APPLICATION FOR APPROVAL OF COMPLIANCE WITH THE TECHNICAL STANDARDS AND GRANT OF CONCURRENCE

FOR

470 MW LOWER SPAT GAH HYDROPOWER PROJECT

Submitted by	**:**	**LSG Hydro Power Limited**
Submitted to	**:**	**National Electric Power Regulatory Authority**
Date	**:**	**August 23rd, 2023**

[redacted]

LSG HYDRO POWER LIMITED

LLI-LGI-23-095L

4th Floor, Emirates Tower, Jinnah Super, F-7,
Islamabad Pakistan
Tel: +92-51-6134782
http://www.lsg-hydro.com

August 22, 2023

Reply Required ☒ Yes ☐ No

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

SUBJECT: APPLICATION FOR APPROVAL OF COMPLIANCE WITH THE TECHNICAL STANDARDS AND GRANT OF CONCURRENCE TO THE DETAILED SCHEME SUBMITTED BY LSG HYDRO POWER LIMITED FOR 470 MW LOWER SPAT GAH HYDRO POWER PROJECT, LOCATED AT KOHISTAN DISTRICT, KHYBER PAKHTUNKHWA

I, Seung-yeol Lim, being the duly authorized representative of LSG Hydro Power Limited (the "**Company / Applicant**") for 470 MW Lower Spat Gah Hydro Power Project (the "**Project**"), by virtue of Board Resolution dated 22nd August 2023, hereby apply to the National Electric Power Regulatory Authority for the approval of compliance with the technical standards and grant of concurrence to the detailed scheme submitted by the Company pursuant to section 14-B and Section 23-E of the Regulation of Generation, Transmission and Distribution of Electric Power Act, 1997 (as amended from time to time) (the "**NEPRA Act**").

I hereby certify that the documents-in-support attached with this application are prepared and submitted in conformity with the provisions of the National Electric Power Regulatory Authority Licensing (Application, Modification, Extension and Cancellation) Procedure Regulations, 2021, (the "**Licencing Regulations**") and undertake to abide by the terms and provisions of the above-said regulations. I further undertake and confirm that the information provided in the attached documents-in-support is true and correct to the best of my knowledge and no material omission has been made.

That it is pertinent to mention here that the Applicant previously applied for the Generation Licence on **17th January 2023**, which was subsequently returned to the Applicant on **25th January 2023** on the sole and only ground that the name of the Project was not included in the Indicative Generation Capacity Expansion Plan ("**IGCEP**"). That now the alleged deficiency has been cured and or not applicable / not required.

The Applicant is therefore applying for the approval of compliance with the technical standards and grant of concurrence to the detailed scheme on the following grounds;

GROUNDS

(I) That pursuant to **Section 14-B** of the NEPRA Act, pertains to the Generation licences. That Section 14-B imposes a duty on the Authority for gradual cessation of Electricity Generation Licences and to replace it with compliances with the technical standards and grant of concurrence to the detailed scheme to be submitted by the applicant within 5 years from the amendment of 2018. That now the period of 5 years has lapsed therefore the licensing regime has also lapsed. That in light of **Section 14-B** the Applicant is therefore applying for the approval of compliance with the technical standards and grant of concurrence to the detailed scheme.

(II) That in the meanwhile, it is pertinent to mention that the Project has been successfully incorporated in the IGCEP of 2022-2031; however, the Project has not yet been optimized in the IGCEP. Nevertheless, it is crucial to underscore that pursuant to the NEPRA legal framework, the requirement for optimization in the IGCEP is not prescribed as a mandatory requirement for approval of compliance with the technical standards and grant of concurrence to the detailed scheme pursuant to Section 14B (5) of the NEPRA Act. That in order to obtain approval of compliance with the technical standards and grant of concurrence to the detailed scheme from the Authority it is not required that the Applicant is included in the IGCEP, furthermore it is noteworthy to mention that the Applicant has also signed Memorandum of Understanding ("**MOU**") with the Government of Khyber Pakhtunkhwa and Letter of Intent ("**LOI**") with Pakhtunkhwa Energy Development Organization ("**PEDO**") which shows that the Project is a high potential Project with a significant impact in achieving the electricity demand of the region.

(III) That under the prevailing Competitive Trading Bilateral Contract Market ("**CTBCM**"), the Applicant is actively engaged in exploring opportunities to strengthen its contributions to the power sector. This exploration includes discussions with potential power purchasers such as K-Electric, Central Power Purchasing Agency Ltd, BPCs, Industrial Estates, Special Economic Zones etc. for sale and purchase of electric power services. Furthermore, the Applicant is contemplating supply and sale of electricity into the competitive electricity market or bilaterally conclude power purchasing arrangements with different purchasers.

(IV) That the Applicant aims to sell and supply electric power services at competitive rates and terms and conditions which is in interest of end consumers and legitimately expected to be optimized as committed project in the IGCEP within the business / procurement plan of procuring agencies if so required. That although at this juncture there does not exist any particular power purchasing arrangement, the Applicant expects that with the approval of compliance with the technical standards and grant of concurrence to the detailed scheme pursuant to Section 14B (5) of the NEPRA Act, it will enter into firm power procurement arrangements with various power purchasers such as K-Electric, CPPA-G, and other Bulk-Power Consumers. The ultimate objective is to provide reliable electricity supply and potentially contribute to reduced tariff rates, further supporting the market's competitive dynamics.

(V) Pursuant to Section 14D (3) of the NEPRA Act, a generating company may supply electricity to any transmission, distribution, supply or market trader licensee in accordance with NEPRA Act, Rules and Regulations.

(VI) In light of the aforesaid, the Applicant prays as follows:

(i) to approve compliance with the technical standards pursuant to Section 14B (5) of the NEPRA Act;

(ii) to grant the concurrence to the detailed scheme pursuant to Section 14B (5) of the NEPRA Act; and

That criteria of IGCEP may not be applied given that (a) the approval of compliance with the technical standards and grant of concurrence to the detailed scheme pursuant to Section 14B (5) of the NEPRA Act is required and (b) the Applicant intends to generate and supply electricity to any transmission, distribution, and supply or market trader licensee in accordance with NEPRA Act, Rules and Regulations

Seung-yeol Lim
Chief Executive Officer
LSG Hydro Lower Ltd.

LSG HYDRO POWER LIMITED
LSG

Enclosures: ☒ Yes ☐ No

1. Application For Approval of Compliance with The Technical Standards and Grant of Concurrence – 3 Sets
2. Bank Draft - No 6581687
3. Feasibility Study – 1 set

CC:

Document Delivery: ☐ Email ☐ Courier ☐ Fax ☒ Hand Delivered

TABLE OF CONTENTS

[redacted]

LSG HYDRO
POWER LIMITED

4th Floor, Emirates Tower, Jinnah Super, F-7,
Islamabad Pakistan
Tel: +92-51-6134782
http://www.lsg-hydro.com

Power of Attorney

LSG Hydro Power Limited (the "LSG" or the "Applicant"),

I, SEUNG-YEOL LIM, S/O IN-GYU LIM having Passport No. M39696501 Resident of 23, Jinhyeon-ro, Gyeongju-si, Gyeongsangbbuk-do, Korea and authorized representative of LSG Hydro Power Limited, do hereby appoint, authorize and constitute M/s Lincoln's Law Chamber through Barrister Asghar Khan, to file, sign, appear, plead and act for us as our advocate(s) in connection with the Application before NEPRA in the matter of "Approval of Compliance with the Technical Standards and Grant of Concurrence" (the "**Application**").

LSG has specifically authorized the said Barrister / Advocate or any member of M/s Lincoln's Law Chamber to do all acts and things necessary for the processing, completion and finalization of the Application with NEPRA.

For and on Behalf of

SEUNG-YEOL LIM
Korean National
Passport No: M39696501
CEO and Director

LSG HYDRO POWER LIMITED ★ LSG

DOCUMENTS REQUIRED UNDER SCHEDULE-I

1. APPLICATION FOR COMPLIANCE WITH THE TECHNICAL STANDARDS AND GRANT OF CONCURRENCE

DOCUMENTS REQUIRED UNDER SCHEDULE-II

1. APPLICATION PROCESSING FEE

The Company has paid the Grant of Concurrence processing fee as per the latest SRO in the form of a Bank Draft. The details of the Bank Draft are as follows:

Name of the Bank	:	MCB Bank Limited
Beneficiary	:	National Electric Power Regulatory Authority
Amount in Numbers	:	Rs. 2,033,118
Amount in Words	:	Rupees Two Million Thirty-Three Thousand One Hundred Eighteen only
Date	:	January 10, 2023

The original draft is attached to this Application as Appendix-1.

DOCUMENTS REQUIRED UNDER REGULATION-3

1. DECLARATIONS BY THE COMPANY

(i) This application for approval of compliance with the technical standards and grant of concurrence(the "Application") has been submitted in triplicate, i.e., one original and two copies.

(ii) The Company is being incorporated as a public limited company under the Companies Act 2017 by the Securities and Exchange Commission of Pakistan (the "SECP").

(iii) The Company is registered with the official name of LSG Hydro Power Limited, having registered office at 4th Floor, Emirates Tower, Jinnah Super, F-7, Markaz Islamabad Pakistan.

(iv) The Company is incorporated as a special purpose company (the "SPC") to design, develop, finance, construct, own & operate and transfer the proposed 470 MW hydropower generation facility in the Kohistan district of Khyber Pakhtunkhwa.

(v) It is hereby declared that the Company has not applied for any other compliance with the technical standards and grant of concurrence for any other project in Pakistan.

(vi) All documents required for the approval of compliance with the technical standards and grant of concurrence are attached with this Application, as per the National Electric Power Regulatory Authority Licencing (Application, Modification, Extension and Cancellation) Procedure Regulations, 2021 (the "Regulations").

(vii) The Company shall promptly respond to any queries during the processing of the Application by the Authority and shall submit any additional documents required during this process.

2. PROSPECTUS

The prospectus of the Company is attached as Appendix-2 with this Application.

3. SPONSOR'S PROFILE

The Sponsor's Profile is attached as Appendix-3 with this Application

4. CORPORATE DOCUMENTS

The corporate documents are attached as follows.

Certificate of Incorporation	:	Appendix-4
Memorandum & Articles of Association	:	Appendix-5
Annual Report of the Company	:	Appendix-6

5. ANNUAL RETURN OF THE COMPANY

The Form-A, i.e., the Company's Annual Return, is attached as Appendix-7.

6. SHARE CAPITAL DETAILS

The Form-34, i.e., the Share Capital details of the Company, is attached Appendix-8. The summary of Share Capital is as follows. [We are waiting for Form 34 and shall replace the document in Appendix-8]

Authorised Share Capital	:	205,000,000.00
Issued Share Capital	:	100,000
Subscribed Share Capital	:	100,000
Paid Up Share Capital	:	100,000

7. FINANCIAL & TECHNICAL RESOURCES

7.1 CASH & BANK BALANCES

Bank Name	Currency	Account Balance
Habib Metropolitan Bank Limited	PKR	173,486,332.20
Habib Metropolitan Bank Limited	USD	10
Cash in hand	PKR	0

The account balances are as prevailing on June 30, 2023, for the PKR account and June 30, 2023, for the USD account. The Cash in hand balance is as prevailing on June 30, 2023.

7.2 BANK CERTIFICATE

The Account Maintenance Certificates are attached as Appendix-9.

7.3 DETAILS OF CHARGES & ENCUMBRANCES

There are no charges & encumbrances against the assets of the Company.

7.4 AUDITED FINANCIAL STATEMENTS

The Audited Financial Statements for the year 2022 are attached as Appendix-10.

7.5 EXPRESSION OF INTEREST IN FINANCING

The feasibility study of the Project has just been completed, and the Company plans to approach more lenders after the issuance of LOS. At this stage, the Asian Development Bank and Korea EXIM Bank have expressed their interest in financing the Project. The LOIs from these banks are attached as Appendix-11.

7.6 NET WORTH & DEBT RATIOS

The Company has just started its operations. so the net worth and debt ratios are unavailable. The Company shall provide these details at the financial close stage of the Project.

7.7 PROFILES OF SENIOR MANAGEMENT & STAFF

The Profiles of Senior Management, technical and professional staff are attached as Appendix-12.

7.8 PROFILES OF SUBCONTRACTORS

The Company does not have any subcontractors at this stage. However, after the issuance of the tripartite Letter of Support from PPIB, the Company shall select the construction contractor per the guidelines of NEPRA.

7.9 EXPERIENCE OF SPONSORS

The verifiable relevant experience of Sponsors is attached as Appendix-13.

8. TECHNICAL & FINANCIAL PROPOSAL

The technical & financial proposal is attached as Appendix-14.

9. APPROVED FEASIBILITY STUDY

The Feasibility Study of the Project was approved by the Panel of Experts (the "POE"), of the Pakhtunkhwa Energy Development Organisation (the "PEDO") on November 23, 2022.

The approval letter of the feasibility study is attached as Appendix-15. The Approved Feasibility Study is attached as Annex-A to this Application.

10. AFFIDAVIT FOR ANY OTHER COMPLIANCE WITH THE TECHNICAL STANDARDS AND GRANT OF CONCURRENCE

The Applicant has not applied for any other compliance with the technical standards and grant of concurrence licence in the past. The Affidavit of the authorised person is attached as Appendix-16.

11. STATEMENT ON REFUSAL OF LICENCE IN PAST

The Applicant has not been refused to issue compliance with the technical standards and grant of concurrence for the Project. The Affidavit of the authorised person is attached as Appendix-16.

12. BOARD RESOLUTION FOR APPLICATION.

The board resolution permitting the authorised person to file compliance with the technical standards and grant of concurrence application is attached as Appendix-17.

13. AFFIDAVIT OF CORRECTNESS & AUTHENTICITY OF THE CONTENTS.

The Affidavit regarding the correctness, authenticity, and accuracy of the contents of the Application by the authorised person is attached as Appendix-18.

SCHEDULE-III DOCUMENTS

1. ENVIRONMENTAL & SOCIAL IMPACT ASSESSMENT

The Environmental and Social Impact Assessment (ESIA) is a predictive study undertaken prior to the development of the Project. It has essentially two aims:

(i) Identify the potential environmental and social impacts of the proposed project,

(ii) Design measures to minimise any anticipated adverse impact of the proposed Project and enhance the benefits for the environment and the people

The Environmental and Social Impact Assessment of the Project was prepared as a separate study and was approved as part of the full feasibility study of the Project. Volume 11 of the feasibility study (attached as Annex-A) is the detailed ESIA Study.

2. GRID INTERCONNECTION STUDY

Upon issuance of LOI by PEDO, the Company requested PEDO to assist with the release of data from NTDC vide letter No HLKL/PE-210008L. The PEDO vide letter no 480-82/PEDO/DREPP/LSG/GIS requested the NTDC to assist the Company. The Company also requested NTDC directly vide letter no LSGHPP-NTDC:0001. In response, NTDC GM PSP allowed using the data vide letter No GMPSP-TRO-300-4356-71. Power Planners International (the "PPI"), the consultant for conducting the study, required additional information, and the Company requested the same vide letter No LSGHPP-NTDC/ADM:006L. In response, the NTDC Dasu HPP office allowed to use of the route survey data vide email dated 08.11.2022. The Sponsors Completed the route survey and submitted the same to NTDC vide letter No LLI-LGL-23-013L dated 17.02.2023

The correspondence summary on the subject is attached as Appendix-19.

The draft Grid Interconnection Study, Power Market Survey and Route Survey is attached as Appendix-22.

3. PROJECT INFORMATION

The Project is located in the Kohistan District in the Khyber Pakhtunkhwa Province of Pakistan. The Lower Spat Gah Headworks is located at the Spat Gah River, the Lower Gabarband Intake is located at the Gabarband River, and the Powerhouse Tailrace Outlet Structure is at the Indus River. The Spat Gah valley is located on the left bank of the Indus

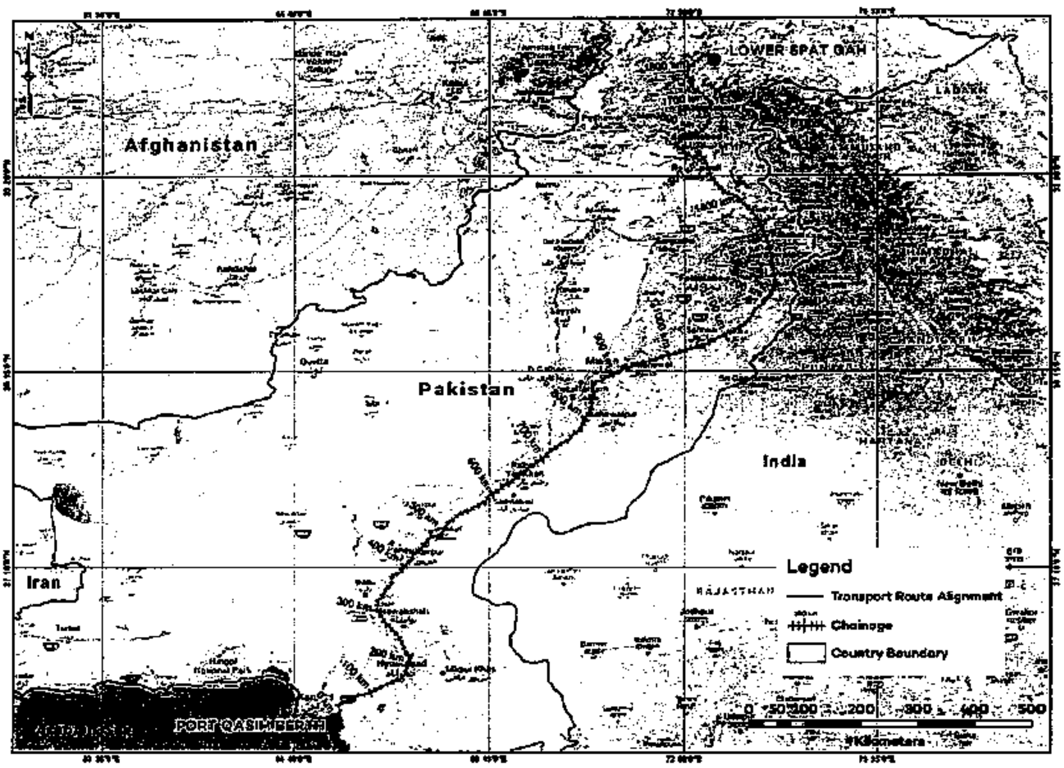


Figure 1: Lower Spat Gah Project location in the Area

River and starts about 4 km downstream of Dasu town.

The Project is part of a hydropower cascade in the Spat Gah and Gabarband valleys, which includes three stages Upper Spat Gah, Middle Gabarband and Lower Spat Gah HPPs. The Project has previously been developed and optimised as part of that cascade. The status and future development of the upper two stages is unknown at the time of this study. It has to be assumed that the Lower Spat Gah Project will be operated as a stand-alone project for at least a few years.

The water is conveyed from the Lower Spat Gah Headworks to the Powerhouse for power generation, with a secondary intake on the Gabarband River connecting to the Headrace Tunnel. Excess water will spill back into the rivers. The water is released from the Powerhouse to the Indus River about 1.2 km upstream of the confluence with the Spat Gah River.

The Project consists of the following main structures:

(i) Lower Spat Gah Headworks with rockfill dam, flushing channels, intake on the right bank, surface desander and forebay,

(ii) Lower Gabarband Intake with weir structure, intake on the left bank, surface desander and forebay,

(iii) 2.4 km long Gabarband Intake Tunnel connecting to the Headrace Tunnel with a free-flow section at the beginning and pressurised section after,

(iv) 10.9 km long pressurised Headrace Tunnel,

(v) 0.5 km high-Pressure Shaft,

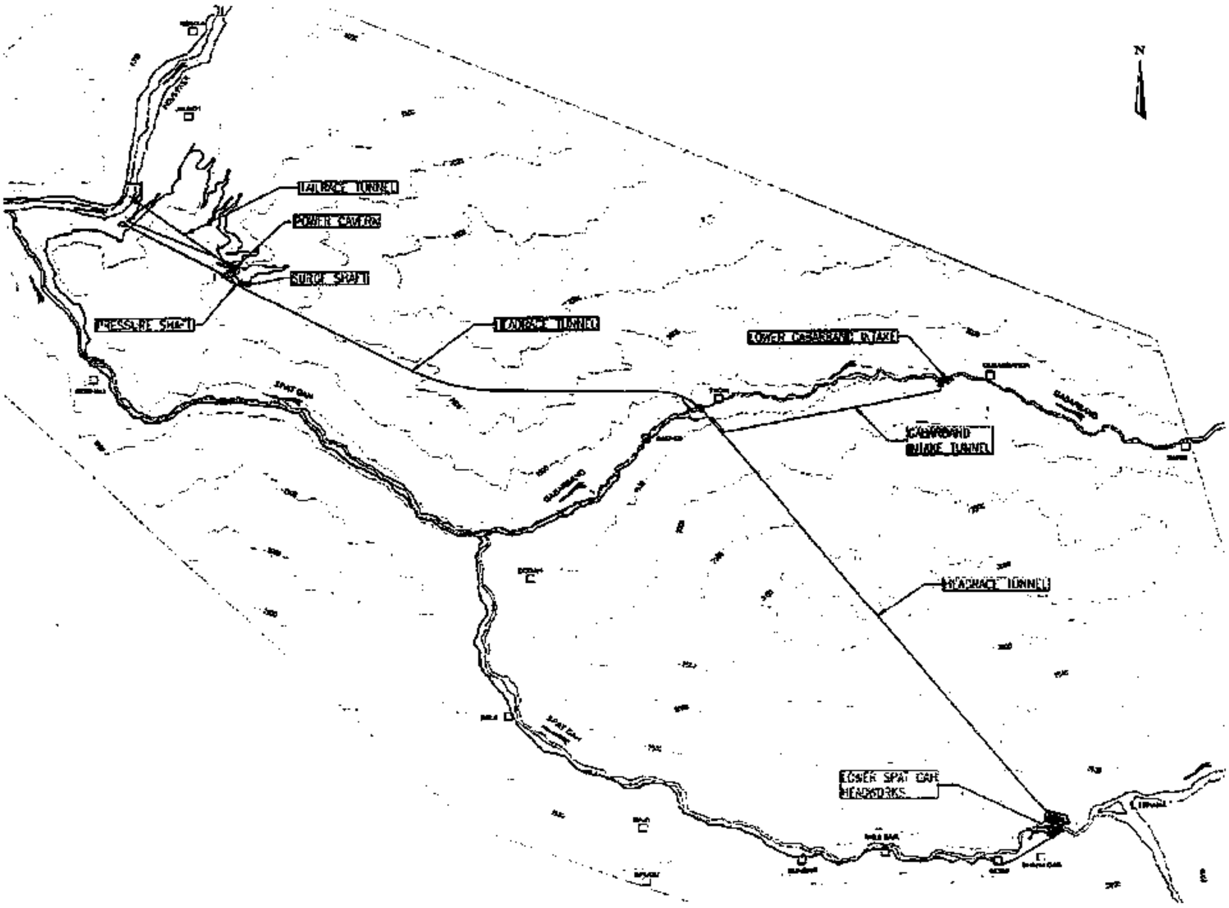
(vi) 0.2 km long High-Pressure Tunnel including penstock,

(vii) Power Cavern with 3 Pelton turbines,

(viii) 1.3 km long free-flow Tailrace Tunnel

4. PLANT TYPE

The Project is a high-head run-of-river scheme with limited peaking capabilities.



5. PLANT CHARACTERISTICS

Figure 2: Project Layout Overview

Plant Parameter	Description
Gross Capacity	470 MW
Annual Generation	1,925.5 GWh
Voltage	220 kV
Power Factor	0.8 lagging/ 0.9 leading
Frequency	50 Hz.
Ramping Rate	47 MW/ minute
Minimum Head	734.25 m
Maximum Head	744.58 m
Technology	Pelton

Plant Parameter	Description
Number of Units	3
Tunnel Length	10.9 km
Tunnel Diameter	5.30 m concrete/ 4.00 m steel lining
Peaking/ Base Load	Peaking Load
Efficiency Parameters	Turbine: 91.7% (max) Generator: 97.5% Transformer: 97.5%
Construction Period	60 Months
Project Life	80 Years

6. RESETTLEMENT ISSUES

The resettlement issues are covered in the Environmental and Social Impact Assessment Study. Please see Vol.11 of Annex-A for more information.

7. APPROVALS FROM THE GOVERNMENT

7.1 LETTER OF INTENT

The Letter of Intent (the "LOI") of the Project was issued to the sponsors on June 29, 2021, by the PEDO. A copy of the LOI is attached as Appendix-20.

7.2 FEASIBILITY STUDY APPROVAL

The feasibility study was supervised by the POE of the PEDO and PPIB. The POE approved the feasibility study after detailed due diligence and various site visits. The feasibility study was approved by the POE on November 23, 2022. The approval letter is attached as Appendix-15.

7.3 ENVIRONMENTAL APPROVALS

7.3.1 BACKGROUND

LSG Hydro Power Ltd (The Company) submitted the ESIA report to EPA vide Letter No. LSGHPP:EPA:0001 dated 4th March 2022 for initial vetting by EPA, whereas EPA Invited the Project Sponsors for committee review meeting vide letter No. EPA/EIA/HPP/496MW/22/4047-48 dated 1st April 2022. Upon initial review by the EPA committee, EPA shared written comments/observations with the Sponsors vide letter No. EPA/EIA/HPP/496MW/22/223-24 dated 20th June 2022. The Company submitted the response to EPA Comments/Observation vide letter No. LSGHPP:EPA:003 dated 5th July 2022 to EPA.

7.3.2 PUBLIC HEARING

EPA requested the Company to organize public hearing vide letter No. EPA/EIA/HPP/496MW/22/273-75 dated 28th June 2022, Whereas the Company shared with them the Newspaper Advertisement and Other related material vide letter No. LSGHPP:EPA:0013QL dated 15th July 2022. After the successful conduct of Public Hearing, the EPA gave written comments vide letter No. EPA/EIA/HPP/496MW/22/588-589 dated 24th August 2022, and the Company responded vide letter No. LSGHPP:EPA:0014QL dated 19th September 2022.

7.3.3 SITE VISIT

The Company arranged the site visit for forest officials on the request of EPA. After the site visit EPA shared set of Documents vide letter No. EPA/EIA/HPP/496MW/22/209-210 dated 7th November 2022 in which the EPA has mentioned that the proponent must obtain NOC from the KP Forest Department.

7.3.4 FOREST NOC:

To obtain Forest NOC, LSG HPL did five (5) site visits and submitted reports to the KP Forest department. During the 2nd site visit in January 2023, it was revealed that a small area (2.26 hac) of the project component (Mose Construction Camp) falls within forest land. However, the area which was falling inside forest land has been relocated and confirmed by the KP forest department. Forest NOC has been issued by the KP Secretary (Forest, Environment and Wildlife Department) which was received by LSG HPL from the office of the Chief Conservator of forest Central Southern Region-I Peshawar vide letter No. 269/GB/D-XII-97/Vol-06 dated 24th July 2023.

7.3.5 EPA:

LSG HPL submitted Clarification/Justification to EPA's Comments along with Forest NOC vide LSG letter No. LLI-LZP-23-087L dated 2nd August 2023. EPA is reviewing the Clarification/Justification of LSG HPL and if the EPA finds the Clarification/Justification satisfactory, EPA will give approval of ESIA Report of Lower Spat Gah Hydropower Project.

7.3.6 SUMMARY OF COMMUNICATIONS

The summary of correspondence regarding environmental approvals is attached as **Error! Reference source not found.**.

8. TRAINING & DEVELOPMENT

Hydropower project development, construction and operations require the employment of a wide variety of technical and professional teams, including engineers from various fields, project management professionals, financial analysts, contract specialists, accounting, and administrative staff etc. Skill development of staff is very important in hydropower projects. Skills required for developing hydropower projects are multifaceted, and they play a vital role in successfully implementing these projects. The purpose of training is to improve the performance of employees in their jobs.

The Company plans to develop an effective human resource department for this purpose. The human resource department shall be responsible for the training and development of staff. Human resource managers shall be primarily responsible for the following:

(i) Assessing the training needs of staff

(ii) Delivering training and development programs related to organisational policies and procedures and their specific field of knowledge.

(iii) Promoting a culture of continuous learning by identifying and creating opportunities for training.

(iv) Ensuring staff are aware of the training available and how it can help them develop their careers.

Training can be provided by internal training departments or external suppliers such as consultants and contractors.

APPENDICES

APPENDIX-1
BANK DRAFT

Account Payee Only

MCB MCB Bank Limited

G-11 MARKAZ BRANCH ISLAMABAD (1556)

Not Over : PKR 2,033,118.00**

[redacted]

Pay to [redacted] Or Order

Rupees [redacted]

PKR [redacted]

Signatory

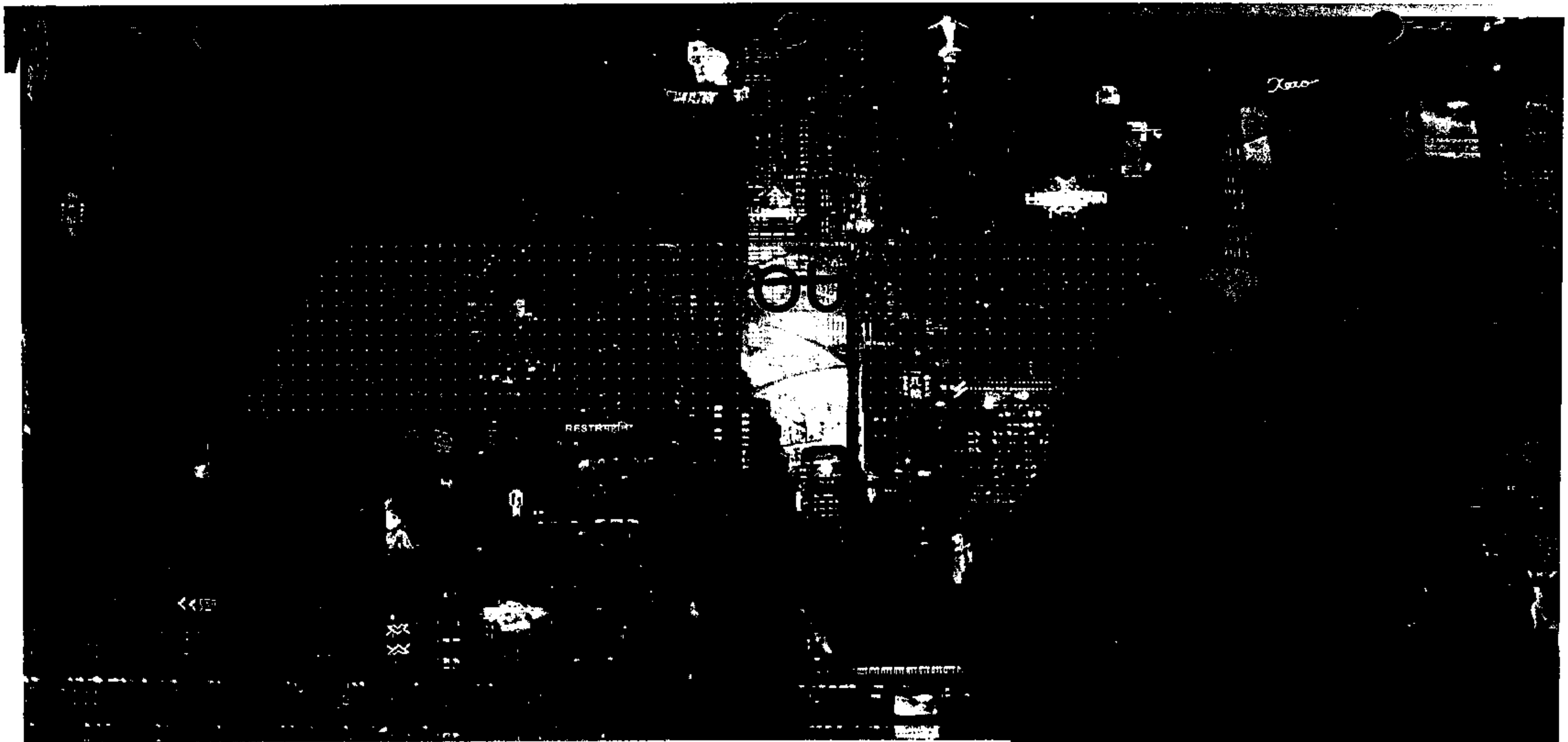
PA/Attorney No.

Signatory

PA/Attorney No

Payable at any MCB Branch in Pakistan.
Please do not write below this line.

⑈093457110⑈06 28888⑆0000000000000000⑈010⑈



470 MW SPAT GAH HYDRO POWER PROJECT

Pakistan's First Public Private Partnership Hydro Power Project

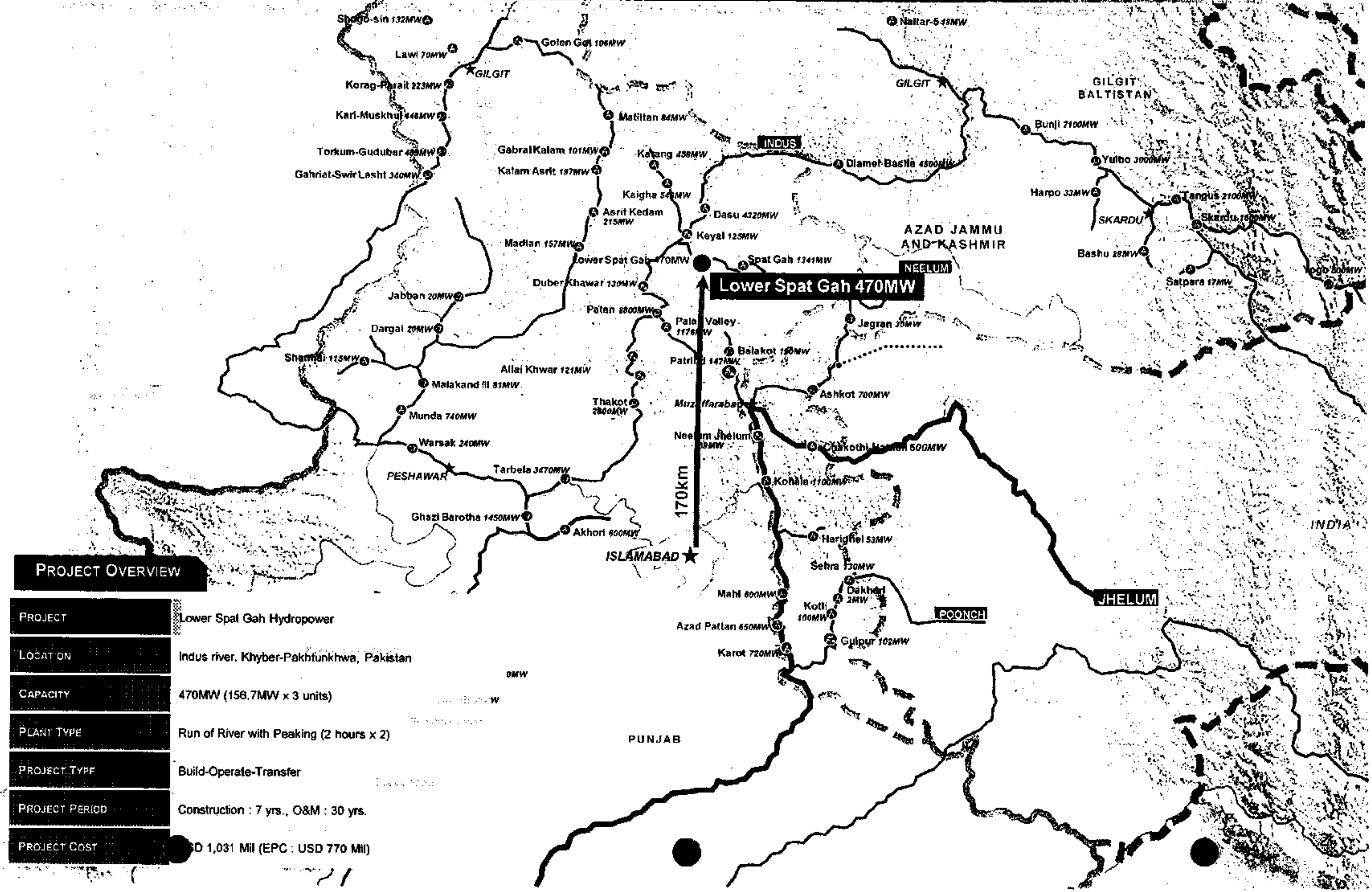
LSG Hydro Power Ltd is subsidiary of KOREA HYDRO & NUCLEAR POWER CO. LTD (KHNP). KHNP produces over 28,000 MW electricity in Korea. KHNP is developing various Hydro Power Project all over the Globe

Address: 4th Floor, Emirates Tower, Jinnah Super, F-7, Islamabad
Web: http://www.lsg-hydro.com
Email: info@lsg-hydro.com
Phone: +92 51 8435288

LSG HYDRO POWER LIMITED

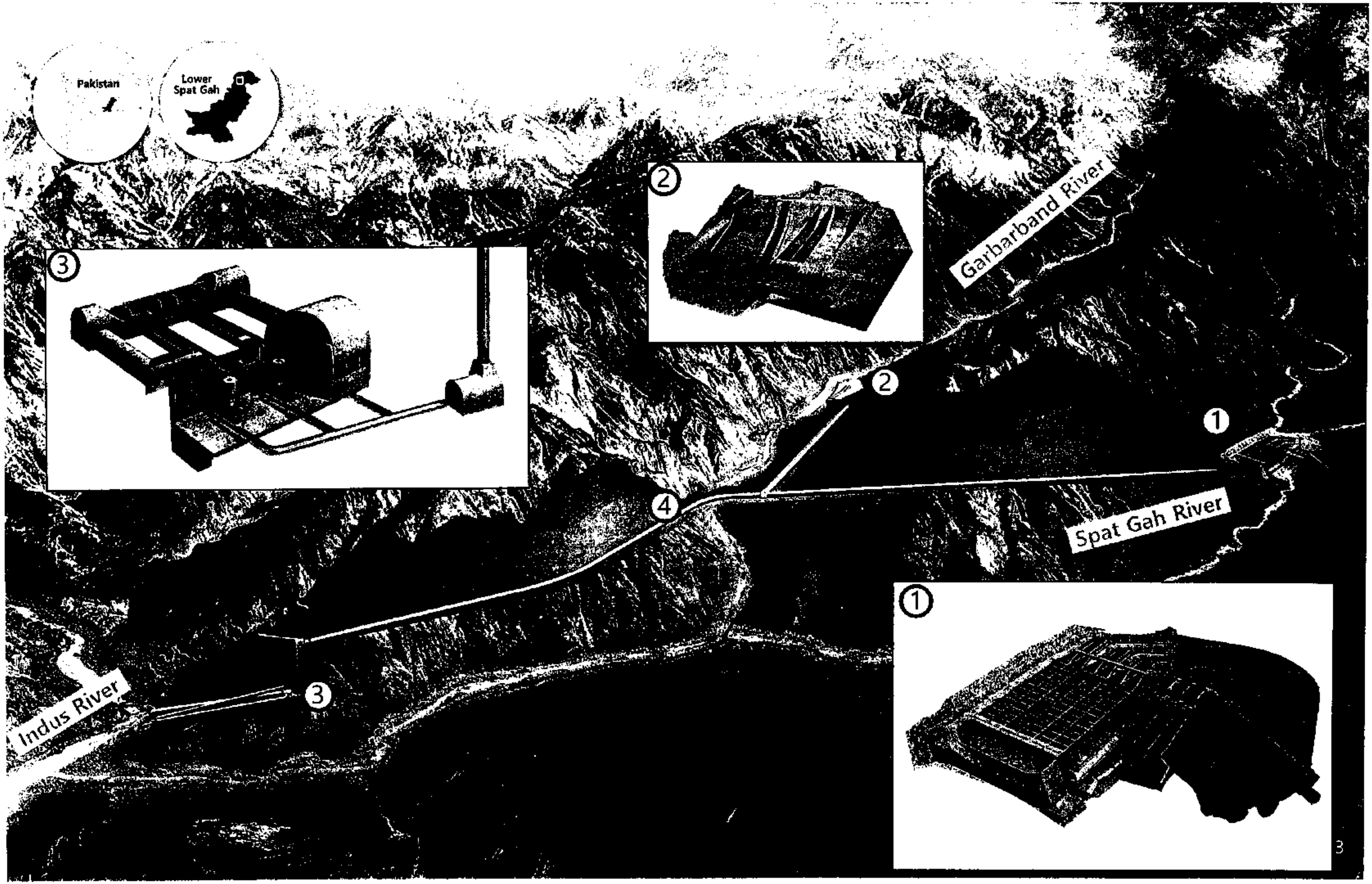
Project Conspectus

LOWER SPAT GAH
470MW
HYDROPOWER PROJECT



PROJECT OVERVIEW

PROJECT	Lower Spat Gah Hydropower
LOCATION	Indus river, Khyber-Pakhtunkhwa, Pakistan
CAPACITY	470MW (156.7MW x 3 units)
PLANT TYPE	Run of River with Peaking (2 hours x 2)
PROJECT TYPE	Build-Operate-Transfer
PROJECT PERIOD	Construction : 7 yrs., O&M : 30 yrs.
PROJECT COST	USD 1,031 Mil (EPC : USD 770 Mil)


Pakistan
Lower Spat Gah
Garbarband River
Spat Gah River
Indus River
1
2
3
4

Project History

Sep 2018	Submit an Expression Of Interest (EOI) to the KP Government
Nov 2018	MOU signed between KHNP and KP government
Dec 2019	Issuance of Notice to Proceed (NTP) from PEDO
May 2020	Feasibility Study Approved by Ministry of Economy & Finance of Korea
Mar 2021	Establish a Special Purpose Company (LSG Hydro Power Ltd.)
Jun 2021	Issuance of Letter of Intent (LOI) by PEDO
Jul 2022	Conducting Environmental Approval Public Hearing
Nov 2022	Approval of Feasibility Study by POE (Panel of Experts)
Dec 2022	Apply to NEPRA for a Generation Licence (Rejected, not reflected in IGCEP)
Feb 2023	Request NEPRA to determine F/S stage Tariff Petition (Rejected, GL not issued)
Feb 2023	2022-31 IGCEP as a candidate project

- **Development kicks off as a Public-Private Partnership between KHNP and Pakistan's KP gov't**
- **(Sep '19) Update of F/S complete. Undergoing approval process by Gov'ts of Korea and Pakistan**
- **Targets : ('21) SPC established, ('25) Financial Close, ('26) Start construction, ('31) COD**

Project Development (5.5y)	Construction Preparation (2.5y)	Construction (5y)	Operation (30y)
2018.12 ~ 2024.6	*2024.7 ~ 2026.12*	*2027.1 ~ 2031.12*	*2032.1 ~ 2061.12*
LOI ('21.6) / LOS ('24.6)	F/C ('26.12)	COD ('31.12)	
Letter of interest FS approval, Tariff approval Letter of Support	Various Agreements Preparation Work Project Financing	Construction	Operation

KEY WORKS

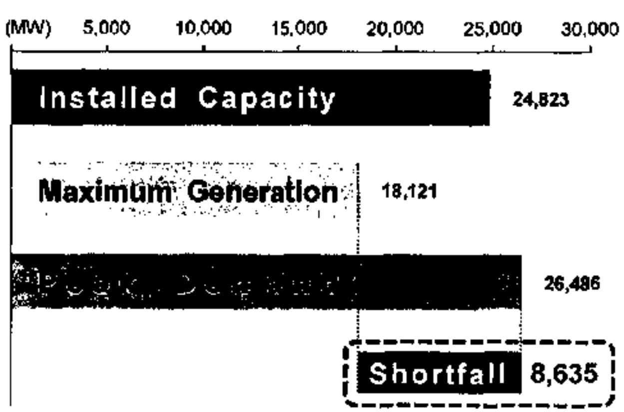
Project Development	Construction Preparation	Construction	Operation
▪ **Feasibility Study** - *Technical/Financial review* - *Bankability as top priority* ▪ **GOK approval** - *Partner with Korean SMEs* - *Ensure profitability, lower risk*	▪ **Detailed Design** - *By an internationally reputable engineering company* - *Reduce technical risk* ▪ **Trustworthy investors** - *MDBs like ADB* - *Insurance by MIGA*	▪ **Partner with local SMEs** - *EPC, E&M, design, etc* - *Maximize working with Korean small&medium companies* ▪ **On-time, quality work** - *By global top EPC contractors* - *Prioritize local construction experience*	▪ **Utilize KHNP experience** - *Experts rich in O&M experience* - *Trustworthy operation* ▪ **CSR** - *Strengthen P-K relations* - *Support local companies to expand reach, customer base*

<Reference : 2014-2015 NEPRA Industry Report>

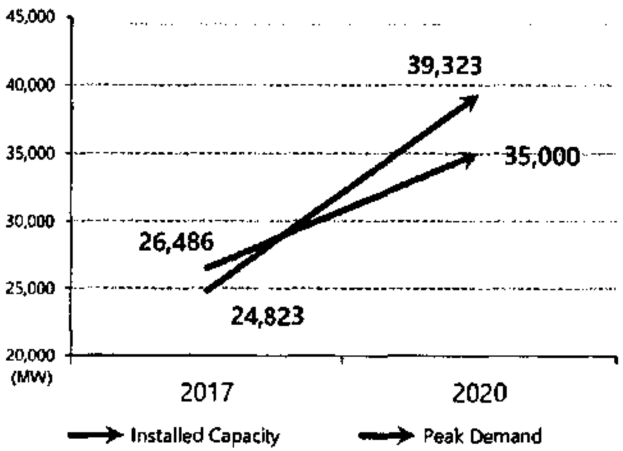
Power Sector Overview

Demand and Supply

SUPPLY-DEMAND GAP

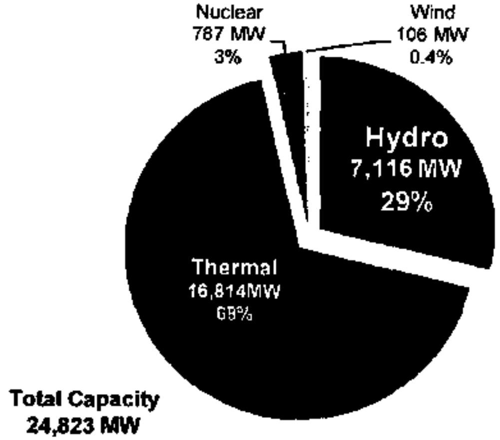


PLAN 2020

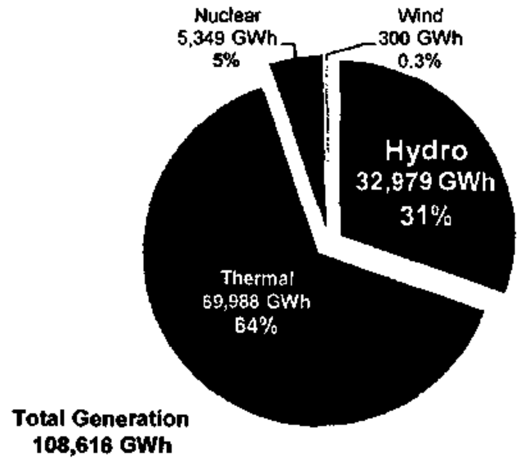


Source of Power Generation

CAPACITY

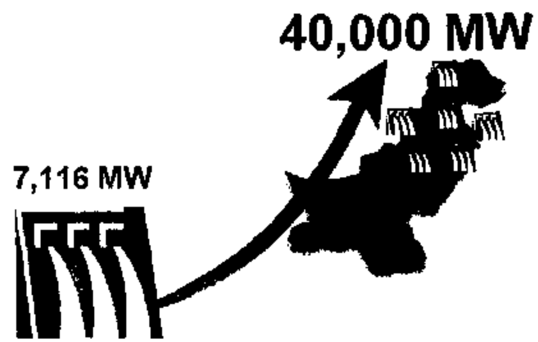


GENERATION



Hydropower

HYDRO POTENTIAL



PUBLIC & PRIVATE

6,902 MW

WAPDA

214 MW

IPP

Project Scheme and Risk Allocation

1. PPA : Revenue(Demand) RISK
2. EPC/O&M : EPC/O&M RISK
3. IA : Off-taker RISK
4. LA : Financing RISK
5. MIGA Covered : Political RISK

PPA Power Purchase Agreement
IA Implementation Agreement
DFI Development Finance Institution
MIGA Multilateral Investment Guarantee Agency

CLIENT

GoP/GoKP PPIB

Private power & Infrastructure Board

CPPA

KE

NEPRA

National Electric Power Regulatory Authority

Tariff Approval

③ IA

① PPA

SPC

EQUITY ⑤ MIGA Covered

Entity	Stake(%)	USD Mil
KHNP	34%	87.7
KIND	26%	67
KPS	15%	38.7
Company1	(7%)	18
Company2	7%	18
Company3	6%	15.4
Company4	2%	5.1
(New FI)	(3%)	7.7
Sum	100%	258

258 Mil. (25%)

④ LA

773 Mil. (75%)

DEBT

Entity	Stake(%)	USD Mil
(MDB1)	31.9%	246.6
(MDB2)	31.0%	239.6
(MDB3)	31.0%	239.6
(ECA)	6.1%	47.1
Sum	100%	773.0

② EPC / O&M contract

EPC

O&M

CI

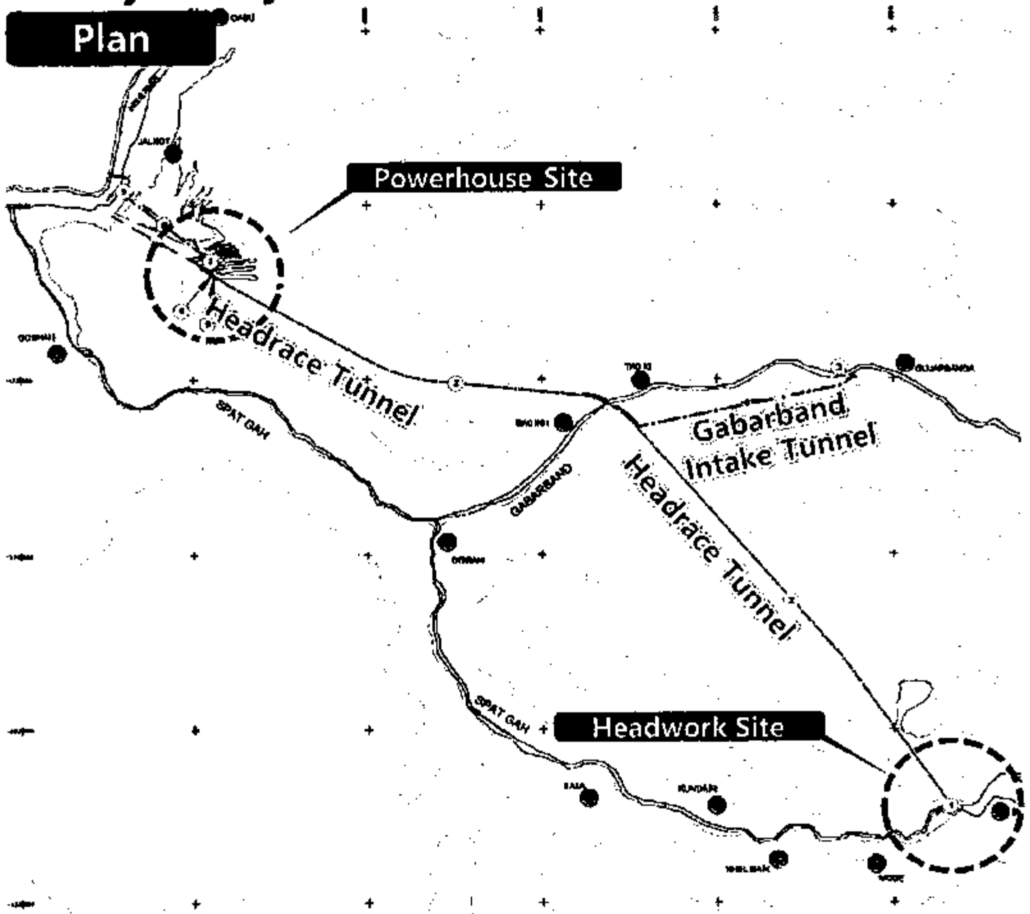
OI

Design Features

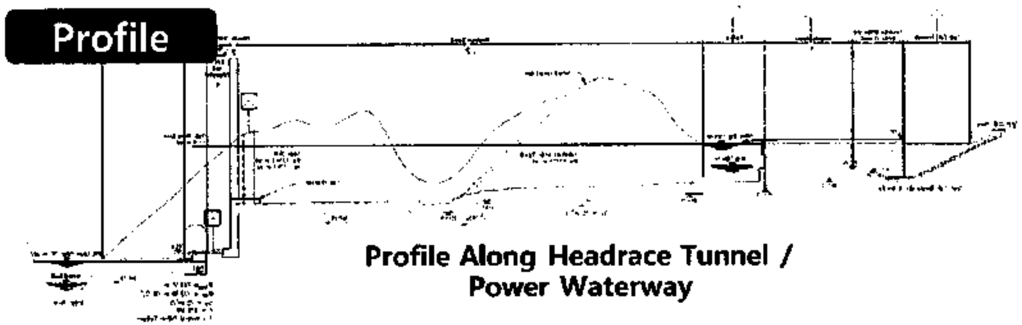
Items		Unit	Features
Plant	Installed Capacity	MW	470
	Plant Discharge	m^3/s	75.0
	Turbine Unit Discharge	m^3/s	25.0 (@ 3 units)
	Gross Head (Net Head)	m	744.58 (722.38)
	Type of Power Generation	-	R.O.R with Peaking (2 hrs)
	Rated Efficiency	-	Turbine : 0.913(Pelton), Generator : 0.975
	Annual Energy	GWh/yr	1,921 (at Generator)
	Plant Factor	%	48.0
Water Level	Normal Operating Level	m.a.s.l.	1,510.0
	Minimum Operating Level	m.a.s.l.	1,500.0
	Rated Tailwater Level	m.a.s.l.	752.4
Structures	Weir	m	H 34.0 m × L 260.0 m (Clay Core Rockfill Dam)
	Headrace Tunnel	m	D 5.3m(Concrete), D 4.0m(Steel lining) × L 10.75 km
	Desander	m	W 12.0 m × H 14.5 m × L 140.0 m × 6 ea
	High Pressure Tunnel	m	D 4.0m(Steel lining) × L 100 m
	Powerhouse(Cavern)	m	W 25.2 m × H 45.1 m × L 80.1 m (Underground)

