978.691	1515.426	4141.134
28	5656.560	0.000	536.735	978.691	1515.426	4141.134
29	5656.560	0.000	536.735	978.691	1515.426	4141.134
30	5656.560	0.000	536.735	978.691	1515.426	4141.134

Project Investment Cost	**= Rs. 32,623.040**
Salvage value @ 10%	**= Rs. 3,262.304**
Net Investment	**= Rs. 29,360.736**
Depreciation per annum (assuming 30 years life period)	**= Rs. 978.691**
Total Expected Income for first 10 years	**= Rs. 53,737.320**
Net Investment Ratio (Expected Income / Net Investment)	**1.83 : 1**

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Annex

15A

ECONOMIC & FINANCIAL ANALYSIS

(SPREADSHEETS)



CHAPTER 15

ECONOMIC & FINANCIAL ANALYSIS

SAIFCO HYDRO POWER LIMITED

CHAPTER 15

ECONOMIC & FINANCIAL ANALYSIS

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Annexure 15A: Economic and Financial Analysis (Spreadsheets)

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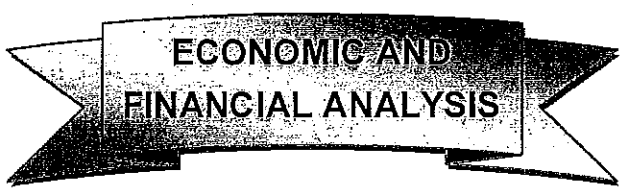


15.1 Economic Analysis

15.1.1 Introduction

Energy sector plays a vital role in the growth and development of any economy, particularly for a developing country like Pakistan. The installed power generation capacity in Pakistan till June 2013, through various sources is; 20,850 MW; out of which hydropower contributes 6928 MW (33.20%), thermal 4,841 MW (23.20 %), IPPs (Thermal) 8381 MW (40.2%), Nuclear 650MW (3.10%) and Wind 50 MW (0.20 %). However, the country is still short of its required demand for power in all sectors of the national economy and as such energy shortage has become the most pressing economic challenge. The scope of this problem is now so extensive that quick- fixes will no longer allow the economy to move forward; therefore, this alarming situation necessitated implementation of energy generation projects.

It is now crucial to find sustainable energy generation options with high efficiency and broad applications. Following this criteria there are few possibilities of power generation, such as solar, wind and hydropower. Out of various renewable energy sources, hydropower is the most suitable source due to the fact that hydropower plants are reliable and have low maintenance cost as compared to other options. Hydropower has sufficient potential to accommodate the needs of the Khyber Pakhtunkhwa in particular and the whole country in general.

Hydropower can play a dynamic role in meeting our population's energy needs, therefore under the present study; an attempt has been made to develop a run of river (ROR) schemes with installed capacity of 102 MW to achieve the objective of reducing the power shortage crisis. The project will generate clean, renewable, reliable and sustainable energy to offset power shortages in the country, utilizing existing hydropower potential in the country, and will replace electricity otherwise supplied by dominant existing or future planned thermal power sources to the extent of its generation

Economic analysis is a quantitative evaluation of the economic feasibility of the

Project and gives a comparison between the benefits and costs over the life time of the project. The chapter in hand is an economic analysis of 102 MW Shigo Kas Hydropower project. The investment cost of this Hydropower Project has been estimated as Rs.32,623 million including price escalation, physical contingencies and interest during construction.

The objective of the economic analysis is to determine:

- whether the project is beneficial for the economy of Pakistan



- Whether the project is economically viable over its economic life.

15.1.2 Methodology of the Economic Analysis

The economic analysis of the Project has been carried out on the basis of benefits to the overall economy as a consequence of least count optimal development of hydro electric power from Shigo Kas Hydro Power Project. Therefore To demonstrate economic feasibility of the Shigo Kas Hydropower Project the "alternative cost" approach is used. In the alternative cost approach, the life-cycle cost of Shigo Kas Hydropower Project is compared with the life-cycle cost of alternative thermal generating plants. However, for this purpose benefits from the equivalent thermal plant have been evaluated in terms of costs foregone for providing equivalent generation of 520 GWh. The alternative cost approach is internationally acceptable and is used by ADB / World Bank funded projects. The capital cost of alternative candidate thermal power plants is based on typical index US$/kW installed costs as explained in the following Table.