Project Layout

Plan



Profile



Profile Along Headrace Tunnel / Power Waterway

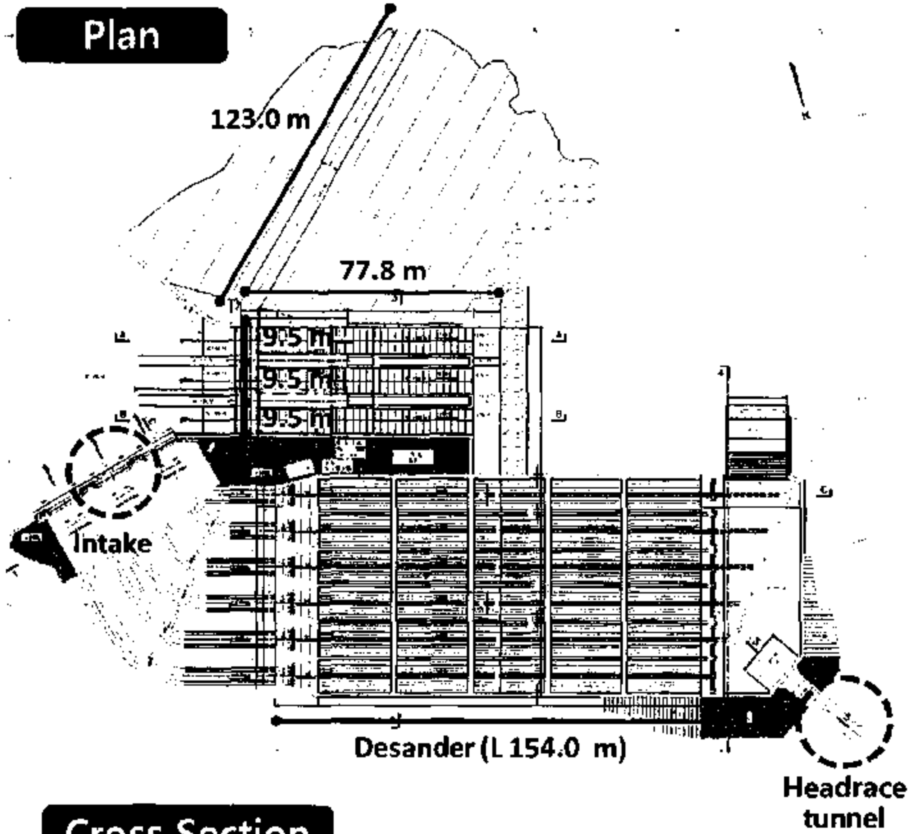
Location	
Country	Pakistan
Province	KPK (Khyber Pakhtunkhwa)

Structure	Specifications
Dam & Weir	• Clay core rockfill dam (CCRD) • Gated flushing channel concrete structure
Headrace Tunnel	• Type : Pressurized • Length : 10.75 km • Shape : Horseshoe • Inner dia : 5.3 m concrete / 4.0 m steel lining
Gabarband Intake	• Type : Concrete gravity weir • Height : 18.4 m • Crest length : 43 m
Intake Tunnel	• Type : Pressurized • Length : 2.9 km • Shape : Horseshoe • Inner dia. : 5.6 m concrete
Tailrace Tunnel	• Type : Free-flow • Length : 1.4 km • Shape : Horseshoe

Energy Production	
Annual	• Stand-alone 1,921GWh • Cascade 1,920GWh
Load factor	• 48%

■ Headwork Site

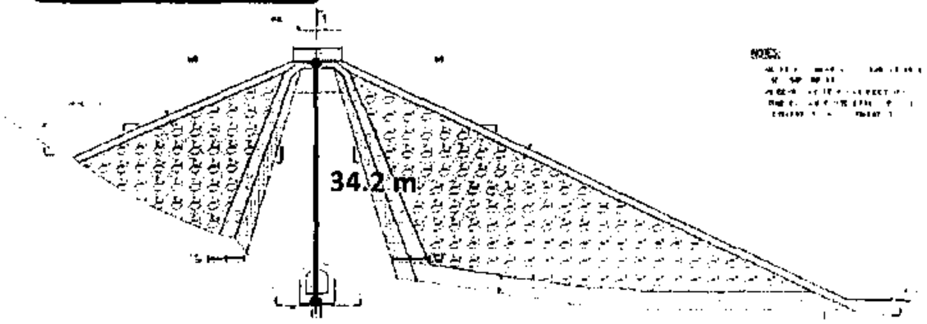
Plan



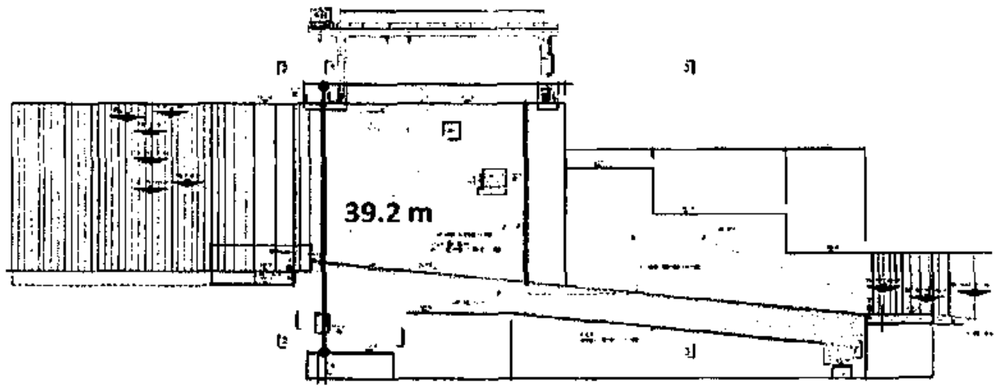
Spat Gah Weir	
Type	Clay core rockfill dam (CCRD)
River bed level	1,487 m asl
Crest elevation	1,512 m asl
Maximum height	34 m
Crest length	123 m
Gates	3 radial gates (W 9.5 m x H 28.7 m)
Residual flow	1.5 – 4.3 m^3/s

Intake & Desander	
Type	Surface type
Inlet	W 14.1 m x H 6.6 m (3ea)
Desander	W 6.0 m X L 154.0 m X H 23.0 m @ 6 basins

Cross Section



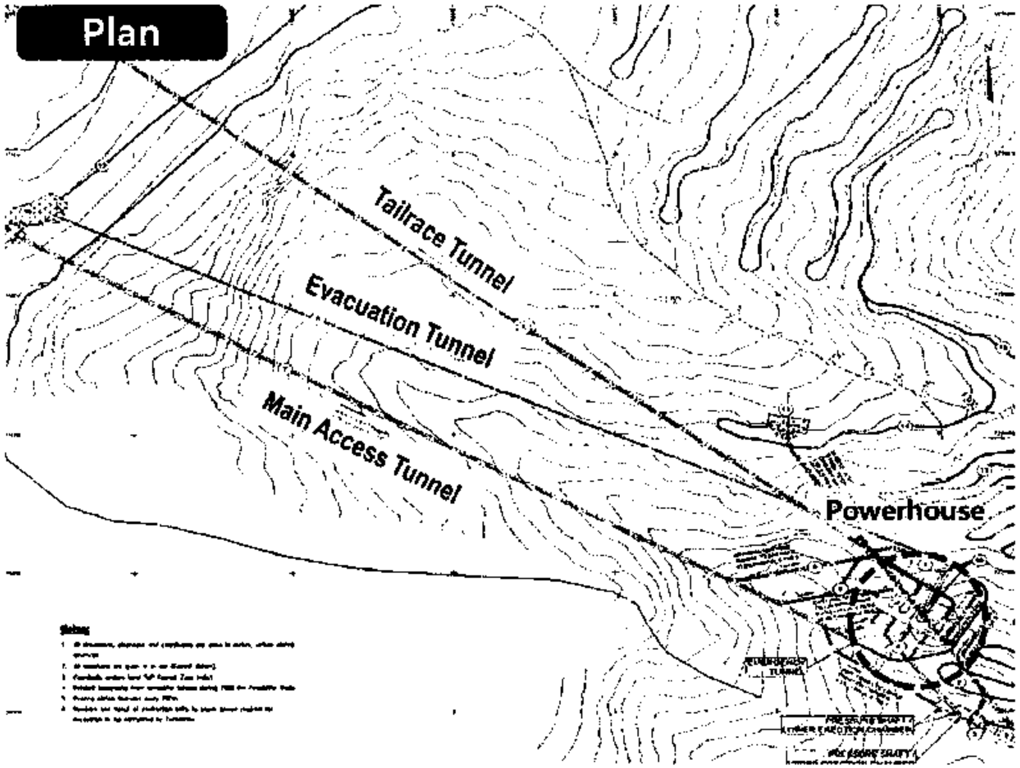
< Typical Section of Spat Gah Weir >



< Typical Section of Spillway >

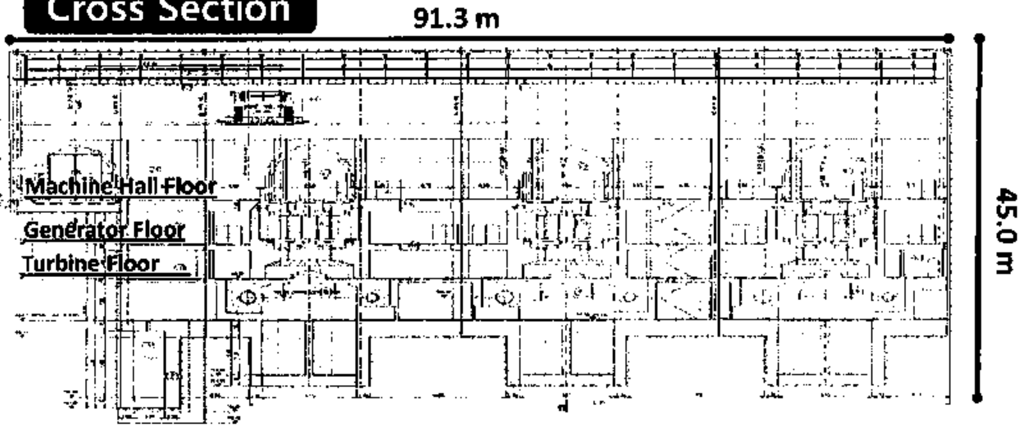
■ Powerhouse

Plan

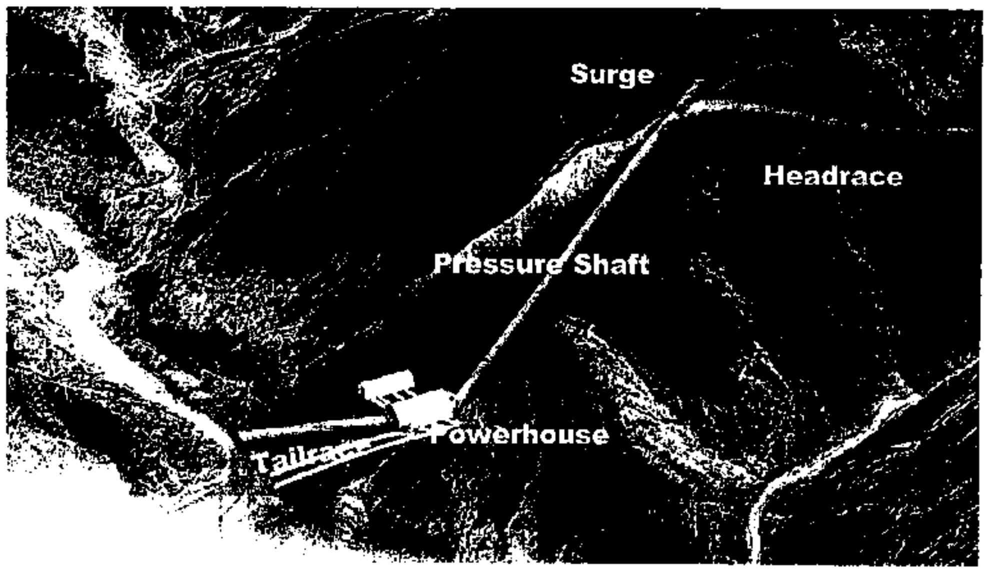


Structure	Specification
Power house	• Type : Cavern • Turbine type & number : Pelton x 3 units • Design discharge : 75 m³/s • Net head : 722.4 m • Installed Capacity : 470MW
Tailrace Tunnel	• Type : Free-flow • Length : 1.4 km • Shape : Horseshoe
Switchyard& Transmission Line	• Switchyard : GIS (220 kV) • Transmission line : 3 km (765 kV)

Cross Section



< Cross Section of Powerhouse >



■ Access Road (Dasu → Dam Site)

Paved(about 70% of the total road)

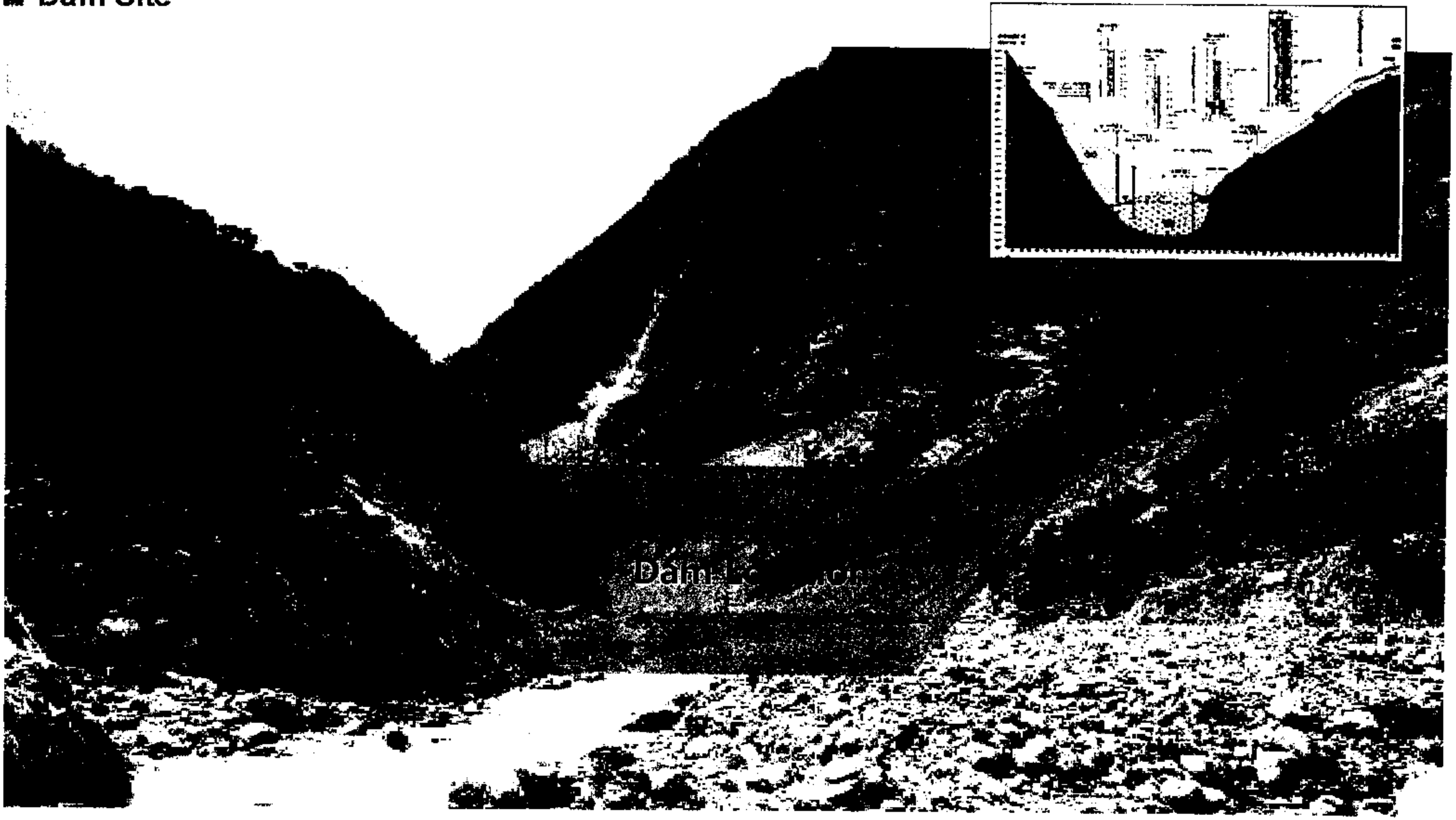
A small bridge (Goshali)

Unpaved road

Pedestrian only access

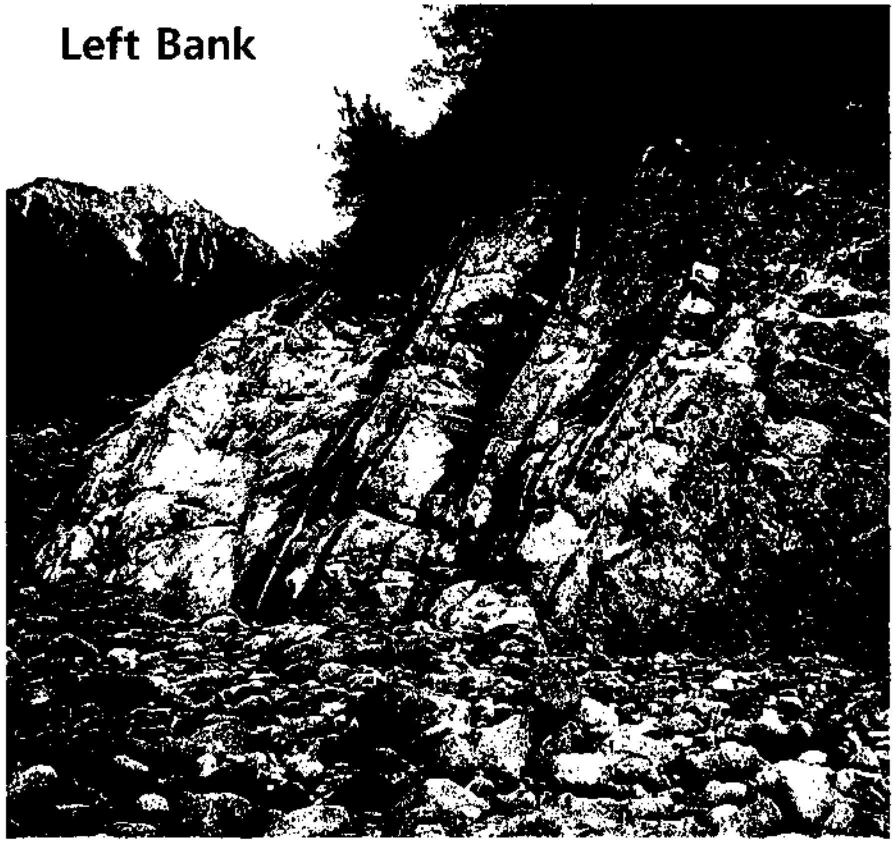
- ■ Spat Gah : Vehicle access available up to 3~4km from the dam
- ■ Garbarband : Vehicle access available up to 6~7km from the weir
- ■ Da[illegible](weir) site condition, flow is good.

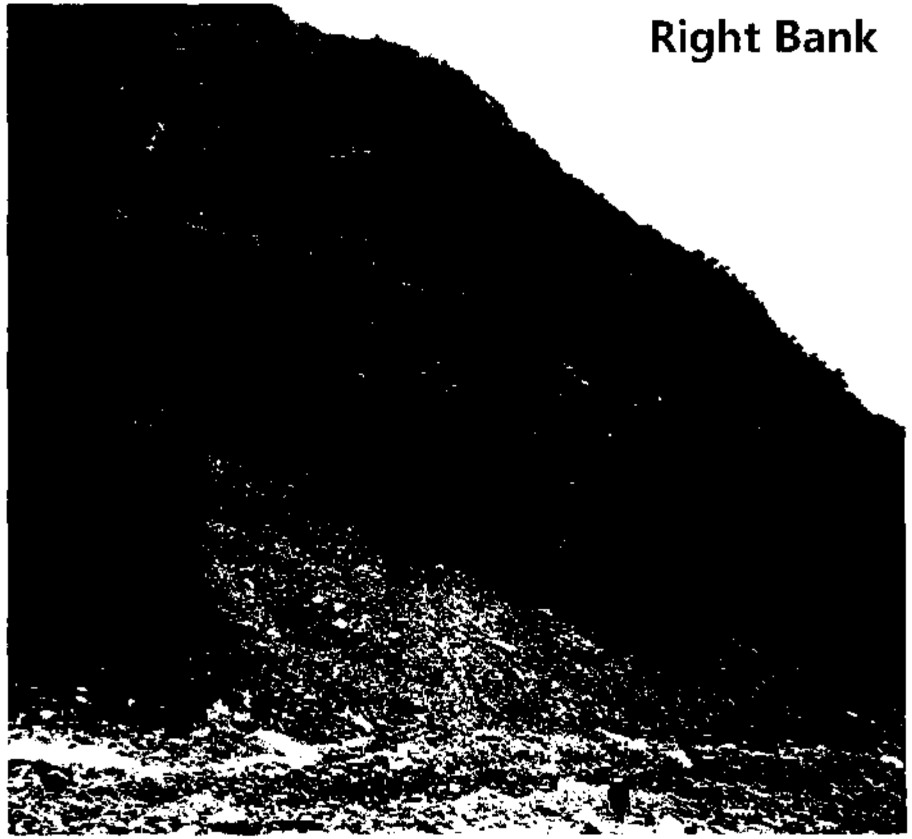
■ Dam Site



- ■ Left bank(right side) of Dam : Steep slope with bedrock exposed,
- ■ Right bank(left side) of Dam : Covered with colluvium, upper sides have very steep cliffs

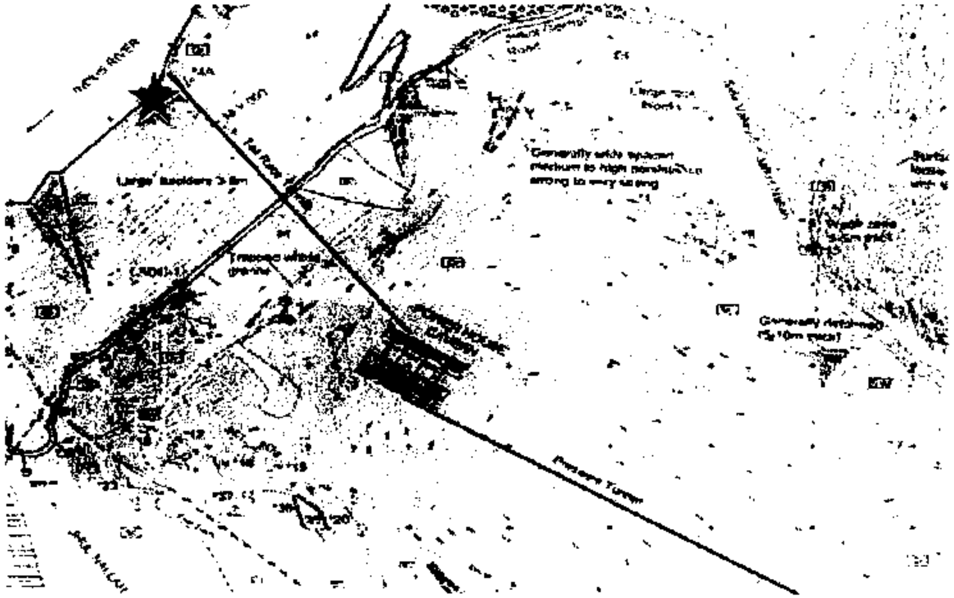
■ Dam Site

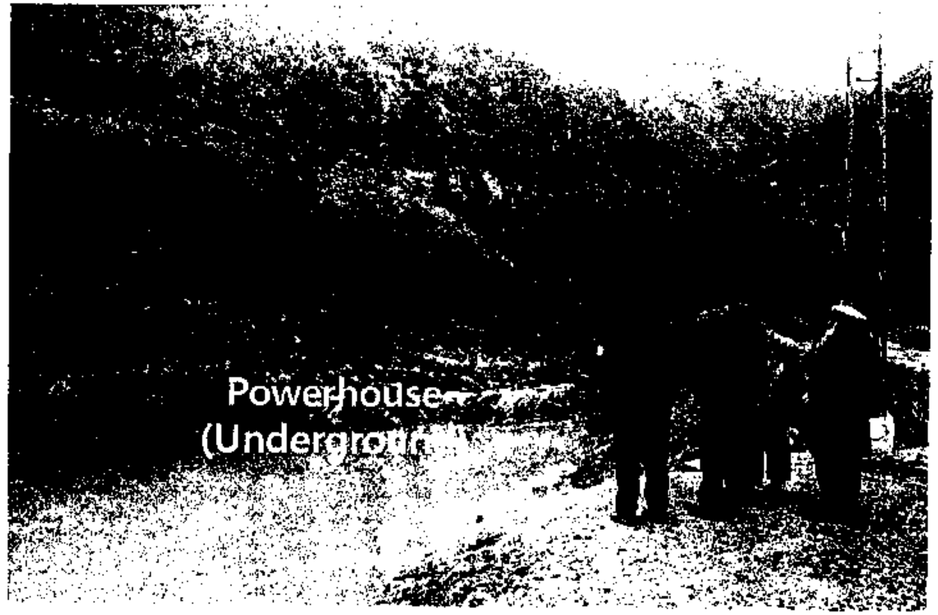




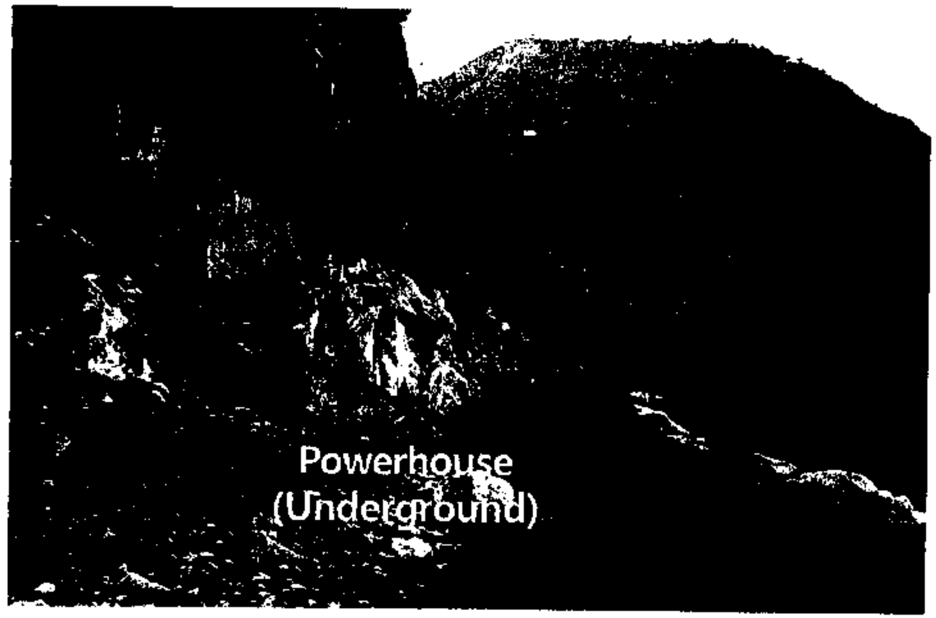
- Left bank(right side) of Dam : The exposed bedrock has very strong strength
- Right bank(left side) of Dam : Covered with colluvium containing small rocks

■ Dam Site





- Tunneling underground from left riverbank of Indus
- Headrace Tunnel(1.43km), Energy Tunnel(1.18km)
  Tailrace Tunnel(1.35km)
- Underground P/H (W 25.2m × H 45.1m × L 80.1m)
- Geology of P/H location is mostly granite and
  has amenable conditions



■ Investment Costs - Construction

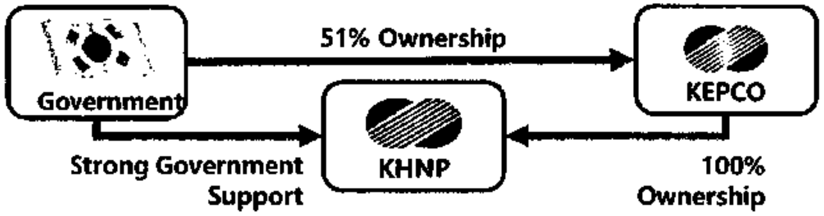
CATEGORY	ITEM	COST(USD)	Share(%)	Remarks
EPC	Civil Works	515,266,178	49.96	Dam, Tunnel, Powerhouse
	Electro-Mechanical Work	254,546,882	24.6	TBN, GEN, Including Hydro-Mechanical
	Sum	769,813,060	74.56	1MW - 1.63 mil USD
Non-EPC	Financing/Lenders Fees	17,145,625	1.66	
	Legal Costs	2,679,520	0.26	
	Agency & Advisory Cost	7,755,328	0.75	
	Engineering Supervision	34,998,402	3.39	
	Land Acquisition & Resettlement	7,824,235	0.76	
	Insurance During Construction	24,059,000	2.33	
	O&M Mobilization	4,626,524	0.45	
	Customs Duties	14,089,170	1.37	
	Project Development Cost	38,971,603	3.78	
	Environment	9,616,490	0.93	
	Sum	161,765,897	15.69	
Interest During Construction	Financing Fees	99,620,000	9.66	
Total Investment Cost		1,031,198,957	100.0%	1MW - 2.19 mil USD

※ Optimal project design in progress and may be adjusted for some of the project cost

KHNP (Main Sponsor)

KHNP plays a key role in the national electricity supply as the biggest power generator in Korea

Ownership Structure



- Established on **April 2, 2001**, as a result of a corporate spin-off from KEPCO
- **A public enterprise** indirectly owned by the Korean Government via KEPCO

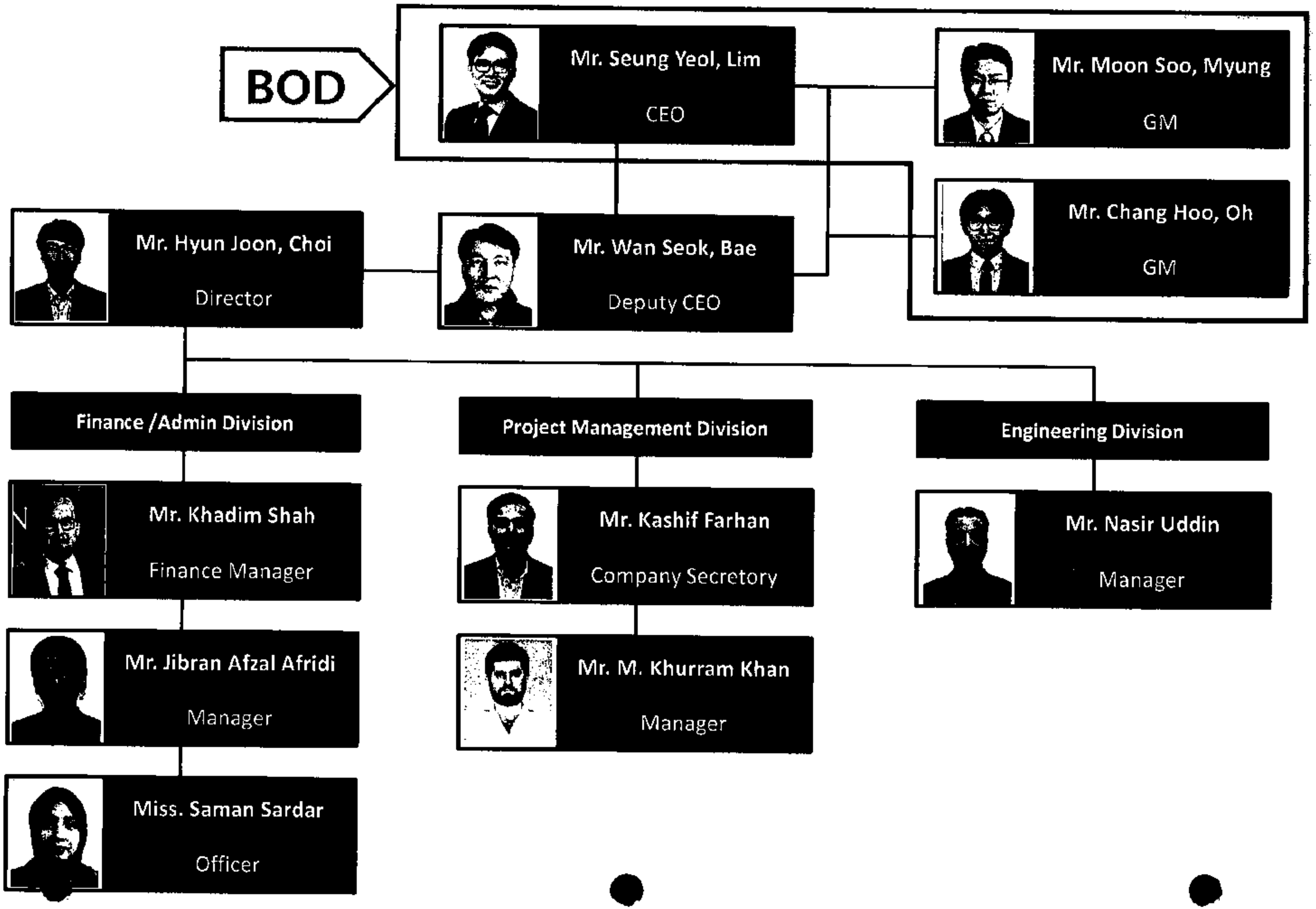
Solid Credit Rating

- **Moody's (Aa2/Stable)**
- **S&P (AA/Stable)**
- **Fitch (AA-/Stable)**
- **R&I (AA-/Stable)**

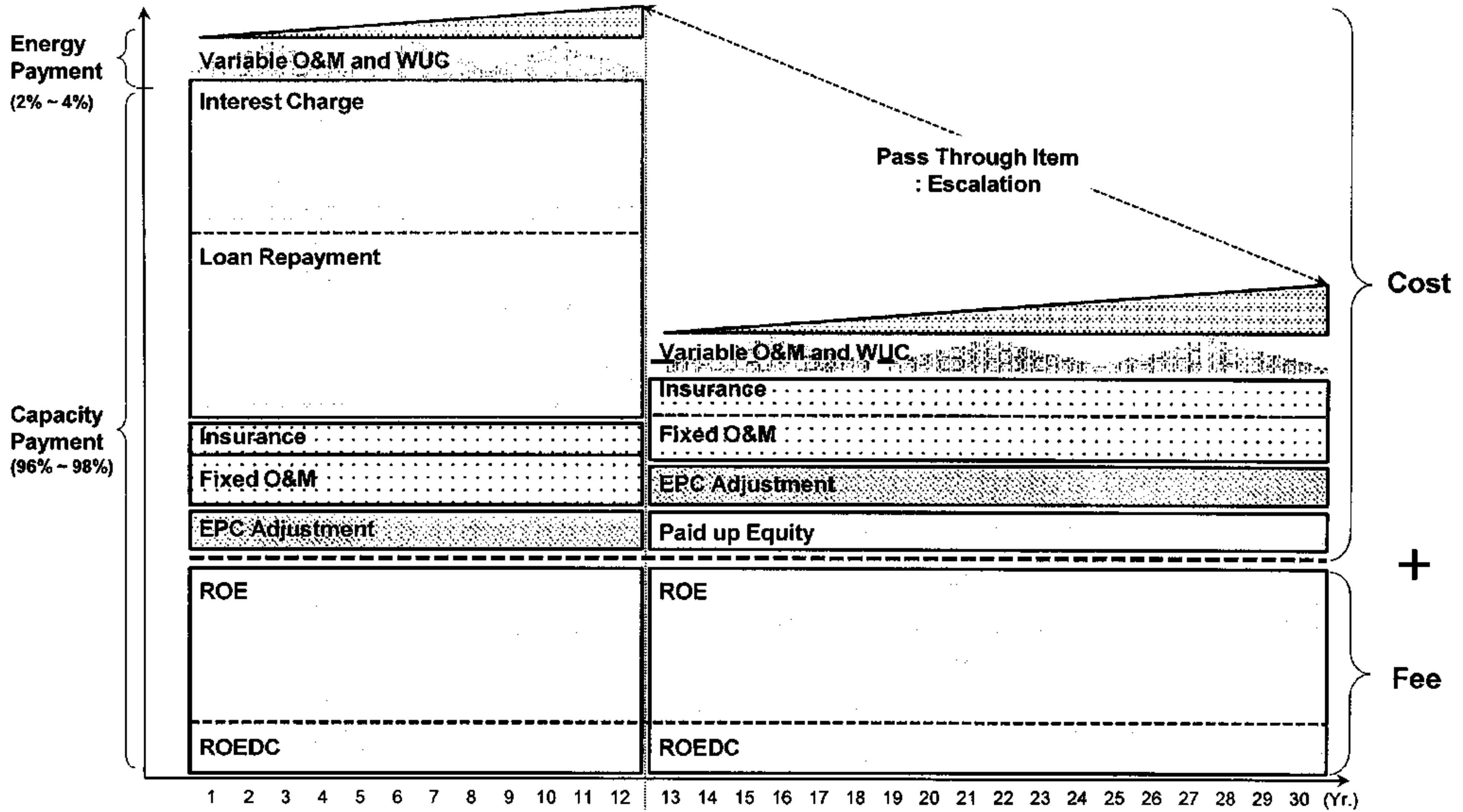
Quick Facts (2021)

Establishment	Spun-off from KEPCO in 2001
Ownership	100% owned by KEPCO (which is majority owned by the Korean government)
Employees	11,303
Assets	KRW80,550 bn(USD 68.5 bn)
Sales	KRW9,999 bn(USD 8.5 bn)
Operating Profit	KRW1,315 bn, (USD 1,120 Mil)
Generation Capacity (as of Jun. 18. 2017)	28,607MW with 108 units (Nuclear: 23,250MW with 24 units)

LSG Organization Chart



Tariff Structure during O&M



*ROEDC : ROE During Construction

LSG HYDRO POWER LIMITED

Invested by KOREA HYDRO & NUCLEAR POWER CO., LTD

Enrich Life through

Clean Hydro Energy

4th Floor, Emirates Tower, Jinnah Super, F-7

Islamabad, Pakistan

Tel : +92-51-613-4782

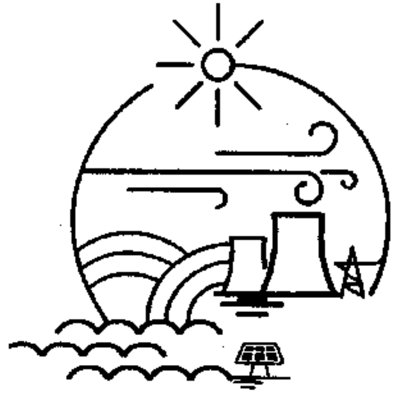
Email : info@lsg-hydro.com

Web : www.lsg-hydro.com

KHNP
www.khnp.co.kr
1655, Bulguk-ro, Munmudaewang-myeon, Gyeongju-si, Gyeongsangbuk-do, Korea(38120)
Publishing Office: Corporate Communications Unit Tel. 82-54-704-1422
Publication Date: August 2022

http://www.facebook.com/ilovekhnp
https://blog.naver.com/i_love_khnp
http://www.instagram.com/ilovekhnp/
https://www.youtube.com/user/ikhnp
https://post.naver.com/i_love_khnp

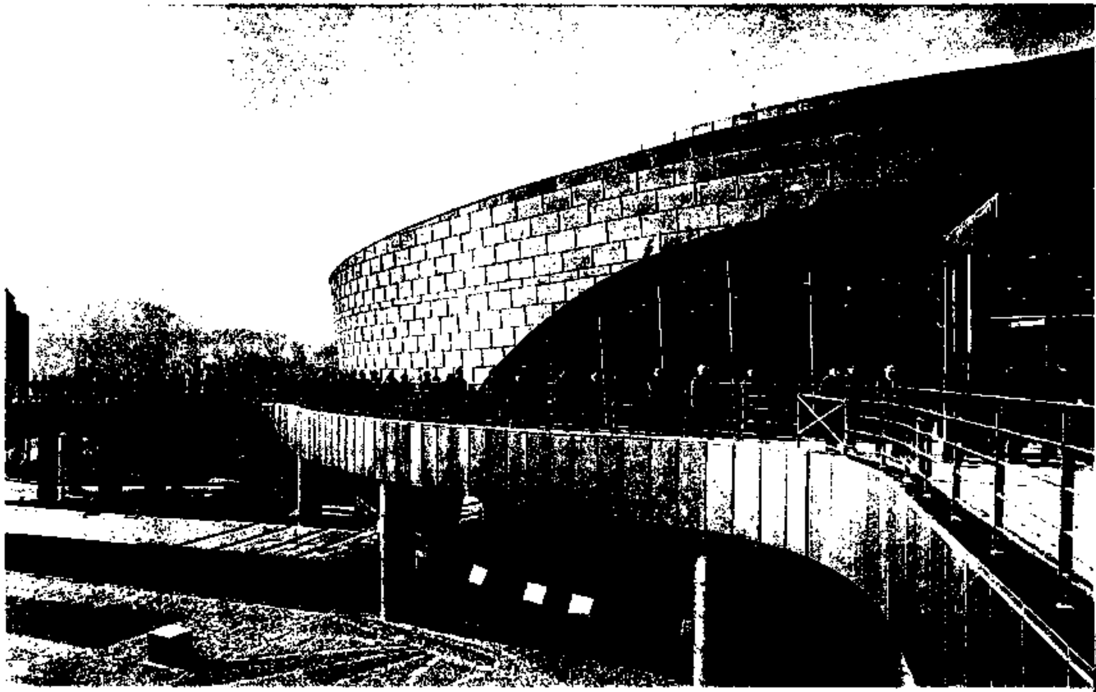
KOREA HYDRO & NUCLEAR POWER CO., LTD
KHNP



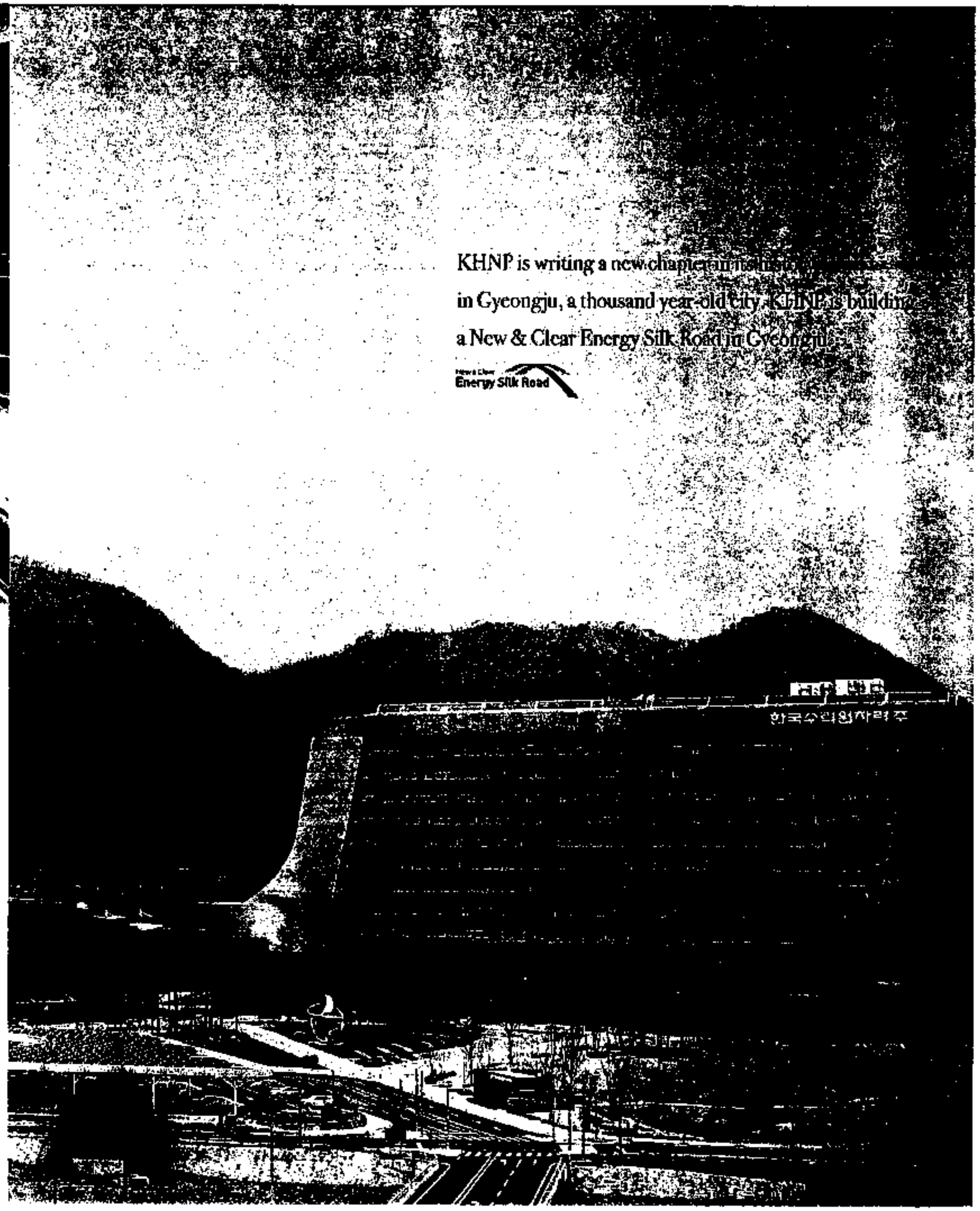
KHNP
KOREA HYDRO & NUCLEAR POWER CO., LTD

● Note

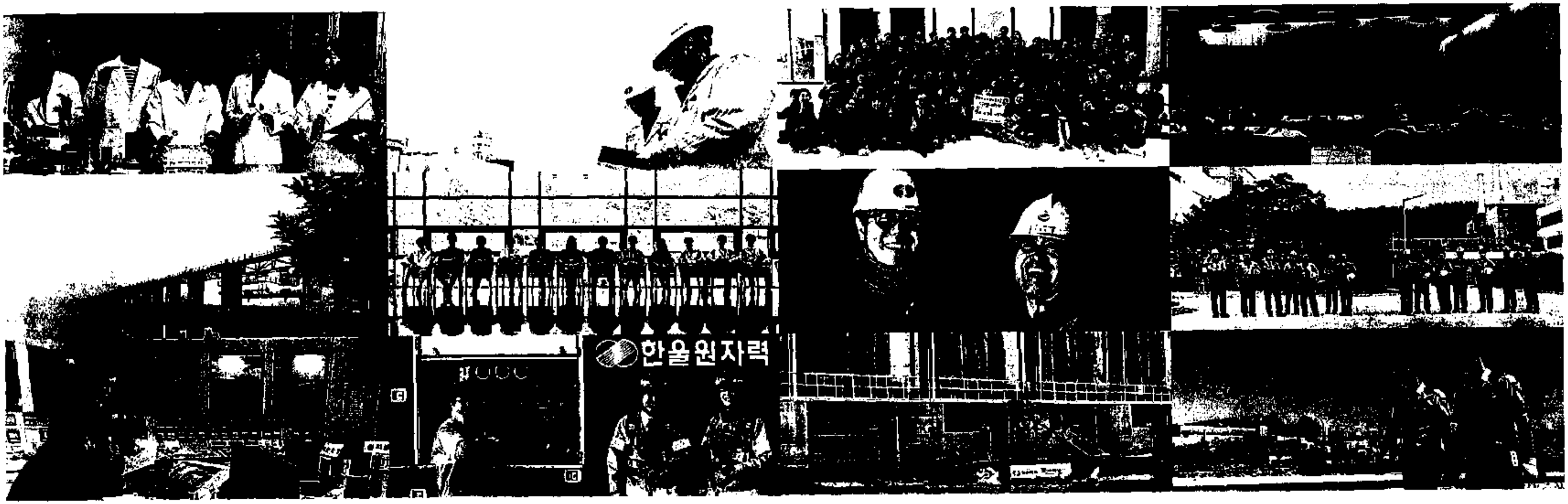
- Throughout this brochure, the abbreviation 'KHNP' is used for 'Korea Hydro & Nuclear Power'.
- The contents of this brochure are based on data that was current as of late December 2021.



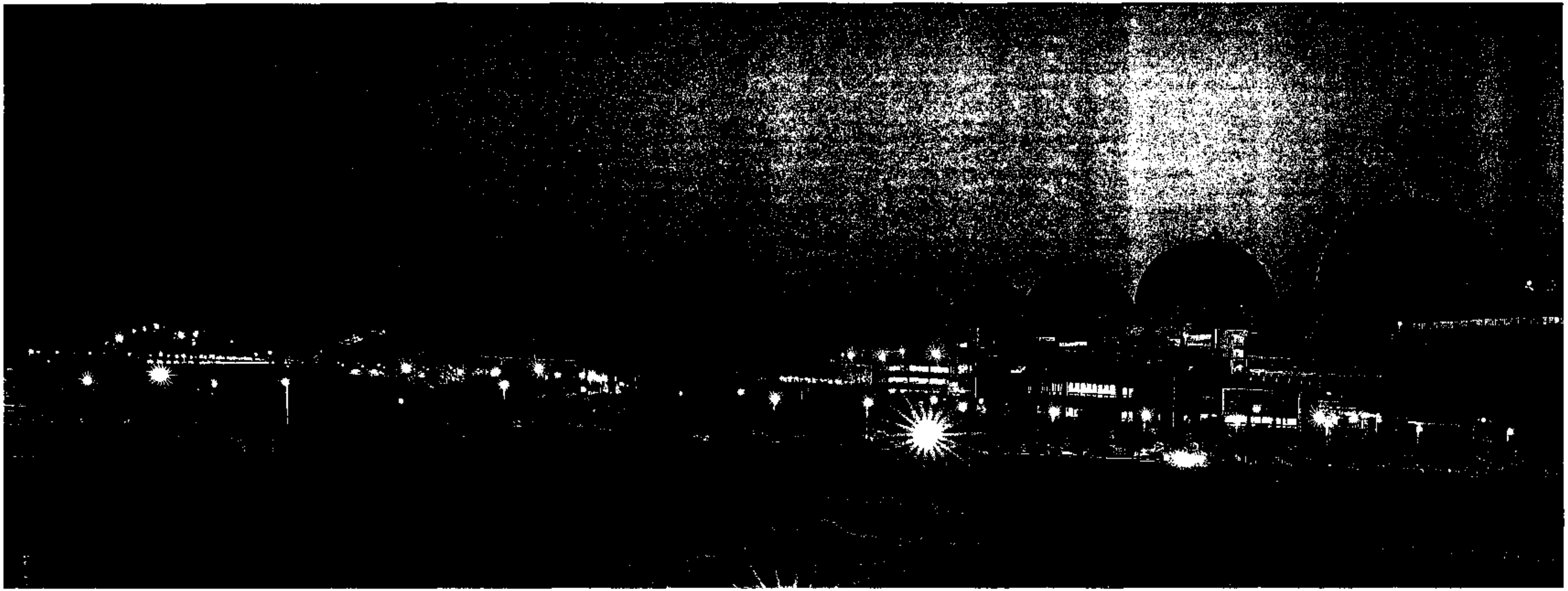

K
H
N
P
F
U
T
U
R
E


KHNP is writing a new
in Gyeongju, a thousand year-old city. KHNP is
a New & Clear Energy Silk Road in Gyeongju.
New & Clear
Energy Silk Road

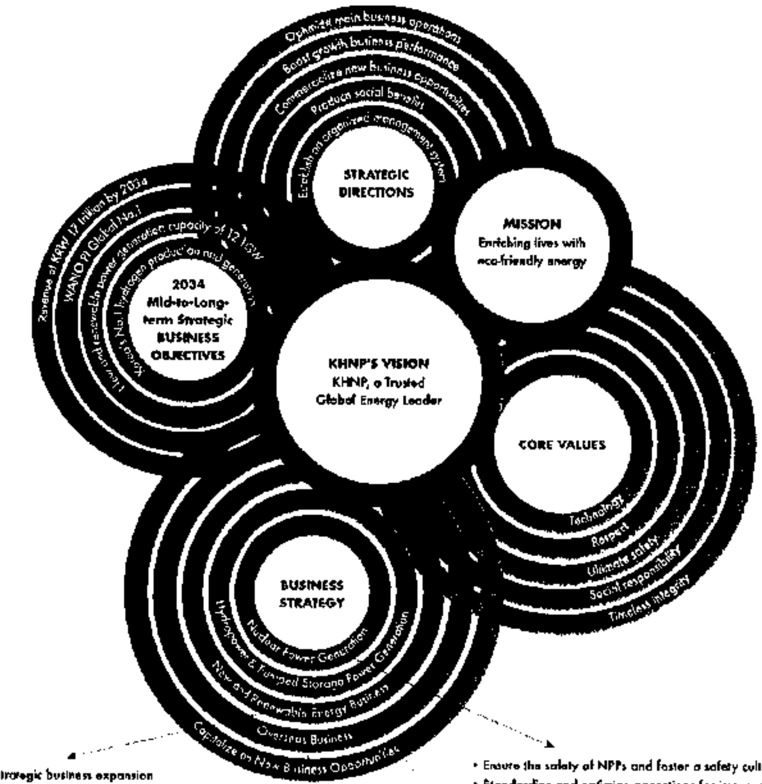
Everyone has a dream.
KHNP makes dreams come true
by shedding a bright glow on the invisible but
precious dreams
inside each and everyone of us.



The future we dream of is full of hope.
KHNP makes the world a place of hope
by giving out a radiant light
for the future happiness that everyone has dreamt of,
a tomorrow full of hopes and happiness.



MISSION & VISION



- Promote strategic business expansion through diverse business models
- Develop capacity and expand business models
- Strengthen business infrastructure and human resource and technology capacity

- Ensure the safety of NPPs and foster a safety culture
- Standardize and optimize operations for improved efficiency
- Establish an organized business management system

- Upgrade operation systems for power generation
- Secure competitiveness in the future energy markets
- Expand our base in the hydro sector through a value chain

- Diversify contract acquisition strategies (for nuclear/hydro/renewables)
- Improve our overseas business development capabilities
- Strengthen our business management system

- Commercialize the entire life cycle of hydrogen and establish a hydrogen ecosystem
- Lead self-sufficient energy-powered digital convergence projects
- Enter into overseas energy markets based on rich nuclear decommissioning experience in Korea
- Develop and commercialize multipurpose SMR in time
- Commercialize radioisotopes and radiopharmaceuticals

PRESIDENT & CEO MESSAGE

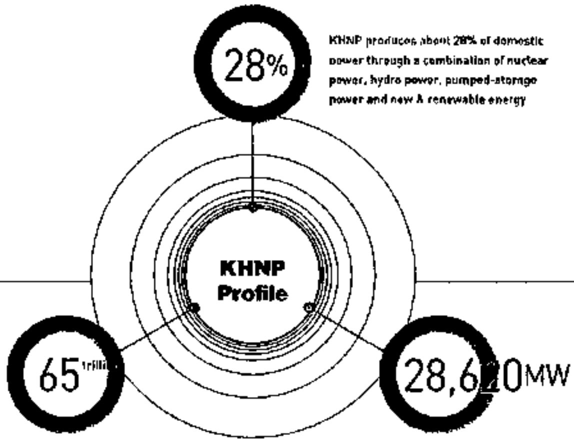
"Our promise to keep
A safer and prouder KHNP"

President & CEO WHANG, Jooho

With safety as our priority, We'll maximize our competitiveness in nuclear power business and become the front-runner of clean energy along with new growth business.

KHNP is the Nation's Largest Power Generator

Producing approximately 28% of the electricity used in Korea, KHNP has grown to become the nation's largest power generator, based on its strong dedication and pride in 'enriching the lives of citizens and providing a foundation for the nation's economic development through the stable supply of power'.



KHNP produces about 28% of domestic power through a combination of nuclear power, hydro power, pumped-storage power and new & renewable energy

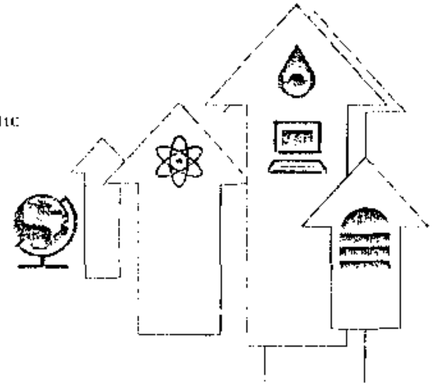
As a leading company with assets of about KRW 65 trillion, KHNP recorded annual revenue of about KRW 9.46 trillion in 2021

KHNP currently operates 24 nuclear power units, 37 hydro power units and 16 pumped-storage power units, producing over 28,620MW of power annually

"We cannot imagine a world without energy. From the moment we wake until after we go to bed, every activity we pursue in our lives requires energy. Energy is with us around the clock, even when we are asleep. Every human activity involves the use of energy, including watching TV at home, studying at schools, using computers at work, shopping at a department store and crossing the road using traffic lights. Korea's per capita energy consumption volume is even higher than that of Japan, whose economy is five times larger. KHNP is doing its utmost to ensure that the Korean people can lead happy lives without concern over energy shortages."

KHNP Produces Approximately 28% of Domestic Power

The weight of nuclear power generation has shown a steady increase for more than 40 years since Kori Unit 1 entered into commercial operation in April 1978. Currently, three out of ten households in Korea are using electricity generated by nuclear power. KHNP has significantly contributed to ensuring a stable supply of power by producing about 28% of domestic power through hydro power generation, pumped-storage power generation, and renewable energy as well as nuclear power generation.

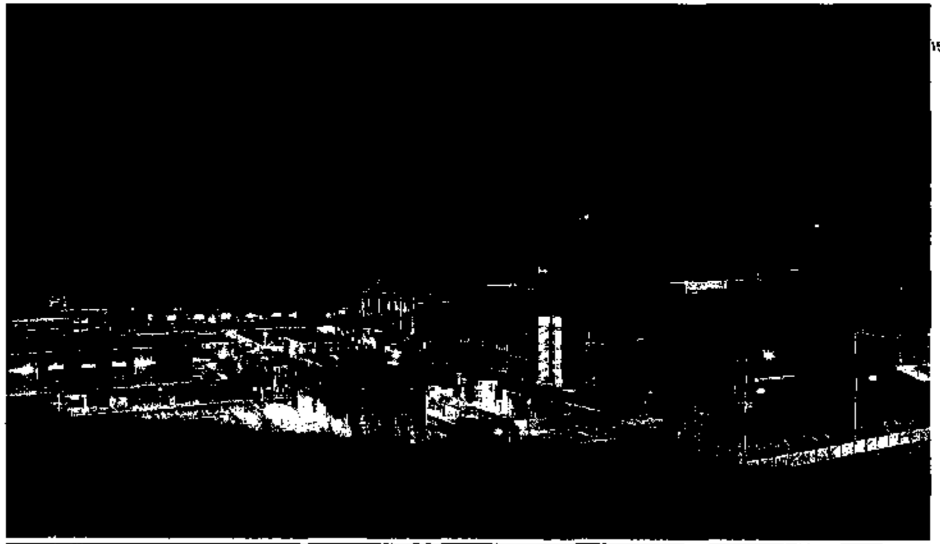


Financial soundness and profitability

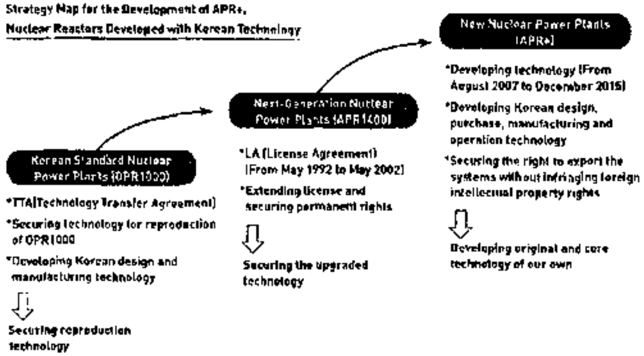
KHNP is a leading company with approximately KRW 65 trillion in capital and achieved total sales of KRW 9.46 trillion in 2021. The key factor in this success was increasing power production by reducing the number of suspensions of power plants and shortening the maintenance period. KHNP has outstanding credit ratings from the international credit rating institutions, including an Aa2 from Moody's, an AA from S&P and an AA- from Fitch, AA- from R&I, thanks to its a solid financial structure and active support of policies. KHNP has also managed to maintain its top AAA rating from three credit rating institutions in Korea.

KHNP leads the efforts to make Korea a nuclear powerhouse

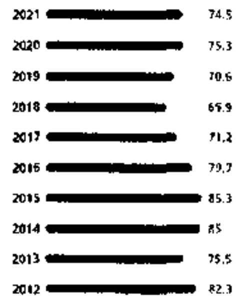
KHNP operates 24 units of nuclear power plants, 37 units of hydro power plants and 16 units of pumped-storage power plants, and has a total installed capacity of about 28,620MW. In particular, its nuclear power capacity reaches 23,250MW, leading power production within Korea. Currently 4 units of nuclear power plants are under construction. Shin-Kori Units 5 and 6, and Shin-Hanul Units 1 and 2 are under construction as new light-water nuclear reactors [APR 1400]. By increasing the reliability of its nuclear power facilities and fulfilling self-supporting technologies related to nuclear power, KHNP will lead Korea as an energy powerhouse.



Strategy Map for the Development of APR+, Nuclear Reactors Developed with Korean Technology

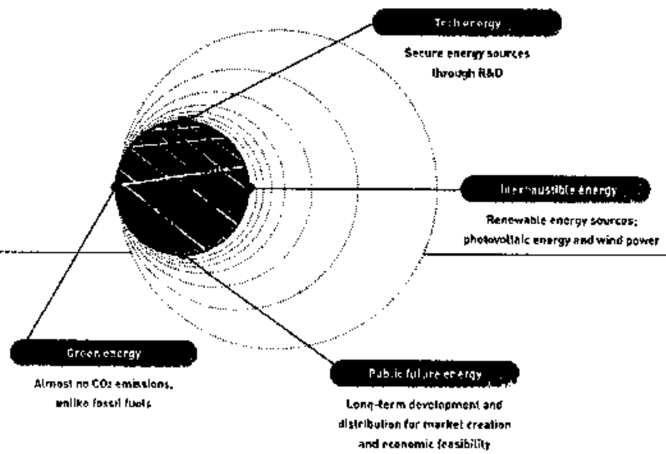


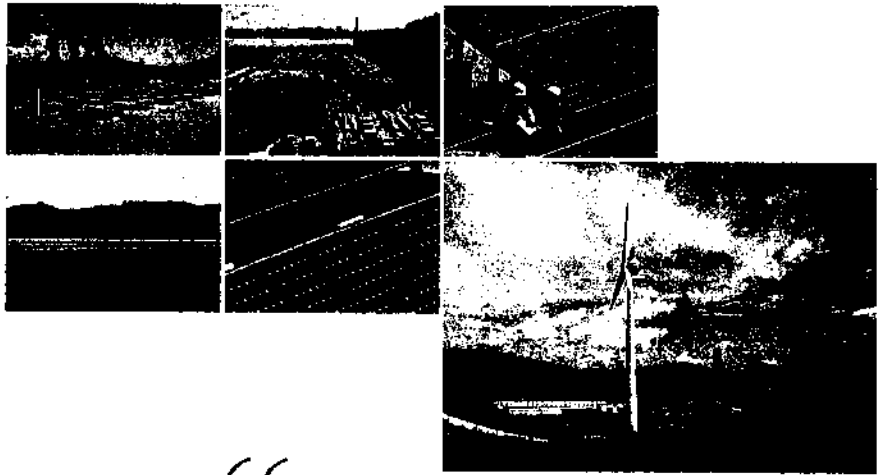
Capacity Factor of Domestic Nuclear Power Plants (Unit: %)



KHNP Invests in Developing New & Renewable Energy and R&D

KHNP is not only concerned with the happiness of humanity, but also actively develops new & renewable energy sources so that human beings can coexist with nature. KHNP is steadily preparing for the future through continuous R&D investments so that people can lead happy lives without concerns over energy shortages.



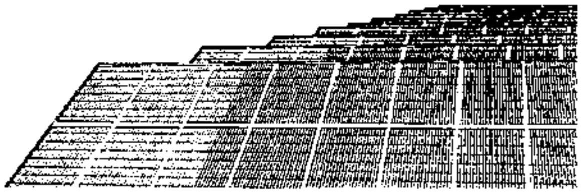


"With rapid population growth and economic growth, energy consumption is continuously increasing worldwide. In particular, emerging countries are consuming more energy as their economies rapidly grow. Fossil fuels such as coal, oil and natural gas, which account for 90% of the world's energy sources, are not limitless. Therefore, we need to develop alternative energy before fossil fuels run out.

The new & renewable energy that KHNP has developed as green energy is a pollution-free energy that can replace fossil fuels such as coal and oil, and is a future energy source that is sustainable. KHNP is making steady R&D investments to free Korea from energy concerns."

KHNP Reinforces Competitiveness through Aggressive Investments

Major energy sources such as oil, coal and natural gas are being exhausted. It is estimated that we have enough oil to last about 53.5 years, enough coal for 139 years, and enough natural gas for 48.8 years. As the nation's largest power generator, KHNP is preparing for the future early by aggressively developing new & renewable energy and continuously investing in R&D.

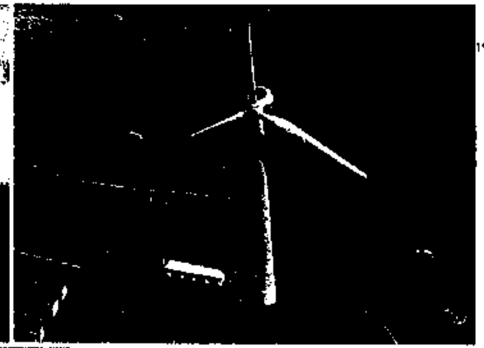


A future leader in the new and renewable energy markets

As domestic energy markets face increasing uncertainty and reinforced environmental regulations, the need to develop new & renewable energy sources is greater than ever before. Nuclear power is an ideal alternative energy that should be sustained for an economic and stable power supply, and new & renewable energy must be developed through long-term, continuous investments. In proactive response to the changes in the environment, KHNP has set strategic objectives to transform itself into a comprehensive energy corporation from a dedicated nuclear power plants operator, and to secure a leadership in the new and renewable energy markets. With these objectives, KHNP has diversified its project development methods and increased the target ratio of its own businesses significantly from 15% to 30%. As for equity participation projects, KHNP is now focusing on Bigeum-do (an island in Sinan County) photovoltaic power complex development and Saemangeum floating solar power plant development projects. Also, it is dedicated to upgrading the current management system for the existing power generation facilities in operation and developing new and renewable power generation technologies.

Global visions for carbon neutrality in a climate crisis

Global economy is making a great shift towards fighting the climate crisis, making climate change a top priority in national industrial policies. As a responsible member of the international community to reduce the effects of climate change, the Republic of Korea pledged to achieve carbon neutrality by 2050 and revealed its '2050 Carbon Neutral Strategy'. With the rising global energy demand and a growing need to reduce greenhouse gas emissions, a significant expansion in generation capacity of new and renewable energy is required. In this context, the Korean government has identified the challenges and strategic solutions for the nation's new and renewable energy sector and announced its plan to increase the nation's renewable energy generation ratio to 25.8% by 2034 in the 9th Basic Plan for Power Supply and Demand. In response, KHNP aims to achieve a total of 12.1GW of power generation capacity in new and renewable power generation facilities by investing in 13.1 trillion won by 2034.



Technological Development through Selection and Concentration

Items	PROJECT-Type Development Areas	General Development Areas	Basic Development Areas
Alternative Energy Sources	Photovoltaic energy, wind power and fuel cells	Solar power, waste-to-energy, bio, geothermal and small hydro power	Hydrogen, IGCC* and marine
Selection Criteria	- Technologies that can be developed and commercialized due to small gaps with advanced countries - Technologies with large markets and growth potentials	-Technologies that can be rapidly distributed thanks to existing technological excellence - Technologies whose markets have been formed to a certain extent	- Technologies that cannot be commercialized rapidly - Technologies used in specific sectors, and technologies whose markets have not been formed
Methods of Technological Development	3 Key Areas	Development of Technologies for Distribution	Development of Key Basic Technologies

* IGCC: Integrated Gasification Combined Cycle

Overview of New & Renewable Energy Facilities

Total of
1006.15MW
As of December 2021

Self-developed facility + SPC's installed capacity

Hydro Power
607MW

Wind Power
79.95MW

Photovoltaic Power
170MW

Fuel cell
149.2MW

KHNP has Technological Excellence

KHNP has an exceptional track record for nuclear power plant operation, and rich expertise in nuclear power plant construction. KHNP has been recognized worldwide for its leading technological excellence. But rather than resting on its laurels, the company is making untiring efforts in the area of R&D to grow and secure higher levels of global competitiveness.

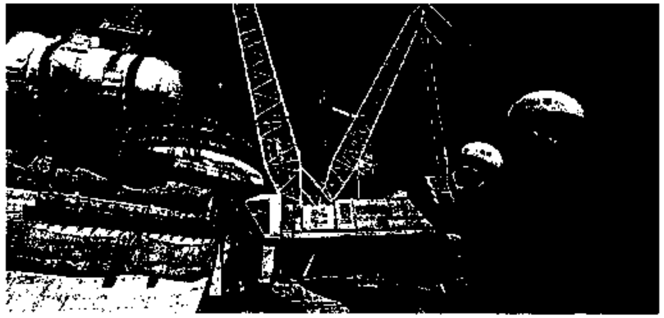
New-concept technology
- 4 Train Direct safety injection system

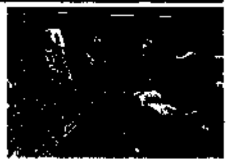
Improved safety
- Adoption of verified and improved technology
- Less frequent damage of reactor cores and reactor containment buildings
- Tightening of earthquake resistant design criteria
- Quadrant arrangement of physically separated safety system

Improved convenience in operation and maintenance
- Increase of operator response time
- Reduction of exposure dose of staff
- Installation of maintenance and inspection convenience facilities

Improved economic feasibility
- Extension of Design life
- Reduction of operation and maintenance costs
- Minimization of site area through optimized power plant layout
- Selection of cutting-edge construction techniques

Flow controls in safety injection tanks and safe injection system
- In-containment Refueling Water Storage Tank (IRWST)
- Digital instrumentation & control equipment and computer systems

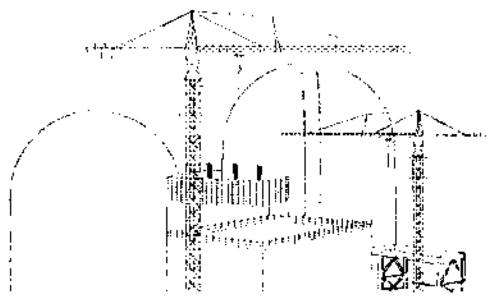




“ If KHNP had settled on its past achievements, the company would have fallen behind by now. Since its early days, KHNP has gained global recognition for its technological excellence, but it has never settled for the status quo, paying attention to global trends and sharpening its technological capability by developing new technologies. Korea has become a global nuclear powerhouse thanks to its dedication to R&D and its untiring efforts for innovation. Global energy consumption is growing due to rapid population growth and economic development. With limited resources, the competition for securing energy resources and developing technologies has become fiercer than ever before. Nevertheless, KHNP is not threatened by cut-throat energy competition, as it has fortified its competitiveness by focusing on R&D. ”

KHNP Strives to Develop New Technologies to Lead the Global Nuclear Industry

The history of Korea's nuclear power development began in 1957, when Korea became a member of IAEA. 20 years later, in 1978, Korea was operating Kori Unit 1, East Asia's second commercial nuclear reactor. Through continuous R&D, KHNP has developed more efficient and stable nuclear reactors.

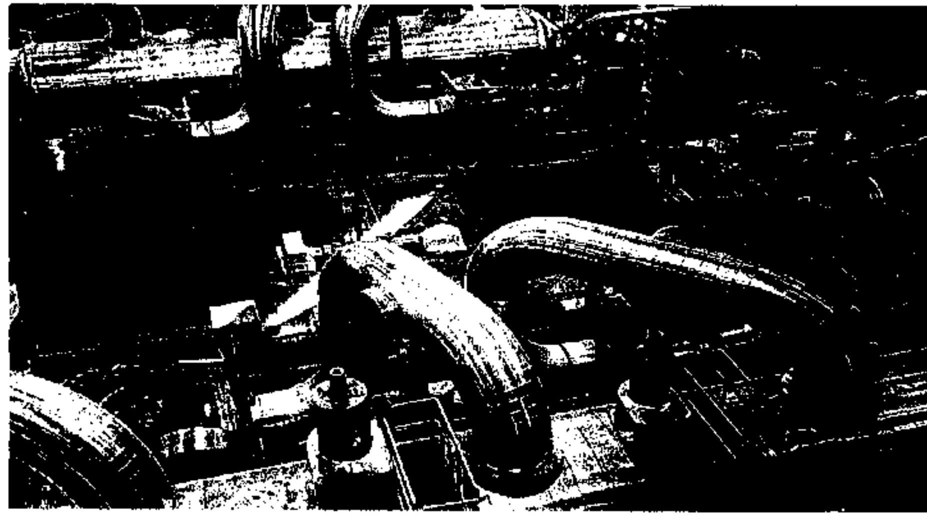


The world's first nuclear power plant centralized monitoring center

The KHNP's nuclear power plant centralized monitoring center in headquarter (Energy-Tower) monitors the status of all operating nuclear power plants in Korea in real-time, 24 hours a day. It is the world's first and only state-of-the-art operating system that simultaneously monitors as many as 24 units. Especially, its early warning system alerts failures in equipment one step earlier than the main control room and enables prompt responses. All workers in the E-Tower are experienced workers of operating NPPs. When an emergency occurs at the power plant, they can provide quick and skilled technical support to improve the safety of the power plants.

KHNP is diversifying the export market with OPR1000

Based on its more than 30 years of experience in the construction, operation and design of nuclear power plants since Kori Unit 1, KHNP developed the Korean standard nuclear reactor, OPR1000. Following the construction of Hanbit Unit 3 and Hanbit Unit 4, which marked the beginning of Korean standard nuclear power plants, KHNP has launched and operated Hanbit Unit 5, Hanbit Unit 6, Hanul Unit 3, Hanul Unit 4, Hanul Unit 5, Hanul Unit 6 and Shin-Kori Unit 1, Shin-Kori Unit 2, Shin-Wolsong Unit 1, Shin-Wolsong Unit 2.



KHNP wins global recognition with state-of-the-art Advanced Power Reactor, APR1400

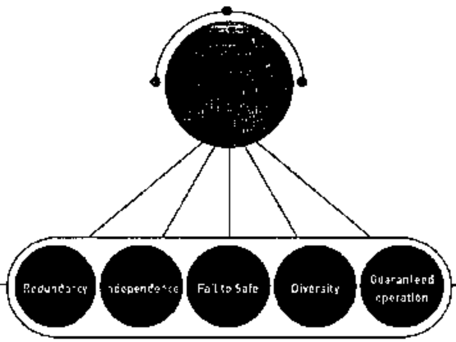
Using the design expertise it accumulated while developing OPR1000, KHNP upgraded the capacity of APR1400 to 1,400MW, making it a globally competitive reactor, and applied domestic and foreign requirements for the design of the state-of-the-art nuclear reactors. In particular, the newly developed APR1400 is equipped with systems for the prevention and management of severe accidents, including cooling systems embedded in the reactors for improved safety. The competitiveness of APR 1400 has been highly recognized, and KHNP signed contracts for the construction of four nuclear power units in the UAE in December 2009, prevailing over nuclear industry leaders such as the US, France and Japan.

1,500,000 kW-class APR+ developed only with Korean technology

APR+, the next-generation nuclear power plant, acquired approval for the standard design from the Nuclear Safety and Security Commission. As Korea has secured the new 1,500,000 kW-class reactor type by developing APR+ technology, it will be able to diversify export markets. APR+ is based on the Korean standard nuclear power plant (OPR1000) and the next-generation power plant (APR1400) exported to UAE with improved structural safety.

KHNP Always Pursues a Safety-First Philosophy

Since the nuclear accident at Fukushima, Japan, many have raised concerns over the safety of nuclear power. KHNP is an international safety leader in the operation and management of its nuclear power plants, and this is proven by the fact that there have been no safety accidents since KHNP launched operations at its first nuclear power plant more than 40 years ago. This remarkable safety achievement can be attributed to the safety-first philosophy of KHNP.

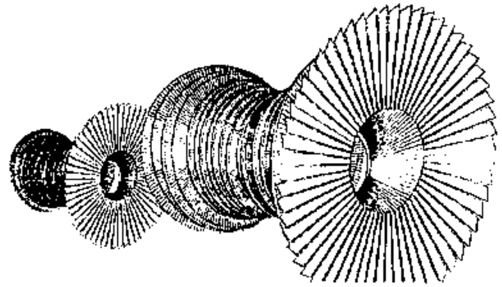


- **Redundancy :** Two or more units of equipment with the same functions are installed
- **Independence :** Two or more units of equipment shall not be linked physically or electrically
- **Fail to Safe :** Equipment shall be designed to ensure safe operation in the case of malfunction
- **Diversity :** Two or more units of equipment with different properties shall be installed for a single function
- **Guaranteed operation :** Equipment shall be designed to ensure the suspension of operation when requirements are not satisfied

"Today, people enjoy many conveniences thanks to advancements in science and technology. It is important to note, however, that these same advancements can be dangerous unless we use them with caution and knowledge. The same holds true for nuclear power. Many have a vague fear of nuclear power because they lack a detailed understanding of its operation. In the wake of the nuclear accident at Fukushima nuclear power plants, KHNP aspires to take the opportunity to highlight our commitment to safety in nuclear power generation, and our dedication to technological advancements in this area. KHNP will make unceasing efforts to win your trust and confidence in the safety of nuclear power."

KHNP Prioritizes Safety in its Nuclear Power Plants

The safety of nuclear power plants is very important, and shall be prioritized in all aspects. KHNP applies stricter standards to the entire construction and operation cycle of nuclear power plants than in any other industrial facilities, in order to ensure the highest level of safety.

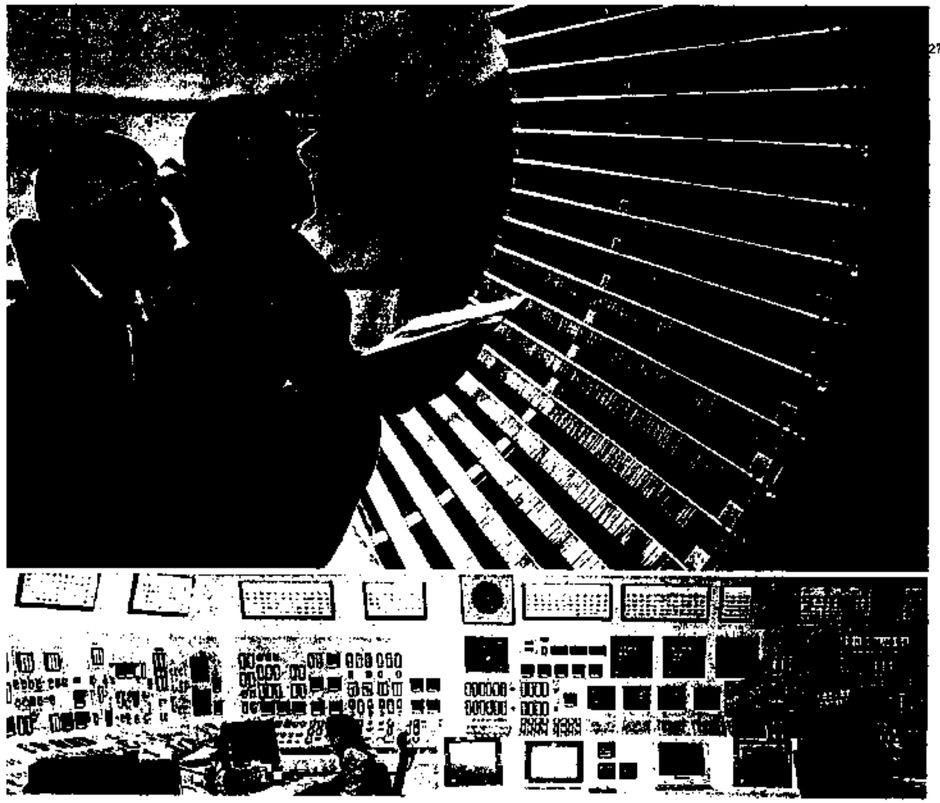


Nuclear power plants are safely managed

Nuclear power plants are designed by considering all potential causes of accidents. The design of nuclear power plants enables the elimination of root cause and the prevention of accidents through detection of abnormal operations. Even when abnormal conditions develop into accidents, radioactive materials are not leaked, as nuclear power plants are equipped with a defense in-depth system. KHNP strengthens the internal quality assurance and safety management process during the construction and operation of nuclear power plants, and operates a redundant safety inspection system that includes safety audits by regulatory agencies, safety inspections by government agents, and special inspections by international expert organizations.

Nuclear power plants are natural disaster-proof

The nuclear power plant in Fukushima, Japan experienced a hydrogen explosion, and leaked radioactive materials as it lost control due to strong earthquakes and tsunami. While this accident has led to growing concerns over the safety of nuclear power plants, Korea's nuclear power plants are equipped with natural disaster - proof systems, as all risk factors were considered in the site selection, design, procurement, construction and operation. In addition, as Korea is located in the Eurasia Plate, which is approximately 600 km away from the border between the plates where earthquakes frequently occur, it is regarded as having a very low risk of experiencing a massive earthquake. On average, Korea experiences only about 10 earthquakes per year that measure 3.0 or higher on the Richter scale.



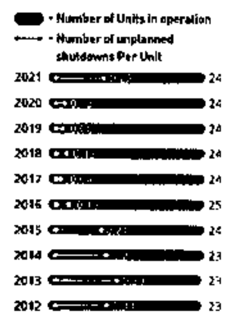
Annual unplanned shutdowns of nuclear power units is less than one per unit

Unplanned shutdowns are unexpected power plant shutdowns caused by failures of equipment or human error during normal operation. The number of unplanned shutdowns is an indicator of the operation management of nuclear power plants in terms of safety and power quality. Since 1998, Korea has recorded less than one unplanned shutdown per year. per unit. In 2021, there were a total of six unplanned shutdowns at 24 nuclear power units, or 0.25 unplanned shutdowns per unit.

Scale and number of earthquakes occurring in a year

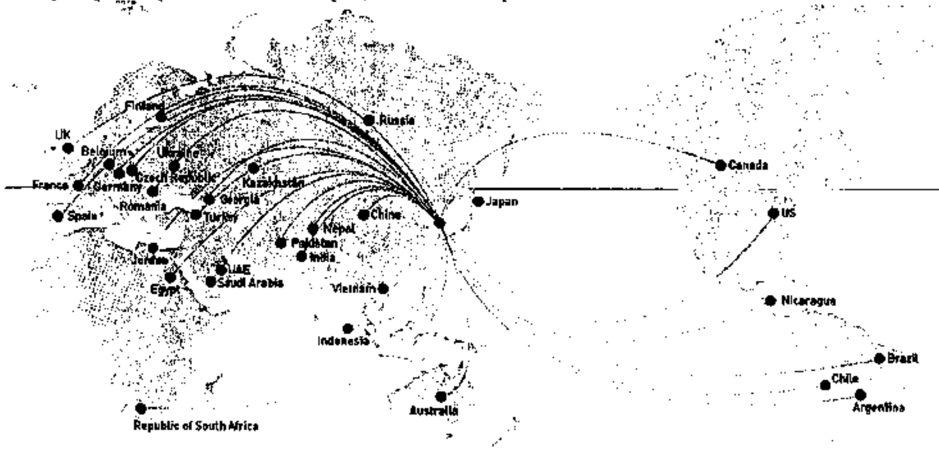
Richter Scale	Korea	Japan	Global
3.0 -	9.2	3,500	144,500
4.0 -	1.16	370	16,500
5.0 -	0.14	50	1,470
6.0 -	-	7	150

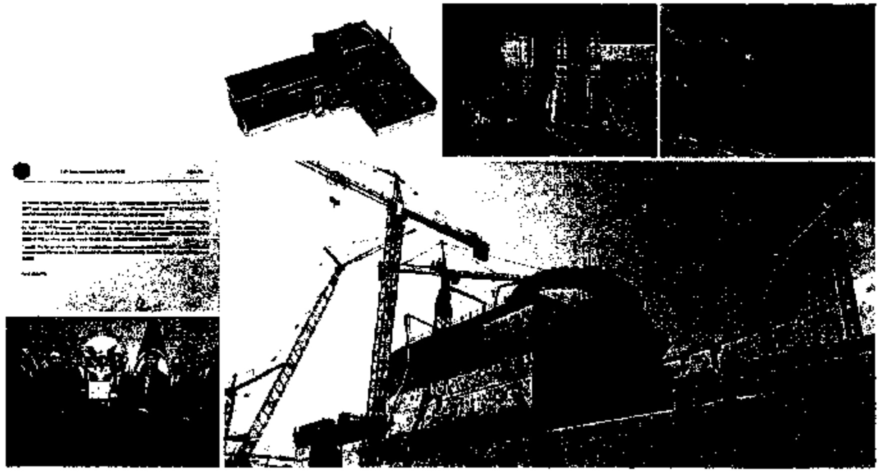
Number of unplanned shutdowns of Domestic Nuclear Power Units



KHNP is Recognized Globally

Kori Units 1 & 2 and Wolsong Unit 1, which were ordered in the 1970s, were designed, manufactured, constructed and commissioned by foreign companies. However, Korea has shown a remarkable growth in terms of nuclear energy, which has been proven by its winning of the 5,600MW-class international competitive bid for the UAE, prevailing over nuclear powerhouses such as the US and France. As well, after EU-APR acquired design certification in Sep 2017 and US NRC issued standard design approval for APR1400 in Sep 2018, KHNP has been exporting Korea's excellent nuclear power plant operation technology to the UAE, enhancing the profile of Korea's nuclear power plants in overseas markets and proving our excellence in nuclear power plant operation. In Feb 2018, the Chameliya hydropower plant was completed, and KHNP acquired exclusive rights to the hydropower plant construction project in Lower Spat Gah, Pakistan.





“ KHNP has always worked for a brighter future. New challenges have both risks and expectations, which mean opportunities for KHNP. KHNP has strengthened its capability and achieved growth through opportunity. KHNP is venturing beyond its services for domestic customers, and is stepping out into the world with the goal of making Korea the world's energy leader. The global market will be KHNP's platform for growth. KHNP asks for your support on its journey toward global energy leadership. ”

KHNP is Growing into the World's Best Energy Firm

The UAE nuclear power plant project is a milestone in the history of Korea's nuclear industry, as it was the first export of APR1400 since Korea launched its nuclear power business over 30 years ago. Korea is now the world's fifth-largest nuclear power exporter, following the US, France, Russia and Canada. KHNP is making diverse efforts to make Korea a world-leading nuclear exporter by maximizing the strengths of Korean nuclear power plants.

Nuclear energy cooperation to lay the foundation for nuclear power exports and the advancement of nuclear power technology

Korea has signed nuclear energy cooperation agreements with 29 countries, including the US, China and Japan, in order to maintain the cooperation system for the peaceful use and development of nuclear power based on the philosophy of non-proliferation of nuclear weapons. Korea has two objectives in terms of international nuclear energy cooperation. First, it aims to expand technology exchanges with developing countries to lay the foundation for the export of nuclear energy. It will promote the excellence of its nuclear power technologies and create favorable conditions for overseas market entry by hosting joint coordination committees, dispatching research teams, inviting leaders from developing countries, hosting technology briefings and conducting joint feasibility studies on the establishment of nuclear power plants under cooperation agreements with developing countries. Second, it aims to expand technology cooperation with advanced countries in order to further advance its nuclear energy technologies.

Korea's first export of Korean Advanced Power Reactor

Korea started cooperating with the UAE in the nuclear power sector in September 2003, when the UAE revealed its intention to cooperate with Korea for SMART industry at the 47th IAEA conference. In September 2009, the two countries signed a nuclear power cooperation contract, which marked the start of full-fledged cooperation. In December 2009, Korea exported its first nuclear power reactor to the UAE, which proved the excellence of Korea's nuclear power technologies. Korea successfully laid the stepping-stones that would enable it to become a global leader in nuclear energy, and based on this achievement, KHNP will actively export Korean standard nuclear reactors in the future.

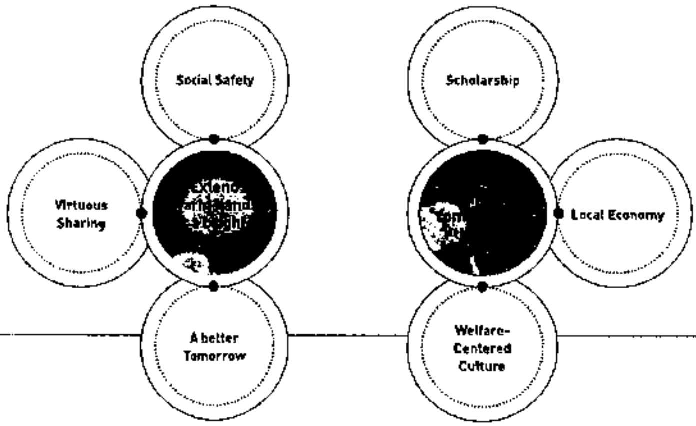
Overview of UAE Nuclear Power Plant Project

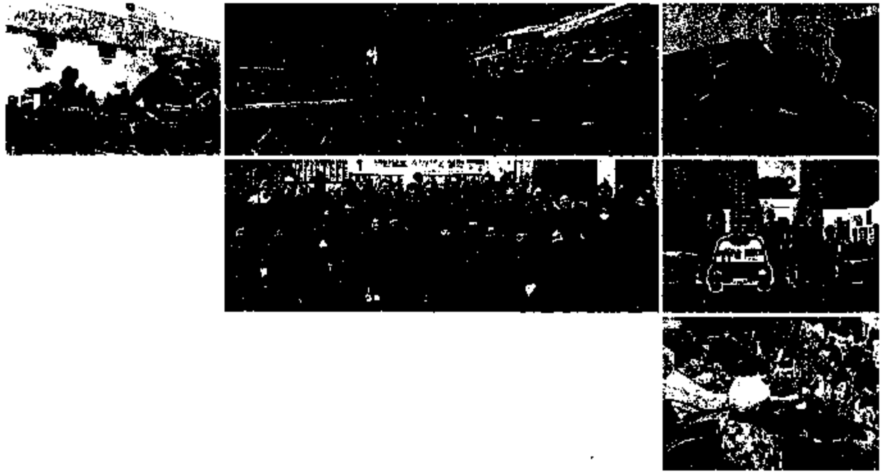
- **Project Overview**: Construction of four units of Korean Advanced Power Reactor(APR1400, 5,600MW)
- **Amount of Order**: Approximately USD 18.6 billion(KRW 21 trillion)
- **Scope of Contract**: Construction of four units of nuclear power plants (1400MW, EPC-OSS) Supply of nuclear fuels (three years) + Support for operation
- **Method of Project / Bidding**: Turn-key Contract / International Competitive Bid
- **Commercial operation**: Barakah Unit 1 (April 2021) Barakah Unit 2 (March 2022)
- **Scale**: 10,000,000 square meters (1.6x Yeouido)
- **Location**: Barakah, 270km West of Abu Dhabi, the capital of the United Arab Emirates (UAE)
- **Operating Support Agreement (by 2030)**
  - EOSA: from July 2016 to completion of BNPP Unit 4
  - OSSA: from construction of BNPP Unit 1 to 10 years after completion of BNPP Unit 4
  - total contract amounts: approximately USD 600 million by 2030 (except for indirect costs)

* EOSA : Early Operating Support Agreement
OSSA : Operating Support Service Agreement

KHNP Fulfills its Social Responsibilities

As KHNP is well aware of the contributions made by residents in the areas where its nuclear power plants are located, it has actively supported the development of local communities and local residents. KHNP operates a range of support programs, from basic support packages to special support programs, so that it can actively facilitate the development of local communities.





"Sharing with others is a value that everyone recognizes but not easily put into practice. KHNP is well aware of the significance of practices and actions, and makes social contributions to share with society.
KHNP is committed to working for the convenience and happiness of every citizen of Korea, and makes wide-ranging efforts to repay local communities the support it has received.
KHNP hopes that it can help communities to prosper, and that local residents can benefit from its contributions."

KHNP Prospers with Local Communities through Social Contributions

KHNP could not build and operate its nuclear power plants without the understanding and support of local residents. KHNP is pursuing the successful operation of nuclear power plants by improving public awareness of its power businesses, and is operating support programs in an efficient manner to contribute to the development of local communities.

KHNP aggressively expands the scope of its contributions

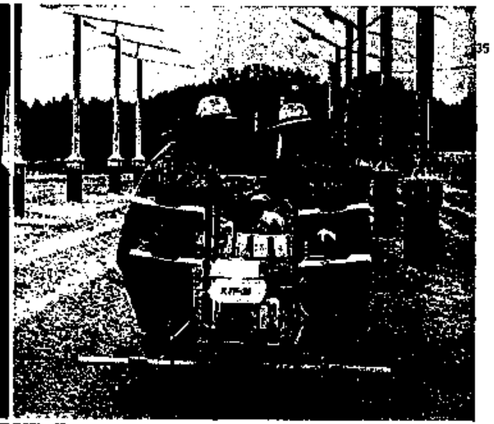
As the method of calculating contributions has been changed to a method based on the amount of power generation in accordance with the Supporting Act on areas adjacent to nuclear power plants, revised in 2005, the scope of support extended by KHNP has dramatically increased. In 2022, the amount of support provided by KHNP through basic support programs and other programs, including programs for public facilities, income growth and education, totaled KRW 53.2 billion.

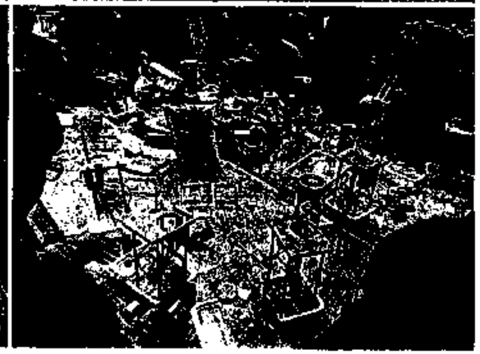
KHNP pursues co-prosperity with local communities through business support programs

Under the slogan, 'KHNP cannot survive without local communities, and local communities cannot prosper without the growth of KHNP,' KHNP operates business support programs that aim to strengthen the foundations of local communities, facilitate local economies, boost the sense of unity with local communities, build sustainable local communities, and put the KHNP philosophy into practice through volunteer activities. Through programs in which KHNP directly identifies and operates businesses for residents for the co-prosperity and co-existence of enterprises and local communities, KHNP has extended KRW 52.5 billion in business support to the areas adjacent to nuclear power plant sites in 2022 alone. KHNP is also operating projects in Gyeongju, its new base, for its new take-off to become an organization with a history of a hundred years, working together with the residents of Gyeongju.

KHNP brings a hopeful future through volunteer services for local communities based on its spirit of sharing and love

In June 2004, KHNP launched a social volunteer corps consisting of 13 units, including units dedicated to social services, healthcare services and local services, and has since worked actively to fulfill its social responsibilities and pursue local community-centered management. Its activities have shaped the corporate culture through volunteer services of its members, in an effort to develop a model for shared prosperity between the enterprise and the local community. The executive office of the volunteer corps has matched the advice received from expert organizations to each unit, developing a strategic framework for volunteer activities. In addition, a medical services team comprised of healthcare experts from the Radiation Health Institute has continuously provided free healthcare services at remote areas near nuclear power plants, hydro power plants and pumped - storage hydroelectric power stations. KHNP has adopted clear goals and directions for its volunteer activities by selecting themes such as 'Social Safety', 'Virtuous Sharing' and 'A better Tomorrow.' KHNP has also actively encouraged its members to participate in volunteer activities by designating and enforcing the 'Week of Volunteering.'





Total assistance from the Basic Assistance Program (1990-2022)

(Unit: KRW 0.1 billion)

Plant	Kori	Saeul	Wolsong	Hanbit	Hanul	Hydro	Pumped storage	New and renewable
total	2,551	537	1,906	2,430	3,234	783	1,113	8

Total assistance from the Energy Sector Management Assistance Program (2006-2022)

(Unit: KRW 0.1 billion)

Plant	Kori	Saeul	Wolsong	Hanbit	Hanul	Hydro	Pumped storage
total	2,156	531	1,448	1,756	2,514	464	165

KHNP is operating diverse businesses that can help every citizen of Korea to lead happier, more convenient and safer lives.

THE TOTAL AMOUNT OF ENERGY GENERATION REPRESENTED BY NUCLEAR POWER : 27%

As a main energy source that accounts for 27% of the total energy generation, nuclear power has supported the development of the national economy.

Korea is the world's sixth-largest nuclear powerhouse

As of late December 2021, Korea is operating 24 commercial nuclear reactors with a total installed capacity of 23,250MW. Nuclear power accounts for 17.3% of Korea's total installed capacity (134,020MW), which is less than the 21.8% at the end of 2016. This can be attributed to the growth of power generation capacity from other power sources including alternative energy. Korea's nuclear power generation capacity of 23,250MW is 39 times the capacity it had in 1978, when Kori Unit 1, Korea's first nuclear power plant, entered into commercial operation (587MW). In a short period of time, Korea has grown to become the world's sixth-largest nuclear powerhouse.

Nuclear power accounted for 50.1% of Korea's total power generation in 1989, but this decreased to 27% by 2021 due to the construction of large-scale thermal power plants in Samcheonpo, Boryeong and Hadong that started in the early 1990s. But still, Nuclear power has significantly contributed to the stable supply of power as a major power source.

Nuclear power supports the national economy

As a main energy source that accounts for 27% of the total energy generation, nuclear power has supported the development of the national economy. Every two years, the government establishes the basic energy supply plan with optimal financing for power plants through a comprehensive review of economic feasibility, environmental feasibility, supply of fuel and reliability.

In its 2nd 2014 Energy Master Plan, the government set a nuclear power plant facilities ratio target of 29% by 2035. In 2019, the Korean government published its 3rd Basic Energy Plan and promised that it would increase the share of new and renewables in energy mix to 30-35% by 2040 and reduce the share of nuclear.

Radioactive wastes are safely managed and disposed of

As the nuclear business expands, the safe management and disposal of radioactive wastes have emerged as very serious issues for the sustainable use of nuclear energy. All of the radioactive wastes generated by the domestic nuclear power industry are low and intermediate level radioactive wastes, with the exception of the spent-fuel discharged by nuclear power plants.

Low and intermediate level radioactive wastes are contained in designed drums and then the drums are transferred to a radioactive waste treatment facility which has been operated by Korea Radioactive Waste Agency in Gyeong-ju since 2010. High-level radioactive waste, such as spent nuclear fuel, is temporarily stored for a certain period of time in a storage facility before being treated in accordance with the government's plans for high-level radioactive waste management.

NUMBER OF UNITS UNDER CONSTRUCTION : 4

As of late December 2021, Korea is building four units of nuclear power plants in Korea, and 2 units in abroad.

KHNP has verified Korea's nuclear power plant construction technology

By pursuing technological independence through the construction of Hanbit Unit 3 and Hanbit Unit 4 which began in early 1987, Korea built six units of Korean standard nuclear power plants, including Hanul Unit 6. It finally secured technological independence for the construction of 1,000MW-class nuclear units.

In addition, there are the improved Korean Standard Nuclear Power Plants (OPR1000) of Shin-Kori 1&2 and Shin-Wolsong 1&2, the new next-generation light water reactor (APR1400) of Shin-Kori 3&4, and the upcoming Shin-Hanul 1&2 and Shin-Kori 5&6 that are still under construction. These nuclear units will verify Korea's advanced nuclear power plant construction technologies in the global nuclear power market with stable power supply domestically, and place Korea in a favorable position in the overseas nuclear power plant construction market. For Korean nuclear power plants to become more competitive, Korea needs to expand its application of new technologies and techniques to all areas, including design, manufacturing and construction, to significantly shorten the construction periods and to improve the quality of construction. KHNP will keep up the efforts to be competitive in the overseas market by developing APR+, as the successor of APR1400, which is much advanced in terms of security and credibility, and a nuclear fusion reactor.

History of Nuclear Power Plant Construction Business

Stage of Foreign Technology Dependence

- Turn-key Contracts with Foreign Contractors

Kori Units 1 & 2 and Wolsong Unit 1

▼

Stage of Technology Accumulation

- Non Turn-key contracts
- Korean companies participate as subcontractors

Kori Units 3 & 4, Hanbit Units 1 & 2 and Hanul Units 1 & 2

▼

Stage of Technological Self-reliance

- KEPCO leads the projects
- Korean companies participate as major contractors
- Develops Korean Standard Nuclear Power Plants

Hanbit Units 3, 4, 5 & 6, Wolsong Units 2, 3 & 4 and Hanul Units 3, 4, 5 & 6

▼

Stage of Technological Advancements

- Develops the improved Korean Standard Nuclear Power Plant (OPR 1000)
- Develops the next-generation pressurized reactor, APR1400

Shin-Kori Units 1 & 2 and Shin-Wolsong Units 1 & 2 (OPR1000)

Shin-Kori Units 3, 4, 5 & 6 and Shin-Hanul Units 1 & 2 (APR1400)

▼

Stage of Technological Independence

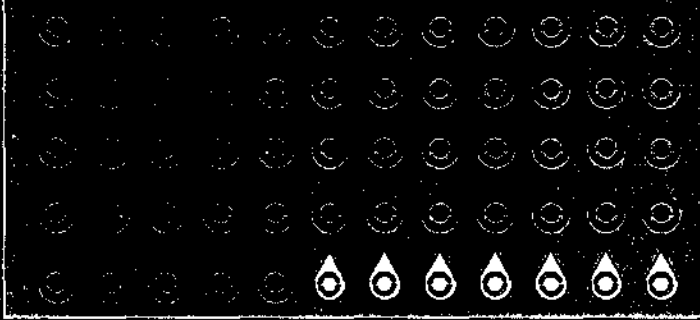
- APR+ Technological development
- (Total) Localization of core technologies (RCP, MMIS and core design codes)

Nuclear power plants since completion of Shin-Hanul 1 & 2

NUMBER OF HYDRO AND PUMPED-STORAGE HYDRO POWER PLANTS IN OPERATION : 53 UNITS

53

KHNP is also operating 53 units of hydro and pumped-storage hydro power plants. In the area of new & renewable energy, KHNP is actively involved in small hydro power, photovoltaic, wind power businesses.