Alternative Thermal Power Plant Cost Summary

Description	(Simple) Cycle Gas Turbine	Combined Cycle Plant	Slow/Medium Speed Diesel
Capital Cost, Excluding Interest during Construction (US$/kW)	852	1230	946
Implementation Period (Years)	1.75	2	1.5
Auxiliary Consumption (%)	1.5%	2%	1.5%
Sent Out Efficiency (%)	31%	49%	41%
Fixed O&M Cost (US$/kW/month)	4.51	6.31	9.46
Variable O&M Cost (US$/MWh)	2.42	3.67	7.34
Fuel Cost (US Cents/kWh)	11.98	8.42	11.78
Equipment Life (Years)	25	25	25
Refurbishment Cost (US$/kW)	682	984	757

- **Source:** 1/ Commodity Priced Data World Bank
  2/ Projection of Fuel Prices by World Bank

15.1.3 Assumptions

The economic analysis is based on the following input parameters and assumptions:

- All costs and benefits have been expressed at price level of January, 2014. The studies of the project have been carried out using economic costs and benefits. Thus in order to reflect real prices in the economy, the financial prices have been shadow priced to remove price distortions due to government's intervention through monetary and fiscal policies (such as taxes and subsidies) and trade union interference well as shortage or surpluses of labour resources.

- Traded goods are valued on the basis of their marginal international (border) prices, cif for imports and fob for exports. To arrive at the project value, the border prices are adjusted for the resource costs of internal transport and distribution costs that are incurred or saved. For conversion financial prices of traded commodities, international prices, published in World Bank Document, have been used after making adjustment of port handling and transportation charges.

- The values of non traded goods have been brought at par with border prices by using Standard Conversion Factor (SCF).The following conversion factors have been applied to convert financial cost local component to economic cost:-

- The SCF is a measure of the divergence between domestic and border prices, expressed in domestic currency. This allows for the general distortion between international and domestic prices that is caused by import/export duties, taxes and tariffs subsidies and other price distortion to trade. The value of this general conversion factor is estimated from statistics representing traded goods for the whole economy. The financial prices of non-tradable commodities have been converted into economic values by multiplying with a standard conversion factor (SCF) of 0.9. The derivation of standard conversion factor is given in **Table-15.1** in Annexure-15A.

- Specific conversion factors have been calculated for the important non traded inputs to the project. These important inputs are cement and reinforced steel used in civil works of the project. The specific conversion factors have thus been worked as 0.81for Reinforcing Steel and 0.75 for Portland / sulphate cement.

- Regarding unskilled labour, the market wage rates prevailing in the organized urban centers are high as compared to daily rates paid to agricultural labour in the unorganized rural sector. Taking the casual lobour rates as the marginal productivity of unskilled labour this is then adjusted by the SCF, and expressed as a ratio of the organized wage rates, to give shadow wage rate for unskilled lobour as 0.81 -

- In Pakistan there is low unemployment of skilled workers and at the same time employers are not complaining shortage of skilled workers. Therefore, the market for skilled workers is assumed to be in equilibrium, and as such is valued at its domestic market rate. The conversion factor is taken as 1.

- All transfer payments such as custom duties, interest during construction and water charges have been excluded from the economic cost. No price contingencies have been taken into account in economic analysis. The reason is that these are not economic costs but merely transfer from one account to another. Beside certain costs such as working capital,

commissions and taxes incurred in Private Sector development scenario are also not included in economic cost.