Construction of overseas hydro power plants

In 2009, KHNP received an order from Nepal Electricity Authority(NEA) for USD 48 million to construct Chamelia Hydroelectric Power Plant. As its first overseas hydro project, KHNP developed a new model for its overseas hydro power business by organizing a strategic consortium with private partners. In addition, KHNP has actively participated in projects in countries with abundant water resources such as, Indonesia and former Soviet Union countries, based on more than 70 years of technology and experience in the operation of hydro power plants.

Development of Han River water system and operation of water management system

Korea is categorized as a country that has a water shortage, and as such, managing water is as important a national infrastructure project as power generation. By establishing a PAROS (Power And Reservoir Operating System) within Chuncheon Hydro Power Plant of Hangang Hydro Power Site, KHNP remotely supervises and controls power generation, flood adjustment and water supply at the same time. By collecting and providing operational information of hydro power plants and prediction data on the inflow of each dam to the related organizations including Han River Flood Control Office, K-water and Korea Meteorological Administration in real time, KHNP aims to improve the generation efficiency of hydro power plants and to control the flooding of Hangang (River).

Upgrade of old hydraulic and pumped-storage power plants

KHNP is modernizing its outdated hydro power plants, including the Cheongpyeong and Hwacheon Hydro Power Plants that were completed in the 1940s, in order to improve the reliability, capacity and efficiency of the plants. Modernization of power plants is a large-scale construction project of replacing not only outdated power generators and turbines but also various apparatuses, pipelines and controlling systems in order to complete state-of-the-art power plants. Since 2009, KHNP has completed the modernization of two hydro power plants in Chuncheon, three in Cheongpyeong, two in Uiam and two in Goesan. Seomjingang Hydro Power Plant Unit 2 was fully developed in Korea for the first time in the history of the mid- and large-sized turbine sector. This plant was built and tested in 2016. In addition, Samnangjin 1&2 (300K*2 units) became the first modernized pumped storage power plants in Korea as of December 2020. KHNP is also preparing for modernization of the pumped-storage power plant in Cheongpyeong, and will develop the master plan of the power plant next year. KHNP will continuously and in a timely manner modernize its hydraulic and pumping-up power plants in order to improve the reliability of its facilities and secure the long-term sustainability of the power plants.

Low-carbon future energy development (photovoltaic energy, wind power and solar cells)

With the aim of becoming a comprehensive energy corporation successfully keeping up with the global trends of carbon neutrality and hydrogen economy, KHNP is actively operating its new and renewable energy businesses. In the photovoltaic sector, KHNP has completed construction of a new floating solar power plant in the reservoir of the Cheongsong pumped storage power plant (4.4MW, March 2021), a rooftop solar power system on the roof of the headquarters of KHNP (1.3MW, July 2021) and a small-scale solar power plant in Jeju Island (14MW, October 2021). In addition, it is working on the construction of a 27MW solar plant on the idle site of Hyundai Motors, a 200MW solar power complex on the salt farms in Bigeum-do (an island in Sinan County) and the world's largest floating solar power plant with a capacity of 300MW in Saemangeum. In the wind power sector, starting with the commercial operation of KHNP's first wind power plant the Cheongsong Norae-san wind power generation complex (19.2MW, November 2019), KHNP has been working on 3 additional projects to expand the wind power generation: Yangyang Suri wind power plant (90MW), Sinan Jaeun offshore wind power plant (99MW) and Saemangeum offshore wind power plant (99MW) as of 2022. Meanwhile, it is undertaking feasibility studies for the Yecheon-Samrangjin wind power project (52MW) and Wolsong offshore wind power project (200MW), while running follow-up projects under the government's R&D initiative such as Yeongwang Anma offshore wind power project (224MW), Yeongdeok offshore wind power project (100MW) and Yeongdeok wind power repowering project (30MW). KHNP is working with the KEPCO group and other wind power developers to devise various new wind power projects, which are expected to have a power generation capacity of 4.2 GW by 2034. Lastly, in the fuel cell sector, KHNP is operating the world's largest fuel cell power plant Gyeonggi Green Energy (58.8MW, December 2013), Noeul Green Energy (20MW, March 2017), Busan Green Energy (30MW, September 2017) and Incheon Fuel Cell (39.6MW, June 2021), while working on other fuel cell projects such as Gangneung Sacheon (19.8 MW), Chuncheon (29.4 MW) and Godeok Fuel Cell (19.8 MW) projects.

NUMBER OF COUNTRIES IN NUCLEAR PARTNERSHIPS : 29 COUNTRIES

29

As of late December 2021, Korea has entered into nuclear power cooperation agreements with 29 countries, and has maintained the partnership system to promote the peaceful use and development of nuclear power.

Korea exports first Korean standard nuclear reactor to the UAE

The United Arab Emirates (UAE) placed an order for a 5,600MW nuclear power plant in the form of an international competitive bidding to meet the future energy demand. The plant will be located in the Arabian coast to the west of Abu Dhabi. KEPCO and ENEC (Emirates Nuclear Energy Corporation) entered into a contract on December 27, 2009. The UAE's first nuclear power plant Barakah Unit 1 was completed and started commercial operation in April 2021, while Unit 2 started operation in March 2022; Unit 3 and 4 will be completed in order.

KHNP has established a regional headquarters in Baraka to supervise around 1,000 dispatched KHNP employees and actively manage the Baraka Nuclear Power Plant construction project. After signing an Operating Support Services Agreement (OSSA) in June 2016 and a Long Term Maintenance Service Agreement (LTMSA) in June 2019, these employees are also supporting the operation and maintenance of the nuclear power plants operating in UAE. Since signing the contract, both countries have actively pursued exchanges in diverse sectors, including diplomacy, industry and culture.

Overview of Korean nuclear power technology overseas

With the global power market shifting from one that is based on monopolies to a free market, developing countries experiencing growing power demand, and a global market that is more open than ever before, Korea is pursuing overseas projects based on the technology and experience it has accumulated through the operation of its domestic nuclear power projects. These overseas projects will help KHNP overcome the growth limits of domestic markets, enhance its management efficiency through improved profitability, and contribute to building the status of the nation based on technology.

Korea, which has grown from a country with zero knowledge of nuclear power plant technology to one of the most advanced nuclear countries within 30 years, serves as a model to the countries that have later adopted nuclear power. More and more countries are showing interest in introducing Korea's experiences in nuclear plant construction and management. Korea is exporting its nuclear power technology to countries (Czech Republic, Poland, Kazakhstan, Bulgaria, etc.) that intend to build new nuclear power plants.

KHNP continuously promotes the export of Korean standard nuclear power plants in European countries, and maintains cooperative channels with its clients. Based on its outstanding nuclear power operation and maintenance technology, KHNP is also offering a number of services including training, equipment supply and construction technology support to nuclear power plant operators in China and Canada.

KHNP is running overseas nuclear and renewable power plant projects with the goal of expanding their shares to 14% of the total overseas business sales by 2034. With such an extensive export portfolio covering all business areas, KHNP will take a bigger leap forward towards becoming a truly global energy company.

COMPLETION OF NU-TECH 2012 AND PROGRESS OF NU-TECH 2030

KHNP has secured the basic technologies for exporting nuclear power plants based on the Nuclear Technology Development Roadmap (Nu-Tech 2012). Now, it is moving ahead with a new Nu-Tech 2030 to strengthen core capabilities for the safe operation and overseas export of nuclear power plants.

Development of world-class nuclear power plant safety operation technologies

Currently, KHNP is focusing on the improvement of safety in emergency responses, natural disaster responses, radiation treatment , securing facility reliability, and adopting latest technologies. With these focus areas, it conducts periodic safety review for operating nuclear power plants, draws up an accident management plan for all nuclear power plants, and develops an artificial intelligence decision-making support system for nuclear power plant operation and a failure/damage prediction and diagnosis system as specified in the 'Development of core technologies for improving safety in operating nuclear power plants operations', a multi-ministerial joint preliminary feasibility study project passed in June 2021.

Acquiring independence and leadership in decommissioning technology

Currently, KHNP is focusing on decommissioning design/licensing, decontamination of polluted facilities, safe decommissioning of nuclear power plant facilities, management of decommissioning waste, and securing eco-friendly site restoration technology. In relation to the timely implementation of the Kori Unit 1 decommissioning project and preparation for permission for the decommissioning of Wolsong Unit 1, KHNP is developing the packaging, transportation and disposal containers for the decommissioning waste, and the integrated management process and procedures of nuclear power plant decommissioning. Also, KHNP has secured essential decommissioning technologies such as restoration for light water reactor sites, and it is now focusing on the development of technologies for the evaluation of the characteristics of the radioactive structures, and basic technologies for the decommissioning process for heavy water reactors.

Securing radioactive waste safety management technology

Currently, KHNP is focusing on the safety management of low- and mid-level radioactive waste development of a standardized management system of spent nuclear fuel, and establishment of a safety management platform. With these focus areas, KHNP is developing a system for examining and evaluating the characteristics of spent nuclear fuel (SF) compared to dry storage, an integrated solution for the assessment of SF storage cooling function, radiation amount and safety information, and an assessment method of the radionuclides inventory of radioactive waste. Also, as part of the multi-ministerial joint preliminary feasibility study project 'development of long-term storage demonstration test technology for spent nuclear fuel' that was passed in August 2020 and the government project 'development of safety transfer design technologies for the spent nuclear fuel management facility', KHNP is leading the development of the on-site dry storage (project to fulfill the Korean government's SF management policy) and the world's first upright modular dry storage model with our own technology.

Securing next-generation nuclear technology

Currently, KHNP is focusing on boosting export competitiveness of the APR-type nuclear power plants, strengthening export capabilities of operating nuclear technologies and equipment, and securing small and medium-sized nuclear power plant technologies of the future. In order to diversify export reactor types and enhance competitiveness, KHNP aims to develop an APR1000 standard design and acquire a SMART100 standard design approval by 2024, and identify and advance technologies on nuclear power plant by such as, localizing the pilot operated safety relief valve (POSRV) to meet the tightened regulatory requirements of nuclear power plant importing countries and improve safety. Moreover, KHNP is developing the conceptual design and basic design of the innovative SMR to commercialize export-type nuclear power plants, while undertaking the Korean government's preliminary feasibility projects at the same time.

Nu-Tech 2030: A New Leap

KHNP is preparing for a new leap forward by securing the safety of nuclear power plants, fostering the nuclear power plant decommissioning industry which is a new promising industry, building a foundation for safety management of radioactive wastes, and strengthening competitiveness of Korea's nuclear power plant industry tailored to the needs of the global markets.

Efforts to Achieve Sustainable Growth

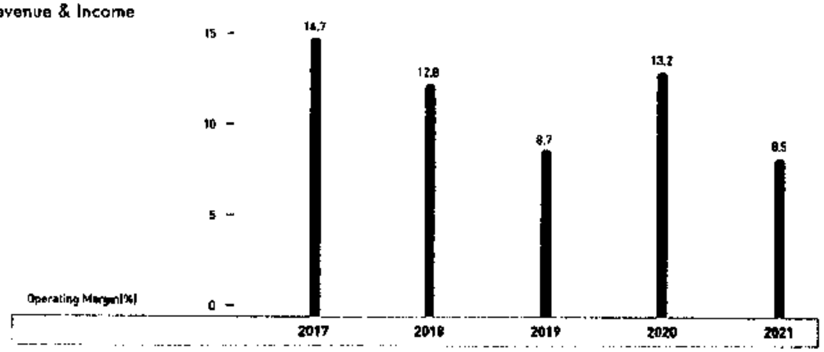
With the Paris Agreement, the global energy market has been gradually changing due to low-carbon energy policies.
As robust external financing is expected, KHNP will apply an optimized financing strategy by diversifying its financing sources and maintaining Korea's highest credit ratings.

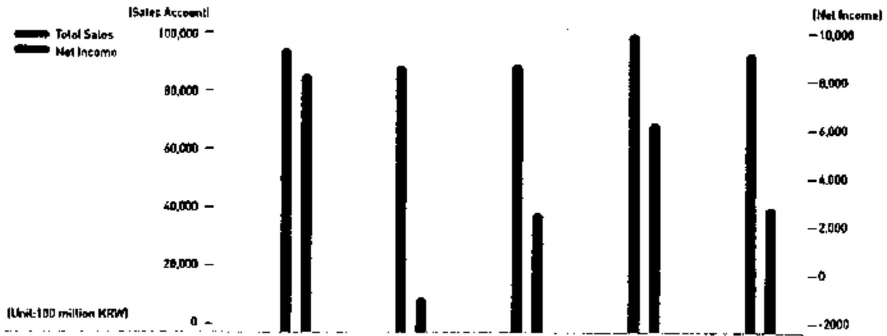
Record High Financial Soundness

KHNP will dedicate itself to maintaining its financial soundness by applying advanced management techniques and reducing costs through management innovations, even in the face of rapidly changing business conditions and internal and external challenges.

Financial Highlights

Revenue & Income

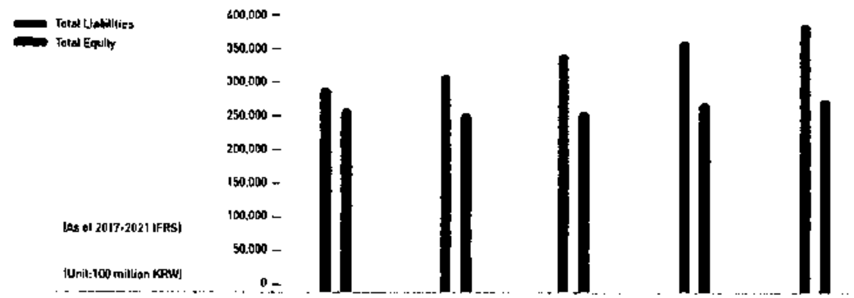




Year	2017	2018	2019	2020	2021
Total Sales	95,109	89,552	89,826	99,997	94,691
Operating Profit	13,972	11,456	7,831	13,158	8,046
Profit before income tax	9,542	-2,088	2,738	7,660	3,527
Net Income	8,618	-1,020	2,465	6,179	2,867
Operating Margin	14.7	12.8	8.7	13.2	8.5
ROE	3.4	-0.4	1.1	2.4	1.1

• Operating Margin: Operating Income/Revenue
• ROE (Return on Equity) : Net Income/Average Equity

Assets & Liabilities



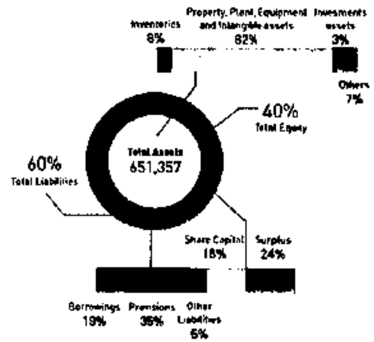
(As of 2017-2021 IFRS)

(Unit:100 million KRW)

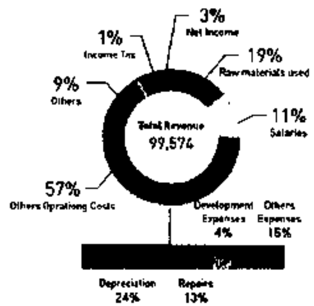
Year	2017	2018	2019	2020	2021
Current Assets	57,693	66,377	65,633	73,270	75,229
Non-current Assets	494,634	493,978	531,794	549,574	576,128
Total Assets	552,327	560,355	597,427	622,844	651,357
Current Liabilities	27,339	25,397	28,546	40,029	45,090
Non-current Liabilities	267,116	281,133	312,222	320,755	343,181
Total Liabilities	294,455	306,530	340,768	360,784	388,271
Common Stock	12,122	12,122	12,122	12,122	12,122
Paid-in Capital	94,923	94,923	94,923	94,923	94,923
Retained Earnings	150,843	146,637	149,727	155,188	155,849
Other components of Equity	-395	-427	-399	-444	-98
Equity belongs to Parent Company	257,493	253,257	256,373	261,789	262,796
Non-controlling Interest	379	568	286	271	290
Total Equity	257,872	253,825	256,659	262,060	263,086
Total Liabilities and Equity	552,327	560,355	597,427	622,844	651,357

Financial Statements

Consolidated Statements of Financial Position(4Q 2021)



Consolidated Statements of Comprehensive Position(4Q 2021)



Ownership

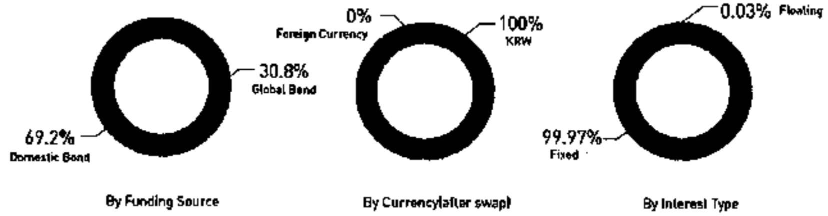
Shareholder	Capital (Unit: million KRW)	Number of Shares Issued and Outstanding
Korea Electric Power Corporation (100%)	1,212,214	242,442,838

Borrowings

(Unit : Korean Won in millions, USD, HKD and CHF in thousands)

Type		2016	2017	2018	2019	2020	2021
Domestic	Bond	W 5,110,000	W 5,470,000	W6,220,000	W 6,670,000	W 7,290,000	W 7,480,000
	etc	W 7,888	W 6,760	W5,834	W 4,908	W 3,982	W 3,056
Overseas	Bond			$2,750,000	$ 2,450,000	$ 2,450,000	$ 2,450,000
		$ 2,850,000	$ 2,950,000	HK$1,650,000	HK$ 1,650,000	HK$ 1,650,000	HK$1,650,000
					CHF 300,000	CHF 300,000	CHF 300,000
Total		W 8,205,105	W 8,694,669	W9,483,869	W 9,977,097	W 10,596,171	W 10,816,413

* When converting foreign bonds into Korean won, the contract exchange rate at the time of swap is applied.



(as of Dec. 2021)

Credit Rating

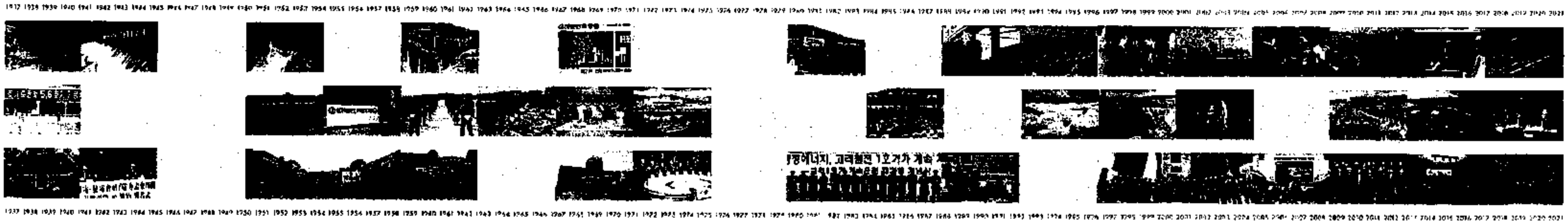
KHNP has maintained the highest credit ratings of any company in Korea, which reflect its excellent business results and financial conditions. KHNP's management capability and operating capacity have been globally recognized, as can be seen in its overseas credit ratings, which are equal to those of the national government.

International	Standard & Poor's	Moody's	Fitch	R & I
	AA / Stable	Aa2 / Stable	AA- / Stable	AA-

Domestic	KIS	KR	NICE
	AAA / Stable	AAA / Stable	AAA / Stable

HISTORY

KHNP is growing to become a global nuclear energy company through the development of Korean nuclear power technology!



1931 Completed construction of Unam Power Plant

1937 Completed construction of Boseonggang Hydro Power Plant

1943 Completed construction of Cheongpyeong Hydro Power Plant

1944 Completed construction of Hwacheon Power Plant

1945 Completed construction of Chilbo Power Plant

1957 Korea joined the International Atomic Energy Agency (IAEA)

Completed construction of Goesan Power Plant

1965 Completed construction of Chuncheon Power Plant

1966 Completed construction of Uiam Power Plant

1973 Completed construction of Paldang Power Plant

1978 Completed construction of Kori Unit 1

1983 Completed construction of Wolsong Unit 1 and Kori Unit 2

1985 Completed construction of Kori Unit 3

1986 Completed construction of Kori Unit 4 and Hanbit Unit 1

1987 Achieved nuclear power generation capacity of 100 billion kWh

1988 Completed construction of Hanul Unit 1

1998 Completed construction of Hanul Unit 3, the first Korean Standard Nuclear Power Plant

Won first overseas nuclear power plant order (Guangdong Nuclear Power, China)

2001 KHNP established by separating from KEPCO

2002 Became the world's largest company in the industry in terms of installed capacity with the construction completion of Hanbit Units 5&6

2003 Achieved total nuclear power generation capacity of 100 billion kWh with Hanul Unit 2

2004 Completed the ERP system
Established KHNP Community Volunteer Corps

2005 Completed the construction of Hanul Units 5 & 6 (Total 20 units in operation)

Selected Gyeongju as a low and intermediate level radioactive waste disposal site

2006 Achieved total nuclear power generation capacity of 400 billion kWh with Hanul Nuclear Power Plant Units

Groundbreaking ceremony for Shin-Wolsong Units 1 & 2

Declared the 2015 Mid-to-Long-term Vision of KHNP

2007 Ceremony to mark the 70th anniversary of completion of Boseonggang Hydro Power Plant

Kori Unit 1 reached the end of its 30-year design life cycle

Completed construction of the tritium removal facility at Wolsong Nuclear Power Plant

Started construction of Wolsong Environment Management Center

2008 Exported nuclear power plant construction technology to China (GPEC, Yangjiang Units 3 & 4)

Achieved total domestic nuclear power generation capacity of 2 trillion kWh

2009 Installed reactor in Shin-Kori Unit 2

Achieved the world's fifth-highest Capacity Factor with Hanbit Unit 1 (Nucleonics Week)

Ranked 1st in the management evaluation on power companies for a second consecutive year

Completed the room temperature hydraulic test with Shin-Kori Unit 1

Set record for largest number of employees awarded the Korea National Quality Award

Received order for UAE Nuclear Power Plant Project as part of a consortium with KEPCO

2010 Kim Jong-Shin, KHNP's 5th President, took office and declared the KHNP New Challenge

Installed reactor in Shin-Kori Unit 3

Ceremony for the 1st Day of Nuclear Power (presenting merit awards and prizes to contributors to the UAE Nuclear Power Plant project order)

Completed the construction of Shin-Kori Unit 3 reactor building

2011 Acquired pumped-storage hydro power facilities of five thermoelectric companies

Groundbreaking ceremony for UAE Nuclear Power Plant (Barakah site, attended by President Lee, Myung-Bak)

Completed Shin-Kori Unit 1 (OPR1000)

Selected Yeongdeok and Samcheok as the candidate sites for construction of new nuclear power plants

2012 Groundbreaking ceremony for Shin-Hanul Unit 1 & 2 as the first 100% Korea-developed nuclear power plants

Completion of Yecheon pumped-storage electric power plant, the single power plants with the largest capacity

Appointment of Kim, Gyun-seop as the 6th President (June 11)

Completion of Shin-Kori Unit 2 and Shin-Wolsong Unit 1

2013 Completion of expanded concrete wall at Kori Nuclear Power Plant

Renaming of nuclear power plants (from Youngkwang to Hanbit and from Uljin to Hanul)

Appointment of Cho Seok as the 7th President (September 26)

First concrete placing at Shin-Hanul Unit 2

2014 Approval of the scheme of execution of the power development project for Shin-Kori Unit 5 and Shin-Kori Unit 6

Groundbreaking ceremony for the headquarters building in Gyeongju

Installation ceremony of Baraka Nuclear Power Unit 1 in UAE (Attended by President Park, Geun-Hye)

Installed reactor in Shin-Hanul Unit 1

Acquisition of approval for 1,500,000 kW-class the APR+ standard design from government authorities

2015 Achieved accumulated nuclear power amount of 3 trillion kWh

Began continued operation of Wolsong Unit 1

Opened Yeongdeok office at the reserved site for Cheonji Nucelar Power Plant

Shin-Wolsong Unit 2 entered into commercial operation

President & CEO Cho Seok took office as Chairman of WANO

2016 Selected as the No. 1 organization at the Anti-Corruption & Civil Rights Commission's evaluation on integrity

Moved the headquarters to Gyeongju

Entered into operating support agreements (EOSA/OSSA) with nuclear power plants in UAE

Awarded hydropower project in Athmuqam, Pakistan

Lee, Kwansup inaugurated as the 8th CEO (November 15)

Shin-Kori Unit 3 entered into commercial operation (December 20)

2017 Established Saeul nuclear power site

Earned presidential prize in the category of anti-corruption from the Anti-Corruption & Civil Rights Commission

Completed Noeul fuel cell power plant

Permanently halted operation of Kori 1, Korea's first NPP

EU-APR certified for European Utility Requirements

2018 Completed Chameliya hydro power plant in Nepal

Chung, Jae-Hoon appointed as 9th President (April 5)

Obtained NRC standard design approval for APR1400

project commencement ceremony for world's largest 300MW offshore photovoltaic power plant in Saemangeum

Acquired exclusive right to hydro power plant construction project in Lower Spat Gah (Pakistan)

2019 Completion of solar power plant in the Samrangjin pumped storage power plant

APR1400 nuclear power plant acquired a design certification from the US Nuclear Regulatory Commission

Commencement of commercial operation of Shin-Kori Unit 4

Permanent shutdown of Wolsong Unit 1

2020 UAE Barakah Unit 1 obtained permission for operation

Additional installation of MACSTORs in Wolsong Nuclear Power Plant was confirmed

Completion of a wind farm complex and a groundbreaking floating solar power plant in Cheongsong area

2021 Signing of MOU for cooperation in R&D with UAE Emirates Nuclear Energy Corporation (ENEC)

Completion of modernization project for Samrangjin pumped storage power plant

Shin-Hanul Unit 1 obtained permission for operation

2022 Construction completion ceremony of MACSTORs in Wolsong

WHANG, Jooho appointed as 10th President (August 22)

KHNP Facility Overview (as of December 2021)

※ ●In Operation ○Under Construction permanent stop (△power generation capacity under construction)
※ Total capacity: 28,620MW (nuclear power: 23,250MW / general hydro: 595.78MW / small hydro: 11.7MW / pumped-storage hydro: 4,700MW/ Photovoltaic: 63.94MW Wind: 0.75MW

∴ Nuclear Power Plants (24 Units, 23,250MW)

- Kori Nuclear Power Site (Gijang-gun, Busan Metropolitan City) ● ● ● ● ● 4,550MW
- Hanbit Nuclear Power Site (Hongnong-eup, Yeonggwang-gun, Jeonnam) ● ● ● ● ● ● 5,900MW
- Wolsong Nuclear Power Site (Naa-ri, Gyeongju, Gyeongbuk) ● ● ● ● ● 4,100MW
- Hanul Nuclear Power Site (Buk-myeon, Uljin-gun, Gyeongbuk) ● ● ● ● ● ● ○ ○ 5,900MW (△2,800)
- Saeul nuclear power site(Ulju-gun, Ulsan) ● ● ○ ○ 2,800MW (△2,800)
- UAE Nuclear Power Plants (Barakah, UAE) ● ● ○ ○ (△2,800MW)

∴ Hydro Power Plants (21 Units, 595.78MW)

- Hwacheon Hydro Power Site (Hwacheon, Gangwon-do) ● ● ● ● 108MW
- Chuncheon Hydro Power Site (Chuncheon, Gangwon-do) ● ● 62.28MW
- Uiam Hydro Power Site (Chuncheon, Gangwon-do) ● ● 48MW
- Cheongpyeong Hydro Power Site (Gapyeong, Gyeonggi-do) ● ● ● ● 140.1MW
- Paldang Hydro Power Site (Namyangju, Gyeonggi-do) ● ● ● ● 120MW
- Chilbo Hydro Power Site (Jeongeup, Jeollabuk-do) ● ● ● 35.4MW
- Gangneung Hydro Power Site (Gangneung, Gangwon-do) ● ● 82MW

∴ Small Hydropower in Hydro Power Plants (8 Units, 7.85MW)

- Goesan Small Hydropower Site (Goesan, Chungcheongbuk-do) ● ● 2.6MW
- Boseonggang Small Hydropower Site (Boseong, Jeollanam-do) ● ● 4.5MW
- Gangrim Small Hydropower Site (Hoengseong, Gangwon-do) ● ● ● 0.48MW
- Topyeong Small Hydropower Site (Guri, Gyeonggi) ● 0.065MW

∴ Pumped · Storage Power Plants (16 Units, 4,700MW)

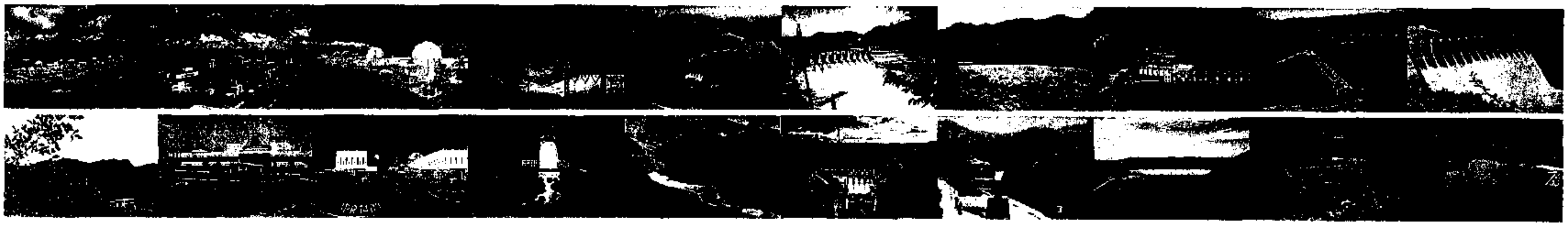
- Muju Pumped-Storage Power Plant (Muju, Jeollabuk-do) ● ● 600MW
- Cheongpyeong Pumped-Storage Power Plant (Gapyeong, Gyeonggi-do) ● ● 400MW
- Yangyang Pumped-Storage Power Plant (Yangyang, Gangwon-do) ● ● ● ● 1,000MW
- Samrangjin Pumped-Storage Power Plant (Miryang, Gyeongsangnam-do) ● ● 600MW
- Cheongsong Pumped-Storage Power Plant (Cheongsong, Gyeongsangbuk-do) ● ● 600MW
- Sancheong Pumped-Storage Power Plant (Sancheong, Gyeongsangnam-do) ● ● 700MW
- Yecheon Pumped-Storage Power Plant (Yecheon, Gyeongsangbuk-do) ● ● 800MW

∴ Small Hydropower in Pumped · Storage Hydro Power Plants (8 Units, 3.85MW)

- Muju Small Hydro Power Plant (Muju, Jeollabuk-do) ● 0.4MW
- Yangyang Small Hydro Power Plant (Yangyang, Gangwon-do) ● ● 1.55MW
- Sancheong Small Hydro Power Plant (Sancheong, Gyeongsangnam-do) ● ● 1.0MW
- Yecheon Small Hydro Power Plant (Yecheon, Gyeongsangbuk-do) ● ● 0.9MW

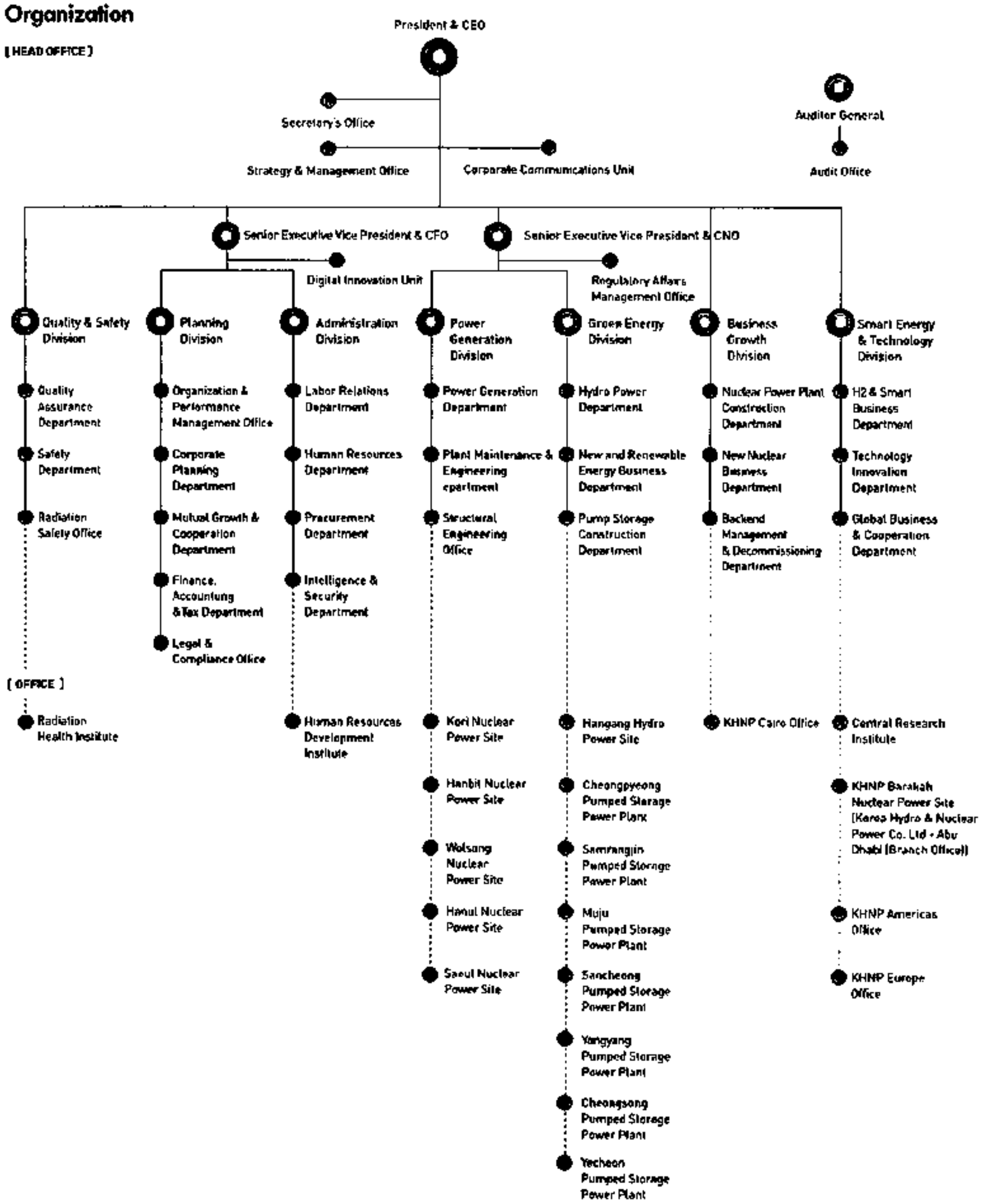
∴ Photovoltaic, Wind and Fuel cell (213.89MW)

- Photovoltaic power : 63.94MW
- Wind power : 0.75MW
- Fuel cell(SPC) : 149.2MW



Organization

[HEAD OFFICE]



www.khnp.co.kr

Gyeongju Head Office	[illegible]	[illegible]
Kori Nuclear Power Site	[illegible]	[illegible]
Hanbit Nuclear Power Site	[illegible]	[illegible]
Wolsong Nuclear Power Site	[illegible]	[illegible]
Hanul Nuclear Power Site	[illegible]	[illegible]
Saeul Nuclear Power Site	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
Yangyang Pumped Storage Power Plant	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
Central Research Institute	[illegible]	[illegible]
Human Resources Development Institute	[illegible]	[illegible]
Radiation Health Institute	[illegible]	[illegible]
Barakah Nuclear Power Site	[illegible]	[illegible]
KHNP Americas Office	[illegible]	[illegible]
KHNP Europe Office	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

[illegible]

www.khnp.co.kr
1655, Bulguk-ro, Munmudaewang-myeon, Gyeongju-si, Gyeongsangbuk-do, Korea(38120)
Publishing Office: Corporate Communications Unit Tel. 82-54-704-1422
Publication Date: August 2022

http://www.facebook.com/ilovekhnp
https://blog.naver.com/i_love_khnp
http://www.instagram.com/ilovekhnp/
https://www.youtube.com/user/ikhnp
https://post.naver.com/i_love_khnp

APPENDIX-4
CERTIFICATE OF INCORPORATION

SECURITIES AND EXCHANGE COMMISSION OF PAKISTAN

Company Registration Office

CERTIFICATE OF INCORPORATION

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

Corporate Unique Identification No. 0172063

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

Given at **Islamabad** this **Twenty Sixth** day of **March,** Two **Thousand** and **Twenty One**

Saila Jamshaid
Joint Registrar

SEAL OF REGISTRAR OF COMPANIES
SECP

https://eservices.secp.gov.pk/eServices/ControllerServlet?request_id=VERIFY_ONLINE_INCORP_CERT&id=0172063

CERTIFIED TO BE TRUE COPY

Deputy Registrar
Company Registration Office Islamabad

APPENDIX-5
MEMORANDUM & ARTICLES OF ASSOCIATION

THE COMPANIES ACT, 2017 (XIX of 2017)

(COMPANY LIMITED BY SHARES)

ARTICLES

OF

ASSOCIATION

OF

LSG HYDRO POWER LIMITED

THE COMPANIES ACT, 2017 (XIX of 2017)

(Company Limited by Shares)

ARTICLES OF ASSOCIATION

OF

LSG HYDRO POWER LIMITED

PRELIMINARY

1. (1) In these regulations-

   (a) "section" means section of the Act;

   (b) "the Act" means the Companies Act, 2017; and

   (c) "the seal" means the common seal or official seal of the company as the case may be.

   (d) "the Company" or "this Company" means **LSG HYDRO POWER LIMITED**

(2) Unless the context otherwise requires, words or expressions contained in these regulations shall have the same meaning as in this Act; and words importing the singular shall include the plural, and *vice versa*, and words importing the masculine gender shall include feminine, and words importing persons shall include bodies corporate.

PUBLIC COMPANY

2. The Company is a "public company" within the meaning of section 2(1)(52) of the Act.

The minimum subscription upon which the directors may proceed to make the first allotment has been fixed at Rs. 100,000/- (One Hundred Thousand Pakistani Rupees).

BUSINESS

3. The directors shall have regard to the restrictions on the commencement of business imposed by section 19 if, and so far as, those restrictions are binding upon the company.

SHARES

4. In case of shares in the physical form, every person whose name is entered as a member in the register of members shall, without payment, be entitled to receive, within thirty days after allotment or within fifteen days of the application for registration of transfer, a certificate under the seal specifying the share or shares held by him and the amount paid up thereon:

Provided that if the shares are in book entry form or in case of conversion of physical shares and other transferable securities into book-entry form, the company shall, within ten days after an application is made for the registration of the transfer of any shares or other securities to a central depository, register such transfer in the name of the central depository.

The company shall not be bound to issue more than one certificate in respect of a share or shares in the physical form, held jointly by several persons and delivery of a certificate for a share to one of several joint holders shall be sufficient delivery to all.

6. If a share certificate in physical form is defaced, lost or destroyed, it may be renewed on payment of such fee, if any, not exceeding one hundred rupees, and on such terms, if any, as to evidence and indemnity and payment of expenses incurred by the company in investigating title as the directors think fit.

7. Except to the extent and in the manner allowed by section 86, no part of the funds of the company shall be employed in the purchase of, or in loans upon the security of, the company's shares.

TRANSFER AND TRANSMISSION OF SHARES

8. The instrument of transfer of any share in physical form in the company shall be executed both by the transferor and transferee, and the transferor shall be deemed to remain holder of the share until the name of the transferee is entered in the register of members in respect thereof.

9. Shares in physical form in the company shall be transferred in the following form. or in any usual or common form which the directors shall approve: -

Form for Transfer of Shares

(First Schedule to the Companies Act, 2017)

I................... s/o .... r/o...................... (hereinafter called "the transferor") in consideration of the sum of rupees .... paid to me by.................................. s/o .... r/o...................... (hereinafter called "the transferee"), do hereby transfer to the said transferee...................theshare(orshares)withdistinctivenumbersfrom ....to...................inclusive, in the............................ Limited, to hold unto the said transferee, his executors, administrators and assigns, subject to the several conditions on which I held the same at the time of the execution hereof, and I, the said transferee, do hereby agree to take the said share (or shares) subject to the conditions aforesaid.
As witness our hands this................ day of............................ , 20.....

Signature ....
Transferor
Full Name, Father's / Husband's Name
CNIC Number (in case of foreigner,
Passport Number)
Nationality
Occupation and usual Residential Address

Signature....................date ....
Name, CNIC Number and Full Address

Witness 1:

Signature ....

Transferee

Full Name, Father's / Husband's Name
CNIC Number (in case of foreigner, Passport Number)
Nationality
Occupation and usual Residential Address

Cell number
Landline number, if any
Email address

Witness 2:

Signature.....................date ....
Name, CNIC Number and Full Address

Bank Account Details of Transferee for Payment of Cash Dividend
(Mandatory in case of a listed company or optional for any other company)

It is requested that all my cash dividend amounts declared by the company, may be credited into the following bank account:

Tile of Bank Account	
Bank Account Number	
Bank's Name	
Branch Name and Address	

It is stated that the above mentioned information is correct and that I will intimate the changes in the above-mentioned information to the company and the concerned Share Registrar as soon as these occur.

....
Signature of the Transferee(s)

10. (1) Subject to the restrictions contained in regulation 10 and 11, the directors shall not refuse to transfer any share unless the transfer deed is defective or invalid. The directors may also suspend the registration of transfers during the ten days immediately preceding a general meeting or prior to the determination of entitlement or rights of the shareholders by giving seven days' previous notice in the manner provided in the Act. The directors may, in case of shares in physical form, decline to recognise any instrument of transfer unless—

a) a fee not exceeding fifty rupees as may be determined by the directors is paid to the company in respect thereof; and

b) the duly stamped instrument of transfer is accompanied by the certificate of the shares to which it relates, and such other evidence as the directors may reasonably require to show the right of the transferor to make the transfer.

(2) If the directors refuse to register a transfer of shares, they shall within fifteen days after the date on which the transfer deed was lodged with the company send to the transferee and the transferor notice of the refusal indicating the defect or invalidity to the transferee, who shall, after removal of such defect or invalidity be entitled to re-lodge the transfer deed with the company.

Provided that the company shall, where the transferee is a central depository the refusal shall be conveyed within five days from the date on which the instrument of transfer was lodged with it notify the defect or invalidity to the transferee who shall, after the removal of such defect or invalidity, be entitled to re-lodge the transfer deed with the company.

TRANSMISSION OF SHARES

11. The executors, administrators, heirs, or nominees, as the case may be, of a deceased sole holder of a share shall be the only persons recognised by the company to deal with the share in accordance with the law. In the case of a share registered in the names of two or more holders, the survivors or survivor, or the executors or administrators of the deceased survivor, shall be the

persons recognised by the company to deal with the share in accordance with the law.

12. The shares or other securities of a deceased member shall be transferred on application duly supported by succession certificate or by lawful award, as the case may be, in favour of the successors to the extent of their interests and their names shall be entered to the register of members.

13. A person may on acquiring interest in a company as member, represented by shares, at any time after acquisition of such interest deposit with the company a nomination conferring on a person, being the relatives of the member, namely, a spouse, father, mother, brother, sister and son or daughter, the right to protect the interest of the legal heirs in the shares of the deceased in the event of his death, as a trustee and to facilitate the transfer of shares to the legal heirs of the deceased subject to succession to be determined under the Islamic law of inheritance and in case of non-*Muslim* members, as per their respective law.

14. The person nominated under regulation 12 shall, after the death of the member, be deemed as a member of company till the shares are transferred to the legal heirs and if the deceased was a director of the company, not being a listed company, the nominee shall also act as director of the company to protect the interest of the legal heirs.

15. A person to be deemed as a member under regulation 11, 12 and 13 to a share by reason of the death or insolvency of the holder shall be entitled to the same dividends and other advantages to which he would be entitled if he were the registered holder of the share and exercise any right conferred by membership in relation to meetings of the company.

ALTERATION OF CAPITAL

16. The company may, by special resolution-

(a) increase its authorised capital by such amount as it thinks expedient;

(b) consolidate and divide the whole or any part of its share capital into shares of larger amount than its existing shares;

(c) sub-divide its shares, or any of them, into shares of smaller amount than is fixed by the memorandum;

(d) cancel shares which, at the date of the passing of the resolution in that behalf, have not been taken or agreed to be taken by any person, and diminish the amount of its share capital by the amount of the share so cancelled.

17. Subject to the provisions of the Act, all new shares shall at the first instance be offered to such persons as at the date of the offer are entitled to such issue in proportion, as nearly as the circumstances admit, to the amount of the existing shares to which they are entitled. The offer shall be made by letter of offer specifying the number of shares offered, and limiting a time within which the offer, if not accepted, will deem to be declined, and after the expiration of that time, or on the receipt of an intimation from the person to whom the offer is made that he declines to accept the shares offered, the directors may dispose of the same in such manner as they think most beneficial to the company. The directors may likewise so dispose of any new shares which (by reason of the ratio which the new shares bear to shares held by persons entitled to an offer of new shares) cannot, in the opinion of the directors, be conveniently offered under this regulation.

The new shares shall be subject to the same provisions with reference to transfer, transmission and otherwise as the shares in the original share capital.

The company may, by special resolution-

(a) consolidate and divide its share capital into shares of larger amount than its existing shares;

(b) sub-divide its existing shares or any of them into shares of smaller amount than is fixed by the memorandum of association, subject, nevertheless, to the provisions of section 85;

(c) cancel any shares which, at the date of the passing of the resolution, have not been taken or agreed to be taken by any person.

20. The company may, by special resolution, reduce its share capital in any manner and with, and subject to confirmation by the Court and any incident authorised and consent required, by law.

GENERAL MEETINGS

21. The statutory general meeting of the company shall be held within the period required by section 131.

22. A general meeting, to be called annual general meeting, shall be held, in accordance with the provisions of section 132, within sixteen months from the date of incorporation of the company and thereafter once at least in every year within a period of one hundred and twenty days following the close of its financial year.

23. All general meetings of a company other than the statutory meeting or an annual general meeting mentioned in sections 131 and 132 respectively shall be called extraordinary general meetings.

24. The directors may, whenever they think fit, call an extraordinary general meeting, and extraordinary general meetings shall also be called on such requisition, or in default, may be called by such requisitionists, as provided by section 133. If at any time there are not within Pakistan sufficient directors capable of acting to form a quorum, any director of the company may call an extraordinary general meeting in the same manner as nearly as possible as that in which meetings may be called by the directors.

25. The company may provide video-link facility to its members for attending general meeting at places other than the town in which general meeting is taking place after considering the geographical dispersal of its members:

Provided that in case of listed companies if the members holding ten percent of the total paid up capital or such other percentage of the paid up capital as may be specified, are resident in any other city, the company shall provide the facility of video-link to such members for attending annual general meeting of the company, if so required by such members in writing to the company at least seven days before the date of the meeting.

NOTICE AND PROCEEDINGS OF GENERAL MEETINGS

26. Twenty-one days' notice at the least (exclusive of the day on which the notice is served or deemed to be served, but inclusive of the day for which notice is given) specifying the place, the day and the hour of meeting and, in case of special business, the general nature of that business, shall be given in manner provided by the Act for the general meeting, to such persons as are, under the Act or the regulations of the company, entitled to receive such notice from the company; but the accidental omission to give notice to, or the non-receipt of notice by, any member shall not invalidate the proceedings at any general meeting.

27. All the business transacted at a general meeting shall be deemed special other than the business stated in sub-section (2) of section 134 namely; the consideration of financial statements and the reports of the board and auditors, the declaration of any dividend, the election and appointment of directors in place of those retiring, and the appointment of the auditors and fixing of their remuneration.

28. No business shall be transacted at any general meeting unless a quorum of members is present at that time when the meeting proceeds to business. The quorum of the general meeting shall be-

(a) in the case of a public listed company, not less than ten members present personally, or through video-link who represent not less than twenty-five percent of the total voting power, either of their own account or as proxies;

(b) in the case of any other company having share capital, two members present personally, or through video-link who represent not less than twenty-five percent of the total voting power, either of their own account or as proxies.

29. If within half an hour from the time appointed for the meeting a quorum is not present, the meeting, if called upon the requisition of members, shall be dissolved; in any other case, it shall stand adjourned to the same day in the next week at the same time and place, and, if at the adjourned meeting a quorum is not present within half an hour from the time appointed for the meeting, the members present, being not less than two, shall be a quorum.

30. The chairman of the board of directors, if any, shall preside as chairman at every general meeting of the company, but if there is no such chairman, or if at any meeting he is not present within fifteen minutes after the time appointed for the meeting, or is unwilling to act as chairman, any one of the directors present may be elected to be chairman, and if none of the directors is present, or willing to act as chairman, the members present shall choose one of their number to be chairman.

31. The chairman may, with the consent of any meeting at which a quorum is present (and shall if so directed by the meeting), adjourn the meeting from time to time but no business shall be transacted at any adjourned meeting other than the business left unfinished at the meeting from which the adjournment took place. When a meeting is adjourned for fifteen days or more, notice of the adjourned meeting shall be given as in the case of an original meeting. Save as aforesaid, it shall not be necessary to give any notice of an adjournment or of the business to be transacted at an adjourned meeting.

32. (1) At any general meeting a resolution put to the vote of the meeting shall be decided on a

w of hands unless a poll is (before or on the declaration of the result of the show of hands) manded. Unless a poll is so demanded, a declaration by the chairman that a resolution has, on how of hands, been carried, or carried unanimously, or by a particular majority, or lost, and an y to that effect in the book of the proceedings of the company shall be conclusive evidence of the fact, without proof of the number or proportion of the votes recorded in favour of, or against, that resolution.

(2) At any general meeting, the company shall transact such businesses as may be notified by the Commission, only through postal ballot.

33. A poll may be demanded only in accordance with the provisions of section 143.

34. If a poll is duly demanded, it shall be taken in accordance with the manner laid down in sections 144 and 145 and the result of the poll shall be deemed to be the resolution of the meeting at which the poll was demanded.

35. A poll demanded on the election of chairman or on a question of adjournment shall be taken at once.

36. In the case of an equality of votes, whether on a show of hands or on a poll, the chairman of the meeting at which the show of hands takes place, or at which the poll is demanded, shall have and exercise a second or casting vote.

37. Except for the businesses specified under sub-section (2) of section 134 to be conducted in the annual general meeting, the members of a private company or a public unlisted company (having not more than fifty members), may pass a resolution (ordinary or special) by circulation signed by all the members for the time being entitled to receive notice of a meeting. The resolution by circulation shall be deemed to be passed on the date of signing by the last of the signatory member to such resolution.

VOTES OF MEMBERS

38. Subject to any rights or restrictions for the time being attached to any class or classes of shares, on a show of hands every member present in person shall have one vote except for election of directors in which case the provisions of section 159 shall apply. On a poll every member shall have voting rights as laid down in section 134.

39. In case of joint-holders, the vote of the senior who tenders a vote, whether in person or by proxy or through video-link shall be accepted to the exclusion of the votes of the other joint-holders; and for this purpose seniority shall be determined by the order in which the names stand in the register of members.

40. A member of unsound mind, or in respect of whom an order has been made by any court having jurisdiction in lunacy, may vote, whether on show of hands or on a poll or through video link, by his committee or other legal guardian, and any such committee or guardian may, on a poll, vote by proxy.

41. On a poll votes may be given either personally or through video-link, by proxy or through postal ballot:

Provided that nobody corporate shall vote by proxy as long as a resolution of its directors

...ccordance with the provisions of section 138 is in force.

... (1) The instrument appointing a proxy shall be in writing under the hand of the appointer or ...is attorney duly authorised in writing.

(2) The instrument appointing a proxy and the power-of-attorney or other authority (if any) under which it is signed, or a notarially certified copy of that power or authority, shall be deposited at the registered office of the company not less than forty-eight hours before the time for holding the meeting at which the person named in the instrument proposes to vote and in default the instrument of proxy shall not be treated as valid.

43. An instrument appointing a proxy may be in the following form, or a form as near thereto as may be:

INSTRUMENT OF PROXY

.... Limited

"I .... s/o .... r/o .... being a member of the .... Limited, hereby appoint .... s/o .... r/o .... as my proxy to attend and vote on my behalf at the (statutory, annual, extraordinary, as the case may be) general meeting of the company to be held on the .... day of ...., 20...... and at any adjournment thereof."

44. A vote given in accordance with the terms of an instrument of proxy shall be valid notwithstanding the previous death or insanity of the principal or revocation of the proxy or of the authority under which the proxy was executed, or the transfer of the share in respect of which the proxy is given, provided that no intimation in writing of such death, insanity, revocation or transfer as aforesaid shall have been received by the company at the office before the commencement of the meeting or adjourned meeting at which the proxy is used.

DIRECTORS

45. The following subscribers of the memorandum of association shall be the first directors of the company, so, however, that the number of directors shall not in any case be less than that specified in section 154 and they shall hold office until the election of directors in the first annual general meeting:

1. Changhoo Oh
2. Byungsoo Jung
3. Yongsuk Jung

46. The remuneration of the directors shall from time to time be determined by the company in general meeting subject to the provisions of the Act.

47. Save as provided in section 153, no person shall be appointed as a director unless he is a member of the company.

POWERS AND DUTIES OF DIRECTORS

The business of the company shall be managed by the directors, who may pay all expenses incurred in promoting and registering the company, and may exercise all such powers of the company as are not by the Act or any statutory modification thereof for the time being in force, or by these regulations, required to be exercised by the company in general meeting, subject nevertheless to the provisions of the Act or to any of these regulations, and such regulations being not inconsistent with the aforesaid provisions, as may be prescribed by the company in general meeting but no regulation made by the company in general meeting shall invalidate any prior act of the directors which would have been valid if that regulation had not been made.

49. The directors shall appoint a chief executive in accordance with the provisions of sections 186 and 187.

50. The amount for the time being remaining undischarged of moneys borrowed or raised by the directors for the purposes of the company (otherwise than by the issue of share capital) shall not at any time, without the sanction of the company in general meeting, exceed the issued share capital of the company.

51. The directors shall duly comply with the provisions of the Act, or any statutory modification thereof for the time being in force, and in particular with the provisions in regard to the registration of the particulars of mortgages, charges and pledge affecting the property of the company or created by it, to the keeping of a register of the directors, and to the sending to the registrar of an annual list of members, and a summary of particulars relating thereto and notice of any consolidation or increase of share capital, or sub-division of shares, and copies of special resolutions and a copy of the register of directors and notifications of any changes therein.

MINUTE BOOKS

52. The directors shall cause records to be kept and minutes to be made in book or books with regard to:

(a) all resolutions and proceedings of general meeting(s) and the meeting(s) of directors and Committee(s) of directors, and every member present at any general meeting and every director present at any meeting of directors or Committee of directors shall put his signature in a book to be kept for that purpose:

(b) recording the names of the persons present at each meeting of the directors and of any committee of the directors, and the general meeting; and

(c) all orders made by the directors and Committee(s) of directors:

Provided that all records related to proceedings through video-link shall be maintained in accordance with the relevant regulations specified by the Commission which shall be appropriately rendered into writing as part of the minute books according to the said regulations.

THE SEAL

53. The directors shall provide for the safe custody of the seal and the seal shall not be affixed to

instrument except by the authority of a resolution of the board of directors or by a committee of directors authorized in that behalf by the directors and in the presence of at least two directors and of the secretary or such other person as the directors may appoint for the purpose; and those two directors and secretary or other person as aforesaid shall sign every instrument to which the seal of the company is so affixed in their presence.

DISQUALIFICATION OF DIRECTORS

54. No person shall become the director of a company if he suffers from any of the disabilities or disqualifications mentioned in section 153 or disqualified or debarred from holding such office under any of the provisions of the Act as the case may be and, if already a director, shall cease to hold such office from the date he so becomes disqualified or disabled:

Provided, however, that no director shall vacate his office by reason only of his being a member of any company which has entered into contracts with, or done any work for, the company of which he is director, but such director shall not vote in respect of any such contract or work, and if he does so vote, his vote shall not be counted.

PROCEEDINGS OF DIRECTORS

55. The directors may meet together for the dispatch of business, adjourn and otherwise regulate their meetings, as they think fit. A director may, and the secretary on the requisition of a director shall, at any time, summon a meeting of directors. Notice sent to a director through email whether such director is in Pakistan or outside Pakistan shall be a valid notice.

56. The directors may elect a chairman of their meetings and determine the period for which he is to hold office; but, if no such chairman is elected, or if at any meeting the chairman is not present within ten minutes after the time appointed for holding the same or is unwilling to act as chairman, the directors present may choose one of their number to be chairman of the meeting.

57. At least one-third ($1/3^{rd}$) of the total number of directors or two (2) directors whichever is higher, for the time being of the company, present personally or through video-link, shall constitute a quorum.

58. Save as otherwise expressly provided in the Act, every question at meetings of the board shall be determined by a majority of votes of the directors present in person or through video-link, each director having one vote. In case of an equality of votes or tie, the chairman shall have a casting vote in addition to his original vote as a director.

59. The directors may delegate any of their powers not required to be exercised in their meeting to committees consisting of such member or members of their body as they think fit; any committee so formed shall, in the exercise of the powers so delegated, conform to any restrictions that may be imposed on them by the directors.

60. (1) A committee may elect a chairman of its meetings; but, if no such chairman is elected, or if at any meeting the chairman is not present within ten minutes after the time appointed for holding the same or is unwilling to act as chairman, the members present may choose one of their number to be chairman of the meeting.

(2) A committee may meet and adjourn as it thinks proper. Questions arising at any meeting shall be determined by a majority of votes of the members present. In case of an equality

votes, the chairman shall have and exercise a second or casting vote.

61. All acts done by any meeting of the directors or of a committee of directors, or by any person acting as a director, shall, notwithstanding that it be afterwards discovered that there was some defect in the appointment of any such directors or persons acting as aforesaid, or that they or any of them were disqualified, be as valid as if every such person had been duly appointed and was qualified to be a director.

62. A copy of the draft minutes of meeting of the board of directors shall be furnished to every director within seven working days of the date of meeting.

63. A resolution in writing signed by all the directors for the time being entitled to receive notice of a meeting of the directors shall be as valid and effectual as if it had been passed at a meeting of the directors duly convened and held.

FILLING OF VACANCIES

64. At the first annual general meeting of the company, all the directors shall stand retired from office, and directors shall be elected in their place in accordance with section 159 for a term of three years.

65. A retiring director shall be eligible for re-election.

66. The directors shall comply with the provisions of sections 154 to 159 and sections 161, 162 and 167 relating to the election of directors and matters ancillary thereto.

67. Any casual vacancy occurring on the board of directors may be filled up by the directors, but the person so chosen shall be subject to retirement at the same time as if he had become a director on the day on which the director in whose place he is chosen was last elected as director.

68. The company may remove a director but only in accordance with the provisions of the Act.

DIVIDENDS AND RESERVE

69. The company in general meeting may declare dividends but no dividend shall exceed the amount recommended by the directors.

70. The directors may from time to time pay to the members such interim dividends as appear to the directors to be justified by the profits of the company.

71. Any dividend may be paid by a company either in cash or in kind only out of its profits. The payment of dividend in kind shall only be in the shape of shares of listed company held by the distributing company.

72. Dividend shall not be paid out of unrealized gain on investment property credited to profit and loss account.

73. Subject to the rights of persons (if any) entitled to shares with special rights as to dividends, all dividends shall be declared and paid according to the amounts paid on the shares.

74. (1) The directors may, before recommending any dividend, set aside out of the profits of the

pany such sums as they think proper as a reserve or reserves which shall, at the discretion of directors, be applicable for meeting contingencies, or for equalizing dividends, or for any er purpose to which the profits of the company may be properly applied, and pending such lication may, at the like discretion, either be employed in the business of company or be invested in such investments (other than shares of the company) as the directors may, subject to the provisions of the Act, from time to time think fit.

(2) The directors may carry forward any profits which they may think prudent not to distribute, without setting them aside as a reserve.

75. If several persons are registered as joint-holders of any share, any one of them may give effectual receipt for any dividend payable on the share.

76. (1) Notice of any dividend that may have been declared shall be given in manner hereinafter mentioned to the persons entitled to share therein but, in the case of a public company, the company may give such notice by advertisement in a newspaper circulating in the Province in which the registered office of the company is situate.

(2) Any dividend declared by the company shall be paid to its registered shareholders or to their order. The dividend payable in cash may be paid by cheque or warrant or in any electronic mode to the shareholders entitled to the payment of the dividend, as per their direction.

(3) In case of a listed company, any dividend payable in cash shall only be paid through electronic mode directly into the bank account designated by the entitled shareholders.

77. The dividend shall be paid within the period laid down under the Act.

ACCOUNTS

78. The directors shall cause to be kept proper books of account as required under section 220.

79. The books of account shall be kept at the registered office of the company or at such other place as the directors shall think fit and shall be open to inspection by the directors during business hours.

80. The directors shall from time to time determine whether and to what extent and at what time and places and under what conditions or regulations the accounts and books or papers of the company or any of them shall be open to the inspection of members not being directors, and no member (not being a director) shall have any right of inspecting any account and book or papers of the company except as conferred by law or authorised by the directors or by the company in general meeting.

81. The directors shall as required by sections 223 and 226 cause to be prepared and to be laid before the company in general meeting the financial statements duly audited and reports as are referred to in those sections.

82. The financial statements and other reports referred to in regulation 80 shall be made out in every year and laid before the company in the annual general meeting in accordance with sections 132 and 223.

83. A copy of the financial statements and reports of directors and auditors shall, at least twenty-one days preceding the meeting, be sent to the persons entitled to receive notices of general

etings in the manner in which notices are to be given hereunder.

The directors shall in all respect comply with the provisions of sections 220 to 227.

85. Auditors shall be appointed and their duties regulated in accordance with sections 246 to 249.

NOTICES

86. (1) A notice may be given by the company to any member to his registered address or if he has no registered address in Pakistan to the address, if any, supplied by him to the company for the giving of notices to him against an acknowledgement or by post or courier service or through electronic means or in any other manner as may be specified by the Commission.

(2) Where a notice is sent by post, service of the notice shall be deemed to be effected by properly addressing, prepaying and posting a letter containing the notice and, unless the contrary is proved, to have been effected at the time at which the letter will be delivered in the ordinary course of post.

87. A notice may be given by the company to the joint-holders of a share by giving the notice to the joint-holder named first in the register in respect of the share.

88. A notice may be given by the company to the person entitled to a share in consequence of the death or insolvency of a member in the manner provided under regulation 85 addressed to them by name, or by the title or representatives of the deceased, or assignees of the insolvent, or by any like description, at the address, supplied for the purpose by the person claiming to be so entitled.

89. Notice of every general meeting shall be given in the manner hereinbefore authorised to (a) every member of the company and also to (b) every person entitled to a share in consequence of the death or insolvency of a member, who but for his death or insolvency would be entitled to receive notice of the meeting, and (c) to the auditors of the company for the time being and every person who is entitled to receive notice of general meetings.

WINDING UP

90. (1) In the case of members' voluntary winding up, with the sanction of a special resolution of the company, and, in the case of creditors' voluntary winding up, of a meeting of the creditors, the liquidator shall exercise any of the powers given by sub-section (1) of section 337 of the Act to a liquidator in a winding up by the Court including *inter-alia* divide amongst the members, in specie or kind, the whole or any part of the assets of the company, whether they consist of property of the same kind or not.

(2) For the purpose aforesaid, the liquidator may set such value as he deems fair upon any property to be divided as aforesaid and may determine how such division shall be carried out as between the members or different classes of members.

(3) The liquidator may, with the like sanction, vest the whole or any part of such assets in trustees upon such trusts for the benefit of the contributories as the liquidator, with the like sanction, thinks fit, but so that no member shall be compelled to accept any shares or other securities whereon there is any liability.

INDEMNITY

Every officer or agent for the time being of the company may be indemnified out of the assets of the company against any liability incurred by him in defending any proceedings, whether civil or criminal, arising out of his dealings in relation to the affairs of the company, except those brought by the company against him, in which judgment is given in his favour or in which he is acquitted, or in connection with any application under section 492 in which relief is granted to him by the Court.

We, the several persons whose names and addresses are subscribed below, are desirous of being formed into a company, in pursuance of this Articles 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	Registration / Passport No.	Father's Name	Nationality	Occupation	Usual residential address in full or the registered/ principal office address	Number of Shares taken by each subscriber (in figures and words)	Signatures
Korea Hydro & Nuclear Power Co., Ltd through Changoo Oh passport no. M44506788	KHNP Registration no. 120-86-18943 /	N/A	Republic of Korea	Korea Hydro & Nuclear Power Co., Ltd	P.O.38120 1655, Bulguk-ro, Yangbuk-myeon, Gyeongju-si, Gyeongsangbuk-do, Korea	Nine Hundred and Ninety-Eight (998) Ordinary Shares	
Yongsuk Jung	M02552758	Hoon Jung	Republic of Korea	Employee of Korea Hydro & Nuclear Power Co., Ltd	1218, Yangjae-daero, Songpa-gu, Seoul, KOREA	One (1) Ordinary Share	
Byungsoo Jung	M77337136	Jongtae Jung	Republic of Korea	Employee of Korea Hydro & Nuclear Power Co., Ltd	171, Dongtanjungang-ro, Hwaseong-si, Gyeonggi-do, KOREA	One (1) Ordinary Share	
		Total number of shares taken (in figures and words)				One Thousand (1000) Ordinary Shares	

Dated the 3rd day of March, 2021

THE COMPANIES ACT, 2017 (XIX of 2017)

(COMPANY LIMITED BY SHARES)

MEMORANDUM OF ASSOCIATION

OF

LSG HYDRO POWER LIMITED

1. The name of the company is LSG Hydro Power Limited (hereinafter referred to as the "Company").

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

3. (i) The principal line of business of the company shall be to carry on all or any of the businesses of generating, purchasing, importing, transforming, converting, distributing, supplying, exporting and dealing in electricity and all other forms of energy and products or services associated therewith and of promoting the conservation and efficient use of electricity and to perform all other acts which are necessary or incidental to the business of electricity generation, transmission, distribution and supply, subject to permission of concerned authorities; and to locate, establish, construct, equip, operate, use, manage and maintain thermal power plants, coal fired power plants, hydel power plants, wind mills, power grid station, grid stations, cables, overhead lines, substations, switching stations, tunnels, cable bridges, link boxes, heat pumps, plant and equipment for combined heat and power schemes, offices, computer centres, shops and necessary devices, showrooms, depots, factories, workshops, plants and to provide transforming, switching, conversion and transmission facilities, subject to permission of relevant authorities.

   (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, 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. 205,000,000 (Rupees Two Hundred and Five Million only) divided into 2,050,000 (Two Million and Fifty Thousand) ordinary shares of Rs. 100 (Rupees Hundred) 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 name(s):

Name and surname	Registration/ Passport No.	Father's/ Name	Nationality	Occupation	Usual residential address in full or the registered / principal office	Number of shares taken by each subscriber (in figures and words)	Signatures
Korea Hydro & Nuclear Power Co.,Ltd through Changoo Oh Passport no. M44506788	KHNP Registration no.120-86-18943	N/A	Republic of Korea	Korea Hydro Nuclear Power Co.,Ltd	P.O.38120 1655, Bulguk-ro, Yangbuk-myeon, Gyeongju-si, Gyeongsangbuk-do, Korea	Nine Hundred and Ninety-Eight (998) Ordinary Share	
Yongsuk Jung	M02552758	Hoon Jung	Republic of Korea	Employee of Korea Hydro Nuclear Power Co., Ltd	1218, Yangjae-daero,Sonpa-gu, Seoul, KOREA	One (1) Ordinary Share	
Byungsoo Jung	M77337136	Jongtae Jung	Republic of Korea	Employee of Korea Hydro Nuclear Power Co., Ltd	171 Dongtanjungang-ro, Hwaseong-si, Gyeonggi-do, KOREA	One (1) Ordinary Share	
		Total number of shares taken (in figures and words)				One Thousand (1000) Ordinary Share	

Dated the 3rd day of March, 2021

APPENDIX-6
ANNUAL REPORT OF THE COMPANY

Directors Report LSG Hydro Power Limited

For the financial year ended December 31, 2022

The members of the Board of Directors of LSG Hydro Power Limited ("LSG" or the "Company") feel pleasure in presenting the Directors Report for the financial year ended December 31, 2022.

BOARD OF DIRECTORS

The Board comprises two directors who were elected in the First Annual General Meeting held on July 18, 2022. During the year there has been no change in the composition of the Board. Names of the Directors are as follows:

1- Mr. Moon-Soo Myung
2- Mr. Chang-hoo Oh

OBJECTIVE, PRINCIPAL ACTIVITIES, DEVELOPMENT AND PERFORMANCE OF THE COMPANY'S BUSINESS DURING THE FINANCIAL YEAR-2022

OBJECTIVE

LSG Hydro Power Limited (LSG), is a 100% wholly owned subsidiary of Korea Hydro & Nuclear Power Co Limited (KHNP), which is a South Korea-based company. KHNP operated 24 nuclear power plants, 37 hydroelectric power plants and 32 renewable power plants globally. including South Korea. New York. Washington, Paris and Tokyo.

LSG was incorporated in 2021 and intends to establish hydropower plants in Pakistan.

COMMENCEMENT AND OPERATIONS

The company is in the process of obtaining regulatory approvals from different regulators for the commencement of operations in Pakistan.

The letter of intent (the "LOI") to conduct the feasibility study of the Project was awarded by the Pakhtunkhwa Energy Development Organization (the "PEDO") to a consortium of Korean companies led by Korea Hydro & Nuclear Power Company (the "KHNP") on June 29, 2021. The LOI is issued to the KHNP consortium under the KP Hydropower Policy, 2016.

The Project is being developed as the first-ever public-private partnership (the "PPP") between KHNP and the government of Khyber Pakhtunkhwa (the "GoKP"). A memorandum of understanding (the "MoU") was signed between KHNP and GoKP on November 5, 2018. As per

MoU, the GoKP shall maintain a shareholding of up to 26% in LSG Hydro Power Limited (the "Company"), a special purpose company incorporated under the laws of Pakistan to carry out the development, construction, and operations of the Project.

After the issuance of the LOI, the Company hired the services of internationally reputable consultants to conduct the Project's feasibility study. The PEDO constituted a Panel of Experts (the "POE") to oversee the progress and quality of the feasibility study. The members of POE included experts from the PEDO, the Private Power & Infrastructure Board (the "PPIB"), the National Transmission and Despatch Company (the "NTDC"), the Environmental Protection Agency of GoKP (the "EPA") and Peshawar Electric Supply Company (the "PESCO").

The POE conducted multiple site visits and internal meetings to discuss the findings of the feasibility study consultant. The technical and financial contents of the feasibility study were amended per the recommendations of the POE. The Project cost was deliberated in detail and optimised after the analysis of unit rates. The POE approved the Project's feasibility study on November 23, 2022.

FUTURE OUTLOOK

To increase hydropower and renewable energy generation along with better-functioning institutions to improve local living and economic development in the Project area. It was agreed that the Project would be used as a launching pad for the program for developing energy resources of GoKP and would include activities, assistance and catalytic investments for realizing the vast energy potential of the province.

The Project is the first PPP venture in the country's hydropower sector and shall pave the way for increased investment, where governments play an active and vital role in developing natural and indigenous local resources. The Project's role is to increase the province's installed capacity by adding 470 MW with cheaper and renewable annual energy generation of about 1,926 GWh.

CAPITAL

The Company's Authorised Share Capital is Rupees 205 million comprising 2,050,000 ordinary shares of Rs.100 each. Currently, the Issued Capital is PKR 100,000 comprising 1,000 ordinary shares of Rs. 100 each.

PRINCIPAL RISKS AND UNCERTAINTIES FACING THE COMPANY

Effective risk management is the key to sustainable business. Our risk management framework, coupled with our internal control policies and checks helped us to maintain our focus and mitigate principal risks affecting our Company. The internal control framework established by the Company ensures appropriate risk mitigation plans by assigning designated accountability and policy framework for upward communication of any material issues and incidents.

AUDITORS AND AUDIT REPORT

LSG Hydro Power Limited's Auditors, Grant Thornton Anjum Rahman Chartered Accountants have completed their assignment for FY2022 and shall stand retired at the conclusion of the next Annual General Meeting. Being eligible, they offered themselves for re-appointment for FY2023. The Auditors have not made any reservations, observations, qualifications, or adverse remarks in their Audit Report.

FINANCIAL RESULTS

The LSG project is in the development stage. Its financial results show an after-tax loss of Rs. 1.8 million for the year ended December 31, 2022, which is due to charging certain expenditures during the period as per the requirements of applicable International Financial Reporting Standards.

The Project Capitalisation is in progress and will reflect the projected Project Costs and the various components of its Funding comprising of Equity and Loans.

EARNINGS PER SHARE

There is no earning per share to declare as operations were not started as of December 31, 2022.

DIVIDEND DECLARATION

No dividend has been declared by the Board of Directors during the Financial year 2022 as the Company had not started commercial operations.

REPORTING

The Company complies with all statutory reporting requirements. All statements, financial and otherwise, duly reviewed by the Company's auditors are provided to shareholders, financial institutions, and the relevant authorities on a responsible basis.

ANY MATERIAL CHANGES AND COMMITMENTS AFFECTING THE FINANCIAL POSITION OF THE COMPANY

No material changes or commitments affecting the financial position of the Company have occurred between the end of the financial year of the Company and the date of this report except as disclosed in this report.

ADEQUACY OF INTERNAL FINANCIAL CONTROLS

The management of LSG's is responsible for the establishment and maintenance of the Company's system of internal control in order to identify and manage risks faced by the Company. This system reasonable assurance that:

• Assets are safeguarded against unauthorized use or disposition:
• Proper and reliable accounting records are available for use within the business; and
• Adequate control mechanisms have been established within the operational businesses
• Internal financial controls deployed within the Company have been satisfactory throughout the Year.

SHAREHOLDING PATTERN

The pattern of shareholdings is attached to this Report.

CHAIRMAN'S REVIEW

The Directors endorse the contents of the Chairman's Review for the year ended December 31. 2022, which contains the current state of the Company's affairs, operational performance and other requisite information. The contents of the said review shall be read along with the directors' report and shall form an integral part of the Director's report under Section 227 of the Companies Act, 2017.

The Board of Directors is grateful to the Company's staff and foreign and local associates and partners for continuing to advance LSG's nationally important project.

For and on behalf of the Board of Directors,

Mr. Seung-yeol Lim
Chairman/ Chief Executive

Mr. Moon-Soo Myung
Director

Islamabad, March 15, 2023

PATTERN OF SHAREHOLDING

LSG Hydro Power Limited's pattern of shareholding as on December 31, 2022, was as follows:

Ordinary Share Holding

Shareholders (No.)	Range of Shareholding	Number of Shares
1	1 to 998	998
1	998 to 999	1
1	999 to 1,000	1

Category	No. of Shareholders	No. of Shares Held	Percentage of Shareholding
Chief Executive, Directors, Spouses and Minor Children	2	2	0.20%
Associated Undertakings	1	998	99.80%
Shareholding 10%	-	-	-
General Public	-	-	-
Total	3	1,000	100.00%

APPENDIX-7
ANNUAL RETURN OF THE COMPANY

Form A
THE COMPANIES ACT, 2017
THE COMPANIES (GENERAL PROVISIONS AND FORMS) REGULATIONS, 2018
[Section 130(1) and Regulation 4]
ANNUAL RETURN OF COMPANY HAVING SHARE CAPITAL

PART-I

(Please complete in typescript or in bold block capitals)

1.1 CUIN (Registration Number)	0172083
1.2 Name of the Company	LSG HYDRO POWER LIMITED
1.3 Fee payment details	1.3.1 Challan No E-2023-1475659 1.3.2. Amount 1000.0
1.4 Form A made upto (dd mm yyyy)	26/04/2023
1.5 Date of AGM	26/04/2023

PART - II

Section A

2.1 Registered Office Address	4th floor, Emirates tower, Jinnah super, F-7 Markaz Islamabad Islamabad Islamabad Capital Territory (I.C.T.) 44210
2.2 Email Address	info@lsg-hydro.com
2.3 Office Tel. No.	516134782
2.4 Office Fax No.	
2.5 Principle line of business	--POWER GENERATION - ALLIED (OTHER)
2.6 Mobile No. of Authorized officer (Chief Executive/ Director/ Company Secretary/ Chief Financial Officer)	03333334471

2.7 Authorized Share Capital

Classes and kinds of Shares	No. of Shares	Amount	Face Value
Ordinary Shares		206,000,000.00	

2.8 Paid up Share Capital

Classes and kinds of Shares	No. of Shares	Amount	Face Value
Ordinary Shares		100,000.00	

2.9 Particulars of the holding /subsidiary company, if any

Name of Company	Holding/Subsidiary	% Shares Held
Korea Hydro and Nuclear Power Co. Ltd.		99.80

2.10 Chief Executive

Name	Seung-yeol Lim
Address	Po:38120, 1655, Bulguk-ro, Yangbuk-myeon, Gheongju-si
NIC No	M39696501

[redacted]

2.11 Chief Financial Officer

Name	
Address	
NIC No	

2.12 Secretary

Name	Kashif Farhan
Address	House Number 220, Street Number 1, Sector D-12/3, Islamabad
NIC No	6110102241931

2.13 Legal Advisor

Name	
Address	
NIC No	

2.14 Particulars of Auditors

Name	Grant Thornton Anjum Rahman, Chartered Ac
Address	302-B, Third Floor, Evacuee Trust Complex, Sir Agha Khan Road, F-5/1, Islamabad

2.15 Particulars of Shares Registrar (if applicable)

Name	
Address	
Email	

Section-B

2.16 List of Directors on the date Annual return is made

S#	Name of Director	Residential Address	Nationality	NIC (Passport No. if foreigner)	Date of appointment /election	Name of Member/Creditors nominating/appointing
1	Moonsoo Myung	1655, bulguk-ro munmudawang-myeon, Gyeongju-si Gyeongsangbuk	Korea South	M04655694	18/07/2022	
2	Changhoo Oh	380, Honggok-ro, Nam-gu, Busan Korea N/A Korea South	Korea South	M44506788	18/07/2022	
3	Seung-yeol Lim	Po:38120, 1655, Bulguk-ro, Yangbuk-myeon, Gheongju-si	Korea South	M39696501	29/12/2022	

2.17 List of members & debenture holders on the date upto which this Form is made

S#	Folio#	Name *	Address	Nationality	No of shares	Percentage	NIC No(Passport if foreigner)
Members							
1		Yongsuk Jung	1218 Yangjae-daero Songpa-gu Seoul Korea	Korea South	1	0.10%	M02552758
2		Byungsoo Jung	171 Dongtanjungang-ro Hwaseong-si Gyeong	Korea South	1	0.10%	M77337136
3		Korea Hydro and Nuclear Power Co. Lt	PO 38120 1655 Bulguk-ro Yangbuk-myeon G	Korea South	998	99.80%	M44506786
Debenture Holders							

* In case the member or debenture holder is holding shares or debentures on behalf of other person(s), the name of such other person(s) shall be mentioned in parentheses alongwith the name of the member or debenture holder

[redacted]

2.18 Transfer of shares (debentures) since last Form A was made

S#	Name of Transferor	Name of Transferee	No of Shares Transferred	Date of Registration of transfer
Members				
Debenture Holders				

PART-3

3.1 Declaration:
I do hereby solemnly, and sincerely declare that the information provided in the form is:
(i) true and correct to the best of my knowledge, in consonance with the record as maintained by the Company and nothing has been concealed; and
(ii) hereby reported after complying with and fulfilling all requirements under the relevant provisions of law, rules, regulations, directives, circulars and notifications whichever is applicable.

3.2 Name of Authorized Officer with designation/ Authorized Intermediary	Kashif Farhan	Secretary
3.3 Signatures	Electronically signed by Kashif Farhan	
3.4 Registration No of Authorized Intermediary, if applicable		
		Day Month Year
3.5 Date		17/05/2023

[redacted] [redacted]

APPENDIX-8
SHARE CAPITAL DETAILS

Form 3

THE COMPANIES ACT, 2017

THE COMPANIES (GENERAL PROVISIONS AND FORMS) REGULATIONS, 2018

[Section 70 and Regulations 4 & 12]

RETURN OF ALLOTMENTS OF SHARES

PART - I

Please complete in typescript or in bold block capitals

1.1 CUIN (Registration 0172063

1.2. Name of the Company LSG HYDRO POWER LIMITED

1.3 Fee Payment Details 1.3.1. E-2023-1549937 **1.3.2. Challan Amount** 0.00

PART - II

2. Share Capital

2.1. Authorized Capital 205,000,000.00

2.2. Paid up Capital 204,655,100.00

Inclusive of present allotment

2.3. Kind of Shares *Check relevant checkbox*

- [x] Ordinary
- [ ] Preference

2.4. Class of Shares *Check relevant checkbox*

- [ ] Ordinary Class A
- [ ] Ordinary Class B
- [ ] Preferred: Participatory: Redeemable at company's option
- [ ] Preferred: Non Participatory: Non Redeemable
- [ ] Preferred: Non Participatory: Redeemable at company's option
- [ ] Preferred: Non Participatory: Redeemable at Shareholder's option
- [ ] Preferred: Participatory: Redeemable at Shareholder's option

2.5. Date of Allotment * (Day Month Year) 30/06/2023

(if share were allotted on different dates, the date of first allotmenet shall be mentioned)*

2.6 SECTION A - SHARES ALLOTTED AGAINST CASH CONSIDERATION

	No of Shares	Indicating class, if any
2.6.1	2045551	Ordinary
	Per share (Rs.)	**Total Amount (Rs.)**
2.6.2 Nominal Amount	100.00	204,555,100.00
2.6.3 Premimum		
2.6.4 Discount		0.00
2.6.5 Total (Amount paid on each share 2.6.2 to 2.6.4)	100.00	204,555,100.00
	Specify Currency	**Total Amount of Foreign Currency**
2.6.6 Consideration recieved against		

against allotment in foreign current

(equivalent amount in PKR included in total amount mentioned at 2.6.5)

2.7 SECTION B - SHARES ALLOTTED FOR CONSIDERATION OTHERWISE THAN IN CASH

	No of Shares	indicating class if any
2.7.1 No. of Shares (indicating class, if any)		Ordinary
	Per Share (Rs.)	Total Amount (Rs.)
2.7.2 Nominal Amount	100.00	0.00
2.7.3 Premium		
2.7.4 Discount		0.00
2.7.5 Total (2.7.2 to 2.7.4)	100.00	0.00

2.7.6 The consideration for which shares have been allotted is

	Amount (Rs.)
a) Property and Assets Acquired (give description)	
b) Good will	
c) Services (give nature of services)	
d) Other Items (to be specified)	
e) Total (a to d)	0.00

2.8 SECTION C - ALLOTMENT OF BONUS SHARES

	No of Shares	indicating class if any
2.8.1 No. of Shares (indicating class, if any)		Ordinary
	Allotment ratio (existing share / bonus shares)	Total Amount (Rs.)
2.8.2 Details of Bonus Shares		0.00
	Resolution No.	Day Month Year
2.8.3 Particulars of Resolution of Board of Directors /		

2.9 SECTION D - NAMES, ADDRESSES, OCCUPATIONS, ETC OF THE ALLOTTEES

Date of Allotment	Name of the Allotee in Full	Father/Husband's Name	Nationality	Country of origin in case of foreign national	Occupation of the Allotee	Address of the Allotee	No of Shares	CNIC
30/06/2023	Korea Hydro and Nuclear Power Co. Ltd.	Not Applicable	South Korea	South Korea	Not Applicable	1655, Bulguk-ro, Munmudaewang-myeon,	2045551	0000000

PART III

3.1 I do hereby solemnly, and sincerely declare that the information provided in the form is:
(i) true and correct to the best of my knowledge, in consonance with the record as maintained by the Company and nothing has been concealed; and
(ii) hereby reported after complying with and fulfilling all requirements under the relevant provisions of law, rules, regulations, directives, circulars and notifications whichever is applicable

3.2. Name of Authorized Officer with Designation/ Atuhorized — Kashif Farhan | Secretary

3.3. Signatures — Electronically sign by Kashif Farhan

3.4 Reg No of Authoized Intermediary (If

Day Month Year

3.5. Date — 06/08/2023

Enclosures
1. In case shares are allotted against cash consideration a report from Auditor of the Company in terms of section 70(1)(b) of the Act as per Appendix attached herewith, to the effect that the amount of consideration has been received in full
2. In case shares are allotted against consideration otherwise than in cash a copy of the contract in writing constituting the title of the allottee to the allotment together with a contract of sale, or for services or other consideration in respect of which that allotment was made, such contract being duly stamped
3. In case bonus shares are issued copies of the resolution of Board of Directors /members authorizing the issue of such shares
4. In case the shares are issued at discount a copy of the special resolution passed by the members authorizing such issue and where the maximum rate of discount exceeds limits specified in the Act a copy of the order of the Commission permitting the issue at the higher percentage
5. In case of allotment of shares in consequence of the exercise of the option for conversion in terms of an agreement for participation term certificates term finance certificates, redeemable capital musharika or hire-purchase shall be reported in Section-B and copies of the relevant documents

0000000

APPENDIX-9
BANK CERTIFICATE

HABIBMETRO

BUILDING TOGETHER
Habib Bank AG Zurich
SINCE 1967

20-Jul-2023

TO WHOM IT MAY CONCERN

This is to certify that M/s. LSG HYDRO POWER LIMITED of OFF 29 3RD FLOOR PLOT #14 EXECUTIVE COMPLEX G-8 MARKAZ, Islamabad, Pakistan is/are maintaining Account under Demand Deposit - IBB Number 6-99-2-29301-714-126625 having IBAN PK31MPBL9902177140126625 with us since 22-Apr-2021 and having a balance of PKR 173,486,332.20 (One Hundred Seventy Three Million Four Hundred Eighty Six Thousand Three Hundred Thirty Two PKR and Twenty paisa) on 30-Jun-2023.

This certificate is being issued at the specific request of our customer and without any risk and responsibility on the part of this bank or any of its officers.

For Habib Metropolitan Bank Limited

Habib Metropolitan Bank Ltd. Islamic Banking Islamabad Br.

Authorised Signatory **Authorised Signatory**

Habib Metropolitan Bank Ltd.
(Subsidiary of Habib Bank AG Zurich)
Islamic Banking Branch - Islamabad: Shop No. 7 & 8. Hill View Plaza. Near Fresco Sweets. Jinnah Avenue. Blue Area. Islamabad, Pakistan. Tel: 92 51 2605 971-77 Fax: 92 51 2605 970

HABIBMETRO

BUILDING TOGETHER
Habib Bank AG Zurich
SINCE 1967

20-Jul-2023

TO WHOM IT MAY CONCERN

This is to certify that M/s. LSG HYDRRO POWER LIMITED of OFF 29 3RD FLOOR PLOT #14 EXECUTIVE COMPLEX G-8 MARKAZ, Islamabad, Pakistan is/are maintaining Account under Demand Deposit - IBB Number 6-99-2-29301-333-126625 having IBAN PK23MPBL9902173330126625 with us since 22-Apr-2021 and having a balance of USD 10.00 (Ten USD) on 30-Jun-2023.

This certificate is being issued at the specific request of our customer and without any risk and responsibility on the part of this bank or any of its officers.

For Habib Metropolitan Bank Limited

Habib Metropolitan Bank Ltd. Islamic Banking Islamabad Br.

Authorised Signatory **Authorised Signatory**

LSG HYDRO POWER LIMITED
FINANCIAL STATEMENTS
FOR THE YEAR ENDED
DECEMBER 31, 2022

Grant Thornton

Grant Thornton Anjum Rahman
302 B, 3rd Floor,
Evacuee Trust Complex,
Aga Khan Road, F-5/1,
Islamabad, Pakistan.

T +92 51 2271906
F +92 51 2273874

INDEPENDENT AUDITOR'S REPORT

To the members of LSG Hydro Power Limited
Report on the Audit of the Financial Statements
Opinion

We have audited the annexed financial statements of **LSG Hydro Power Limited**, which comprise the statement of financial position as at December 31, 2022, and the statement of profit or loss, the statement of comprehensive income, the statement of changes in equity, the statement of cash flows for the year then ended, and notes to the financial statements, including a summary of significant accounting policies and other explanatory information, and we state that we have obtained all the information and explanations which, to the best of our knowledge and belief, were necessary for the purposes of the audit.

In our opinion and to the best of our information and according to the explanations given to us, the statement of financial position, the statement of profit or loss, the statement of comprehensive income, the statement of changes in equity and the statement of cash flows together with the notes forming part thereof conform with the accounting and reporting standards as applicable in Pakistan and give the information required by the Companies Act, 2017 (XIX of 2017), in the manner so required and respectively give a true and fair view of the state of the Company's affairs as at December 31, 2022 and of the loss and comprehensive loss, the changes in equity and its cash flows for the year then ended.

Basis for Opinion

We conducted our audit in accordance with International Standards on Auditing (ISAs) as applicable in Pakistan. Our responsibilities under those standards are further described in the *Auditor's Responsibilities for the Audit of the Financial Statements* section of our report. We are independent of the Company in accordance with the International Ethics Standards Board for Accountants' *Code of Ethics for Professional Accountants* as adopted by the Institute of Chartered Accountants of Pakistan / Institute of Cost and management Accountants (the Code) and we have fulfilled our other ethical responsibilities in accordance with the Code. We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our opinion.

Emphasis of matter

We draw attention to note 1 to the financial statements which describes the status of implementation of 496 MW Lower Spat Gah hydro power project. Our opinion is not modified in respect of this matter.

Grant Thornton

Responsibilities of Management and Board of Directors for the Financial Statements

Management is responsible for the preparation and fair presentation of the financial statements in accordance with the accounting and reporting standards as applicable in Pakistan and the requirements of Companies Act, 2017(XIX of 2017) and for such internal control as management determines is necessary to enable the preparation of financial statements that are free from material misstatement, whether due to fraud or error.

In preparing the financial statements, management is responsible for assessing the Company's ability to continue as a going concern, disclosing, as applicable, matters related to going concern and using the going concern basis of accounting unless management either intends to liquidate the Company or to cease operations, or has no realistic alternative but to do so.

Board of directors are responsible for overseeing the Company's financial reporting process.

Auditor's Responsibilities for the Audit of the Financial Statements

Our objectives are to obtain reasonable assurance about whether the financial statements as a whole are free from material misstatement, whether due to fraud or error, and to issue an auditor's report that includes our opinion. Reasonable assurance is a high level of assurance, but is not a guarantee that an audit conducted in accordance with ISAs as applicable in Pakistan will always detect a material misstatement when it exists. Misstatements can arise from fraud or error and are considered material if, individually or in the aggregate, they could reasonably be expected to influence the economic decisions of users taken on the basis of these financial statements.

As part of an audit in accordance with ISAs as applicable in Pakistan, we exercise professional judgment and maintain professional skepticism throughout the audit. We also:

- Identify and assess the risks of material misstatement of the financial statements, whether due to fraud or error, design and perform audit procedures responsive to those risks, and obtain audit evidence that is sufficient and appropriate to provide a basis for our opinion. The risk of not detecting a material misstatement resulting from fraud is higher than for one resulting from error, as fraud may involve collusion, forgery, intentional omissions, misrepresentations, or the override of internal control.
- Obtain an understanding of internal control relevant to the audit in order to design audit procedures that are appropriate in the circumstances, but not for the purpose of expressing an opinion on the effectiveness of the Company's internal control.
- Evaluate the appropriateness of accounting policies used and the reasonableness of accounting estimates and related disclosures made by management.
- Conclude on the appropriateness of management's use of the going concern basis of accounting and, based on the audit evidence obtained, whether a material uncertainty exists related to events or conditions that may cast significant doubt on the Company's ability to continue as a going concern. If we conclude that a material uncertainty exists, we are required to draw attention in our auditor's report to the related disclosures in the financial statements or, if such disclosures are inadequate, to modify our opinion. Our conclusions are based on the audit evidence obtained up to the date of our auditor's report. However, future events or conditions may cause the Company to cease to continue as a going concern.
- Evaluate the overall presentation, structure and content of the financial statements, including the disclosures, and whether the financial statements represent the underlying transactions and events in a manner that achieves fair presentation.

We communicate with the board of directors regarding, among other matters, the planned scope and timing of the audit and significant audit findings, including any significant deficiencies in internal control that we identify during our audit.

Grant Thornton

Report on Other Legal and Regulatory Requirements

Based on our audit, we further report that in our opinion:

a) proper books of account have been kept by the Company as required by the Companies Act, 2017 (XIX of 2017);

b) the statement of financial position, the statement of profit or loss, the statement of comprehensive income, the statement of changes in equity and the statement of cash flows together with the notes thereon have been drawn up in conformity with the Companies Act, 2017 (XIX of 2017) and are in agreement with the books of account and returns;

c) investments made, expenditure incurred and guarantees extended during the year were for the purpose of the Company's business; and

d) no zakat was deductible at source under the Zakat and Usher Ordinance, (XVIII of 1980).

The engagement partner on the audit resulting in this independent auditor's report is Hassaan Riaz.

Grant Thornton Anjum Rahman

Grant Thornton Anjum Rahman
Chartered Accountants
Islamabad
April 3, 2023
UDIN: AR20221016441ulpb07Y

LSG HYDRO POWER LIMITED
STATEMENT OF FINANCIAL POSITION
AS AT DECEMBER 31, 2022

	Note	2022 Rupees	2021 Rupees
ASSETS			
Current assets			
Bank balance - current account		204,655,864	105,984
EQUITY AND LIABILITIES			
Share capital and reserves			
Share capital	4	**100,000**	100,000
Accumulated losses		**(3,201,756)**	(1,362,797)
Advance against equity	5	**204,555,100**	-
		201,453,344	(1,262,797)
Current liabilities			
Trade and other payables	6	**3,202,520**	1,368,781
Total equity and liabilities		204,655,864	105,984
Contingencies and commitments	7		

The annexed notes from 1 to 14 form an integral part of these financial statements.

CHIEF EXECUTIVE OFFICER

DIRECTOR

LSG HYDRO POWER LIMITED
STATEMENT OF PROFIT OR LOSS ACCOUNT
FOR THE YEAR ENDED DECEMBER 31, 2022

	Note	Year ended December 31, 2022 Rupees	For the period from March 26, 2021 to December 31, 2021 Rupees
Revenue		-	-
Cost of revenue		-	-
Gross loss/profit		-	
Administrative and general expenses	8	(1,838,959)	(1,362,797)
Operating loss before taxation		(1,838,959)	(1,362,797)
Taxation		-	-
Loss after taxation		(1,838,959)	(1,362,797)

The annexed notes from 1 to 14 form an integral part of these financial statements.

CHIEF EXECUTIVE OFFICER

DIRECTOR

LSG HYDRO POWER LIMITED
STATEMENT OF COMPREHENSIVE INCOME
FOR THE YEAR ENDED DECEMBER 31, 2022

	Year ended December 31, 2022	For the period from March 26, 2021 to December 31, 2021
	Rupees	Rupees
Loss after taxation	(1,838,959)	(1,362,797)
Other comprehensive income	-	-
Total comprehensive loss	(1,838,959)	(1,362,797)

The annexed notes from 1 to 14 form an integral part of these financial statements.

CHIEF EXECUTIVE OFFICER

DIRECTOR

LSG HYDRO POWER LIMITED
STATEMENT OF CHANGES IN EQUITY
FOR THE YEAR ENDED DECEMBER 31, 2022

	Share capital	Advance against equity	Accumulated loss (Revenue reserves)	Total
	Rupees			
Balance as at March 26, 2021	-	-	-	-
Activity during the period	100,000	-	-	100,000
Total comprehensive income				
Loss after taxation	-	-	(1,362,797)	(1,362,797)
Other comprehensive income	-	-	-	-
Total comprehensive loss	-	-	(1,362,797)	(1,362,797)
Balance at December 31, 2021	100,000	-	(1,362,797)	(1,262,797)
Activity during the year	-	204,555,100	-	204,555,100
Total comprehensive income				
Loss after taxation	-	-	(1,838,959)	(1,838,959)
Other comprehensive income	-	-	-	-
Total comprehensive loss	-	-	(1,838,959)	(1,838,959)
Balance at December 31, 2022	100,000	204,555,100	(3,201,756)	201,453,344

The annexed notes from 1 to 14 form an integral part of these financial statements.

CHIEF EXECUTIVE OFFICER

DIRECTOR

LSG HYDRO POWER LIMITED
CASH FLOW STATEMENT
FOR THE YEAR ENDED DECEMBER 31, 2022

	Year ended December 31, 2022	For the period from March 26, 2021 to December 31, 2021
	Rupees	Rupees
CASH FLOW FROM OPERATING ACTIVITIES		
Loss before taxation	(1,838,959)	(1,362,797)
Changes in working capital		
Increase in trade and other payables	1,833,739	1,368,781
Net cash from/(used in) operating activities	(5,220)	5,984
CASH FLOW FROM INVESTING ACTIVITIES		
Cash flow from investing activities	-	-
CASH FLOW FROM FINANCING ACTIVITIES		
Share capital	-	100,000
Advance against equity	204,555,100	-
Net cash inflow from financing activities	204,555,100	100,000
Net increase in cash and cash equivalents	204,549,880	105,984
Cash and cash equivalents at the beginning of the year	105,984	-
Cash and cash equivalents at the end of the year	204,655,864	105,984

The annexed notes from 1 to 14 form an integral part of these financial statements.

CHIEF EXECUTIVE OFFICER

DIRECTOR

LSG HYDRO POWER LIMITED
NOTES TO THE FINANCIAL STATEMENTS
FOR THE YEAR ENDED DECEMBER 31, 2022

1 THE COMPANY AND ITS OPERATIONS

LSG Hydro Power Limited ("Company") was incorporated in Pakistan as a public unlisted company limited by shares, under the Companies Act, 2017, on March 26, 2021. The registered address of the Company is situated at Office 29, 3rd Floor, Executive Complex, G-8 Markaz Islamabad. The Company is a subsidiary of Korea Hydro and Nuclear Power Company Limited ("the Parent Company"), incorporated in the Republic of Korea and headquartered at Honggok-ro, Nam-gu, Busan, Korea.

The Company is formed to develop, construct, and operate 496 MW Lower Spat Gah hydro power project ("the Project") in public private partnership with the Government of KPK, through its executing arm Pakhtunkhwa Energy Development Organization ("PEDO"). In this regard government of KPK has issued a Letter of Intent (LOI) in favor of the Parent Company on June 29, 2021 whose conditions are required to be complied within 18 months of its issuance. In pursuance of the terms of LOI the Parent Company has successfully updated the Project's feasibility study that has been duly approved by PEDO on November 23, 2022. An Environmental and Social Impact Assessment (ESIA) report as also required by LOI has been submitted to the environmental protection agency (EPA) which is currently under its review. Similarly, the inclusion of the Project in the 'Indicative Generation Capacity Expansion Plan' (IGCEP) is being pursuit so that National Electric Power Regulatory Authority (NEPRA) could be applied for the issuance of generation license and the feasibility stage tariff being the important milestones of LOI. In connection with the development of the Project and pursuant to the LOI, the Parent Company has arranged a Performance Guarantee of USD 496,000 (2021: USD 496,000) expiring on June 24, 2024, in favor of PEDO, under the KPK Hydro Policy 2016. The management is fully committed and rigorously pursuing the compliance of the terms of LOI being the basic condition of letter of support to be issued by Pakistan Power and Infrastructure Board ("PPIB").

The parent company is fully committed in extending all the technical and financial support necessary for complying the terms of LOI and securing the letter of support (LOS) for setting up the Project. Based upon the parent's commitment and the Project development work that has been carried out to date the Company is confident to achieve the milestones indicated in LOI and secure LOS for Project development.

The Parent Company is directly incurring the development expenses of the Project and as of current reporting date expenses aggregating to USD 2,000,000 have been incurred in this respect, while, the determination of the extent and the mode of charging these expenses to the Company is contingent on signing of cost sharing agreement among the potential equity partners. Whereas, the cost sharing agreement is still in negotiations stage. Due to the above, the extend and the nature of future economic outflow from the Company against these expenses not being certain have not been recorded in these financial statements.

2 BASIS OF PREPARATION

2.1 Statement of compliance

These financial statements have been prepared in accordance with the accounting and reporting standards as applicable in Pakistan. The accounting and reporting standards applicable in Pakistan comprise of International Financial Reporting Standards (IFRS Standards) issued by the International Accounting Standards Board (IASB) as notified under the Companies Act, 2017 and provisions of and directives issued under the Companies Act, 2017. Where provisions of and directives issued under the Companies Act, 2017 differ from the IFRS Standards, the provisions of and directives issued under the Companies Act, 2017 have been followed.

2.2 Basis of measurement

These financial statements have been prepared under "historical cost basis".

2.3 Significant accounting estimates

The preparation of financial statements in conformity with the accounting and reporting standards as applicable in Pakistan requires management to make judgments, estimates and assumptions that affect the application of policies and reported amounts of assets and liabilities, income and expenses. The estimate and associated assumptions are based on historical experience and various other factors that are believed to be reasonable under the circumstances, the results of which form the basis of making the judgments about the carrying values of assets and liabilities that are not readily apparent from other sources. Actual results may differ from these estimates.

The estimates and underlying assumptions are reviewed on an ongoing basis. Revisions to accounting estimates are recognized in the period in which the estimates are revised if the revision affects only that period, or in the period of revision and future periods.

LSG HYDRO POWER LIMITED
NOTES TO THE FINANCIAL STATEMENTS
FOR THE YEAR ENDED DECEMBER 31, 2022

2.4 New and revised standards and interpretation

2.4.1 New accounting standards, interpretations and amendments

There are new and amended standards and interpretations that are mandatory for accounting periods beginning 1 January 2022, are considered not to be relevant or do not have significant effect on the Company's financial statements.

IAS 16	Property, Plant and Equipment: Proceeds before intended use – Amendments	January 1, 2022
IFRS 03	Business Combinations - Amendments	January 1, 2022
IAS 37	Onerous Contracts – Cost of Fulfilling a Contract - Amendments	January 1, 2022

2.4.2 Standards, interpretations and amendments to published approved accounting standards that are not yet effective:

The following International Financial Reporting Standards (IFRS Standards) as notified under the Companies Act, 2017 and the amendments and interpretations thereto will be effective from the dates mentioned below:

		Effective date (annual periods beginning on or after)
IAS 12	Deferred Tax related	January 1, 2023
IAS 1	Classification of Liabilities as Current or Non-current – Amendments	January 1, 2023
IFRS 17	Insurance Contracts	January 1, 2023
IAS 2 &	Disclosure of Accounting Policies – Amendments	January 1, 2023
IAS 8	Definition of accounting estimates - Amendments	January 1, 2023
IFRS 10 and IAS 28	Sale or contribution of assets between an investor and its associate or joint venture – Amendments	n/a*

* The Effective date is not yet issued

3 SIGNIFICANT ACCOUNTING POLICIES

The accounting policies set out below have been applied in these financial statements:

3.1 Functional and presentation currency

Items included in the financial statements are measured using the currency of the primary economic environment in which the Company operates. The financial statements are presented in Pakistani Rupees, which is the Company's functional currency. All financial information presented in PKR has been rounded off to the nearest of PKR, unless otherwise stated.

3.2 Foreign currency translation

Transactions in foreign currencies are recorded at the rate of exchange ruling on the date of transaction. All monetary assets and liabilities in foreign currency are translated into Pakistani Rupees at the rate of exchange ruling at the statement of financial position date. Exchange differences are recognized in profit or loss.

3.3 Cash and cash equivalents

Cash and cash equivalents in the statement of financial position comprise cash at banks and on hand and short term highly liquid deposits with a maturity of three months or less, that are readily convertible to a known amount of cash and subject to an insignificant risk of changes in value are included as a component of cash and cash equivalents for the purpose of the statement of cash flow statement.

3.4 Trade and other payables

Trade and other payables are recognized initially at their fair value and subsequently measured at amortized cost using effective interest rate. They are presented as current liabilities unless payment is not due within 12 months after the reporting period.

3.5 Trade and other receivables

Most sales are made on the basis of normal credit terms, and the receivables do not bear interest. Where credit is extended beyond normal credit terms, receivables are measured at amortized cost using the effective interest method. At the end of each reporting period, the carrying amounts of trade and other receivables are reviewed to determine whether there is any objective evidence that the amounts are not recoverable. If so, an impairment loss is recognized immediately in profit or loss.