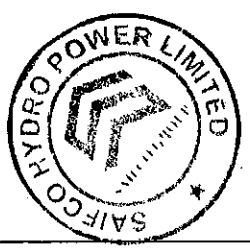
- The economic value of the hydropower project is the anticipated total cost of delivering about 520 GWh of energy per annum which shall be sold to PESCO/Central Power Purchasing Agency (CPPA) through existing Grid System.
- The period for project activities has been assumed as Sixty (60) months, excluding period for pre-construction activities. The project has been phased out as follows;

Year 1	Year 2	Year 3	Year 4	Year 5
12%	24 %	28 %	30 %	6 %

- Summary of the project capital cost is illustrated in the **Table-15.2** and component wise phasing of project cost is given in **Table 15.3** in Annexure-15A. For detailed cost estimates reference is made to chapter 14 of the feasibility report.
- The analysis considers a 50-years useful economic life for the Hydropower Project. Replacement/refurbishment costs are considered for equivalent thermal plants which have lesser economic lives of 25 years for simple cycle gas turbine, combined cycle plants and diesel power plant.
- The Shigo Kas Hydropower Project will have some residual value at the end of analysis period; these residual values have been taken as 10% of economic cost and included in the economic analysis.
- Financial O&M cost of Rs. 536.735 Million has been converted into economic cost as Rs.483.061 Million by applying Standard Conversion Factor (SCF) of 0.9.

15.1.4 Results of Economic Analysis

The EIRR calculated for comparison with equivalent thermal plant in replacement of the proposed project ranges from 21.58% to 25.73%. It clearly establishes that the project is economically viable. Detailed computations and stream flows over 50-years period are given in Tables-15.4 to 15.6 in Annexure-15A. While summarized results of economic comparison of Shigo Kas Hydropower Plant with alternative equivalent thermal power plants are given hereunder;



Economic Comparison Indicators

Economic Indicators	EIRR%	BC Ratio
Simple Cycle Gas Turbine	23.13	1.85
Combined Cycle Plant	21.58	1.61
Slow or Medium Speed Diesel Plant	25.73	2.06

Key; **EIRR** = Economic Internal Rate of Return; **BC Ratio** = Benefit Cost Ratio

15.1.5 Sensitivity Analysis

During project planning, the costs and benefits used are only estimates. The actual costs and benefits will diverge from these estimates, as the project is implemented, for various reasons. The assessment of how changes in project costs and benefits will affect the economic and financial viability of the project is done using sensitivity analysis.

The results of sensitivity analysis may greatly modify the overall assessment of the project. It highlights those variables which have the greatest potential impact on the economic and financial viability of the project, and gives a measure of the overall robustness of the economic and financial analyses.

Being a fundamental element of project analysis, sensitivity analysis is used to test the stability of project returns as different assumptions are made about future planning scenarios. It enables the analyst to assess the risk.

To test the robustness of the economic appraisal of the project, a sensitivity analysis has been carried out. This test has been performed only for the combined cycle plant thermal equivalent as this is the alternative that shows least benefits as compared to the proposed project. The robustness of this analysis would automatically cover other alternatives. The summary of the results of sensitivity analysis is presented as under. Sensitivity analysis has been performed under following three scenarios:

i) 10 % cost over-run.

ii) One year's delay in benefits

iii) Combination of i & ii above.

The sensitivity analysis in detail is presented in **Table-15.7** in Annexure-15A. While the summary of the results of sensitivity analysis is presented as under:

Scenario	NPV (Rs. Millions)	EIRR	BC Ratio
10 % cost over-run.	11118	19.21 %	1.47: 1
One year delay in benefits	9530	17.69 %	1.44: 1
Combination of above	7368	16.03%	1.31: 1

-NPV = Net Present Value

- EIRR = Economic Internal Rate of Return;

- BC Ratio = Benefit Cost Ratio

15.1.6 Conclusion

The results reveal that this project is economically viable as the EIRR is greater than the opportunity cost of capital and BC Ratio is greater than unity. Therefore, making investment on this project does not involve any risk and is thus recommended for implementation.