3.6 Financial Instruments

Financial assets and financial liabilities are recognized in the statement of financial position when the Company becomes a party to the contractual provisions of the instrument. All the financial assets are derecognized at the time when the Company loses control of the contractual rights that comprise the financial assets. All financial liabilities are derecognized at the time when they are extinguished that is, when the obligation specified in the contract is discharged, cancelled, or expired. Any gains or losses on de-recognition of the financial assets and financial liabilities are taken to the statement of profit or loss.

3.6.1 Initial recognition

At initial recognition, the Company measures a financial asset at its fair value plus, in the case of a financial asset not at FVTPL, transaction costs that are directly attributable to the acquisition of financial asset. Transaction costs of financial assets carried at FVTPL are expensed out in profit or loss. All financial liabilities of the Company are initially recognized at fair value and, in case of loans and borrowings and payables, net of directly attributable transaction costs.

3.6.2 Classification of financial assets

The Company classifies its financial instruments in the following categories:

- fair value through profit or loss (FVTPL);
- fair value through other comprehensive income (FVTOCI); and
- at amortized cost

Financial assets that meet the following conditions are subsequently measured at amortized cost:

- the financial asset is held within a business model whose objective is to hold financial assets in order to collect contractual cash flows; and
- the contractual terms of the financial asset give rise on specified dates to cash flows that are solely payments of principal and interest on the principal amount outstanding.

Financial assets that meet the following conditions are subsequently measured at FVTOCI:

- the financial asset is held within a business model whose objective is achieved by both collecting contractual cash flows and selling the financial assets; and
- the contractual terms of the financial asset give rise on specified dates to cash flows that are solely payments of principal and interest on the principal amount outstanding.

By default, all other financial assets are subsequently measured at FVTPL.

3.6.3 Classification of financial liabilities

The Company classifies its financial liabilities in the following categories:

- at fair value through profit or loss ("FVTPL"); and
- at amortized cost.

Financial liabilities are measured at amortized cost, unless they are required to be measured at FVTPL (such as instruments held for trading or derivatives) or the Company has opted to measure them at FVTPL.

3.6.4 Subsequent measurement

- **Financial assets and liabilities at amortized cost**

  Financial assets and liabilities at amortized cost are initially recognized at fair value, and subsequently carried at amortized cost, and in the case of financial assets, less any impairment.

- **Financial assets and liabilities at FVTPL**

  Financial assets and liabilities carried at FVTPL are initially recorded at fair value and transaction costs are expensed in the statement of profit or loss. Realized and unrealized gains and losses arising from changes in the fair value of the financial assets and liabilities held at FVTPL are included in the statement of profit or loss in the period in which they arise.

- **Financial assets at FVTOCI**

  Elected investments in equity instruments at FVTOCI are initially recognized at fair value plus transaction costs. Subsequently, they are measured at fair value, with gains or losses arising from changes in fair value recognized in other comprehensive income / (loss).

3.6.5 Impairment of financial assets

The Company recognizes loss allowance for Expected Credit Losses (ECL) on all financial assets which are measured at amortized cost. The Company uses General 3-stage approach for deposits and other receivables, interest receivable on deposit account and cash and bank balances to measure ECL through loss allowance at an amount equal to 12-month ECL if credit risk on a financial instruments has not increased significantly since initial recognition.

12 months' ECL are portion of ECL that result from default events that are possible within 12 months after the reporting date.

ECLs are a probability weighted estimate of credit losses. Credit losses are measured as the present value of all cash shortfalls (i.e. the difference between cash flows due to the entity in accordance with the contract and cash flows that the Company expects to receive).

The gross carrying amount of a financial asset is written off when the Company has no reasonable expectation of recovering a financial asset in its entirety or a portion thereof.

General approach for loans, deposits and cash and bank balances

The measurement of expected credit losses is a function of the probability of default, loss given default (i.e. the magnitude of the loss if there is a default) and the exposure at default. The assessment of the probability of default and loss given default is based on historical data adjusted by forward-looking information (adjusted for factors that are specific to the counterparty, general economic conditions and an assessment of both the current as well as the forecast direction of conditions at the reporting date, including time value of money where appropriate). As for the exposure at default for financial assets, this is represented by the assets' gross carrying amount at the reporting date. Loss allowances are forward-looking, based on 12 month expected credit losses where there has not been a significant increase in credit risk rating, otherwise allowances are based on lifetime expected losses.

Expected credit losses are a probability weighted estimate of credit losses. The probability is determined by the risk of default which is applied to the cash flow estimates. In the absence of a change in credit rating, allowances are recognized when there is reduction in the net present value of expected cash flows. On a significant increase in credit risk, allowances are recognized without a change in the expected cash flows, although typically expected cash flows do also change; and expected credit losses are rebased from 12 month to lifetime expectations.

Simplified approach for trade debts

The Company recognizes life time ECL on trade receivables and contract assets using the simplified approach. The measurement of ECL reflects:

- an unbiased and probability-weighted amount that is determined by evaluating a range of possible outcomes.
- reasonable and supportable information that is available at the reporting date about past events, current conditions and forecasts of future economic conditions.

As the Company applies simplified approach in calculating ECLs for trade debts and contract assets the Company does not track changes in credit risk, but instead recognized a loss allowance based on life time ECLs at each reporting date. ECLs on these financial assets are estimated using a provision matrix approach adjusted for forward looking factors specific to the debtors and economic environment.

The Company recognizes an impairment gain or loss in the statement of profit or loss for all financial instruments with a corresponding adjustment to their carrying amount through a loss allowance account, except for investments in debt instruments that are measured at FVTOCI, for which the loss allowance is recognized in other comprehensive income and accumulated in the investment revaluation reserve, and does not reduce the carrying amount of the financial asset in the statement of financial position.

3.6.6 Derecognition

Financial assets

The Company derecognizes financial assets only when the contractual rights to cash flows from the financial assets expire or when it transfers the financial assets and substantially all the associated risks and rewards of ownership to another entity. On derecognition of a financial asset measured at amortized cost, the difference between the asset's carrying value and the sum of the consideration received and receivable is recognized in profit or loss. In addition, on derecognition of an investment in a debt instrument classified as FVTOCI, the cumulative gain or loss previously accumulated in the investments revaluation reserve is reclassified to profit or loss. In contrast, on derecognition of an investment in equity instrument which the Company has elected on initial recognition to measure at FVTOCI, the cumulative gain or loss previously accumulated in the investments revaluation reserve is not reclassified to profit or loss, but is transferred to statement of changes in equity.

Financial liabilities

The Company derecognizes financial liabilities only when its obligations under the financial liabilities are discharged, cancelled or expired. The difference between the carrying amount of the financial liability derecognized and the consideration paid and payable, including any non-cash assets transferred or liabilities assumed, is recognized in the statement of profit or loss.

3.6.7 Off-setting

Financial assets and liabilities are offset and the net amount is presented in the statement of financial position when, and only when, the Company has a legal right to offset the amounts and intends either to settle them on a net basis or realize the asset and settle the liability simultaneously.

3.7 Taxation

Tax expense represent tax currently payable and deferred tax measurement for the current period. Tax is recognized in the statement of profit or loss account except that a change attributable to an item of income or expense recognized as other comprehensive income is also recognized directly in other comprehensive income.

Current

The profits and gains of the Company derived from electric power generation are exempt from tax in terms of clause 132 of Part I of the Second Schedule to the Income Tax Ordinance, 2001, subject to the conditions and limitations provided therein. The exempted income is also excluded from the purview of Alternate Corporate Tax, applicable otherwise at 17% of accounting profit, under section 113C of the Ordinance. Under clause 11A of Part IV of the Second Schedule to the Income Tax Ordinance, 2001, the Company is also exempt from levy of minimum tax on 'turnover' under section 113 of the Ordinance.

Deferred

Deferred tax is accounted for using the balance sheet liability method in respect of all temporary differences arising from differences between the carrying amount of assets and liabilities in the financial statements and the corresponding tax bases used in the computation of the taxable profit. However, the deferred tax is not accounted for if it arises from initial recognition of an asset or liability in a transaction other than a business combination that at the time of transaction neither affects accounting nor taxable profit or loss.

Deferred tax liabilities are generally recognized for all taxable temporary differences and deferred tax assets are recognized to the extent that it is probable that taxable profits will be available against which the deductible temporary differences, unused tax losses and tax credits can be utilized.

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

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

3.8 Provisions & contingency

Provisions are recognized when the Company has a present legal or constructive obligation as a result of past events, it is probable that an out flow of resources embodying economic benefits will be required to settle the obligation and a reliable estimate can be made of the amount of obligation. The effect of time value of money for such provisions is immaterial.

A contingent liability is disclosed when the Company has a possible obligation as a result of past events, whose existence will be confirmed only by the occurrence or non-occurrence, of one or more uncertain future events not wholly within the control of the Company; or the Company has a present legal or constructive obligation that arises from past events, but it is not probable that an outflow of resources embodying economic benefits will be required to settle the obligation, or the amount of the obligation cannot be measured with sufficient reliability.

3.9 Fair value measurement

Fair value is the price that would be received to sell an asset or paid to transfer a liability in an orderly transaction between market participants at the measurement date. The fair value measurement is based on the presumption that the transaction to sell the asset or transfer the liability takes place either:

- In the principal market for the asset or liability; or
- In the absence of principial market, in the most advantageous market for the asset or liability.

The principal or the most advantageous market is accessible by the Company. The fair value of an asset or a liability is measured using the assumptions that market participants would use when pricing the asset or liability, assuming that market participants act in their economic best interest.

A fair value measurement of a non-financial asset takes into account a market participant's ability to generate economic benefits by using the asset in its highest and best use or by selling it to another market participant that would use the asset in its highest and best use.

The Company uses valuation techniques that are appropriate in the circumstances and for which sufficient data are available to measure fair value, maximizing the use of relevant observable inputs and minimizing the use of unobservable inputs.

All assets and liabilities for which fair value is measured or disclosed in the financial statements are categorized within the fair value hierarchy, described as follows, based on the lowest level input that is significant to the fair value measurement as a whole:

- Level 1 — Quoted (unadjusted) market prices in active markets for identical assets or liabilities;
- Level 2 — Valuation techniques for which the lowest level input that is significant to the fair value measurement is directly or indirectly observable; and
- Level 3 — Valuation techniques for which the lowest level input that is significant to the fair value measurement is unobservable.

For assets and liabilities that are recognized in the financial statements at fair value on a recurring basis, the Company determines whether transfers have occurred between levels in the hierarchy by re-assessing categorization (based on the lowest level input that is significant to the fair value measurement as a whole) at the end of each reporting period.

The Company's Chief Financial Officer determines the policies and procedures for both recurring fair value measurement and for non-recurring measurement. External valuers may be involved for valuation of significant assets and significant liabilities. For the purpose of fair value disclosures, the Company determines classes of assets and liabilities on the basis of the nature, characteristics and risks of the asset or liability and the level of the fair value hierarchy, as explained above.

		2022	2021
4	**SHARE CAPITAL**	**Rupees**	Rupees
	Authorized share capital		
	1,000 (2021: 1,000) ordinary shares of Rs 100 each	100,000	100,000
	Issued, subscribed and paid up capital		
	1,000 (2021: 1,000) ordinary shares of Rs 100 each fully paid in cash	100,000	100,000

The Company has only one class of ordinary shares which carries no right to fixed income. The shareholders are entitled to receive dividend as declared from time to time and are entitled to one vote per share at meetings of the Company. All shares rank equally with regard to the Company's residual assets. 100% shareholding in the Company is held by Korea Hydro and Nuclear Power Company Limited along with its nominee directors.

5 ADVANCE AGAINST EQUITY

This represents the amount received from the parent Company for further shares in the Company. Process of issuance of shares is in progress.

		Note	2022	2021
6	**TRADE AND OTHER PAYABLES**	**Note**	**Rupees**	Rupees
	Accrued expenses		2,518,249	1,320,661
	Payable to parent Company	12	684,271	48,120
			3,202,520	1,368,781

7 CONTINGENCIES AND COMMITMENTS

There were no contingencies and commitments at reporting date (2021:Nil) except as disclosed in note 1 to the financial statements.

		Note	2022	2021
8	**ADMINISTRATIVE AND GENERAL EXPENSES**	**Note**	**Rupees**	Rupees
	Professional charges		1,158,775	1,000,000
	Auditor's remuneration	8.1	362,250	361,261
	Exchange loss - net		317,934	-
	Bank charges		-	1,536
			1,838,959	1,362,797
8.1	**Auditor's remuneration**			
	Audit fee		315,000	320,661
	Out of pocket expenses		47,250	-
	Certification charges		-	40,600
			362,250	361,261

9 FINANCIAL INSTRUMENTS AND RISK MANAGEMENT

		Note	2022	2021
9.1	**Financial assets and liabilities**			
	Maturity upto one year - amortized cost			
	Bank balance		204,655,864	105,984
	Financial liabilities :			
	Maturity up to one year - amortized cost			
	Trade and other payables	6	3,202,520	1,368,781

LSG HYDRO POWER LIMITED
NOTES TO THE FINANCIAL STATEMENTS
FOR THE YEAR ENDED DECEMBER 31, 2022

9.2 Credit quality of financial assets

The credit quality of the Company's financial assets comprising the bank balance only have been assessed below by reference to external credit ratings of counterparties determined by PACRA.

	Rating	2022 Rupees	2021 Rupees
Counterparties with external credit rating			
Habib Metropolitan Bank Ltd	A1+	**204,655,864**	105,984

9.3 FINANCIAL RISK MANAGEMENT

The Company's activities expose it to a variety of financial risks: credit risk, liquidity risk and the currency risk. The Company's overall risk management policy focuses on the unpredictability of financial markets and seeks to minimize potential adverse effects on the Company's financial performance.

Credit risk

Credit risk is the risk of financial loss to the Company if a customer or counterparty to a financial instrument fails to meet its contractual obligations, and arises principally from bank balances. The carrying amount of financial assets represents the maximum credit exposure.

Currency risk

Currency risk is the risk that the fair value or future cash flows of a financial instrument will fluctuate because of changes in foreign exchange rates. Currency risk arises mainly from future commercial transactions or USD bank balance. However there is USD 10 balance in USD account of the Company therefore the Company has negligible exposure to currency risk.

Liquidity risk

Prudent liquidity risk management implies maintaining sufficient cash and availability of funding to an adequate amount. The Company follows an effective cash management and planning policy to ensure availability of funds and to take appropriate measures for new requirements. Company's parent (Korea Hydro and Nuclear Power Limited) is committed to provide all necessary financial support to enable the Company to fulfil its liquidity requirements.

10 REMUNERATION OF CHIEF EXECUTIVE, EXECUTIVES AND DIRECTORS

The chief executive and directors of the Company are not entitled for any remuneration or benefits.

11 NUMBER OF EMPLOYEES

Total and average numbers of the employees of the Company were Nil (2021:Nil) at reporting date.

12 TRANSACTIONS WITH RELATED PARTIES

Related parties comprise of the holding company, associated companies due to common directorships and directors. Transactions with related parties are disclosed below, while balances are reflected in relevant notes:

Korea Hydro and Nuclear Power Company Limited (the Parent Company)

Provided corporate services to the Company free of any charge.

Expenses of Rs. 320,661 (2021: Rs. 147,440) paid on behalf of the Company.

DL E&C Co. Ltd. (Associated Company/Prospective equity partner)

Provided consultancy charges of Rs. 1,063,285 to the Company free of any charge.

13 GENERAL

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

14 DATE OF APPROVAL OF FINANCIAL STATEMENTS

These financial statements were approved by the Board of Directors of the Company in their meeting held on 15 MAR 2023

LSG HYDRO POWER LIMITED LSG

CHIEF EXECUTIVE OFFICER

DIRECTOR

APPENDIX-11
EXPRESSION OF INTEREST IN FINANCING

ADB

18 November 2021

Byung Soo, Jung
General Manager
Global Business & Cooperation Department
Global Hydropower Business Section
Korea Hydro and Nuclear Power Company Limited
1655 Bulguk-ro, Munmudaewang-myeon,
Gyeongju-si, Gyeongsangbuk-do, Korea 38120

Expression of Interest: 496 MW Lower Spat Gah Hydropower Project (the "Project")

Dear Mr. Jung,

We refer to the aforementioned Project which Korea Hydro & Nuclear Power Company Limited (KHNP) is presenting and requesting us to participate in its financing. KHNP has indicated that the Project consists of the design, engineering, construction and operation of a 496 MW hydro power plant located in the Kohistan District of Khyber Pakhtunkhwa Province, Pakistan. The power generated by the Project will be sold to state owned Central Power Purchasing Authority under a 30 year take-or-pay Power Purchase Agreement (PPA). It is also understood that in line with power policy of the country, the power purchaser will take the hydro risk and its obligations under the PPA will be counter guaranteed by the Government of Pakistan under an Implementation Agreement. Total project costs are estimated to be around USD 1.08 billion, to be financed by 75% debt and 25% equity. The Korean Consortium[1] will be the majority shareholder of the Project and will be responsible to develop, complete, commission and the maintain the Project.

The Asian Development Bank (ADB) is interested to consider participating - both as a lender and as a minority shareholder - in the financing of the Project. Such financing would be dependent upon a number of factors including our full satisfaction with the Project's financial, economic, environmental, integrity, social, procurement, [2] structural and documentary underpinnings as well as the receipt of all requisite internal approvals and compliance with other guidelines set by ADB. Accordingly, ADB's interest in providing financing to the Project is subject to satisfaction of its due diligence review of the Project, and approval by ADB's management, Investment Committee, and Board of Directors. The amount and terms of ADB's financing facilities will be discussed at the appropriate stage but will be capped at up to $150 million of A Loan and up to $150 million of B loan with PRG and Parallel loans.

[1] The Korean Consortium is comprised of KHNP, Korea Oversees Infrastructure and Urban Development Corporation (KIND), Lotte Engineering and Construction, and Korea Plant Service and Engineering collectively holding 83% of the Project equity with respective company's shareholding being 34%, 26%, 18% and 15%.

[2] Including valid Memorandum of Understanding, which approves KHNP as the main sponsor of the Project replacing Korea Midland Power (KOMIPO) issued by relevant authorities.

ASIAN DEVELOPMENT BANK
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
Tel +63 2 8632 4444
Fax +63 2 8636 2444
www.adb.org

We would be pleased to enter into more detailed discussions with you on the financing of the Project once you have further advanced your discussions with the relevant Government authorities. Nothing herein shall constitute an offer or commitment by ADB to provide financing for the Project. If you have any questions or clarifications, please do not hesitate to contact Haroun Khawaja, Principal Investment Specialist (phone: +63-2-8632-6312 / email: hkhawaja@adb.org).

Yours sincerely,

Shantanu Chakraborty
Director
Infrastructure Finance, South Asia,
Central Asia, and West Asia
Private Sector Operations Department

Korea Eximbank
THE EXPORT-IMPORT BANK OF KOREA
38, Eunhaeng-ro, Yeongdeungpo-gu, Seoul 07242, Korea
Tel. 822-3779-6114 Fax. 822-784-1030

www.koreaexim.go.kr

May 11th, 2022

To: Korea Hydro & Nuclear Power Co., Ltd. ("KNHP")
1655 Bulguk-ro, Munmudaewang-myeon, Gyeongju-si
Gyeongsangbuk-do, Republic of Korea

Re: Lower Spat Gah Hydroelectric Power Plant Project ("Project")

Dear Sirs/Madams,

We, the Export-Import Bank of Korea ("KEXIM"), refer to your request for an indication of our willingness to consider financial support for the Project.

On the basis of the information available at this stage, we are pleased to advise you that we would consider providing financing for the Project. Please note however that our decision to provide financing shall be conditional upon the financial, technical, and economic soundness of the project. Upon receipt of a formal application for financing, KEXIM will conduct its standard due diligence and make a decision to provide financing in accordance with the prevailing KEXIM policies.

It should be noted that this letter does not constitute a commitment to provide financing for the Project. Nothing in this letter creates any legally binding obligation or constitutes a basis for any liability on the part of us. A formal commitment for financing shall be based upon legal and policy considerations in effect at such time the commitment is made.

We thank you for inviting us to consider this Project and we look forward to working with you in the near future. If you have any question arising from this Letter of Support, please contact Hyunshik Hwang (Director, Alternative Energy Industry Team) at +82-2-6255-5381, hshwang@koreaexim.go.kr.

Sincerely yours,

양 구 정

Koo-jung Yang
Director General
Infrastructure Finance Department
The Export-Import Bank of Korea

APPENDIX-12
PROFILES OF TECHNICAL & PROFESSIONAL STAFF

1.	**Curriculum Vitae/Resume**
a	Name: (former name if any): Seung-yeol Lim
b	Father's Name: In-gyu Lim
c	Passport #: M39696501
d	Latest photograph: 
e	Nationality: Republic of KOREA
f	Age: 51
g	Contact details:
	i) Residential address: 23, Jinhyeon-ro, Gyeongju-si, Gyeongsangbbuk-do Korea
	ii) Business address: [PO:38120] 1655, Bulguk-ro, Yangbuk-myeon, Gheongju-si,
	iii) Tel: +82-54-704-7600
	iv) Mobile: +82-10-6246-4059
	v) Fax: +82-502-734-0263
	vi) E-mail: sylim000@khnp.co.kr
g	National Tax Number: N/A
h	Present occupation: Korea Hydro & Nuclear Power co., LTD.
i	Qualification(s):
	(i) Academic: Bachelor's degree Yonsei University (ii) Academic: MBA, University of North Carolina
j	**Trainings**: N/A

k	**Experience:** 2022 ~ Present : Vice President, Overseas Business Development Department, KHNP 2019 ~ 2022 : Vice President, New Nuclear Business Department 2018 ~ 2019 : Vice President, Global Strategy Office
2.	**Status of directorship** **Shareholder** ☐ **Nominee** ■ **Name of the shareholders/ Group of shareholders he is representing:** **Nature of directorship** Executive ■ Non-executive ☐ **Independent** ☐ **Non-independent** ■ Number of shares subscribed or held:
3.	The proposed person is a CEO.

Signature ______________________

CV Format

Moonsoo Myung
Address: 5-22, Gumae3-gil Gyeongju-si Gyeongsangbuk-do Korea
☎: Tel: +82-54-704-7900 Fax: +82-502-734-0214

Email: ms.myung@khnp.co.kr | **Mobile:** +82-10-8865-5137 | **CNIC/Passport:** M04655694

Education

Degree Year	Degree Name	Institute
2001	Bachelor's degree Mechanical Engineering	Hanyang University

Experience

Position Title	**General Manager**
Organization	Korea Hydro and Nuclear Power Co. Ltd.
From - To	2021 to Present
Responsibilities	Business Development
Position Title	**Senior Manager**
Organization	Korea Hydro and Nuclear Power Co. Ltd.
From - To	2012 ~ 2021
Responsibilities	Hanggang Hydro Power Site, KHNP

CV Format

Changhoo Oh

Address: 1655, Bulguk-ro, Yangbuk-myeon, Gheongju-si, Gyeongsangbuk-do, Korea
Tel: +82-54-704-7842

Email: chang.oh@khnp.co.kr | **Mobile:** +82-10-8539-9169 | **CNIC/Passport:** M44506788

Education

Degree Year	Degree Name	Institute
2003	Bachelor of Engineering	Pusan National University
2017	Master of Engineering	KEPCO International Nuclear Graduate School

Experience

Position Title	**Senior Manager**
Organization	Global Business Department, Korea Hydro and Nuclear Power Co. Ltd.
From - To	2019.01 to present
Responsibilities	Development New Business
Position Title	**Senior Manager**
Organization	Construction Engg. Department, Korea Hydro and Nuclear Power Co. Ltd.
From - To	2018.01 to 2019.01
Responsibilities	Construction Engineering for Nuclear Power Plant
Position Title	**Senior Manager**
Organization	Public Relation Department, Korea Hydro and Nuclear Power Co. Ltd.
From - To	2016.01 to 2018.01
Responsibilities	Public Relation for Power Plant

CV Format

Bae Wan Seok
Address: One Constitution Avenue, Islamabad
Tel: 051- 6134782

Email: baewanseok@lsg-hydro.com | **Mobile:** +82-1030018779 | **CNIC/Passport: M72066660**

Education

Degree Year	Degree Name	Institute
1991	High School	Kumho High School
1997	Bachelor of Civil Engineering	Honam University

Experience

Position Title	**Senior Manager**
Organization	Korea Hydro & Nuclear Power Co., Ltd..
From - To	1996 – till Date
Responsibilities	• **Senior Manager** - Global Hydro-Power Business Department,Head office (2017 ~) - CheonJi Nuclear Power Division (2016 ~ 2017) - UAE Nuclear Power Project (2011 ~ 2016) - Shin Han-ul Nuclear Power 1&2 Project (2009 ~ 2011) • **Manager** - Nuclear Power Project Division. (2005 ~ 2009) - KEDO Nuclear Power Project Team (2001 ~ 2005) • **Supervisor** - Seoul Distribution Line Undergrounding Project Site (1999 ~ 2001) - Young-Gwang Nuclear Power 5&6 Construction Site (1996 ~ 1999)

CV Format

Choi Hyun Joon

Address: House 10, St20, F8/2, Islamabad

☎Tel:

Email: hyunjoon.choi@lsg-hydro.com Mobile: +92-0318-053-2977 | CNIC/Passport: M570L0621

Education

Degree Year	Degree Name	Institute
2008	Bachelor of Mechanical Engineering	Gyeongsang National University
2021	Master of Energy Change	Australian National University

Experience

Position Title	**Senior Manager**
Organization	Korea Hydro & Nuclear Power Co., Ltd
From - To	2009 – Till Date
Responsibilities	**Senior Manager** - Global Hydro-Power Business department, Head office (2016 ~) ▪ **Manager** - Project manager Hydropower Tech. Team, Head office (2012 ~ 2015) - Supervisor, Nepal Chameliya Hydro Power Project (2011 ~ 2012) - Supervisor, Yecheon Pumped Storage Power Plant (2009 ~ 2011)

CV Format

Kashif Farhan
Address: House No 220, Street No 1, D12/3
☎: Tel: 051-6134728

Email: kashif@lsg-hydro.com | **Mobile:** 0333- 333 4471 | **CNIC/Passport:** 61101-0224193-1

Education

Degree Year	Degree Name	Institute
2009	BSC Business Management	Queen Mary, University of London
2011	MSC Banking and Finance	Queen Mary, University of London

Experience

Position Title	**Senior Manager**
Organization	LSG Hydro Power Ltd.
From - To	June 2018 - Till date
Responsibilities	• Meetings with Government Officails regarding Project Development • Handling company business with various departments including Ministry of Energy and Power GoKPK, Ministry of Planning and Development GoKPK, NEPRA,PEDO,PPIB, CPPA-G, NTDC and EPA
Position Title	**General Manager**
Organization	Global Green Solution
From - To	Nov 2015 – Jan 2017
Responsibilities	• Business Development

CV Format

Muhammad Khurram Khan
Address: House. No 40/B, Street 8, Westridge 1, Rawalpindi.
■: Tel: 051-6134728
Email: Khurram_khan@lsg-hydro.com | **Mobile:** 0301- 5133322 | **CNIC/Passport:** 3745-6261490-5

Education

Degree Year	Degree Name	Institute
2016	Bachelor of Business Administration	University of Southern Queensland

Experience

Position Title	**Manager**
Organization	LSG Hydro Power Ltd.
From - To	2 May 2023 - Till date
Responsibilities	• Meetings with Government Officials regarding Project Development • Handling company business with various departments including Ministry of Energy and Power GoKPK, Ministry of Planning and Development GoKPK, NEPRA,PEDO,PPIB, CPPA-G, NTDC and EPA
Position Title	**Project Coordinator**
Organization	Target Energy (Pvt) Ltd
From - To	Dec 2016 – Apr 2023
Responsibilities	• Development of 50 MW Solar Power Project • Meetings with Government Officials regarding Project Development • Coordination with departments including, GoKPK, NEPRA, PEDO, CPPA-G, NTDC and EPA • Coordination with other Consultants related to the Project and EPC Contractors

CV Format

Jibran Afzal Afridi

Address: House No 220, Street No 1, D12/3
: Tel: 051-613-4782

Email: jibran@lsg-hydro.com | **Mobile:** 0321- 5046300 | **CNIC/Passport:** 13101-0873274-3

Education

Degree Year	Degree Name	Institute
2007	BBIT Marketing	IQRA University – Islamabad
2010	MBA Finance	Bahria University – Islamabad

Experience

Position Title	**Manager**
Organization	LSG Hydro Power Ltd.
From - To	Feb 2023 - Till date
Responsibilities	• Sourcing and Supplier Management • Office Operations • Budgeting and Expense Management • Human Resources Support • Team Support • Compliance and Ethics • Administrative Support
Position Title	**Office Manager**
Organization	RIZ Consultancy
From - To	1st Dec 2014 –30th Nov 2021
Responsibilities	• Day-to-day management of the Facility in consultation with the EOC emergency coordinator • Prepare detailed work-plans for seamless EOC functioning. • Organize, facilitate, participate in and follow-up with meetings with all stakeholders. • Review all materials generated during the project.

CV Format

Nasir Uddin

Address: Mohalla Hakamabad Village Tighak PO Totanobandai, Kabal, Swat, KPK
☎: 0341-9421996

Email: nasir@lsg-hydro.com | **Mobile:** 0341-9421996 | **CNIC/Passport:** 15602-2809790-1
nasir92swt@gmail.com

Education

Degree Year	Degree Name	Institute
2014	BE/BSc Civil Engineering	Sarhad University of Science & IT, Peshawar

Experience

Position Title	**Manager**
Organization	LSG Hydro Power Limited
From - To	Aug-2022 to Present
Responsibilities	• Working as a technical team member, collection of information, coordination and networking with relevant governmental authorities, negotiation and issuance of business documents and any other activities associated with project.
Position Title	**Planning Engineer**
Organization	Sambu Construction Co. Pvt. Ltd. (Lowari Tunnel Project)
From - To	May-2016 to July-2022
Responsibilities	• Work Schedule for the execution of Construction Activities. • Preparation and updating work program according to the site condition. • Monitor day-to-day work progress and prepare the daily, weekly and monthly progress report. • Preparing work method statements as per specifications and drawings. • Preparing Interim Payment Application and Variation Order. • Management of Sub-Contractors. • Application of sources and quality of material for permanent works. • Making Shop Drawings, As-Built Drawings and Bar Binding Schedule. • Coordination meetings with consultant, Employer and local administration regarding site issue.

Saman Sardar
Address: 16 G 720 POF WAHCANTT

Email: saman@lsg-hydro.com | **Mobile:** 0303-8193470 | **CNIC/Passport:** 37101-1887947-2

Education

Degree Year	Degree Name	Institute
2022	BS Accounting & Finance	International Islamic University, Islamabad, Pakistan
2023	Diploma Korean Language	National University of Modern Languages, Islamabad, Pakistan

Experience

Position Title	**Officer**
Organization	LSG Hydro Power Ltd.
From - To	June 2023 - Till date
Responsibilities	• Work with management to accurately track income and expenses, provide reports to the company. • Bookkeeping of data to ensure all financial data is input into accounting software and process invoices, checks, and payroll accurately and on time and resolve any invoice issues. • Responsible for maintaining, organizing, and updating documents for business. Also responsible for using document management software to upload or scan paper documents, retrieving documents for authorized personnel and ensuring document storage to comply with laws and regulations.
Position Title	**Internship**
Organization	United Bank Limited
From - To	July 2022 – August 2022
Responsibilities	• Work with management to manage branch's daily operations in different sections including Account opening, checkbook section, Remittance section, Clearance section

APPENDIX-13
EXPERIENCE OF SPONSORS

PROJECT DEVELOPMENT EXPERIENCE OF SPONSORS

No.	Project Name	Type	Capacity	Completion
1	Yecheon Pumped Storage Power Plant	PSPP	800 MW	2011
2	Cheongsong Pumped Storage Power Plant	PSPP	600 MW	2006
3	Yangyang Pumped Storage Power Plant	PSPP	1,000 MW	2006
4	Sancheong Pumped Storage Power Plant	PSPP	700 MW	2001
5	Shin-Wolsong #1, #2 Nuclear Power Plant	NPP(PWR)	2,000 MW	2015
6	Shin-Kori #1, #2 Nuclear Power Plant	NPP(PWR)	2,000 MW	2012
7	Hanul #5, #6 Nuclear Power Plant	NPP(PWR)	2,000 MW	2005
8	Hanbit #5, #6 Nuclear Power Plant	NPP(PWR)	2,000 MW	2002

PSPP: Pumped Storage Power Project

NPP: Nuclear Power Project

No.	Item	Information
1	**Name of the Applicant or Consortium member**	Korea Hydro & Nuclear Power Co., Ltd.
2	**Applicant or member's role in the project completed**	Lead Project Developer PM, Supervision, Procurement and Commissioning
3	**Name of project**	Yecheon Pumped Storage Power Plant
4	**Applicant or member's share of equity in the completed project** (if applicable)	KHNP's equity: 100%
5	**Location of plant**	Yecheon-gun, Gyeongsangbuk-do, Korea
6	**Name of owner** (including contact person, his address and telephone, fax No. / email address)	Korea Hydro & Nuclear Power Co., Ltd. - Mr. Choonsool Lee - 1655 Bulguk-ro, Gyeongju-si, Gyeongsangbuk-do, Korea - choonsoollee@khnp.co.kr / +82-054-704-7850
7	**Name of power purchaser**	Korea Electric Power Corporation
8	**Capacity of plant**	800 MW
9	**Type of plant**	Pumped Storage Power
10	**Fuel of plant**	Water
11	**Number and rated capacity of units**	400 MW X 2 units
12	**Status of plant**	Commercial Operation
13	**Principal manufacturers of major equipment**	Turbine(Pump): Alstom Generator(Motor): Alstom
14	**List of specific major tasks/services performed by Applicant**	PM, Supervision, Procurement and Commissioning
15	**Date of award of project**	September 2003
16	**Duration of construction period**	100 months (September 2003 ~ December 2011)
17	**Commercial operations date of each unit**	Unit #1: August 2011 Unit #2: October 2011
18	**Total capital cost of project**	USD 637 mil
19	**Companies and institutions who financed the project**	Korea Hydro & Nuclear Power Co., Ltd.
20	**Value of contract**	USD 637 mil
21	**Any other details**	2 CFRDs (Upper & Lower)

No.	Item	Information
1	**Name of the Applicant or Consortium member**	Korea Hydro & Nuclear Power Co., Ltd.
2	**Applicant or member's role in the project completed**	Lead Project Developer PM, Supervision, Procurement and Commissioning
3	**Name of project**	Cheongsong Pumped Storage Power Plant
4	**Applicant or member's share of equity in the completed project** (if applicable)	KHNP's equity: 100%
5	**Location of plant**	Cheongsong-gun, Gyeongsangbuk-do, Korea
6	**Name of owner** (including contact person, his address and telephone, fax No. / email address)	Korea Hydro & Nuclear Power Co., Ltd. - Mr. Choonsool Lee - 1655 Bulguk-ro, Gyeongju-si, Gyeongsangbuk-do, Korea - choonsoollee@khnp.co.kr / +82-054-704-7850
7	**Name of power purchaser**	Korea Electric Power Corporation
8	**Capacity of plant**	600 MW
9	**Type of plant**	Pumped Storage Power
10	**Fuel of plant**	Water
11	**Number and rated capacity of units**	300 MW X 2 units
12	**Status of plant**	Commercial Operation
13	**Principal manufacturers of major equipment**	Turbine(Pump): GE Generator(Motor): GE
14	**List of specific major tasks/services performed by Applicant**	PM, Supervision, Procurement and Commissioning
15	**Date of award of project**	September 2000
16	**Duration of construction period**	75 months (September 2000 ~ December 2006)
17	**Commercial operations date of each unit**	Unit #1: September 2006 Unit #2: December 2006
18	**Total capital cost of project**	USD 363 mil
19	**Companies and institutions who financed the project**	Korea Hydro & Nuclear Power Co., Ltd.
20	**Value of contract**	USD 363 mil
21	**Any other details**	2 CFRDs (Upper & Lower)

No.	Item	Information
1	**Name of the Applicant or Consortium member**	Korea Hydro & Nuclear Power Co., Ltd.
2	**Applicant or member's role in the project completed**	Lead Project Developer PM, Supervision, Procurement and Commissioning
3	**Name of project**	Yangyang Pumped Storage Power Plant
4	**Applicant or member's share of equity in the completed project** (if applicable)	KHNP's equity: 100%
5	**Location of plant**	Inje-gun, Gangwon-do, Korea
6	**Name of owner** (including contact person, his address and telephone, fax No. / email address)	Korea Hydro & Nuclear Power Co., Ltd. - Mr. Choonsool Lee - 1655 Bulguk-ro, Gyeongju-si, Gyeongsangbuk-do, Korea - choonsoollee@khnp.co.kr / +82-054-704-7850
7	**Name of power purchaser**	Korea Electric Power Corporation
8	**Capacity of plant**	1,000 MW
9	**Type of plant**	Pumped Storage Power
10	**Fuel of plant**	Water
11	**Number and rated capacity of units**	250 MW X 4 units
12	**Status of plant**	Commercial Operation
13	**Principal manufacturers of major equipment**	Turbine(Pump): Alstom Generator(Motor): Doosan Heavy Industry & Construction Co., Ltd.
14	**List of specific major tasks/services performed by Applicant**	PM, Supervision, Procurement and Commissioning
15	**Date of award of project**	September 1996
16	**Duration of construction period**	120 months (September 1996 ~ August 2006)
17	**Commercial operations date of each unit**	Unit #1: February 2006 Unit #2: April 2006 Unit #3: June 2006 Unit #4: August 2006
18	**Total capital cost of project**	USD 712 mil
19	**Companies and institutions who financed the project**	Korea Hydro & Nuclear Power Co., Ltd.
20	**Value of contract**	USD 712 mil
21	**Any other details**	1 CFRD (Upper), 1 CGD (Lower)

No.	Item	Information
1	**Name of the Applicant or Consortium member**	Korea Hydro & Nuclear Power Co., Ltd.
2	**Applicant or member's role in the project completed**	Lead Project Developer PM, Supervision, Procurement and Commissioning
3	**Name of project**	Sancheong Pumped Storage Power Plant
4	**Applicant or member's share of equity in the completed project** (if applicable)	KHNP's equity: 100%
5	**Location of plant**	Sancheong-gun, Gyeongsangnam-do, Korea
6	**Name of owner** (including contact person, his address and telephone, fax No. / email address)	Korea Hydro & Nuclear Power Co., Ltd. - Mr. Choonsool Lee - 1655 Bulguk-ro, Gyeongju-si, Gyeongsangbuk-do, Korea - choonsoollee@khnp.co.kr / +82-054-704-7850
7	**Name of power purchaser**	Korea Electric Power Corporation
8	**Capacity of plant**	700 MW
9	**Type of plant**	Pumped Storage Power
10	**Fuel of plant**	Water
11	**Number and rated capacity of units**	350 MW X 2 units
12	**Status of plant**	Commercial Operation
13	**Principal manufacturers of major equipment**	Turbine(Pump): Alstom Generator(Motor): Alstom
14	**List of specific major tasks/services performed by Applicant**	PM, Supervision, Procurement and Commissioning
15	**Date of award of project**	July 1994
16	**Duration of construction period**	90 months (July 1994 ~ December 2001)
17	**Commercial operations date of each unit**	Unit #1: September 2001 Unit #2: November 2001
18	**Total capital cost of project**	USD 532 mil
19	**Companies and institutions who financed the project**	Korea Hydro & Nuclear Power Co., Ltd.
20	**Value of contract**	USD 532 mil
21	**Any other details**	2 CFRDs (Upper & Lower)

No.	Item	Information
1	**Name of the Applicant or Consortium member**	Korea Hydro & Nuclear Power Co., Ltd.
2	**Applicant or member's role in the project completed**	Lead Project Developer PM, Supervision, Procurement and Commissioning
3	**Name of project**	Shin-Kori #3, #4 Nuclear Power Plant
4	**Applicant or member's share of equity in the completed project** (if applicable)	KHNP's equity: 100%
5	**Location of plant**	Seosaeng, Ulju, Ulsan, Korea
6	**Name of owner** (including contact person, his address and telephone. fax No. / email address)	Korea Hydro & Nuclear Power Co., Ltd. - Mr. Choonsool Lee - 1655 Bulguk-ro, Gyeongju-si, Gyeongsangbuk-do, Korea - choonsoollee@khnp.co.kr / +82-054-704-7850
7	**Name of power purchaser**	Korea Electric Power Corporation
8	**Capacity of plant**	2,800 MW
9	**Type of plant**	PWR (Pressurized Water Reactor)
10	**Fuel of plant**	Nuclear
11	**Number and rated capacity of units**	1,400 MW X 2 units
12	**Status of plant**	Commercial Operation
13	**Principal manufacturers of major equipment**	Nuclear Reactor: Doosan Heavy Industry & Construction Co., Ltd. T/G: Doosan Heavy Industry & Construction Co., Ltd.
14	**List of specific major tasks/services performed** by **Applicant**	PM, Supervision, Procurement and Commissioning
15	**Date of award of project**	September 2007
16	**Duration of construction period**	144 months (September 2007 ~ August 2019)
17	**Commercial operations date of each unit**	Unit #3: December 2016 Unit #4: August 2019
18	**Total capital cost of project**	N/A
19	**Companies and institutions who financed the project**	Korea Hydro & Nuclear Power Co., Ltd.
20	**Value of contract**	N/A
21	**Any other details**	N/A

No.	Item	Information
1	**Name of the Applicant or Consortium member**	Korea Hydro & Nuclear Power Co., Ltd.
2	**Applicant or member's role in the project completed**	Lead Project Developer PM, Supervision, Procurement and Commissioning
3	**Name of project**	Shin-Wolsong #1, #2 Nuclear Power Plant
4	**Applicant or member's share of equity in the completed project** (if applicable)	KHNP's equity: 100%
5	**Location of plant**	Yangnam, Gyeongju, Korea
6	**Name of owner** (including contact person, his address and telephone. fax No. / email address)	Korea Hydro & Nuclear Power Co., Ltd. - Mr. Choonsool Lee - 1655 Bulguk-ro, Gyeongju-si, Gyeongsangbuk-do, Korea - choonsoollee@khnp.co.kr / +82-054-704-7850
7	**Name of power purchaser**	Korea Electric Power Corporation
8	**Capacity of plant**	2,000 MW
9	**Type of plant**	PWR (Pressurized Water Reactor)
10	**Fuel of plant**	Nuclear
11	**Number and rated capacity of units**	1,000 MW X 2 units
12	**Status of plant**	Commercial Operation
13	**Principal manufacturers of major equipment**	Nuclear Reactor: Doosan Heavy Industry & Construction Co., Ltd. T/G: Doosan Heavy Industry & Construction Co., Ltd.
14	**List of specific major tasks/services performed by Applicant**	PM, Supervision, Procurement and Commissioning
15	**Date of award of project**	November 2007
16	**Duration of construction period**	96 months (November 2007 ~ November 2015)
17	**Commercial operations date of each unit**	Unit #1: July 2012 Unit #2: July 2015
18	**Total capital cost of project**	N/A
19	**Companies and institutions who financed the project**	Korea Hydro & Nuclear Power Co., Ltd.
20	**Value of contract**	N/A
21	**Any other details**	N/A

No.	Item	Information
1	**Name of the Applicant or Consortium member**	Korea Hydro & Nuclear Power Co., Ltd.
2	**Applicant or member's role in the project completed**	Lead Project Developer PM, Supervision, Procurement and Commissioning
3	**Name of project**	Shin-Kori #1, #2 Nuclear Power Plant
4	**Applicant or member's share of equity in the completed project** (if applicable)	KHNP's equity: 100%
5	**Location of plant**	Gijang, Busan, Korea
6	**Name of owner** (including contact person. his address and telephone. fax No. / email address)	Korea Hydro & Nuclear Power Co., Ltd. - Mr. Choonsool Lee - 1655 Bulguk-ro, Gyeongju-si, Gyeongsangbuk-do, Korea - choonsoollee@khnp.co.kr / +82-054-704-7850
7	**Name of power purchaser**	Korea Electric Power Corporation
8	**Capacity of plant**	2,000 MW
9	**Type of plant**	PWR(Pressurized Water Reactor)
10	**Fuel of plant**	Nuclear
11	**Number and rated capacity of units**	1,000 MW X 2 units
12	**Status of plant**	Commercial Operation
13	**Principal manufacturers of major equipment**	Nuclear Reactor: Doosan Heavy Industry & Construction Co., Ltd. T/G: Doosan Heavy Industry & Construction Co., Ltd.
14	**List of specific major tasks/services performed by Applicant**	PM. Supervision, Procurement and Commissioning
15	**Date of award of project**	June 2006
16	**Duration of construction period**	79 months (June 2006 ~ December 2012)
17	**Commercial operations date of each unit**	Unit #1: February 2011 Unit #2: July 2012
18	**Total capital cost of project**	N/A
19	**Companies and institutions who financed the project**	Korea Hydro & Nuclear Power Co., Ltd.
20	**Value of contract**	N/A
21	**Any other details**	N/A

No.	Item	Information
1	**Name of the Applicant or Consortium member**	Korea Hydro & Nuclear Power Co., Ltd.
2	**Applicant or member's role in the project completed**	Lead Project Developer PM, Supervision, Procurement and Commissioning
3	**Name of project**	Hanul #5, #6 Nuclear Power Plant
4	**Applicant or member's share of equity in the completed project** (if applicable)	KHNP's equity: 100%
5	**Location of plant**	Ulchin, Gyeongsangbuk-do, Korea
6	**Name of owner** (including contact person, his address and telephone, fax No. / email address)	Korea Hydro & Nuclear Power Co., Ltd. - Mr. Choonsool Lee - 1655 Bulguk-ro, Gyeongju-si, Gyeongsangbuk-do, Korea - choonsoollee@khnp.co.kr / +82-054-704-7850
7	**Name of power purchaser**	Korea Electric Power Corporation
8	**Capacity of plant**	2,000 MW
9	**Type of plant**	PWR(Pressurized Water Reactor)
10	**Fuel of plant**	Nuclear
11	**Number and rated capacity of units**	1,000 MW X 2 units
12	**Status of plant**	Commercial Operation
13	**Principal manufacturers of major equipment**	Nuclear Reactor: Doosan Heavy Industry & Construction Co., Ltd./ Kepco-enc / WEC T/G: Doosan Heavy Industry & Construction Co., Ltd. / GE
14	**List of specific major tasks/services performed by Applicant**	PM, Supervision, Procurement and Commissioning
15	**Date of award of project**	October 1999
16	**Duration of construction period**	71 months (October 1999 ~ August 2005)
17	**Commercial operations date of each unit**	Unit #5: July 2004 Unit #6: April 2005
18	**Total capital cost of project**	N/A
19	**Companies and institutions who financed the project**	Korea Hydro & Nuclear Power Co., Ltd.
20	**Value of contract**	N/A
21	**Any other details**	N/A

No.	Item	Information
1	**Name of the Applicant or Consortium member**	Korea Hydro & Nuclear Power Co., Ltd.
2	**Applicant or member's role in the project completed**	Lead Project Developer PM, Supervision, Procurement and Commissioning
3	**Name of project**	Hanbit #5, #6 Nuclear Power Plant
4	**Applicant or member's share of equity in the completed project** (if applicable)	KHNP's equity: 100%
5	**Location of plant**	Yonggwang. Jeollanam-do, Korea
6	**Name of owner** (including contact person. his address and telephone. fax No. / email address)	Korea Hydro & Nuclear Power Co., Ltd. - Mr. Choonsool Lee - 1655 Bulguk-ro, Gyeongju-si, Gyeongsangbuk-do, Korea - choonsoollee@khnp.co.kr / +82-054-704-7850
7	**Name of power purchaser**	Korea Electric Power Corporation
8	**Capacity of plant**	2.000 MW
9	**Type of plant**	PWR(Pressurized Water Reactor)
10	**Fuel of plant**	Nuclear
11	**Number and rated capacity of units**	1,000 MW X 2 units
12	**Status of plant**	Commercial Operation
13	**Principal manufacturers of major equipment**	Nuclear Reactor: Korea Heavy Industry & Construction Co., Ltd. / Kepco-enc / WEC T/G: Korea Heavy Industry & Construction Co., Ltd. / GE
14	**List of specific major tasks/services performed by Applicant**	PM. Supervision. Procurement and Commissioning
15	**Date of award of project**	June 1997
16	**Duration of construction period**	68 months (June 1997 ~ February 2003)
17	**Commercial operations date of each unit**	Unit #5: May 2002 Unit #6: December 2002
18	**Total capital cost of project**	N/A
19	**Companies and institutions who financed the project**	Korea Hydro & Nuclear Power Co., Ltd.
20	**Value of contract**	N/A
21	**Any other details**	N/A

APPENDIX-14
TECHNICAL & FINANCIAL PROPOSAL

470 MW LOWER SPAT GAH HYDROPOWER PROJECT

PROJECT DEVELOPMENT

Approach & Methodology

Table of Contents

SECTION-A: UNDERSTANDING OF PROJECT DEVELOPMENT

1. SECTOR OVERVIEW

Hydropower is one of the renewable energy technologies presently commercially viable on a large scale. It has four major advantages: it is renewable, it produces negligible amounts of greenhouse gases, it is the least cost way of storing large amounts of electricity (in the shape of the reservoir), and it can easily adjust the amount of electricity produced to the amount demanded by consumers. The world's hydropower installed capacity rose to 1,292 gigawatts (GW) in 2018, generating a record 4,200 terawatt hours (TWh). Hydropower is among the cleanest sources of electricity, with an estimated median greenhouse gas emission intensity of 18.5 gCO2-eq/kWh[1].

Electricity in Pakistan is produced through a combination of public and private sector entities, from hydel, thermal, nuclear and wind sources. Public sector entities include Water and Power Development Authority (WAPDA), Pakistan Electric Power Company (PEPCO), Pakistan Atomic Energy Commission (PAEC) and other provincial energy development institutions like PEDO.

The private sector contributes as Independent Power Producers (IPPs), facilitated and overseen by the Private Power & Infrastructure Board (PPIB) and other related authorities designated with the task. As per NEPRA's State of Industry Report, the country's Installed Capacity was 35,979 MW as of June 30, 2018. The share of hydropower in total installed capacity has decreased from 30% in 2014 to 24% in 2018, while the share of thermal projects in total installed capacity of the project has continuously increased since the last decade. Currently, 67% of the total installed capacity in the country is based on thermal power plants.

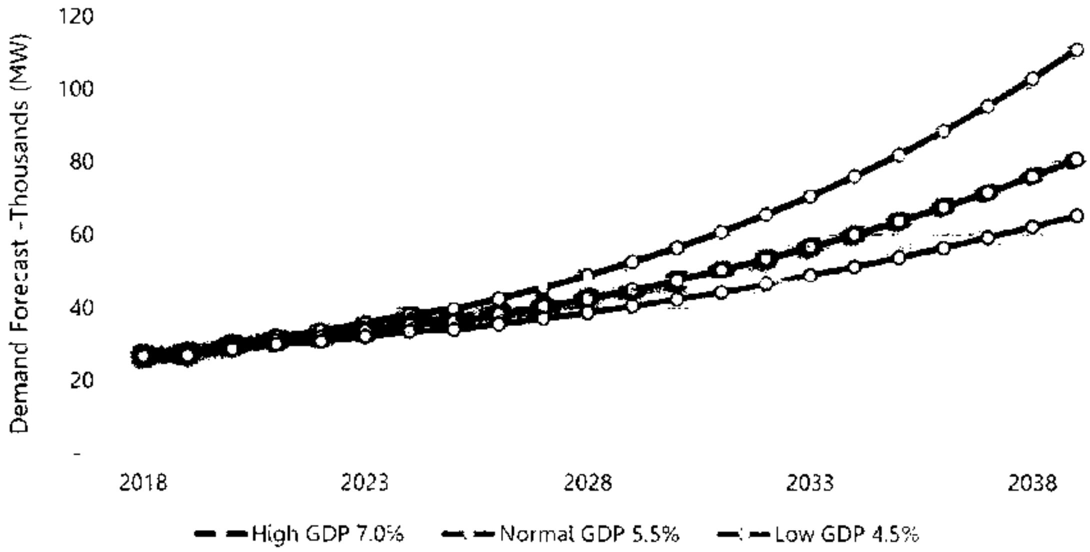
Up till 2014, the total installed capacity of the public sector companies was higher than private power producers; however, the situation has reversed during the last 5 years, and the public sector now holds only 43% of the total installed capacity of the country. Hydropower has rapidly lost its share in the total energy mix during the last 15 years. The year 2003 witnessed a 32% share of hydropower in the total installed capacity of the project connected with the PEPCO system, which has been reduced to 27% in 2017 and 21% in 2018. During the same period, generation from thermal power projects

[1] 2018 Hydropower Status Report by IHA

increased from 36% to 69%. As per NEPRA's State of Industry Report 2018, the hydropower production pattern over the year shows a downward trend compared to the historical trends owing to seasonal variations and water flows.

The country has witnessed an acute energy shortfall since 2008, which has directly squeezed the country's overall economy and caused immense public unrest as well. More than 12,000 MW of generation capacity has been added during the last 5 years, which has helped to curtail the problem to a large extent.

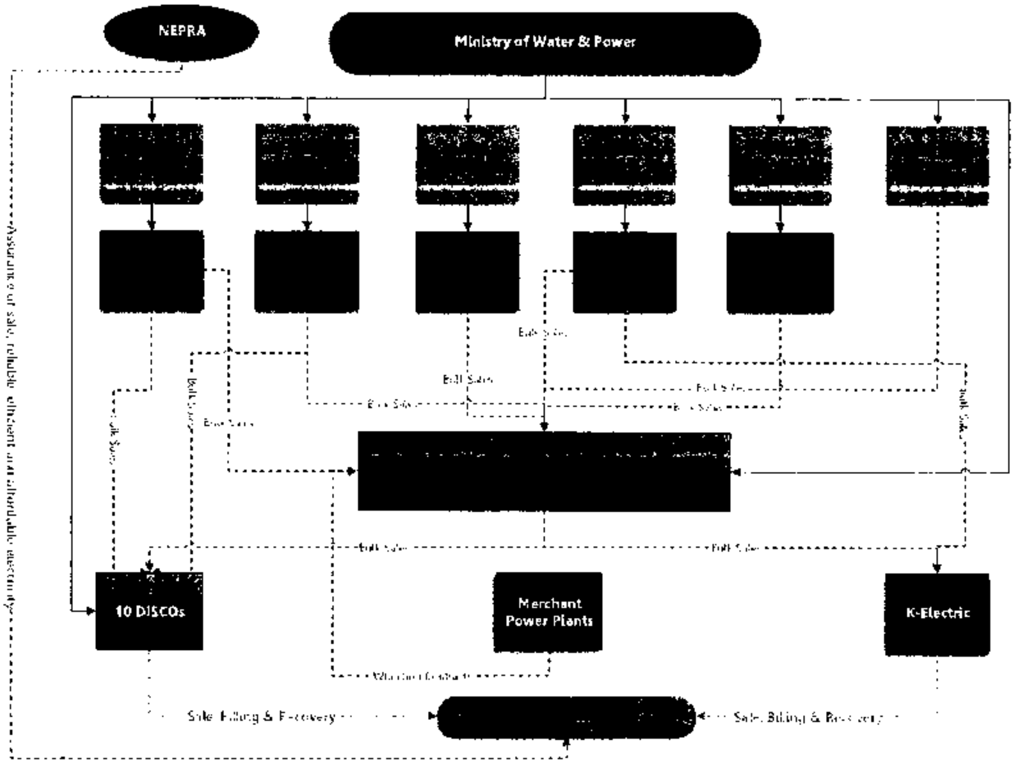
In February 2019, as per NEPRA's Grid Code PC 4 obligation, NTDC submitted an Indicative Generation Capacity Expansion Plan ("IGCEP"), which outlines the expected demand and plan for the induction of new projects to meet this demand.



2. POWER POLICY & REGULATORY FRAMEWORK

The power sector in Pakistan is based on a single-buyer model, where CPPA buys electricity from all generating units (Public & Private) except KESC and some IPPs, which sell electricity directly to KESC. CPPA employs the services of the National Transmission & Despatch Company (NTDC) to evacuate power from generation companies and expends the same to Distribution Companies (DISCOs). Ten DISCOs are functioning under the supervision of PEPCO, which is responsible for dispensing and troubleshooting the electricity to end-use consumers. DISCOs keep a record of & collect bills from end users/ consumers throughout the country except for Karachi.

Power Sector Contractual Framework in Pakistan



The government of Khyber Pakhtunkhwa introduced its updated Policy for Hydropower Generation Projects 2016 to attract foreign investment in the province for the development of new power projects to meet the energy shortfall. Pakhtunkhwa Energy Development Organization ("PEDO") looks after the matters of Independent Power Producers in the development phase and provides one window facility for the development of new power projects in Khyber Pakhtunkhwa province.

3. SALIENT FEATURES OF THE POWER POLICIES

i. Hydropower projects on a BOOT basis

ii. The balanced risk profile for investors, lenders and government agencies through the time-tested institutional and legal framework

iii. Independent Regulator (NEPRA) for balancing interests of consumers and power generation companies

iv. Multi-Year, Long-term Tariff approved by the NEPRA

v. Attractive and competitive return on investment allowed by the NEPRA

vi. Long-term Security Package including Implementation and Power

Purchase Agreements and Water Use License (for Hydropower Projects)

vii. Two-part tariff structure consisting of fixed 'Capacity' and variable 'Energy' components

viii. Capacity Payments to cover fixed costs, i.e. Fixed O&M, Debt Servicing, and Return on Equity (ROE), independent of energy Despatch

ix. Concessionary Customs/Import Duty on Plant & Equipment not manufactured locally

x. Exemption from corporate Income Tax and Turnover Tax

xi. Exemption from Withholding Tax on imports

xii. 100% foreign ownership allowed with a minimum 20% equity contribution

xiii. Sponsors can divest equity after six (6) years of project commissioning

xiv. Conversion of Pak Rupee and remittance of Foreign Exchange for project-related payments ensured by GOP

xv. Performance obligations of Power Purchaser guaranteed by GOP

xvi. Responsibility for power transmission facilities rests with the Power Purchaser

xvii. Continuity of payments in case of Political Force Majeure

xviii. Pass-through of additional taxes/costs incurred due to Change in Law

xix. Adjustments in tariff for variation in Interest Rates (LIBOR/KIBOR)

xx. Compensation payment in case of Project termination due to GOP default

xxi. Indexation of operational cost components to cover inflationary impacts

xxii. The term of the concession period for hydropower projects is up to 30 years

xxiii. In hydropower projects, Hydrological Risk is borne entirely by the Power Purchaser

xxiv. For hydropower projects, certain adjustments in tariff are allowed at COD which are as follows:

a) Cost variation due to geology in the tunnel(s)
b) Cost variation due to Civil Works
c) Cost variation due to Hydraulic Steel Structure and M&E works; and

d) Cost variation due to Resettlement Cost

xxv. For unsolicited proposals, NEPRA will determine tariff in consultation with the IPP and the Power Purchaser

xxvi. IPPs are not exposed to the impact of exchange rate variation for the US Dollar, Euro, Pound Sterling, and Japanese Yen up to the Commercial Operation Date (COD); NEPRA thus accepts EPC contracts denominated in these four currencies besides Pak Rupee

xxvii. At COD, Capital Cost is to be fixed in US dollars based on any of the four currencies of EPC contract accepted by NEPRA at the time of tariff determination, sources of financing, payments, and actual exchange rates against the rupee for these currencies

xxviii. IPP may obtain foreign debt in US Dollar, Pound Sterling, Euro, and Yen; periodic adjustments in the Debt Service Component of tariff will be made to cover exchange rate variation for these currencies

xxix. For foreign O&M costs, adjustments for exchange rate variations between Pak Rupee and US Dollar have been allowed

xxx. Performance Guarantees to PEDO/GOP and Letters of Credit in favour of Power Purchaser to be accepted in Euro, Pound Sterling, and Yen in addition to US Dollar

xxxi. ROE will be adjusted for variations in US Dollar / Pak Rupee rates

4. CONSENTS, PERMISSIONS & APPROVALS

The government of Pakistan require project developers to obtain various consents and permissions to develop the project as an IPP venture. Following is the listing of major consents and permissions required from relevant country departments.

i. PEDO/ PPIB

a) Approval of Feasibility Study by Panel of Experts
b) Approval of EPC Contract and EPC Contractor
c) Approval of Term Sheets & Loan Documents
d) Approval of O&M Contractor and O&M Contract

ii. State Bank of Pakistan

a) Foreign Currency Accounts
b) Registration of loan

c) Registration of Re-payment schedule
d) Repatriation of dividends
e) Availability of Foreign Exchange
f) Pledging the Shares in favour of Lenders

iii. NEPRA

a) Generation License for SPV
b) Approval of Feasibility Stage Tariff
c) Approval of EPC Tariff
d) Approval of COD Tariff

iv. GoP and GoKPK

a) Environment Impact Assessment NOC
b) Land Acquisition Notifications
c) Price Assessment & Land Lease Agreements
d) NOC requiring resettlement etc
e) NOC for supplying electricity to the power purchaser
f) NOC for the use of electricity within complex
g) NOC to connect the complex to the earth
h) Insurance Consent from the Ministry of Commerce
i) Exemption to the Company from excavation tax
j) Consent to store petroleum products
k) Company Registration with SECP
l) Registration of the Company as an Industrial Consumer
m) Permission to obtain an armed license

5. PROJECT DEVELOPMENT PROCESS

Three stages of development are involved in successfully commissioning a hydropower project as an IPP.

i. LOI Stage Development

a) Issuance of LOI
b) Appointment of Feasibility Study Consultants as per TORs in LOI
c) Approval of Feasibility from POE of PEDO
d) Filing of Feasibility Stage Tariff with NEPRA
e) Approval of negotiated Tariff from NEPRA
f) Submission of Performance Guarantee to PEDO/ PPIB
g) Issuance of LOS by PEDO/ PPIB (tripartite)

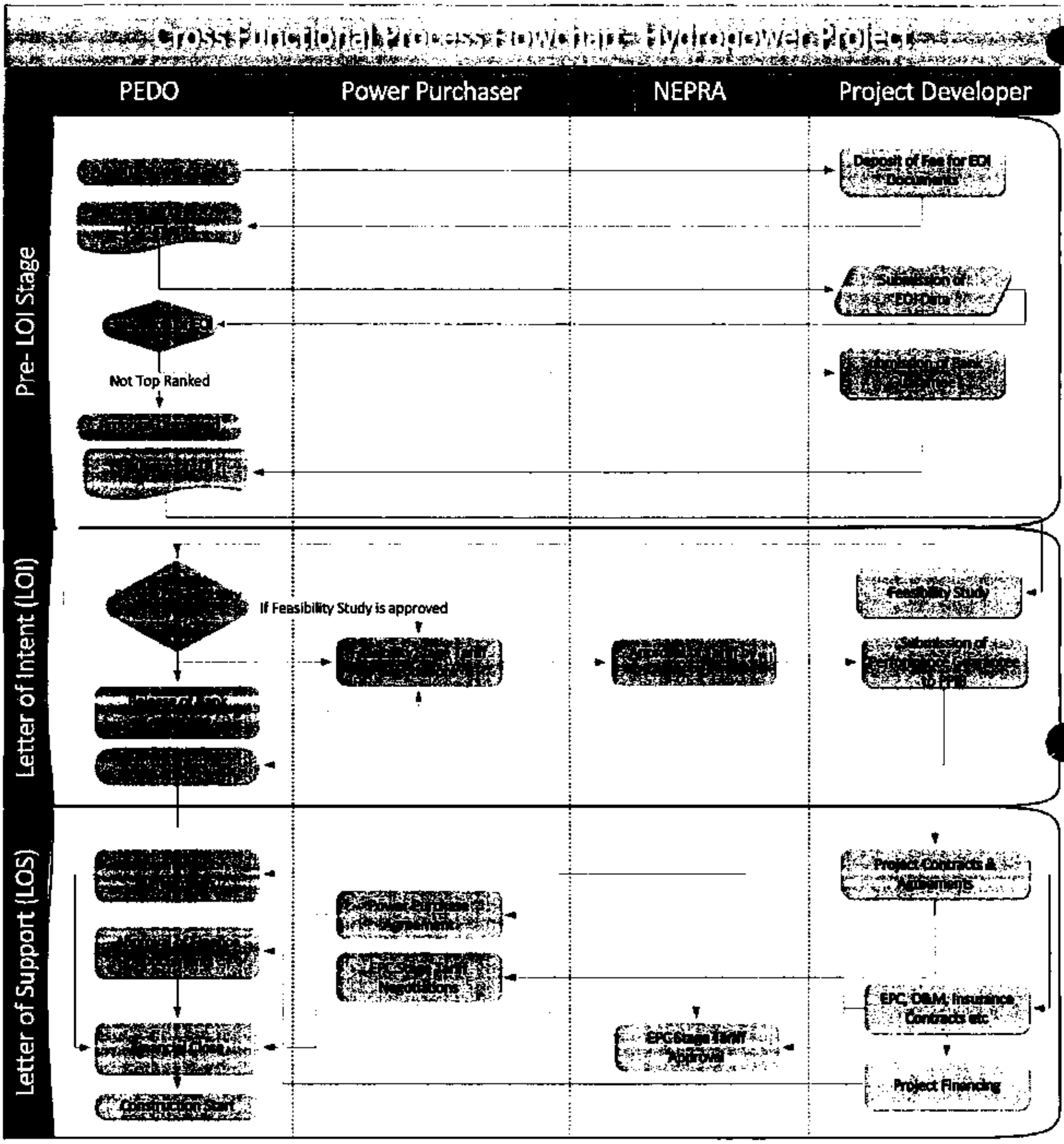
ii. LOS Stage

a) Appointment of Owner Engineer
b) Tender Documents & EPC Contract
c) Appointment of EPC Contractor
d) Appointment of O&M Contractor
e) Appointment of Insurance Agent
f) Environment & Social Impact Assessment
g) Project Financing Arrangement
h) Land Acquisition & Resettlement
i) Finalization of Project Contracts and Agreements
j) Due Diligence of Lenders
k) Power Purchase Agreement
l) Implementation Agreements
m) Water Use Agreement
n) Insurance arrangements for the Project
o) EPC Stage Tariff (Filing & Approval)
p) Acquisition of Consents & Permissions & Approvals
q) Approval of Financing Documents from PPIB
r) Financial Close

iii. Construction Stage

a) Mobilization of Contractor
b) Construction works
c) Mobilization of O&M Contractor
d) Training and Development
e) Testing & Commissioning
f) Commercial Operations
g) Operations & Maintenance

We clearly understand the development process of an IPP hydropower project based on the vast experience of our consortium for similar projects in Pakistan. We understand the financing requirements, environmental concerns and other risks associated with the project and have already strategized the mitigations required to smoothly sail the project.



6. RISKS AND MITIGATION STRATEGY

Hydropower projects are risk prone due to many factors, and developers must understand the dimensions of each project to cater for the expected exposures and cost overruns etc. Fortunately, the Policy and NEPRA's Tariff Mechanism for Hydropower Projects provide safeguards against major risks involved in the hydropower projects.

a) Power Purchaser takes over hydrological risk as per Policy

b) Force Majeure is covered in the Implementation Agreement
c) Cost variations due to geology in the tunnel(s) are allowed as reopener by NEPRA
d) Cost variations due to Civil Works are allowed as reopener by NEPRA
e) Cost variations due to Hydraulic Steel Structure and M&E works are allowed as reopener by NEPRA
f) Cost variations due to Resettlement Costs are allowed as reopener by NEPRA

However, some other risks that may jeopardise the project's development are as follows.

i. Environment & Resettlement Issues
ii. Land Acquisition & Mobilization
iii. Security of Ex-pats working on Project
iv. Interconnection & Transmission Issues
v. Consents & Approvals

Project developers plan to engage experienced, tested and skilled professionals and consultants to work in close collaboration with PEDO and other relevant authorities to mitigate these risks and ensure the speedy development and operations of the project.

SECTION-B: METHODOLOGY

The methodology for project development is the set of strategies developed by project developers to complete the project in the available time and desired quality. We have concrete plans to develop this project quickly by adopting the following actions and plans.

1. PROJECT TEAM

We plan to develop a team of professionals with a proven track record in developing this type of project. Our consortium already has rich experience in completing relevant projects in the country. We also plan to induct local and international consultants with a history of assisting project developers in implementing the hydropower project.

We understand the need for and importance of a professional team for accomplishing a project, and our project will build the capacity of young professionals in Pakistan.

2. COORDINATION WITH PEDO

We understand the importance and responsibility of closely coordinating with PEDO regarding the development of the Project. We plan to regularly update the PEDO about the project's development through monthly progress reports and sharing major accomplishments and impediments in the project's development.

3. APPOINTMENT OF OWNER'S ENGINEER

We understand the importance and pivotal role of an experienced and skilled Owner Engineer (OE) in implementing the Project. We will appoint an OE through the international competitive bidding process and after negotiating budgets and resources required for such purpose, keeping in view the costs allowed by Nepra under this head.

OE will perform the following duties during the implementation of the project.

a) EPC Contract & Design Review
b) Construction Supervision & Monitoring
c) Quality Assurance & Contract Compliance
d) Milestone Verification

4. EPC CONTRACT

The EPC contract is the most critical appointment of any project, especially a hydropower project with an extensive civil works component. The Company has developed a strategy to appoint an EPC Contractor that ensures transparency and competitiveness, resulting in a cost-effective and quality solution for successful project development.

i. Development of a detailed EOI based on Feasibility Study & tender documents

ii. Advertisement in national & international newspapers to invite bids for EPC

iii. Requiring detailed proposals from interested and shortlisted contractors, which include.

   a) Technical Proposal elaborating experience, references, approach, methodology, equipment suppliers, timelines, resources and key personnel.
   b) Due diligence report on Feasibility Study Report & BOQs
   c) Financial Health of the bidder
   d) Financial Proposal (Separate Envelop)

iv. Review and technical ranking of bidders from capable, independent third party

v. Opening of financial proposals

vi. Quality & Cost-Based Selection Scoring

vii. Negotiations with the top-ranked bidder on Contract & Pricing

viii. Approval of draft EPC Contract from relevant authorities and Lenders

ix. Award of Contract

5. PROJECT FINANCING

The consortium plans to finance the project through in-house equity financing and loan from international development Institutes and local banks; however, the capital structure will be finalized at the EPC stage, considering the country's refined project cost and economic and financial scenario.

I. EQUITY FINANCING

The equity is planned to be 100% arranged by consortium members. For any shortfall in equity due to a change in the project cost, a considerable time has been allowed.

The following process will be followed at the time of finalization of equity financing of the project.

a) Analysis of Options Available
b) Finalization of Alternatives
c) Preparation of Shareholders Agreement
d) Meetings among Proposed Equity Partners
e) Presentations of Financial Model
f) Presentation of Concession Documents
g) Finalization of Shareholder Agreement
h) Commitment Letters from Equity Partners
i) The signing of the Shareholders Agreement

This process is not critical and can be executed in any slack time available during the project implementation before the financial close.

II. DEBT FINANCING

Most international development banks have already provided financing for existing hydropower projects; thus, they understand the legal and corporate framework prevailing in Pakistan.

To control the overall project cost, the consortium plans to avail the debt financing with possible minimum interest rates from international development banks. The following process will be followed for the debt financing of the project.

a) Preparation of Sponsors Profile
b) Preparation of Project Profile
c) Application to International Banks
d) Response to the Queries of Banks
e) Mandate Letter by Banks
f) Presentation of Financial Model of Project
g) Presentation on Concession Documents
h) Meetings with Lenders
i) Site Visits of Lenders
j) Appointment of Lenders Engineer
k) Appointment of Lenders Legal Counsel
l) Appointment of Lenders Insurance Agent
m) Appointment of Owner's Engineer
n) Appointment of Owner's Legal Counsel
o) Appointment of Owner's Insurance Agent

p) Negotiations with Lenders Engineer
q) Site Visits by Lenders Engineer
r) Negotiations with Lenders Legal Counsel
s) Lenders Meeting with PEDO/PPIB
t) Lenders Meeting with Power Purchaser
u) Lenders Meeting with EPC Contractor
v) Lenders Meeting with O&M Contractor
w) Lenders' queries regarding EPC Contractor
x) Lender's queries regarding O&M Contractor
y) Queries of Lenders regarding Concession Documents
z) Commitment Letter from Banks
aa) Board Approvals

6. CONCESSION DOCUMENTS

Concession Documents will include the following.

a) Implementation Agreement with GOP
b) Water Use Agreement with GOKPK.

Implementation Agreement offers the framework under which the Company will implement the Project and sets out fundamental obligations of the Company, GOKPK and GOP concerning the implementation of the Project.

If the GOKPK or GOP terminates the Implementation Agreement, GOP is obliged to compensate the Company, thus securing the investments made in the Project. The Water Use Agreement between the Company and the Government of Khyber Pakhtunkhwa primarily is the consent of the Company to utilize the water for electricity generation.

The GOP shall, at Financial Closing, execute and deliver to the Company the Guarantee. The GOP Guarantee is an irrevocable and unconditional guarantee and the key document in the overall structure. Under this document, the GOP guarantees the Power Purchaser's payment obligations (including monetary damages assessed) under the Power Purchase Agreement and the Government of Khyber Pakhtunkhwa under the Water Use Agreement. The key activities involved in this milestone are:

a) Drafting of Concession Agreements
b) Negotiations of Agreements with the Government
c) Approval of the concession documents from Lenders
d) The signing of Concession Agreements

7. POWER PURCHASE AGREEMENT

The Power Purchase Agreement shall be signed with prospective Power Purchaser for 30 years (after the Commercial Operations Date). Under this Agreement, the Company shall be obligated to make available the tested capacity (as applicable from time to time) to the Power Purchaser from the Plant.

The Power Purchaser is obligated to purchase, and the Company is obligated to deliver NEO (the net electrical energy delivered by the Company to the Interconnection Point for sale to the Power Purchaser) produced (i) after Commercial Operations Date at agreed tariff (ii) during testing and commissioning before COD, and (iii) during sectional completion at the rate to be mutually agreed. The key activities involved are:

a) Drafting and negotiations of the Power Purchase Agreement
b) Ensuring that PPA is consistent with the technical and commercial requirements of the Project
c) Approval of all costs and PPA by NEPRA
d) Signing of PPA

8. LAND ACQUISITION

Site/Land acquisition is one of the most critical processes in developing the Project. The area required for the construction of the Project (as per design criteria) shall be demarcated through the installation of monuments. The ownership listing shall be done to identify the land owned by the government and the land owned by private parties.

The Government land shall be leased to the Company for thirty (30) years after COD, i.e. the term of the Project. However, the private land shall be acquired by the government from the private parties and be leased to the Company. The key activities to be carried out are:

a) Demarcation of the Land as per Project design criteria
b) Listing of ownership record of the land with the coordination of local administration of government
c) Filing of land lease applications
d) Public consultation with the community to take them on board for the Project
e) Negotiations of the rates of the land lease and compensation with the government

f) Negotiations and finalization of land lease agreements
g) Ensuring that all land lease costs are part of the approved tariff
h) Approval of the lenders for overall land lease arrangements

9. ENVIRONMENT, HEALTH & SAFETY

Under Section 11 of the 2000 Act, a Project falling under any category (qualifying IEE or EIA) requires the proponent to file IEE or EIA with the Pak-EPA. The Pak-EPA has published a set of environmental guidelines for conducting environmental assessments and the environmental management of different types of development projects. Other important policy documents and legal requirements of the project are the National Environmental Quality Standards (NEQS), the National Resettlement Policy and Ordinance, The Land Acquisition Act of 1894, The Forest Act of 1927 and the Forest (Amendment) Act 2010, The Motor Vehicles Ordinance, 1965, and Rules, 1969, The Factories Act, 1934, The Pakistan Penal Code, 1860, The Explosives Act, 1884. Besides providing an overview of Policy, Legal and Administrative Framework, section 2 also adumbrates guidelines of ADB and requirements of IFC related to the project. To ensure environmental compliance, various studies to be conducted by the Company are:

a) Environmental and Social Impact Assessment (ESIA Study)
b) Land and Resettlement Action Plan (LARP)
c) Ecological Flow Assessment, including Drift Model
d) Climate Change Assessment
e) Bio-Diversity Action Plan
f) Health & Safety Plan
g) Contingency Plan
h) Environment and Social Issue Management Plan

In addition to this, the Company shall be required to:

a) Get approval for the above documents from various stakeholders, including Government and Lenders
b) Ensuring compliance with health and safety requirements for the Project and the Company
c) Managing community relationships and implementation of the CSR program

10. O& M CONTRACT

The Company shall appoint an Operations and Maintenance Contractor for the operations of the Plant following the commercial operations date. The Operator shall be mobilized at the site six to nine months before commercial operations to ensure smooth taking-over of the Plant from the EPC Contractor. During this mobilization phase, the Operator shall run the individual units (partial completion) under the supervision of the EPC Contractor. However, following COD, the Operator shall be responsible for all the ongoing maintenance and repair works of the Plant and will bear all the costs of routine work. The activities involved in this process are:

a) Circulation of RFP for O&M of the Project
b) Evaluation of bids and selection of O&M Contractor
c) NOC of O&M Contract and Contractor from Government
d) Negotiations of the O&M Contract
e) Ensuring the O&M Costs are consistent with the approved tariff and project budgets
f) Approval of O&M Contract and O&M Budget from the Lenders

11. PROJECT INSURANCE

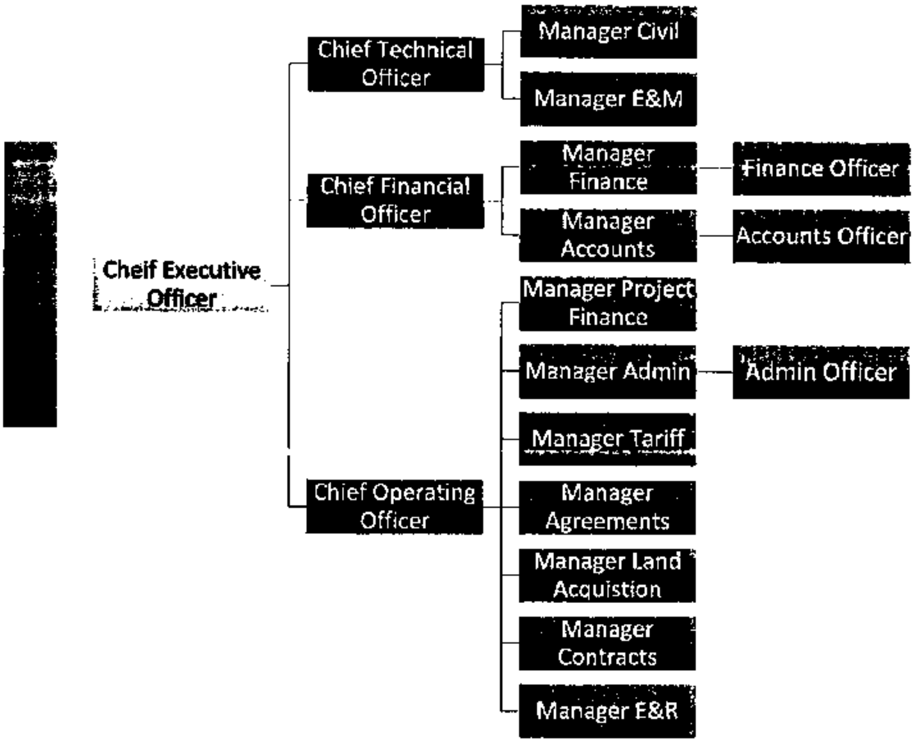
An overall Project Insurance Program, covering certain risks of the construction and operations phase of the Project, shall be arranged by the Company; however, construction phase insurance shall be largely placed offshore. To assist in this, the Company shall appoint and seek the guidance of an internationally reputable insurance broker/advisor.

a) Appointment of Company Insurance Advisor
b) Arrangement of the insurance of the Project on the best suitable rates under the advice of the Insurance Advisor
c) Arrangement of all reinsurances of the Project
d) Approval of the insurance terms from the Power Purchaser and the Lenders

SECTION-C: PROJECT DEVELOPMENT SETUP

Sponsors are already equipped with teams who have successfully delivered projects of similar nature in the past and will enhance the capability of existing and new inductions by providing them with training and job experience. We plan to develop a team of experienced professionals by hunting local and international talent.

Following is our proposed organization chart.



The chart above describes the key positions of the Project, and this team will be responsible for the successful commercial operations of the project. This team will be responsible for all the contracts, agreements, financing and construction supervision of the project; however relevant consultants would be higher on a need basis during the development of the project to support the in-house project team.

Following are the proposed job descriptions of key team members.

1. CHIEF EXECUTIVE OFFICER

Reporting to the Board of Directors

- ✓ Management and supervision of the Project Team.
- ✓ Setting Goals, Objectives, Timelines and budgets for the Project.

- ✓ Review all contracts, agreements and correspondence with all stakeholders of the Project.
- ✓ Real-time review of planning and strategy to develop the Project.
- ✓ Coordination with different stakeholders of the Project, including Lenders, EPC Contractors, PEDO, PPIB & NEPRA.
- ✓ Review the project's technical details and designee changes from time to time, if any.
- ✓ Review monthly progress reports on the Project and debriefing to the Board of Directors and other relevant stakeholders.
- ✓ Reviewing and approving all necessary Project expenditures and variance reports.
- ✓ Review of team performance and incentive plans for employees.
- ✓ Review the progress of various consultants hired by the Project for the Project Development purpose.

2. CHIEF TECHNICAL OFFICER

Reporting to Chief Executive Officer

- ✓ EPC Bidding of the Project.
- ✓ Selection of EPC Contractor.
- ✓ Appointment of Owner Engineer & other technical consultants.
- ✓ Review of Design of the Project and recommend any changes, if required.
- ✓ O&M Contract of the Project.
- ✓ Negotiations with CPPA regarding technical specifications of the Project
- ✓ Inspection visits to the E&M factory
- ✓ Correspondence with Lender's technical advisors
- ✓ Finalization of PPA
- ✓ Construction supervision

3. CHIEF FINANCIAL OFFICER

Reporting to Chief Executive Officer

Assisting CEO in the process of.

- ✓ Preparation and review of Project Costs & Budgets.
- ✓ Corporate and Tax matters of the Project and Project Company.
- ✓ Procurement and maintenance of Project Assets.
- ✓ Overall administration of the Company.
- ✓ Management of accounts of the company and relationship management with banks and lenders.
- ✓ Liaison with Lenders regarding disbursements during the construction period.
- ✓ Liaison with auditors and tax consultants of the Project.

4. CHIEF OPERATING OFFICER

Reporting to Chief Executive Officer

- ✓ Finalization of project agreements, i.e. Implementation Agreement, Land Lease Agreement, Power Purchase Agreement etc.
- ✓ Finalize all contracts, i.e. EPC Contract, O&M Contract, Insurance Contract etc.
- ✓ Project financing, both debt and equity
- ✓ Assistance in Due Diligence of Project by Lenders
- ✓ Finalization of Capital Structure of the Project
- ✓ Finalization of Terms Sheet and Financing Documents
- ✓ Preparation and review of Project Costs & Budgets.
- ✓ Liaison with Lenders E&S staff for environmental due- diligence
- ✓ Assistance in Environmental and Social Impact Assessment (ESIA Study)
- ✓ Assistance in Land Acquisition Resettlement Plan (LARP)

APPENDIX-15
APPROVAL LETTER OF THE FEASIBILITY STUDY

PEDO

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION

Government of Khyber Pakhtunkhwa Peshawar

PEDO House, 38/B-2, phase-V, Hayatabad, Peshawar Tel: (+92-91) 9217246, Fax (+92-91) 9217003

No.755-61/PEDO/CEREP/FS/LSG-KHNP
Dated: November 23, 2022

To

M/s Korea Hydro & Nuclear Power Co. Ltd. (KHNP),
Office 29,3rd Floor, Executive Complex, G-8 Markaz,
Islamabad
Tel: +92 51 8435288

Subject: APPROVAL OF FEASIBILITY STUDY FOR 470 MW LOWER SPAT GAH HYDROPOWER PROJECT, LOCATED ON LEFT TRIBUTARIES OF INDUS RIVER, DISTRICT KOHISTAN, KHYBER PAKHTUNKHWA

References:
- i. *Letter of Interest (LOI) dated June 29, 2021*
- ii. *Minutes of POE Meeting dated August 31, 2022, issued vide PEDO letter no. 584-96/PEDO/DREP/PoE/MoM/LSG/BK/GB dated October 4, 2022 & 582-83/PEDO/CEREPP/LSG/MoM dated October 4,2022*
- iii. *Final updated Feasibility Study submitted dated November 15 , 2022*

PEDO is pleased to communicate following decision of Panel of experts (POE) of PEDO, monitoring the conduct of Feasibility Study for the subject project:

"The feasibility Study for 470 MW Lower Spat Gah Hydropower Project located on left Tributaries of Indus River, District Kohistan, Khyber Pakhtunkhwa carried out by the consultants for M/S Korea Hydro & Nuclear Power Co. Ltd, (KHNP), is approved in accordance with KP Hydropower Policy 2016 and Associated Guidelines subsequent to NOCs from Environment Protection Agency (EPA) and Power Evacuation Consent from National Transmission & Despatch Company Limited (NTDCL)".

2. Due to nature of data and resultant conclusion, Panel of Experts jointly and/or individually will not be responsible for reliability of data, contents and conclusions given in the feasibility study.

3. As the feasibility study has been carried out at the risk & cost of the sponsor, the approval of feasibility study shall not form basis of any claim for compensation from Govt. of KP / PEDO in future.

4. In accordance with the KP Hydropower Policy 2016, upon the approval of the feasibility study by the POE, you are requested to process the case for tariff determination with NEPRA within 90 days.

5. PEDO appreciates your efforts to complete the feasibility study and expect the same pace and spirit for negotiation and finalizing tariff with NEPRA.

Director (Renewable Energy)
Private Power, PEDO

CC:-
1. Managing Director, NTDCL, Lahore.
2. Managing Director, PPIB, Islamabad.
3. CEO, CPPA-G, Islamabad.
4. Registrar, NEPRA, Islamabad.
5. PS to Secretary, E&P Department, Peshawar.
6. PS to CEO, PEDO, Peshawar.

Director (Renewable Energy)
Private Power, PEDO

APPENDIX-16
AFFIDAVIT FOR ANY OTHER GRANT OF CONCURRENCE OR REFUSAL

DU84709 ONLY USED FOR ISLAMABAD

100 Rupees ۱۰۰ روپیہ

AFFIDAVIT

Before

THE NATIONAL ELECTRIC POWER REGULATORY AUTHORITY

Affidavit of **SEUNG-YEOL LIM** S/O In-Gyu Lim having Passport No. M39696501 resident of 23, Jinhyeon-ro, Gyeongju-si, Gyeongsangbbuk-do Korea and authorized representative of LSG Hydro Power Ltd. (the "Company") having its registered office in Office 4th Floor, Emirates Tower, Jinnah Super, F-7, Islamabad Pakistan.

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

I am the Chief Executive Officer of the Company.

I have been authorized representative of LSG Hydro Power Ltd by virtue of Board of Directors Resolution dated 22st August 2023.

I state that Generation License Application for Lower Spat Gah Hydro Power Project was submitted to Nepra Vide letter No LLI-LGI-23-0002L dated January 17, 2023 and same was returned vide letter No NEPRA/R/LSG-30/208 citing Non-Optimization in IGCEP

I further state that the applicant has not been granted any other licence by NEPRA.

LSG HYDRO POWER LIMITED LSG

ATTESTED TARIQ IQBAL MAHER Advocate High Court Notary Public ISLAMABAD

21 AUG 2023

ATTESTED TARIQ IQBAL MAHER Advocate High Court Oath Commissioner ISLAMABAD

21 AUG 2023

Deponent: ____________

Seung-Yeol Lim

S/O In-Gyu Lim

Passport No. M39696501

APPENDIX-17
BOARD RESOLUTION

LSG HYDRO
POWER LIMITED

No. LLI-BOD-23-013

4th Floor, Emirates Tower, Jinnah Super, F-7,
Islamabad Pakistan
Tel: +92-51-6134782
http://www.lsg-hydro.com

TRUE EXTRACTS

APPROVAL OF THE RESOLUTIONS BY THE BOARD OF DIRECTORS

ON 22nd AUGUST 2023

TO RESOLVED THAT THE COMPANY BE AND IS HEREBY AUTHORIZED TO APPLY FOR THE GRANT OF CONCURRENCE TO NATIONAL ELECTRIC POWER REGULATORY AUTHORITY (NEPRA) AND TO AUTHORIZED -AND EMPOWERED CHIEF EXECUTIVE OFFICER OF THE COMPANY TO SIGN. EXECUTE AND DEAL WITH THE NATIONAL ELECTRIC POWER REGULATORY AUTHORITY (NEPRA) REGARDING THE GRANT OF CONURRENCE AND OTHER RELATED APPROVALS AND REPRESENT AND SIGN ALL THE RELATED DOCUMENTS IN RESPECT OF THE SAME ON BEHALF OF THE COMPANY

Whereas, under the conditions of LOI, Company needs to submit its application to National Electric Power Regulatory Authority (NEPRA) for Grant of Concurrence (Generation License) and to authorize and empowered Chief Executive Officer of the Company to sign, execute and deal with the NEPRA regarding the Grant of Concurrence and other related approvals and represent and sign all related documents in respect of the same on behalf of the Company.

Therefore, all Board members unanimously passed the following resolutions.

"**RESOLVED THAT LSG** Hydro **Power LIMITED**, a company incorporated under the laws of Pakistan with its registered office located at 4th Floor, Emirates Tower, Jinnah Super, F-7, Islamabad Pakistan, (the "Company") be and is hereby authorized to submit an application for Grant of Concurrence (including any subsequent modification) to the National Electric Power Regulatory Authority (the "NEPRA") in respect of its 470MW (Gross) Lower Spat Gah Hydropower Project to be located at Upper Kohistan , Khyber Pakhtunkhwa, Pakistan (the "Project") and in relation thereto, enter into and execute all documents, make all filings and pay all applicable fees, in each case, of any nature whatsoever, as required,"

"**RESOLVED FURTHER THAT** in respect of application for the Grant of Concurrence (including any modification to the application for the Grant of Concurrence) to NEPRA, MR. Seung-yeol Lim, the Chief Executive Officer (the "Authorized Representatives"), be and is hereby acting singly empowered and authorized for and on behalf of the Company to;

1. prepare, review, execute, submit and deliver the Grant of Concurrence Application (including any modification to the application for the Grant of Concurrence) and related documentation required by National Electric Power Regulatory Authority, including any contracts, documents, power of attorney, affidavits, statements, letters, forms, applications, deeds, guarantees, undertakings, approvals, memoranda,

amendments, letters, communications, notices, certificates, requests, statements, and any other instruments in respect to the Grant of Concurrence;

2. represent the Company in all negotiations, representations, presentations, hearings, conferences and/or meetings of any nature whatsoever with any entity (including, but in no manner limited to NEPRA, any private parties, companies, partnerships, individuals, governmental and/or semi-governmental authorities and agencies, ministries, boards, departments, regulatory authorities and/or any other entity of any nature whatsoever).
3. sign, certify and execute all necessary documentation, pay the necessary fees, appear before the NEPRA as and when required, and do all acts necessary for the completion and processing of the application for the Grant of Concurrence (including any modification).
4. do all such acts, matters and things as may be necessary for carrying out the purpose aforesaid and giving full effect to the above resolution/resolutions."

Certified further that the above resolutions are included in the minute's book of the Company. It is further stated that the information given above is correct and true to the best of our knowledge and belief.

On behalf of the Board and Company

LSG HYDRO POWER LIMITED LSG

Seung-yeol Lim Korean National Passport # M39696501 CEO and Director	Moon Soo Myung Korean National Passport No. M04655694 Director	Changhoo Oh Korean National Passport No. M44506788 Director

APPENDIX-18
AFFIDAVIT OF CORRECTNESS & AUTHENTICITY

UU84/12 ONLY USED FOR ISLAMABAD

100 Rupees ١٠٠ روپے

AFFIDAVIT

Before

THE NATIONAL ELECTRICAL POWER REGULATORY AUTHORITY

Affidavit of **SEUNG-YEOL LIM** S/O In-Gyu Lim having Passport No. M39696501 resident of 23, Jinhyeon-ro, Gyeongju-si, Gyeongsangbbuk-do Korea and authorized representative of LSG Hydro Power Ltd. (the "Company") having its registered office in Office 4th Floor, Emirates Tower, Jinnah Super, F-7, Islamabad Pakistan.

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

I am the Chief Executive Officer of the Company.

I have been authorized representative of LSG Hydro Power Ltd by virtue of Board of Directors Resolution dated 22nd August 2023.

The contents of accompanying Grant Of Concurrence Application, submitted to National Electrical Power Authority("NEPRA") along with the supporting documents relevant thereto has not been concealed or withheld therefrom

LSG HYDRO POWER LIMITED (LSG)

Deponent: ____________
Seung-Yeol Lim
S/O In-Gyu Lim
Passport No. M39696501

ATTESTED
TARIQ IQBAL MAHER Advocate High Court Notary Public ISLAMABAD
21 AUG 2023

ATTESTED
TARIQ IQBAL MAHER Advocate High Court ISLAMABAD

21 AUG 2023

APPENDIX-19
GRID INTERCONNECTION STUDY

Date	Organisation	Reference	Subject	Remarks	Appendix #
01.07.2021	KOREA HYDRO AND NUCLEAR POWER	HLKL/PE-210008L	Grid Interconnection Study	Request for data to start GIS	19-A
14.07.2021	PEDO	480-82/PEDO/DREPP/LSG/GIS	Grid Interconnection Study	Request for data to start GIS	19-B
28.07.2021	LSG HPL	LSGHPP-NTDC:0001	Grid Interconnection Study	Request For data to start GIS	19-C
15.11.2021	NTDC PSP	GMPSP-TRO-300-4356-71	Grid Interconnection Study	NTDC Allow using the data	19-D
23.11.2022	LSG HPL	LSGHPP-NTDC/ADM:006L	Route Survey Data	ADM to Direct Dasu HPP Islamabad to allow the use of Route Survey	19-E
08.11.2022	Chief Engineer Dasu HPP NTDC	Email dated 08.11.2022	Route Survey data	NTDC Dasu HPP allow using route survey data	19-F
01.12.2022	LSG HPL	LSG/NTDC-22-002L	Power Market Study Report	Submission of Report	19-G
01.12.2022	LSG HPL	LSG/NTDC-22-001L	Grid Interconnection Study	Submission of Report	19-H
25.01.2023	LSG HPL	LLI-LGL-23-003L	Fee Submission	GIS vetting fee	19-I

Date	Organisation	Reference	Subject	Remarks	Appendix #
17.02.2023	LSG HPL	LLI-LGL-23-013L	Transmission Line Route Survey	Submission of Report	19-J

[redacted]

KHNP
KOREA HYDRO & NUCLEAR POWER CO., LTD
1655 Bulguk-ro, Gyeongju-si, Gyeongsangbuk-do, Republic of Korea (38120)
Fax : +82-54-704-2099
http://www.khnp.co.kr

HLKL/PE-210008L
July 1, 2021
Reply Required: ■Yes ☐No

Qazi Muhammad Naeem
CEO Pakhtunkhwa Energy Development
Plot #38, Sect. B-2, Phase-5 Hayatabad

Subject: Grid Interconnection Studies of the 496MW Lower Spat Gah Hydropower Plant
Reference: Letter No.441-48/PEDO/DREPP/KHNP/LOI 「Letter of Intent For Approximately 496MW Lower Spat Gah Hydropower Project」 dated 29.06.2021

Dear Mr. Qazi Muhammad Naeem

We (Korea Hydro Nuclear Power(KHNP) Consortium) have engaged the Consultants AFRY Thailand Ltd. (AFRY) and M/s Power Planners International (Pvt.) Ltd (PPI) to perform the required grid interconnection studies for the planned 496MW Lower Spat Gah Hydro Power Plant, District Kohistan, KPK.

To be in a position to perform the relevant studies, we need the data of the existing and future/planned network in the vicinity of the proposed power plant. Thus, it would be convenient if G.M. Power System Planning (NTDC) could allow the KHNP-Consortium, AFRY and PPI to make use of the system data that is already available to perform similar studies as required for the Feasibility Study of the Project.

In addition, we kindly request you to provide the following data:

1. Updated Generation Expansion Plan prepared by NTDC till the year 2030.
2. Transmission expansion plans involving NTDC's 765kV, 500kV and 220kV network till 2030.
3. Load projections of NTDC and PESCO till 2030.

Sincerely yours,

Byungsoo Jung
General Manager, Global Hydropower Business section
Global Business Department
Korea Hydro & Nuclear Power Co., Ltd.

[redacted]

KHNP

KOREA HYDRO & NUCLEAR POWER CO., LTD

1655 Bulguk-ro, Gyeongju-si, Gyeongsangbuk-do, Republic of Korea (38120)
Fax : +82-54-704-2099
http://www.khnp.co.kr

HLKL/PE-210008L
July 1, 2021

CC: Managing Director, NTDCL, 414-WAPDA House
Chief Technical Officer, CPPA-G, Plot 73-West Shaheen Plaza
Mr. Ahn, Ho Young, Head/Principal Office, Pakistan Branch Office, Lotte E&C
Mr. Stephan Martin, Senior Hydropower Project Manager, Bangkok office, Afry Thailand LTD

Enclosure(s): ☐Yes ■No

Document delivery: ■Email ☐Courier ☐Fax ☐Hand delivery

PEDO

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa [illegible]

No. [illegible]
Date: [illegible]

The General Manager
Planning System Power, NTDCL
4th Floor, PIA Tower, Egerton Road Lahore

Subject: **Grid Interconnection Studies of 496 MW Lower Spat Gah HPP, District Upper Kohistan, KP**

Dear Sir,

I am directed to refer to the letter No. HI K/PI -2100081, dated July 01, 2021, received from M/s Korea Hydro & Nuclear Power Co. Ltd. (KHNP) on the subject noted above **(Annex-I)**.

In this regard, it is to bring into your kind notice that 496 MW Lower Spat Gah Hydropower project located in District Kohistan, KP (the "Project") has been awarded to M/s KHNP under the KP Hydropower Policy 2016 for development in PPP mode. The project sponsor has engaged the consultants AFRY Thailand Ltd. And Power Planner International (Pvt.) Ltd. to carry out the required Grid Interconnection Studies (GIS) for which they need the data of existing and future/planned network data in the vicinity of the proposed power plant.

It is therefore requested to kindly facilitate the project sponsor in the matter and provide the following data to their grid consultant for conducting the GIS, please:

i. Updated Generation Expansion Plan prepared by NTDC till the year 2030.
ii. Transmission expansion plans involving NTDC's 765kV, 500kV and 220kV network till 2030.
iii. Load projections of NTDC and PESCO till 2030.

Your cooperation in this regard shall be highly appreciated.

Manager (REP)
Private Power

Copy to:

1. PS to Chief Executive Officer, PEDO Peshawar.
2. Mr. Ahn, Ho Young, Head/Principal office, Pakistan Branch office, Lotte E & C

Manager (REP)
Private Power

LSG HYDRO POWER LIMITED

LSGHPP-NTDC: 00001
Date: July 28, 2021

General Manager
Power System Planning
National Transmission & Dispatch Company limited
4th Floor, PIA Tower, Egerton Road,
Lahore

Subject: **Grid Interconnection studies of the 496 MW Lower Spat Gah Hydropower Plant:**
Reference: **Letter No.441-48/PEDO/DREPP/KHNP/LOI dated 29.06.2021**
Letter No. 480-82//PEDO/DREPP/LSG/GIS dated 14.07.2021

Dear Mr. Muhammad Waseem Younas,

It is apprised that LSG Hydro Power Limited (Project company) having Korea Hydro & Nuclear Power Ltd., as main sponsor has been entrusted to undertake development of 496 MW Lower Spat Gah Hydro Power Project in PPP mode through LOI dated **29.06.2021** issued by PEDO GoKPK.

Under the LOI, Project Company is required to update the feasibility study of the project including Grid Interconnection study (GIS). For preparation of grid interconnection study the project company has appointed AFRY Thailand Ltd. (AFRY) and M/s Power Planners International (Pvt.) Ltd (PPI) to perform the required grid interconnection studies for the planned lower Spat gah Hydro Power Plant,

In this regard NTDC is requested to facilitate our GIS consultants in relation with provision of required data/information for conducting a meaningful GIS report.

Your corporation will be highly appreciated for timely completion of respective milestones of PPP mode project.

Regards,

Yong Suk Jung

Yongsuk Jung
Chief Executive Officer
LSG Hydro Power Limited
Office No 29, 3rd Floor, Executive Complex
G8 Markaz, Islamabad
Pakistan

LSG HYDRO POWER LIMITED
LSG

LSG HYDRO POWER LIMITED

Enclosed:
Letter No.441-48/PEDO/DREPP/KHNP/LOI dated 29.06.2021
Letter No. 480-82//PEDO/DREPP/LSG/GIS dated 14.07.2021

CC:
Managing Director: NTDC Office Address: Office No. 2, 2nd Floor Shaheen Complex, Lahore
Deputy GM: PSP NTDC Office Address 4th Floor, PIA Tower, Egerton Road
CEO PEDO: Office Address Plot# 38, Sect B-2, Phase-5 Hayatabad, Peshawar
Director RE PEDO: Office Address Plot# 38, Sect B-2, Phase-5 Hayatabad, Peshawar
CEO PPI: Office Address 95-H2 Block H 2 Wapda Town Phase 1 WAPDA Town, Lahore

NATIONAL TRANSMISSION & DESPATCH CO. LTD (NTDC)

General Manager (Power System Planning)

No. GMPSP/TRP-300/4345-71 Dated: 15-11-2021

Director,
LSG Hydro Power Ltd.,
Office 29, 3rd Floor, Executive Complex,
G-8 Markaz, Islamabad.
Tel: 051-8435288

Sub: Grid Interconnection Studies of 496 MW Lower Spat Gah (LSG) HPP District Upper Kohistan, Khyber Pakhtunkhwa

Ref: M/s LSG Hydro Power Limited office letter no: LSGHPP: NTDCL-0002 dated 09-11-2021.

This office has been requested by M/s LSG Hydro Power Limited vide above referred letter for provision of system data to its selected study consultant, M/s Power Planners International (Pvt.) Ltd. (PPI) in order to conduct the grid interconnection/system impact study for 496 MW Lower Spat Gah Hydro Power Plant (HPP).

M/s PPI is required to attend a meeting in this office on 22-11-2021 at 02:30 p.m. in this regard and also receive the following system data/information from this office:

1. Latest demand forecast and Indicative Generation Capacity Expansion Plan (IGCEP), approved by NEPRA on 24-09-2021.
2. The electronic copies of the available base case/grid system data in PSS/E software for the spot year of 2027 which also includes the incorporation of transmission plan upto that spot year.

M/s PPI shall prepare the base cases for the subject study keeping in view the timeline of the subject HPP and for some future scenarios. M/s PPI is advised to conduct an integrated study for evacuation of power from the subject HPP in integration with other HPPs in the vicinity of the subject HPP and in the north.

M/s PPI is allowed to use the above-mentioned system data/information for the grid interconnection/system impact study of 496 MW LSG HPP. However, M/s PPI is advised not to use the system data/information for any other study nor should it be provided to any other company including the sponsor of the subject project without the prior permission of this office.

It is pertinent to mention that the subject 496 MW LSG HPP is not included up to year 2030 in the IGCEP 2021(approved by NEPRA in September 2021). In the above referred letter, the project sponsor has expressed his willingness to: (i) Undertake the GIS study at their own risk and cost; and (ii) Update the GIS at their own risk and cost in case of change in the underlying assumptions or data or due to any other factor. NTDC agrees to this undertaking by the project sponsor and further adds that NTDC shall have no liability or obligation based on its consequences in this regard. Based on these conditions and request by the sponsor of subject project, NTDC is giving grid system data and permission to carry out the grid interconnection/system impact study for the subject 496MW Lower Spat Gah HPP. However, it should not be considered as any consent from NTDC that the subject HPP shall definitely be selected in the next version of IGCEP. The subject HPP shall have to compete with other candidate power projects to become part of IGCEP in future as per least cost principle.

This office is available for further deliberations in this regard.