15.2 Financial Evaluations

15.2.1 Introduction

Financial Analysis of the project determines whether the project is financially viable. The financial assessment shows in other words the projects potential for success or for failure. It gives us all the necessary information needed in decision making process for investors. Thus enabling the project analyst to establish the financial sustainability of the project by identifying any financial shortfalls that are likely to occur during the investment and operating stages of the project, and suggest necessary means for meeting these shortfalls so that the project can become financially viable as well as sustainable.

Financial analysis deals with only costs and returns to project participants and primarily involves assessment of financial impact, judgment of efficient resource use, assessment of incentives, and coordination of financial contribution with resource management competence. Economic analysis on the other hand, deals with the costs and returns to society as a whole and the desirability of carrying out the project from the stand point of its contribution to the development of the national economy. The main objective of financial analysis is to determine the requirements of funds/time and the expected returns on investment from the point of view of various parties involved in the financing of the project. The rationale behind these exercises is to provide the decision-makers with both financial and economic yardsticks for the selection/rejection of projects from among competing alternative proposals for investment.

The techniques of project appraisal can be divided under two heads i.e. (i) Discounted and (ii) Undiscounted approaches. Discounted techniques take into account the time value of money and include (a) Internal Rate of Return (IRR) (b) Present Worth of Cost (c) Present Worth of Benefits (d) Net Present Value (NPV), (e) Benefit Cost Ratio (BCR) and (f) Sensitivity Analysis i.e., treatment of uncertainty in assumptions. Undiscounted techniques include (a) Payback period, and (b) Profit & Loss account Methodology.

15.2.2 General Approach

The objectives of the financial appraisal of the recommended Shigo Kas Hydropower project are to:

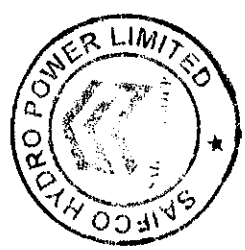
- Establish whether the Financial Internal Rate of return (FIRR) of the project exceeds the opportunity cost of capital (taken as 12%) and
- Assess the project funding requirements, and
- Evaluate the cost of the power and energy generated by the project

The financial appraisal has been based on financial costs, as compared to the economic analysis, in which costs were converted to economic values in order to assess the project in terms of public investment criteria. The financial analysis is undertaken by applying cash flow techniques. The financial analysis involve

- Identification and evaluation of costs and revenues attributable to the project,
- Application of financial investment criteria to the cash flow forecasts of costs and revenues, throughout the life of the project,
- Calculations of such financial indicators as Net Present Value (NPV) and Financial Internal Rate of Return (FIRR) to define the financial feasibility and sustainability of the project, and
- Sensitivity analysis on the FIRR for key variables.

15.2.3 Financial Structure of the Project

The prime objective of the implementation of Shigo Kas Hydropower Project with a total installed capacity of 102 MW and annual energy generation of about 520 GWh is to provide cheaper and most needed power. The estimated financial cost of the project is given below:



Summary of Financial Cost Estimates

Sr. No.	Component	Estimated Cost (Rs.Million)		
		Local	Foreign	Total
A	Preliminary Works	600	0	600
B	Environment & Resettlement Costs(Land Acquisition)	560	0	560
C	Civil Works	18502	0	18502
D	Electrical & Mechanical Works	478	4305	4784
	Transmission Line	105	245	350
	Total Works Cost	**20246**	**4550**	**24796**
E	Physical Contingencies (Unforeseen) @ 3% of C+D	573	137	709
F	Transportation and Erection Charges of E&M Equipments @3% of D	131	0	131
G	Survey, geotech investigation and Detail Design of Civil and E&M Works @ 2% of (C + D)	473	0	473
H	Management Consultancy Cost @ 3% of (A + C + D)	727	0	727
	Total Base Cost	**22150**	**4687**	**26837**
I	Client Expenses, Administration and Legal Costs @1% Base Cost	268	0	268
J	Custom Duty@ 5% of D (on FEC)	228	0	228
K	Escalation @ 6.50% on Local cost & 1.3% on FEC	2330	102	2432
L	Interest during Construction (IDC) @10.65% of Base Cost	2858	0	2858
	Total Project Cost	**27834**	**4789**	**32623**

15.2.4 Terms of Loan

The repayment of the loan would be made in the form of annual amortization charges whereby the principal and interest charges would be repaid in equal annual installments. The rate of interest determined by the GOP as 10.65 % has been used for estimating the interest during construction.

15.2.5 Annual Recurring Expenditure

The annual recurring expenditure covers O&M Cost @ 2 % of the base cost which works out to be Rs. 536.735 million and amortization of project capital at an interest rate of 10.65 % for 30 years thus come to Rs. 3649.637 million. The total Annual Recurring Expenditure comes to Rs.4186.372 million. Details are given in **Table-15.10** in Annexure-15A.

15.2.6 Financial Analysis

15.2.6.1 Assumptions for the Financial Analysis

Necessary parameters / assumptions required for financial analysis are discussed as under:

- Interest Rate: Interest rates for public entity project are determined by the Ministry of Finance, GoP. For calculating Interest During Construction (IDC) the markup rate for 2011-12 fixed by the GoP as 10.65 % on local as well as on FEC, has been adopted.
- Import Duty: As per policy for power generation projects 2002, the Govt. has given fiscal incentive which allows custom duties at the rate of 5% on the import of electric and mechanical equipments. custom duties will be paid on items not manufactured locally.
- Exchange Rate: In view of the existence of the freely floating exchange rate in Pakistan the calculation of shadow exchange rate is not considered necessary as would be the case if the exchange rate was not floating. The exchange rate prevailing of the price index of cost estimates level has been used as 1US$=Rs. 99 as on January, 2014.
- Discount Rate: The discount rate is used to reflect that investment represents foregone consumption with the expectation of receiving profit or interest rate. Consumption in future is shown less than consumption today as such future consumption is discounted at the rate equal to the time preference discount rate. The appropriate value of this time preference discount rate is the opportunity cost of capital. The selection of proper discount rate is thus highly important. The implication of high discount rate discourages investment and growth. For this project 12% discount rate has been applied which is also being used by the Planning Commission, GoP and other National and International Planning Agencies.
- Proposed Tariff: The proposed sale tariff of Rs.11.10 per KWh has been used to carry out financial analysis of the Shigo Kas Hydropower Project.
- Annual O&M Cost:

  The annual O&M charges have been worked out @ 2 % of the project base cost. This cost includes cost of foreign and local supplies, labour, establishment and maintenance which also covers the major overhauling of the plant after every ten years. This arrangement has been assumed to be constant for the economic life of the Project - 50 years
- Price Escalation:

  It has been estimated over the period of project construction using 6.5% for local and 1.3 % for foreign cost components.
- Period of implementation:

  A useful operation time of 50 years has been considered for the project. The construction period is taken as Sixty (60) months excluding pre-construction period.
- Auxiliary Consumption:

Auxiliary consumption has been assumed as 2 % of the energy generated.

15.2.6.2 Results of Financial Analysis

The financial costs and revenues described above have been translated to cash flows throughout the project life. These are summarized in **Table 15.8**

The project FIRR is calculated as 14.85 %. This value clearly exceeds the threshold value for financial feasibility of 12 % and demonstrates that the project is attractive in terms of real return on investment. The project NPV is estimated as Rs.5741 million for a discount rate of 12 % and Benefits cost ratio 1.25:1. The results of financial analysis are robust and acceptable for the proposed investment.

15.2.7 Certified Emission Reduction (CER)

15.2.7.1 General

The Project shall contribute to GHG emission reduction by displacing oil fired expensive thermal power which will result in reduction of CO2 emissions over the period of 21 years crediting period. Since only CO2 emissions from combustion of fossil fuel fired power plants in the public sector, connected to the grid, are considered in the base line, therefore, CO2 will be considered as the baseline emission that will be displaced due to the project activity. As the project activity is generation of electricity from renewable energy sources and the electricity generated from the run-of-the river and as such hydropower plant has zero emissions, there is no material leakage and the Project generation will be fed into the fossil intensive national grid, therefore, the emission reduction would be the equal to baseline emissions.

It can safely be concluded that the Project activity would directly replace oil based thermal generation based on furnace oil and would save emissions by them. In the Feasibility Report CDM project activity has-been proposed to make the Project financially more viable and attractive. Therefore, financial analysis has been conducted by considering the Project activity under with and without CDM benefits for assessing the impact of CDM revenues on the financial viability of the project

The CDM has been considered as an important factor and play key role for the project owners to decide and proceed for the project investment.

Long construction period of 5 years makes the project more risk prone and therefore, the sponsors expect that there should be corresponding increase in return on equity. The enhancement of return on equity can somehow be compensated through the CDM revenues earned in future.

The above referred analysis reveals that the additional revenue from CDM improved and strengthened the project financial viability as well as sustainability in terms of acceptable IRR figures near to hurdle rate.

Based on the official information available for the Pakistan Power System for 2009, 2010 and 2011, the value for the Operating Margin Emissions Factor (OM) is as follows:

SUMMARY- OPERATING MARGIN			
Year	**GWh**	**tCO2**	**CEF**
2009	52,814	36,507,718	0.6912
2010	55,131	38,822,073	0.7042
2011	49,751	34,881,426	0.7011
Grand Total	157,697	110,211,216	0.6989

The build margin emissions factor is the generation-weighted average emission factor (tCO2/MWh) of all power units m during the most recent year y. the BM factor is 0.2619

The calculation of combined margin emission factor is to be based on one of the following method:

(a) Weighted Averages CM; or

(b) Simplified CM.

The Weighted Average CM should be used as the preferred option. The Baseline Emission Factor is the weighted average of the OM emission factor and the BM Emission Factor.

The default weight of the OM and BM are 50% (i.e. Emission factors of OM and are expressed in tCO2/MWh. The default values for all the projects other than wind and solar generation projects would be for the first crediting period and for the second and third crediting period. Thus the default weights will be used 0.5 for both OM & BM and baseline emissions factor (Emission factor for grid connected power generation) is determined as follows:

= (0.5 × 0.6988) + (0.5 × 0.2619) = 0.48041 tCO2/ MWh.

To estimate environmental benefits under Clean Development Mechanism (CDM), it has been estimated as to how many tons of air pollution would be emitted if the energy of Shigo Kas Hydropower were generated by an equivalent thermal alternative plant. The derivation of CO2 emissions are given in the Table below.

Calculation of CDM Benefits

Description	Unit	Quantity / Amount
Installed Capacity	MW	102
Annual Energy Generation	GWh	520
Grid Emission Factor	t CO2 / MWh	0.48041
Annual Certified Emission Reductions (CER)	t CO2 / year	249.8132
Price per CER	US $ / t CO2	16
Annual CDM Revenue (gross)	US $ / year	3997.011
CDM Consultancy, Validation & Verification Cost	US $	399.7011
Net Annual CDM Income	US $ / year	3597.31
Exchange Rate	PKR / US $	99
Net Annual CDM Income	Rs. M / year	356.134

15.2.7.2 Results of Financial Analysis (With CDM)

The project FIRR (With CDM) is calculated as 15.60 %. This value clearly exceeds the threshold value for financial feasibility of 12 % and demonstrates that the project is more attractive in terms of real return on investment. The Net Present Value (NPV) computed at 12% discount rate comes to Rs.7268.767 million and the Benefits/Cost Ratio (BCR) is 1.32: 1 Details are given in **Table-15.9**

15.2.7.3 Impact of CDM on financial viability of the project

The potential impact of CDM on the financial viability of the project has been worked out by considering additional project income from the sale of Certified Emission Reductions (CERs) after deducting the CDM transaction costs. The additional project revenues through CDM at an assumed CER price of US$16 /t CO2 will improve the project results as follows:

Net present Value (NPV) from - Rs. 5741 Million to Rs. 7269 million

Financial Internal Rate of Return (FIRR) from 14.85 % to 15.60 %

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15.2.8 Unit Cost

The cost per kWh of energy generated has been estimated by dividing average annual recurring cost with annual generation over the economic life of the project. The average annual recurring cost is arrived at by amortizing the total project cost of Rs.32623 million (Local Rs. 27834 million and FEC Rs.4789 million) including Interest during construction at the interest rate of 10.65 % for local and foreign costs, respectively, for 30 years. To this has also been added annual O&M cost of Rs. 536.735 million (2% of the Base cost) which gives annual recurring cost of Rs. 4186 million. Further details are given hereunder:

Unit Costs & Revenue

a	Installed Capacity of station	102 MW
b	Average Annual Plant Factor	58 %
c	Units generated per annum	520 GWh
d	Power Station auxiliaries and consumption in colony	10.4 GWh
e	Net units available for sale	509.6 GWh
f	Cost per unit generated	8.05 Rs./kWh
g	Cost per unit generated	8.13 US Cent / kWh
h	Cost per MW	Rs.320 M
		US$ 3.23 M

15.2.9 Costs per kWh & MW

Detailed cost per kWh and MW is given in Table-15.10

15.2.10 Profit & Loss Account

Statement showing profit and loss accounts is attached as Table-15.11

15.2.11 Benefits of the Project

15.2.11.1 Financial Benefits

The maximum power output of this hydro power plant is 102 MW. It will produce an annual energy of 520 GWh and after deducting Power Station auxiliaries and consumption in colony @ 2 %, 509.6 GWh will be available. Based on proposed tariff the Project will earn revenue of Rs. 5657 Million per annum.

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15.2.11.2 Economic Benefits

- This Hydel Project after completion will produce energy at a very low cost as compared to Thermal Power Project of equivalent capacity.
- The Project will result in reduced dependence on thermal power option thereby saving a fair amount of foreign exchange to the country.
- The Project will assist to meet the industrial and agricultural sector power demand for economic development of the country.
- Hydropower is only significant natural resource of relatively backward and undeveloped Project area and provide life-line to economic growth;
- Significant investment and economic activity in an economically depressed region which has no industry and a high level unemployment
- Improvements in social infrastructure and public amenities of the area through construction of new medical center and catering for the improvement of existing schools.

15.2.11.3 Quantifiable Benefits

- The project will generate 520 GWh annually and would yield financial rate of return of 14.85% and B/C ratio of 1.25:1 (Table15.8 Base Case).
- Improvement in the presently low voltage being experienced by the consumers; and resultantly the Project will help in reduction of load shedding
- Facilitate economic and optimal utilization of electric power by reducing energy losses.
- No additional burden on fuel demand and corresponding import bill.
- Employment opportunities in works / businesses run by electric power.

15.2.11.4 Non-Quantifiable Benefits

- The hydel projects need extensive civil works, and can create significant number of job opportunities for engineers, technicians, skilled and unskilled labour during execution and operation of the project.
- The project is envisaged to bring about economic uplift activities of far-reaching effects in the project area, in particular as the pace of electrification would be accelerated with addition in the generating capacity. Rapid urbanization has also increased the demand for electricity.



- The project will provide incentive for the establishment of small and medium-sized industries based on local raw materials, creating gainful employment opportunities for the increasing work force. This will help in alleviating disguised unemployment in agriculture sector. Providing basic infrastructural facility of electricity in rural areas goes a long way in checking large scale migration of rural labour force to urban centers.
- Higher per capita disposable income would create more opportunities, improved health, and education. It would provide incentives to the work force to live near their homes and tendency to migrate to main urban centers would be reduced. In brief, it is envisaged that providing one of the basic infrastructural facilities of electricity at a suitable scale would usher in a continuous prosperity as well as economic emancipation by utilization of indigenous resources of land, labour and capital.
- The revenues of the government would increase due to levies and taxes on the production of goods and services which would be a consequence of the electrification of the area as well as from electricity duty due to additional sale of power. Besides, the annual payment of interest charges to the Federal Govt. would be a substantial amount.
- Ensured power supply will help to promote health, Education and other infrastructural facilities.
- Alleviation of poverty by creating regular employment opportunities to the local community in the economically depressed region having very scarce industry and higher rate of unemployment.
- Improving the local energy generation infrastructure, serve as a catalyst for significant economic and social uplift with poverty alleviation in the economically depressed region having very scarce industry and higher rate of unemployment.
- Improving the skill set for local inhabitants through training and capacity building for employment in the project, hence contributing to growing technical advancement.

15.2.11.5 Conclusion

The financial analysis clearly indicates that the executing agency can easily recover its installation cost of Rs. 32,623 million. The results of financial analysis indicate that the project is financially viable.

This project conforms with, and fits in the policy and objectives of the Government of Khyber Pakhtunkhwa(KPK) and Federal Government, where its objectives is to reduce the dependence on exhaustible fossil fuels for power generation, make the energy sector in general and the power sector in particular more sustainable.

CHAPTER 16

CONCLUSIONS AND RECOMMENDATIONS

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CONCLUSIONS & RECOMMENDATIONS

16.1 Conclusions

- Feasibility Studies have established Shigo Kas Hydropower Project as an attractive run-of-the-river project on Panjkora River. With an installed capacity of 102 MW, the Project will generate 520 GWh of annual energy after its full commissioning.

- Full commissioning of the project is anticipated 60 months including detailed engineering design after notice to proceed to the contractor.

- Base cost of the project is estimated as Rs.26836.74 million, while the capital cost is estimated as Rs.32623.04 million.

- On the basis of field findings during the Environment and Social Impact Examination study, it can be concluded that the proposed project will not have any significant adverse impacts on the local population or any segment of environment provided the mentioned recommendations and mitigation measures suggested in study are fully implemented during construction and by the plant management in letter and spirit. Environmental Impact Assessment Studies have determined the overall impact rating of the project activities as "low to medium".

- Economic analysis of the project reveals that the project is economically viable as the Economic Internal Rate of Return (EIRR) is greater than the opportunity cost of capital.

  The EIRR calculated in comparison with equivalent thermal plants as replacement alternative to the proposed Hydropower Project, has been calculated as 21.58 percent.

- Results of sensitivity analysis also endorse the viability of the project as the EIRR remains well above 12% and the cost: benefit ratio remains more than 1.

- Financial analysis indicates a Financial Internal Rate of Return (FIRR) as 14.85 % and the project is adjudged viable.

16.2 Recommendations

- Flow measurements and gauge observations should be continued at PEDO Gauge Station located approximately 2 km up stream of the proposed weir site in order to have essential data of flows, floods and sediment before project implementation.

- The geological and geotechnical investigations, conducted during the feasibility studies have provided the data required for feasibility level design of the Shigo Kas Hydropower

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Project. At detailed design stage, additional investigations are recommended as briefly described hereunder:

i. Keeping in view the larger size of the tunnel, it is envisaged that the in-situ rock mechanic tests including the flat jack, plate load, over coring and hydro fracturing shall be required for detailed design purposes. It is suggested that an exploratory adit (which at later stage could be converted into access tunnel) be excavated in the middle reaches of the tunnel and used for rock mechanic testing.

ii. The confirmatory testing for the Alkali Silica Reaction (ASR) potential is required through further laboratory testing including the long-term mortar bar testing. Current studies have indicated that no such potential exists in the nearby materials, yet the presence of pegmatites in the tunnel area shall require additional study.

- The access road to weir site, surge area and powerhouse need to be constructed and bridges are to be strengthened.

The successful completion of the project will turn into job opportunities and uplift in the socio economic well being of the adjoining areas. This will result into boosting up economic activities in the locality.

Engineering, economic and financial studies have classified Shigo Kas Hydropower Project as viable. **Hence the project is recommended for detailed engineering design or Engineering Procurement Contract and execution.**