General Manager (Power System Planning)

Distribution to:

i) Chief Executive Officer, PEDO, Peshawar.
ii) Deputy Managing Director (P&E) NTDC
iii) Chief Engineer (T/L Design) NTDC
iv) Chief Engineer (EHV-I) Islamabad, NTDC
v) P.S to Managing Director, NTDC.
vi) M/s PPI, WAPDA Town, Lahore.
- Master File

[redacted]

LSG HYDRO POWER LIMITED
Office 29, 3rd Floor, Executive Complex, G-8 Markaz, Islamabad Pakistan
Tel: +92 51 8435288
http://www.lsg-hydro.com

CE (PMU-DT[illegible]) NTDC	
Diary No. 927	
Dated 25.11.2022	
Manager [illegible]	
Manager (Construction)	
DM (P)	
DM (C)	
DM (C&S)	
DM (S&E)	
DM [illegible]	
DM (CA)	
A[illegible] (HR&A)	
Care Taker	

Ref: LSGHPP/NTDC/ADM-006L
Date:23.11.2022

Deputy Managing Director
Asset Development and Management
Room No. 413, WAPDA House,
Wapda House, Lahore
dmd.adm@ntdc.com.pk, +92-42-99202699,

Subject: **Request for Assistance for Completion of Transmission Line Route Survey for Connecting the 470 MW Lower Spat Gah Hydro Power Plant with the National Grid**

Reference: Letter No: GMPSP/TRP-300/3604-07

Dear Sir,

Greetings from LSG Hydro Power Ltd (LSG HPP). LSG HPP is Project Company of Korea Hydro & Nuclear Power, and we are responsible for development, construction and Operation of 470 MW Lower Spat Gah Hydro Power Project.

We have engaged the consultancy services of Power Planners International (PPI), to carry out the Transmission Line Route Survey for feasibility of connecting the 470 MW Lower Spatgah Hydro Power Plant with the National Grid.

The project is proposed to be connected with planned 765 kV line between Dasu HPP and Mansehra via loop in/out arrangement at a suitable point.

In this regard it is requested to please provide the following details based on design and route survey carried out by NTDC for 765 kV line between Dasu HPP and Mansehra:

1. Tower outline drawings with all cross arms lengths, cross arm heights, tower total height etc.
2. Design criteria used for the main DASU transmission line.
3. Sag Tension calculations for main DASU transmission line
4. Conductor and OPGW technical data for use in PLS CADD software with all stress strain and creep coefficients
5. Survey data in XYZ format along with details of every point mentioning the features.

Looking Forward for your Kind Assistance

Kind Regards

Sangwoo Kim
Chief Executive Officer
LSG Hydro Power Ltd.

LSG HYDRO POWER LIMITED
LSG

Cc:

- Chief Engineer, Dasu Transmission Line Project House 459, Service Road East,E11/3, NPF Islamabad,
- Power Planners International, 95-H/2, Wapda Town, Lahore

kashif

From:	CE DTLP (TL) <cedtlp.tl@ntdc.com.pk>
Sent:	Thursday, 8 December 2022 5:02 pm
To:	Deputy Managing Director Asset Development & Management; General Manager Project Delivery North
Cc:	CHANGHOO.OH@lsg-hydro.com; HYONJOON.CHOI@lsg-hydro.com; kashif@lsg-hydro.com
Subject:	Request for Assistance for Completion of Transmission Line Route Survey for Connecting the 470MW Lower Spat Gah Hydro Power Plant with the National Grid
Attachments:	Letter-LSG Hydro Power Ltd.pdf; L1, DASU-MANSEHRA_AP1- 21.kmz

Respected Sir,

This is with Reference LSG Hydro Letter No **LSGHPP/NTDC/ADM-006L dated 23-11-2022 Endorsed by your office vide Endst. No 4074 dated 01-12-2022 and DMD (AD&M) Diary No 4369 dated 24-11-2022** asking for provision of 765kV Transmission Line data;
It is apprised that DTLP Consultant did Tender Level Design which will be revalidated by the contractor therefore detail design is not available at this stage.
Currently only tentative Transmission Line route of 765kV Dasu Transmission Line Lot-I is available and here by shared for ready reference and further necessary action at your end.

Regards,

Pir Tariq Said

Chief Engineer / Project Director
PMU, Dasu Transmission Line Project, NTDC
T: +92-51-9334941-42-43

A: House#459, Service Road East, E-11/3, NPF, Islamabad

[redacted]

LSG HYDRO
POWER LIMITED
Office 29, 3rd Floor, Executive Complex, G-8 Markaz, Islamabad Pakistan
Tel: +92 51 8435288
http://www.lsg-hydro.com

Reference No: LSG/NTDC-22-002L
Date: 01st December, 2022

To,
General Manager (Power System Planning)
NTDC office 4th Floor, PIA Building
Egerton Road, Lahore

Subject: **POWER MARKET STUDY REPORT OF 470 MW LOWER SPAT GAH (LSG) HPP, DISTRICT UPPER KOHISTAN, KHYBER PAKHTUNKHWA**

Sir,
Please find herewith for your review the Draft Report of Grid Power Market Study Report of 470 MW Lower Spat Gah (LSG) HPP, District Upper Kohistan, Khyber Pakhtunkhwa.

We request you to please expedite the review and consider it in IGCEP as we are moving fast to achieve all the targets of Financial Close to start the Project ASAP.

Thanks and best regards.

SangWoo Kim
Chief Executive Officer
LSG Hydro Power Ltd

Cc:

1. Power Planners International, 95 –H/2, Wapda Town, Lahore
2. Director Renewable Energy, Private Power, PEDO, Peshawar

[redacted]

LSG HYDRO
POWER LIMITED
Office 29, 3rd Floor, Executive Complex, G-8 Markaz, Islamabad Pakistan
Tel: +92 51 8435288
http://www.lsg-hydro.com

Reference No: LSG/NTDC-22-001L
Date: 01st December, 2022

To,
General Manager (Power System Planning)
NTDC office 4th Floor, PIA Building
Egerton Road, Lahore

16/12/22

Subject: **GRID INTERCONNECTION STUDIES OF 470 MW LOWER SPAT GAH (LSG) HPP, DISTRICT UPPER KOHISTAN, KHYBER PAKHTUNKHWA.**

Reference: Letter No. GMPSP/TRP-300/4365-71 dated 15/11/2021

Sir,
Please find herewith for your review and vetting of Draft Report of Grid Interconnection Studies of 470 MW Lower Spat Gah (LSG) HPP, District Upper Kohistan, Khyber Pakhtunkhwa. The data permission was received via letter referred above.

The Report includes all the necessary studies required for the feasibility of interconnection with the main grid as follows;

1. Load flow analysis
2. Short circuit analysis
3. Dynamic and transient stability analysis

We request you to please expedite the review and vetting as we are moving fast to achieve all the targets of Financial Close to start the project ASAP.

Thanks and best regards.

SangWoo Kim
Chief Executive Officer
LSG Hydro Power Ltd

LSG HYDRO POWER LIMITED
LSG

Cc:

1. Power Planners International, 95 –H/2, Wapda Town, Lahore

[redacted]

LSG HYDRO
POWER LIMITED

No. LLI-LGL-23-003L

Office 29, 3rd Floor, Executive Complex, G-8 Markaz,
Islamabad Pakistan
Tel: +92 51 8435288
http://www.lsg-hydro.com

January 25, 2023

Reply Required ☒ Yes ☐ No

General Manager (Power System Planning)
NTDC office 4th Floor, PIA Building
Egerton Road, Lahore

Subject: **Submission of Fee for vetting of Grid Interconnection studies of 470 MW Lower Spat Gah (LSG) HPP, District Upper Kohistan, Khyber Pakhtunkhwa.**

Reference: **Letter No. GMPSP/CETP/TRP-300/4278-84 Dated 26-12-2022**

Sir,
Please find enclosed Bank Draft No: 109345727 for PKR 1,287,500 for fee pertaining to vetting of Report of Grid Interconnection Studies of 470 MW Lower Spat Gah (LSG) HPP, District Upper Kohistan, Khyber Pakhtunkhwa.

We request your good office to please start the review and vetting process.

Thanks and best regards.

Seung-yeol Lim
Chief Executive Officer
LSG Hydro Power Ltd

Enclosures: ☒ Yes ☐ No
1. Bank Draft No: 109345727

CC:
1. Power Planners International, 95 –H/2, Wapda Town, Lahore

Document Delivery: ☐ Email ☒ Courier ☐ Fax ☐ Hand Delivered

[redacted]

LSG HYDRO
POWER LIMITED

Office 29, 3rd Floor, Executive Complex, G-8 Markaz,
Islamabad Pakistan
Tel: +92 51 8435288
http://www.lsg-hydro.com

No. LLI-LGL-23-013L

February 17, 2023

Reply Required ☒ Yes ☐ No

General Manager (Power System Planning)
NTDC office 4th Floor, PIA Building
Egerton Road, Lahore

Subject: **Grid Interconnection Studies of 470 MW Lower Spat Gah (LSG) HPP – Submission of Transmission Line Route Survey.**

Reference: **Our Letter No. LSG/NTDC-22-002L Dated 01-12-2022**

Sir,

With Regards to the subject matter, please find enclosed the Transmission Line Route Survey of 470 MW Lower Spat Gah for your review and vetting and further processing.

Thanks and best regards.

Seung-yeol Lim
Chief Executive Officer
LSG Hydro Power Ltd

Enclosures: ☒ Yes ☐ No
1. Report - Transmission Line Survey

CC: Power Planners International, 95 –H/2, Wapda Town, Lahore
Document Delivery: ☒ Email ☒ Courier ☐ Fax ☐ Hand Delivered

P E D O

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION

Government of Khyber Pakhtunkhwa Peshawar

No. 441-48/PEDO/DREPP/KHNP/LOI
Dated: 29.06.2021

To

Byungsoo Jung, General Manager (Global Hydropower Business Section)
M/s Korea Hydro & Nuclear Power Company
Address: 1655 Bulguk-ro, Gyeongju-si Gyeongsangbuk-do, Republic of Korea (38120).

Subject: **LETTER OF INTENT (LOI) FOR APPROXIMATELY 496 MW LOWER SPAT GAH HYDRO POWER PROJECT**

WHEREAS

A) A Memorandum of Understanding ("MOU") was signed between Korea Hydro & Nuclear Power Company ("KHNP") & Government of Khyber Pakhtunkhwa ("GoKPK") on November 05, 2018 to develop the Project in Public Private Partnership ("PPP") mode;

B) The Preliminary Proposal was submitted on November 19, 2018 under clause 1.5 (10) (vii) of the KP Hydropower Policy 2016 and Notice to Proceed (NTP) was issued on December 09, 2019;

C) The Detailed Proposal as per Qualification Document (QD) dated July 03, 2020 including the Statement of Qualification (SOQ) (the "**Proposal**") was submitted by KHNP, (the "**Main Sponsor**") having its registered address at 1655 Bulguk-ro, Gyeongiu-si Gyeongsabgbuk-do, Republic of Korea (38120), along with other consortium members, including GoKPK (all consortium members jointly referred to as "the **Sponsors**")

D) PEDO issued No Objection Certificate (NOC) dated June 21, 2021;

E) The Sponsors having delivered an irrevocable, unconditional, on demand bank guarantee No. 2221-BG16-2021 dated June 23, 2021, on terms acceptable to PEDO, issued by National Bank of Pakistan, Corporate Branch, G-5/1, Islamabad in the amount of US $ 496,000/- (United State Dollars Four Hundred & Ninety Six Thousands

Only) valid up to June 24, 2024 (hereinafter referred to as the '**Bank Guarantee**') in favour of PEDO; and

F) The audited cost of the feasibility study will be provided by PEDO to the Sponsors after verification & the Sponsors have agreed to pay the audited cost of the feasibility study within four (4) months of issuing of such payment demand by PEDO.

NOW THEREFORE

In terms of the provisions of the KP Hydro Power Policy 2016 and associated Guidelines (the "**Policy**"), the GoKP through PEDO is pleased to issue this LOI for establishing, in PPP mode, an approximately **496 MW Lower Spat Gah Hydropower Project** to be located in Kohistan District, Khyber Pakhtunkwa (KP), Pakistan (the "**Project**") on the following terms and conditions:

1) The Sponsor(s) shall be required to update the feasibility study **at no risk and cost to, and without any obligation on part of, the GOKP and its agencies, within 18 (eighteen) months** from the date of issuance of this LOI. You are advised to liaise with the power purchaser while determining your project layout, hydrology, transmission line and interconnection arrangements, etc. In addition, you will also be required to liaise and coordinate with the Sponsor(s) of other upstream and downstream projects in order to ensure that the design and other parameters/features of the Project do not affect other projects.

2) The Sponsors shall submit detailed Project milestones within one month of signing of this LOI and shall submit monthly progress reports showing progress against these milestones. The Panel of Experts of PEDO shall monitor the conduct of the feasibility study and its progress to verify attainment of the aforesaid milestones and to ensure implementation of the Project consistent with national and provincial needs. Indicative terms of reference for the feasibility study are at **Annex A.**

3) During the term of LOI, upon approval of the feasibility study, you are also required to finalize and file, within ninety (90) days, a (i) complete feasibility stage tariff petition before National Electric Power Regulatory Authority (NEPRA) in accordance with NEPRA's Mechanism for Determination of Tariff for Hydropower Projects and simultaneously, a (ii) petition for the obtainment of the Generation License. Furthermore, within sixty (60) days after such tariff determination by NEPRA of the feasibility stage tariff (tariff determination), the Sponsor(s), after meeting all requirements under the applicable policies including but not limited to posting of an

irrevocable, unconditional, on demand Bank Guarantee on terms acceptable to PEDO/PPIB in an amount equal to US$ 5000/MW shall apply to PPIB for issuance of Tripartite Letter of Support (LOS).

4) In the event, the Sponsor(s) delays, defaults or fails to: file petition before NEPRA for; (i) tariff determination, in accordance with NEPRA's Mechanism for Determination of Tariff for Hydropower Projects within ninety (90) days of approval of the feasibility study; (ii) Generation License; (iii) apply to PPIB for issuance of LOS within sixty (60) days of tariff determination; (iv) pay the audited cost of the feasibility study; and or (v) enter into PPP Agreement with the GoKP in accordance with the MOU, the PEDO shall be entitled to encash the Bank Guarantee and the LOI shall stand terminated without any notice.

5) If PEDO acting in its sole discretion determines that any extension is required by the Sponsors in relation to their obligations to achieve any milestones under the LOI, the PEDO shall be entitled acting on an application in writing made to it by the Sponsors at least thirty (30) days before the expiry of this LOI, to grant in writing to the Sponsors such extension as is prescribed under and subject to such conditions as provided in the Policy.

6) The Bank Guarantee shall secure the Sponsor's obligations under and in accordance with the terms of this LOI. The Bank Guarantee shall remain valid and in full force until the date falling three (3) months beyond the expected date for issuance of LOS. If the Bank Guarantee is due to expire within thirty (30) days and is required to be maintained by the Sponsor(s), the Sponsor(s) shall renew the Bank Guarantee no later than ten (10) days before its expiry, failing which the PEDO shall be entitled to encash the Bank Guarantee in full and hold such cash as security for the obligations of the Sponsor(s) under the LOI.

7) The Sponsor(s) shall hold equity, in accordance with the Proposal, during Lock in Period (commencing from the date of issuance of this LOI until the sixth (6th) anniversary of the commissioning of the Project) as per KP Hydropower Policy, 2016 and its Guidelines (amended from time to time) such that the Main Sponsor shall hold not less than twenty percent (20%) of outstanding share capital of the Project Company and together with other sponsors shall be required to hold minimum fifty one percent (51%) of outstanding share capital of the Project Company at all times during the Lock in Period;

8) The terms and conditions of the PPP shall be settled inter-se the Sponsors through a PPP Agreement which will be finalized in accordance with the MOU. Modalities of GoKPK investment (up to 26% equity in the Project) will be finalized between KHNP and GoKPK after issuance of this

LOI and in any event prior to issuance of LOS pursuant to the terms and conditions of the PPP Agreement.

9) This LOI shall be effective from the date hereof, and remain valid till the issuance of LOS by PPIB or unless earlier terminated or extended earlier in accordance with the terms hereof. **Nevertheless, this LOI shall lapse if the signed copy is not received at PEDO within fifteen (15) days of its issuance.**

10) This LOI shall in no way be construed as an award of the Project as no such vested legal or contractual rights shall accrue, in your favor, till valid Project Agreements (as defined in the Tripartite LOS) are executed in accordance with the terms and conditions contained therein.

11) Issuance of this LOI or any act done in terms hereof or its termination, lapse or expiry or Sponsor(s)' updating of feasibility study hereunder cannot form the basis of any claim for compensation or damages by the Sponsor(s) or any party claiming through them against the Government of Khyber Pakhtunkhwa, PEDO or any of its agencies on any grounds whatsoever, during or after the expiration, lapse or termination of the LOI.

12) The obligations and liabilities of the Sponsor(s) under the LOI and the Bank Guarantee shall be joint and several. Any notice or communication by or to the Main Sponsor under this LOI shall be deemed a notice or communication to or by the entire Sponsor(s).

13) The rights and obligations of the parties pursuant to and under this LOI shall be governed by the laws of Pakistan and the Courts of Peshawar shall have exclusive jurisdiction in relation to any dispute or matter arising out of or in connection herewith.

14) This LOI has been issued in duplicate on the date hereof. Kindly sign the attached copy of this LOI at the place indicated and return the same to us no later than fifteen (15) days.

P E D O

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION

Government of Khyber Pakhtunkhwa Peshawar

Yours Sincerely

28/06/2021

Chief Executive Officer, PEDO

28/06/2021

Mr. Ahn Ho Young

Passport: M83310879

Designation: Chief Representative of

LOTTE E&C Pakistan

For and on behalf of

M/s Korea Hydro & Nuclear Power Company

1655 Bulguk-ro, Gyeongju-si

Gyeongsangbuk-do, Republic of Korea

(38120)

Witness-1

Signature: 28/06/2021.

Name: KASHIF FARHAN

Designation: KNNP MANAGER

CNIC #: 6110102241931

Address: H.220 street 1. D12/3 Islamabad

Witness-2

Signature:

Name: M. Imran Halim

Designation: Dir RFP

CNIC #: 16101-1214883-1

Address: Par hoti Mardan

APPENDIX-21
ENVIRONMENTAL APPROVALS

Date	Organization	Reference	Subject	Remarks	Appendix #
04.03.2022	LSG HPL	LSGHPP:EPA:0001	Submission of ESIA of lower spat gah hydropower project for approval	Submission of ESIA	21-A
01.04.2022	EPA	EPA/EIA/HPP/496 MW/22/4047-48	Submission of ESIA of lower spat gah hydropower project for approval	EPA Inviting for committee review meeting/presentation	21-B
20.06.2022	EPA	EPA/EIA/HPP/496 MW/22/223-24	Submission of ESIA of lower spat gah hydropower project for approval	EPA Written comments on meeting/presentation/ESIA report	21-C
05.07.2022	LSG HPL	LSGHPP:EPA:003	Submission of response to EPA observation on lower spat gah hydropower project	Response to EPA written Comments	21-D
28.06.2022	EPA	EPA/EIA/HPP/496 MW/22/273-75	The public hearing on the EIA report of Lower Spat Gah HPP	EPA requested the arrangement of a Public Hearing.	21-E
15.07.2022	LSG HPL	LSGHPP:EPA:0013 QL	The public hearing on the EIA report of Lower Spat Gah HPP	LSG Delivering Newspaper Advertisements and summary copies	21-F
24.08.2022	EPA	EPA/EIA/HPP/496 MW/22/588-589	The public hearing on the EIA report of Lower Spat Gah HPP	EPA comments on Public Hearing	21-G
19.09.2022	LSG HPL	LSGHPP:EPA:0014 QL	Response on Comments Received from EPA GoKP on Public Hearing	Response on Comments Received from EPA GoKP on Public Hearing	21-H
07.11.2022	EPA	EPA/EIA/HPP/496 MW/22/209-210	Submission of ESIA of lower spat gah hydropower project for approval	Comments received by EPA upon Forest Visit.	21-I
02.08.2023	LSG HPL	LLI-LZP-23-087L	Submission of Clarification/Justification to EPA's Comments for ESIA on Lower Spat Gah Hydropower Project	LSG HPL Submitted reply of the EPA's Comments along with Forest NOC.	21-J

[redacted]

LSG HYDRO POWER LIMITED

Office 29, 3rd Floor, Executive Complex, G-8 Markaz, Islamabad Pakistan,
Tel: +92 51 8435288,
http://www.lsg-hydro.com

Date: March 4, 2022
LSGHPP: EPA: 0001

Mr. Shafi Ullah Khan,
Director General
KP Environmental Protection Agency (KP-EPA)
3rd Floor, SDU Building, Kyber Road,
Peshawar Cantt.
Khyber Pakhtunkhwa
Tel: +92 (91) 9210263

Subject: **Submission of Environmental Impact Assessment (EIA) Report of Lower Spat Gah Hydropower Project for Approval**

Dear Mr. Khan,

The LSG Hydro Power Limited., also called LSG SPC ("Client") is planning to develop the Lower Spat Gah Hydropower Project ("Project") in Upper Kohistan District, in Khyber Pakhtunkhwa Province of Pakistan. The Spat Gah valley is located on the left bank of the Indus River about 4 km downstream of Dasu town. The Installed Capacity of the Project will be 470 MW.

Kindly find with this letter 10 hard copies of the EIA reports and 2 soft copies on CDs along with filled application form (Schedule I and VI) as well as paid fee receipt for grant of environmental approval.

We look forward to your early response and your cooperation in this regard.

Sincerely.

Mr Sangwoo Kim
Chief Executive officer
LSG Hydro Power limited.
Officer no 27, 28&29. Executive Complex
G8 Markaz Islamabad

LSG HYDRO POWER LIMITED
LSG

Contact Person for LSG Hydro Power Limited

Name:	Kashif Farhan
Designation:	Company Secretary- LSG Hydro Power ltd
Email:	kashif@lsg-hydro.com
Phone:	0333 – 333 4471, Phone no 051-843-5289. Fax no 051-831-2459
Address:	Office no 27, 28&29. Executive Complex, G8 Markaz Islamabad.

Encl.

1. 10 hard copies of ESIA report
2. 2 soft copies of ESIA report
3. Application form (Schedule I and VI)
4. Paid fee receipt.

The Bank of Khyber

ISLAMIC BANKING

399[illegible]

DEPOSIT SLIP

CUSTOMER COPY

Branch [illegible] Branch Code (In Case of online transaction) [illegible] Instrument Date [illegible]

Title of Account [illegible] Account Type [ ] Current [ ] Saving

Purpose of Deposit (In Case of Online Transaction) ______ Account No [illegible]

Currency: [ ] PKR [ ] USD [ ] EURO [ ] GBP [ ] JPY [ ] Other (Please Specify) ______

Bank's Name	Branch Name	Instrument No.	Denomination	Quantity	Amount
[illegible]		[illegible]			[illegible]
			TOTAL AMOUNT		[illegible]

Amount in Words [illegible]

Depositor's CNIC No (In Case of Online Deposit) [illegible]

SCHEDULE-I

Proforma for Screening and Scoping of Project

No.	Particulars	Reply submitted
1	Name of the Scheme / project	Lower Spat Gah Hydropower Project
2	Proponent name, address, and contact number	Name: LSG Hydro Power Limited Address: Office 29, 3rd Floor, Executive Complex, G-8 Markaz, Islamabad Contact Number: +92 51 8435288-9
3	Distance of industrial estate, if available, from the proposed scheme / project	NA
4	Brief of production process involved	The proposed Lower Spat Gah Hydropower Project will be a run-of-river project that will utilize the energy of water to generate power. It will have an installed capacity of 470 megawatts (MW). The Project will consist of the Lower Spat Gah Headworks on the Spat Gah River, the Lower Gabarband Intake on the Gabarband River, the Power Waterway, the Power Cavern, and the free-flow Tailrace Tunnel with its Outlet Structure on the Indus River.
5	Production capacity	470 MW
6	Total Project area and covered area	304 Acre
7	GPS Coordinates of the boundaries of the scheme / project	• Lower Spat Gah Headworks on Spat Gah River: 73°18'41" E, 35°10'35" N • Lower Gabarband Intake on Gabarband River: 73°18'60" E, 35°13'18" N • Headrace Tunnel Gabarband Crossing on Gabarband River: 73°16'13" E, 35°13'10" N • Powerhouse on Indus River: 73°13'14" E, 35°14'11" N • Tailrace Tunnel Outlet Structure on Indus River:73°12'36" E, 35°14'39" N • The Project location map is also attached with this schedule.
8	Existing status of the land (Agriculture, barren, forest etc.)	Barren and forest land on communal land 97%, agriculture land 3%, settlements less than 1%
9	Existing status of the scheme / project (proposed, construction phase, operations phase)	Proposed
10	Total cost of the scheme / project	Cost: 1 Billion 76 Million US Dollars (1076 Million USD)
11	Pollution control system (Air, Water, Noise etc.) to be installed	NA
12	Status of surroundings within 500m radius (houses, schools, mosques, agricultural land etc.)	In the surrounding areas there are 13 settlements comprising of almost 10,000 households, 5 schools, 1 BHU, 10-12 mosques, and about 200 acres of agricultural land.
13	Expected completion duration	Duration: 7.0 years (2.5 years early works and 4.5

		years for actual construction)
14	Expected positive impacts	Increased power supply. Provision of employment to people. Creation of service-sector jobs, procurement of consumables and the outsourcing to local service providers. Reduction in power outages and revival of the affected economies. Improved accessibility due to construction of Project access roads. Increase in the stock of skilled human capital due to transfer of knowledge and skill under the Project resulting in enhanced productivity of the local labor.
15	Expected negative impacts	generation of dust, noise, and traffic. affect to soil and water quality. disturbance due to blasting. pressure on existing infrastructure because of influx of job seekers. physical displacement of some households resulting in disruption of existing socioeconomic setup. reduction in water quality and quantity. Changes in sediment load of river. Fragmentation of fish habitat and impact on endangered and migratory species. Damage to natural flora and fauna and river ecosystem. GHG Emissions due to inundation of biomass in the Lower Spat Gah HPP Reservoirs.
16	Any other documents related to environment deemed necessary by the Review Committee.	

Conclusion And Screening Decision

____

____

____

____

____

<u>**SCHEDULE-VI**</u>

(see rule 8 (2) (a)) Application Form

1	Name and Address of Proponent	LSG Hydro Power Limited	Phone:	+92 51 8435288-9
		Office 29, 3rd Floor, Executive Complex, G-8 Markaz, Islamabad	Fax:	+92 51 8312459
2	Description of project		Telex:	Not available

The proposed Lower Spat Gah Hydropower Project will be a run-of-river project that will utilize the energy of water to generate power. It will have an installed capacity of 470 megawatts (MW). The Project will consist of the Lower Spat Gah Headworks on the Spat Gah River, the Lower Gabarband Intake on the Gabarband River, the Power Waterway, the Power Cavern, and the free-flow Tailrace Tunnel with its Outlet Structure on the Indus River.

3 Location of project and GPS Coordinates/GIS map

The Lower Spat Gah Hydropower Project will be located in Upper Kohistan District, in Khyber Pakhtunkhwa Province of Pakistan. The Project location map is also attached with this schedule.

4 Objectives of Project

To generate electricity.

5	IEE/[redacted]/GEA attached?	IEE/[redacted]/GEA		[redacted]/No
6	Have alternative sites been considered and reported in EIA/IEE/GEA?			[redacted]/No
7	Existing land use	[redacted]	Land Requirement	304 acres
	Is basic sites data available, or has it been measured?	(Only tick yes if the data is reported in the [redacted]/IEE/GEA)		[redacted]/No
			Available	Measured
8		Meteorology (including rainfall)	[redacted]/No	Yes/[redacted]
		Ambient air quality	[redacted]/No	[redacted]/No
		Ambient Water Quality	[redacted]/No	[redacted]/No
		Ground Water quality	[redacted]/No	[redacted]/No
9	Have estimates of the following been reported	Water balance	[redacted]/No	Yes/[redacted]
		Solid waste disposal	[redacted]/No	Yes/[redacted]
		Liquid waste treatment	[redacted]/No	Yes/[redacted]
10	Source of power	Local grid nearby and diesel generators as applicable	Power requirement	
11	Labour Force (number)	Construction: 2000 workers(350 skilled, 450		

semi skilled 1,200
unskilled
Operation: 75 workers(20
Skilled 30 Semi Skilled
and 25 Unskilled

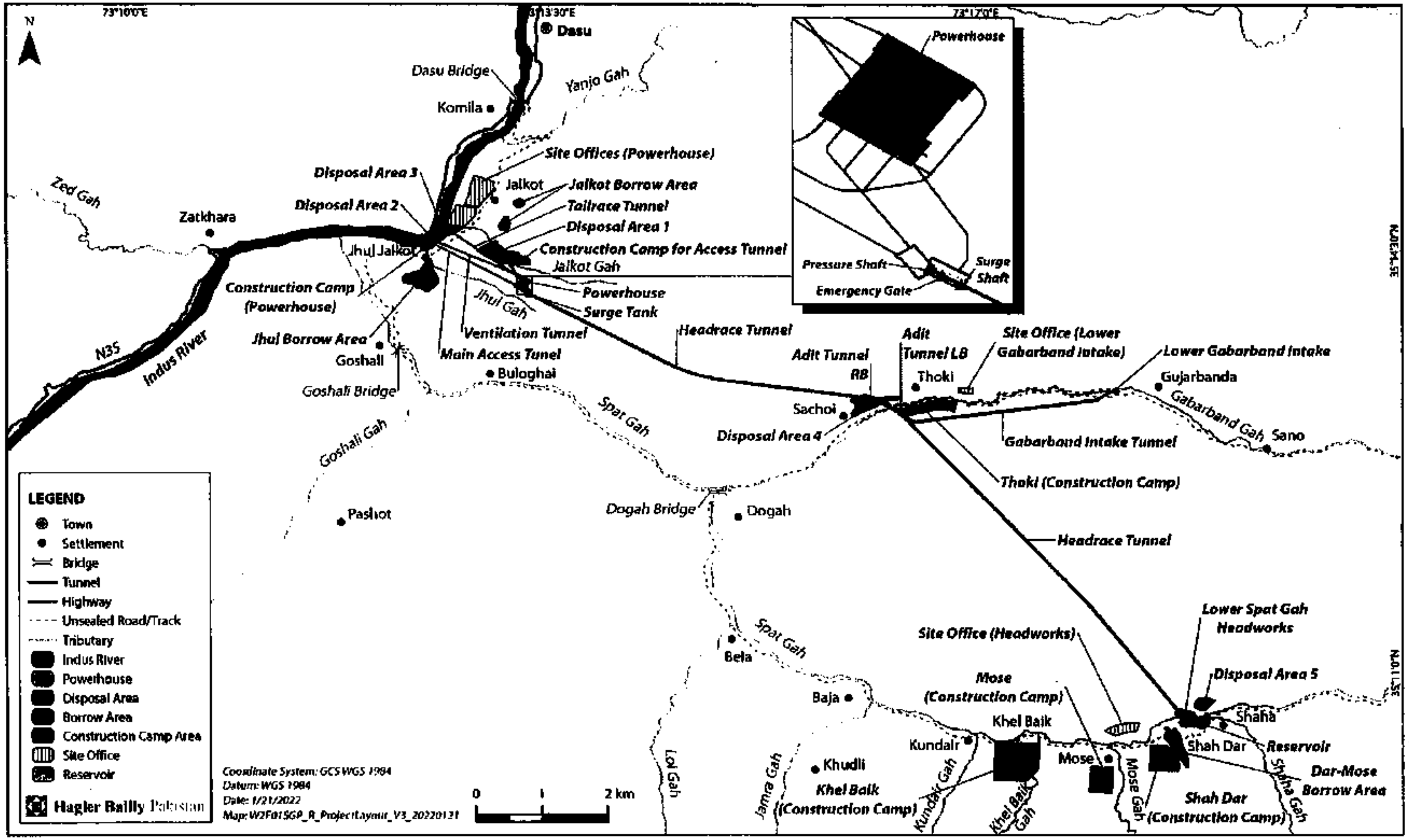
Verification: I do solemnly affirm and declare that the information given above and contained in the attached IEE/EIA/GEA is true and correct to the best of my knowledge and belief.

Date March-04-2022

LSG HYDRO POWER LIMITED LSG

SANGWOO KIM
Chief executive officer
LSG hydro power limited
Office no 27, 28&29.
Executive complex G8 Markaz
Islamabad

Project location map



Environmental Protection Agency
Forestry, Environment & Wildlife Department
Govt. of Khyber Pakhtunkhwa

No. EPA/EIA/HPP/496MW/22/ 4047-48

Dated 01 / 04 /**2022**

To

Mr. Sangwoo Kim,
Chief Executive Officer,
LSG Hydro Power Limited,
Office No. 27,28 & 29, Executive Complex,
G-8 Markaz, Islamabad.

Subject: **SUBMISSION OF ENVIRONMENTAL IMPACT ASSESSMENT (EIA) REPORT OF LOWER SPAT GAH HYDRO POWER PROJECT FOR APPROVAL**

I am directed to refer your letter No. LSGHPP:EPA:0001 dated 04-03-2022 on the subject noted above and to state that the subject EIA Report is forwarded to review committee for review process.

You are, therefore, requested to present your project on **06/04/2022** at **12:00 PM** in the Committee Room of EPA Khyber Pakhtunkhwa, Peshawar to proceed further in the matter, please.

Deputy Director (EIA)

Copy for information to the:

1. PA to Director General, EPA Khyber Pakhtunkhwa.

D:\EIA Section\Sectors\Hydro Power Projects\Spat Gah Hydro Power Project (496 MW)

Environmental Protection Agency
Forestry, Environment & Wildlife Department
Govt. of Khyber Pakhtunkhwa

No.EPA/EIA/HPP/496 MW LSG/22/223-24
Dated 20/06/2022

To

Mr. Sangwoo Kim,
CEO LSG Hydro Power Limited,
Office No. 27, 28, 29, Executive Complex,
G-8, Markaz, Islamabad.

Subject: **SUBMISSION OF ENVIRONMENTAL IMPACT ASSESSMENT REPORT OF LOWER SPAT GAH HPP 470 MW FOR APPROVAL**

I am directed to refer to the presentation on the subject EIA Report held on 30-05-2022 and to state that the following issues/observations were recorded during the presentation which need clarification/justification;

1. Submit comments of Fisheries Department that;
   a. Whether flow of 2.5 m3/s is sufficient for the survival of aquatic life or otherwise?
   b. Whether critically endangered/vulnerable species is located in the project footprint or otherwise. If yes what may be the anticipated impacts on the same and what mitigation measures be adopted for its protection?
   c. Submit fish count and location of fish breading spots in the project area.
2. In the report it is mentioned that hydropower will be operated on peaking mode. Submit justification of the same.
3. As per ESIA report there is no provision of fish ladder, no fish hatchery then what mitigation plan would be adopted by the proponent for aquatic life conservation and protection. Submit details of the same.
4. Detail of Budget allocation for the Biodiversity Action Plan.
5. The proponent will carry out a cumulative impact assessment study to assess and mitigate the impacts of the project on the river morphology and ecology. Moreover submit details of budget allocation in this regard.
6. Some 80 hector of land will be acquired for the project activity. Submit details of houses/structure falling in the mentioned area, land /structures acquisition /compensation plan and budget allocation for the same.
7. The proponent will consult the forest dept for clearance of the project activity in the forest designated area and the cutting involved.

3rd Floor, SDU Building, Khyber Road, Peshawar Cantt
Telephone: 92 (91) 9210263, Fax: 92 (91) 9210280

Moreover the proponent will share an updated KMZ file /boundary GPS coordinates of the project area.

8. The disposal area-1 at power house may block the natural flow of seasonal drain and will damage the nearby population in case of flooding. The same may be relocated and details of same will be shared with the agency.
9. The tunnel excavation via blasting will severly affects the nearby human settlement and surrounding environment. Hence the proponent will adopt environmentally sound safe tunnel excavation method and details of the same will be shared with the agency.
10. Submit detail of water table in the area, depth of the proposed settling tanks and justification that the same will not contaminate water table of the area. Moreover, proper waste water treatment plant shall be installed for permanent colonies and separate approval shall be obtained for the same from this Agency.
11. Submit detail about composition of chemicals mixed effluents generated at tunnel site and treatment mechanism for the same.
12. Provide exact details about main tunnel/access tunnel length,muck material generated, disposal total area and details of compaction and retention wall erection by observing safe engineering techniques for muck material disposal. Moreover ,as per GIS mapping ,the two-diposal sites seems to fall in river ROW, hence provide exact ROW of river dully approved by irrigation department.
13. Separate approvals will be required for the construction of crush plant, asphalt plant, permanent colonies etc.
14. Submit plantation plan along with budget allocation and area designated for the same.
15. In the EIA report, it is mentioned that a hazardous waste management plan, solid waste management and disposal plan will be developed by the contractor. However as per Khyber Pakhtunkhwa environmental protection act 2014 and rule/regulations made there under the same is the responsibility of the proponent .therefore, the above –mentioned plans should be prepared by the proponent in consultation with this agency.
16. Details of CSR activities with budget allocation keeping in view quantum of project activities and demands of the locals.
17. Mechanism should be devised to bound the proponent to pay for protection of the river ecology. Proponent may share their view in this regard.
18. How many jobs are fixed for the locals? Moreover Employment provides to the locals vs. total employment shall be shared with EPA.
19. Provide a plan for surface and ground water quality monitoring. Funds should be allocated for compensation if surface or ground water quality is contaminated by the project activities.

3rd Floor, SDU Building, Khyber Road, Peshawar Cantt
Telephone: 92 (91) 9210263, Fax: 92 (91) 9210280

20. Is it possible for the company to donate funds to environmental improvement fund (EIF) for environmental improvement and monitoring purposes at the project site.

In view of the above, you are, therefore, requested to submit comprehensive reply and clarify the issues/observations at the earliest to proceed further in the case, please.

Deputy Director (EIA)

Copy for information to;

- PA to Director General, EPA Govt. of Khyber Pakhtunkhwa, Peshawar.

3rd Floor, SDU Building, Khyber Road, Peshawar Cantt
Telephone: 92 (91) 9210263, Fax: 92 (91) 9210280

[redacted]

LSG HYDRO POWER LIMITED

Office 29, 3rd Floor, Executive Complex, G-8 Markaz, Islamabad Pakistan,
Tel: +92 51 8435288,
http://www.lsg-hydro.com

Date: July 5 2022
LSGHPP: EPA:003

Mr. Shafi Ullah Khan,
Director General
KP Environmental Protection Agency (KP-EPA)
3rd Floor, SDU Building, Khyber Road,
Peshawar Cantt.
Khyber Pakhtunkhwa
Tel: +92 (92 (91) 9210263

Subject: **Submission of Response to EPA's Observation on Lower Spat Gah Hydropower Project**
Reference: **EPA Letter Ref # EPA/EIA/HPP/496 MW LSG/22/223-24**

Dear Mr. Khan,

The LSG Hydro Power Limited., is planning to develop the Lower Spat Gah Hydropower Project ("Project") in Upper Kohistan District, in Khyber Pakhtunkhwa Province of Pakistan. The Spat Gah valley is located on the left bank of the Indus River about 4 km downstream of Dasu town. The Installed Capacity of the Project will be 470 MW.

Kindly find enclosed the response to Observations received by your esteemed office on Environmental Impact Assessment report of Lower Spat Gah Hydro Power Project.

LSG HYDRO POWER LIMITED

Sincerely.

Chief Executive Officer
LSG Hydro Power limited.
Officer no 27, 28&29. Executive Complex
G8 Markaz Islamabad

No	EPA Comments	LSG Hydro Power Ltd Response
1	Submit comments of Fisheries Department that,	
a	Whether flow of 2.5m3/s is sufficient for the survival of aquatic life or otherwise?	The environmental flow of any project requires running multiple scenarios with different flows and monitoring indicators to find an optimal solution that balances economy and ecology. We consider this level of flow as a balance in the context of sustainable development between the need to protect the fish and river ecology, and the need to generate power to meet the economic needs of the country. The level of EFlow proposed is comparable in terms of ratio of the environmental flow to the flow of river that has been accepted as reasonable for several other projects in the Himalayan region by international lenders as well as other environmental regulators in the region.
b	Whether critically endangered/vulnerable species is located in the project footprint or otherwise. If yes, what may be the anticipated impacts on the same and what mitigation measures be adopted for its protection?	None of the Critically Endangered or Endangered species was observed in the Project footprint area. Only Common Snow Trout Schizothorax plagiostomus (richardsonii) which is Vulnerable according to IUCN Redlist was observed from Spat Gah and Indus River. The anticipated impacts and mitigation measures for them are provided in Section 7.2 (Ecological Environment) of ESIA - Volume A.
c	Submit fish count and location of fish breading spots in the project area.	The requested details are available in the submitted ESIA report. The fish count is provided in Table 4-27 of Section 4.2 (Ecological Baseline) of ESIA - Volume A. The section also provide details on the fish breeding.
2	In the report it is mentioned that hydropower will be operated on peaking mod. Submit justification of the same.	Peaking is required to match the evening peak demand on the power transmission system in the country. The peaking surge in flow downstream of the powerhouse will flow into the much larger Indus River where its impact on the flow will be considerably buffered or attenuated, and the impact on the ecology of the Indus River will be minimal. This is explained in Section 6.1.2 (Impact of Baseload vs. Peaking Generation) of the ESIA - Volume C.01: Environmental Flow Assessment. As a side note, please bear in mind that a decision regarding the operating pattern is yet to be confirmed by the PoE as the Consultant considers that operating the LSG plant as a run-of-river plant would be beneficial for the Project as a whole from both technical and economical point of view.

3	As per ESIA report there is no provision of fish ladder, no fish hatchery then what mitigation plan would be adopted by the proponent for aquatic life conservation and protection. Submit details of the same.	As already explained in the report, fish hatchery and fish ladder are not technically feasible and will not mitigate the impacts of the Project. Snow trout has not as yet been bred in hatchery, and even if it is done in all likelihood it will have an adverse impact on the genetics and population of this fish in the river for reasons explained in the materials on hatchery we have shared with you. Moreover, fish ladder was not considered as a feasible option for this Project by the Fisheries Department, KP during consultation with them (see Section 3.2.1.2 of ESIA - Volume C.02: BAP for reference). In addition to maintaining an environmental flow, we have proposed several other measures in the Report in Section 06 of the ESIA-Volume C.02: BAP, including catch, truck and release of fish across the dam to maintain genetic diversity, investment in protection of the fish in the river under the Biodiversity Action Plan to prevent rapid depletion of fish by unregulated and open fishing by the local community which is a serious threat to survival of the fish in the river, and control of mining of stones and boulders in future to Protect the fish habitats and breeding areas. The Section 06 also provide details of how fish passages will not be a feasible option for this Project.
4	Detail of Budget allocation for Biodiversity Action Plan.	The budget for implementation of the Biodiversity Action Plan has been provided in Section 10 of ESIA-Volume C.02: Biodiversity Action Plan. Table 10-1 and Table 10-2, in Section 10 of ESIA-C.02: Biodiversity Action Plan, present budgets for capital/onetime costs and annual operating or recurring costs respectively, to implement protection in the Area of Management.
5	The proponent will carry out a cumulative impact assessment study to assess and mitigate the impacts of the Project on the river morphology and ecology. Moreover submit details of budget allocation in this regards.	A stand-alone CIA was carried out for the Project, for which Valued Environmental and Social Components were identified. No critical impacts due to the Project on river morphology were identified at a cumulative level as the flow of Spat Gah was assessed to be about 50 times less than Indus River, therefore no significant impact on morphology was identified at a cumulative level. However impacts on aquatic ecology were identified to be significant at a cumulative level. A management strategy at a basin level was discussed in the CIA report. Budgetary allocations were not explicitly provided to implement the management actions proposed, however a financial mechanism is provided in the Report, along with split of responsibilities between the Government and the Client. Budgetary allocations to manage the ecology, which includes the aquatic ecology were however, discussed in the Section 10 (Budget for Implementation) of the ESIA - Volume C.02: Biodiversity Action Plan, which compliments the ecology aspects of the CIA.

6	Some 80 hectares of land will be acquired for the project activity. Submit details of houses/ structures falling in the mentioned area, land/ structures acquisition/ compensation plan and budget allocation for the same.	Section 05 (Project Impacts) of the ESIA - Volume D: Resettlement Action Plan provide details of the land acquisition and resettlement impact due to the Project. Section 14 (Cost and Budget) of the ESIA - Volume D: Resettlement Action Plan present budget allocation for the affected households. Annex C (Census of Affected Households and Inventory of Affected Assets) of ESIA - Volume D: Resettlement Action Plan provide details of all the affected houses/structures.
7	The proponent will consult the forest dept for clearance of the Project activity in the forest designated area and the cutting involved. Moreover the proponent will share an updated KMZ file/ boundary GPS coordinates of the project area.	We like to share that the Forest Department has been consulted as part of the ESIA process for the Project and the concerns were presented in Section 3.2.1.3 (Forest Department, KP) of ESIA - Volume C.02: Biodiversity Action Plan. However, we have well-noted your point, and the proponent will do as per the instructions. The KMZ file showing Project facilities has already been provided to the Client by the way of a separate email. Thus, there is no further action required.
8	The disposal area-1 at powerhouse may block the natural flow of seasonal drain and will damage the nearby population in case of flooding. The same may be relocated and details of same will be shared with the agency.	We understand the point made. However, the risk for this impact will be negligible because Disposal Area 1 will be utilized in a way that will neither dump anything in the tributary nor construct any physical structure that may block the natural flow. In particular, requirements will be included in the Project Technical Specifications requiring the Contractor to implement the necessary mitigation measures incl. care of water and storm water drainage. Also, the disposal areas will be temporary facilities that will only in use during the active construction period. We believe operating in this manner would not result in the relocation of the disposal area, bearing in mind that the topography at the site is very unfavorable and only few flat areas are available for site installations. In particular, placing site installations as an attempt to mitigate the above concerns would result in more severe impacts on the environment. However, the Proponent will remain in coordination with the KP-EPA for an environmentally friendly development that balances the contractor's needs during the construction period.
9	The tunnel excavation via blasting will severely affects the nearby human settlement and surrounding environment. Hence the proponent will adopt environmentally sound safe tunnel excavation method and	The Proponent aims to have minimum impact on the human settlement and focuses on generating clean power, providing employment opportunities, and improving the local economy. Given this, the ESIA assesses the impacts of blasting for the tunnel excavation on the nearby structures/houses and provides the appropriate measures to mitigate the impact. According to the assessment, there will be five structures only falling in the Structural Damage Zone that will be relocated and compensated as and when required. Moreover, there will be a pre-blasting

	details of the same will be shared with the agency.	survey that will assess the condition of the houses/structures and compensate accordingly. For clarity, it is worth mentioning that only D&B method will be used for the Project (i.e. no Tunnel Boring Machine).
10	Submit detail of water table in the area, depth of the proposed settling tanks and justification that the same will not contaminate water table of the area. Moreover, proper waste water treatment plant shall be installed for permanent colonies and separate approval shall be obtained for the same from this agency.	The bottom of any soak pit or septic tank shall be at least 10 m above the groundwater table and about 100 m away from springs and any water bores. The distance can be reduced, based on the soil properties, if it is established that distance shall not result in contamination of groundwater. Moreover, all the sewerage should be pumped from the collection tank once a day into the common septic tank for further treatment. Treatment facilities will be provided for sewerage of toilets and domestic wastes. The above requirements will be included in the Project Technical Specifications for the EPC Contractor to design the installations where such infrastructures will be located during the Project execution (i.e. Detailed Design stage). It is anticipated that the EPC Contractor's design will be reviewed and approved by KP-EPA during Project execution.
11	Submit detail about composition of chemicals mixed effluents generated at tunnel site and treatment mechanism for the same.	We believe that the tunnel excavation via blasting at depth will not result in generation of large wastewater. Requirements for sediments ponds and waste water treatment at the portals locations will be included in the Project Technical Specifications for the EPC Contractor to comply during Project execution.. However, there will be discharge from the construction camps that will first go into the collection tank(s) and then into the septic tank(s). Information about composition of chemicals mixed effluents generated at tunnel sites is not available at Feasibility Study stage as it is common practise at Feasibility Study stage. This information will be available in a next Project design stage (i.e. during Project execution) and will be used as basis to design and construct adequate sediment ponds and wastewater treatment facilities at the portals location (see above). It is anticipated that the EPC Contractor's design will be reviewed and approved by KP-EPA during Project execution.

12	Provide exact details about main tunnel/ access tunnel length , muck material generated, disposal total area and details of compaction and retention wall erection by observing safe engineering techniques for muck material disposal. Moreover, as per GIS mapping, the two-disposal sites seems to fall in river ROW, hence provide exact ROW of river dully approved by irrigation department.	Please see the details below for tunnel lengths and muck material. The details are also provided in the ESIA - Volume A. • 2.4 km long Gabarband Intake Tunnel connecting to the Headrace Tunnel with free-flow section at the beginning and pressurized section after, • 10.9 km long pressurized Headrace Tunnel, • 0.5 km high Pressure Shaft, • 0.2 km long High Pressure Tunnel including penstock, • 1.3 km long free-flow Tailrace Tunnel. • 1.21 + 1.16 km long Main Access and Ventilation Tunnels The total excavated material including underground and surface excavation will be 2.2 million m3 that shall be transported to the destinations. Assuming 30% shall be used for the concrete production, about 1.54 million m3 shall be disposed of to the spoil disposal areas. About 77,400 m3 of clay and filter are needed. Assuming a ratio of about 50% of unsuitable material, then about 155,000 m3 material need to be removed from the borrow areas. Half of this shall be disposed of to the spoil disposal areas (~77,400 m3), the rest shall be used. Of this, at least 100,000 m3 shall be taken from Dar Mose borrow area while the remaining 55,000 m3 shall be taken from the Jhul or Jalkot borrow areas. The total spoil quantity to be transported to the spoil dumping sites shall be 1.61 million m3. According to the technical drawings, no Project facility comes in river ROW and the proponent will make sure that no material is dumped into the river and no structure is built in river ROW. Such requirements including specifications for spoil management will be included in the Project Technical Specifications for the EPC Contractor to follow and submitted to KP-EPA for review and approval during construction. However, the possibility of seeing two disposal areas in river ROW may be due to the transformation or distortion caused while transferring the AutoCAD file to Google Earth to prepare an updated .KMZ file. Also, the Google Earth show change in the river alignment with the time history. Therefore, proponent through its staff, contractors and sub-contractors will ensure that river ROW is not disturbed due to Project activities.
13	Separate approvals will be required for the construction of crush plant, asphalt plant, permanent colonies etc.	Well-noted. The Proponent will look into the list of approvals required for the Project in discussion with KP-EPA.

14	Submit plantation plan along with the budget allocation and area designated for the same.	Section 6.2 (Plantation and Revegetation) of the ESIA - Volume C.02: Biodiversity Action Plan provides details on the vegetation and the corresponding reforestation budget. The number of trees will be replanted with a ratio of 1 (tree removed): 10 (trees planted). The plantation plan and associated detailed budget will be developed by the EPC Contractor incorporating the points discussed in the ESIA. The plan will be submitted to the Proponent and KP-EPA for review and approval.
15	In the EIA report, it is mentioned that a hazardous waste management plan, solid waste management and disposal plan will be developed by the Contractor. However as per Khyber Pakhtunkhwa environmental project act 2014 and rule/ regulations made there under the same is the responsibility of the Proponent therefore, the above-mentioned plans should be prepared by the Proponent in consultation with this agency.	The plans mentioned in the ESIA will indirectly be developed by the Proponent such that the EPC Contractor hired by the Proponent will take the measures and consider the frameworks given in the ESIA and develop site-specific plans for each construction site. These plans will be first reviewed and approved by the Proponent and shared with KP-EPA for their kind review and feedback in a next Project design stage (i.e. during Project execution).
16	Details of CSR activities with budget allocation keeping in view quantum of project activities and demands of the locals.	A Community Development Program is proposed in the ESIA that will be implemented as part of the CSR activities. The program will include measures for employment enhancement and provision of on-site clinics/ambulances, medical camps, health awareness campaigns, school improvement initiatives, infrastructure development, and vocational training. Section 9.3 (Community Development Program) and Section 14 (Cost and Budget) of the ESIA - Volume D: Resettlement Action Plan provide details and budget of the program, respectively.
17	Mechanism should be devised to bound the proponent to pay for protection of the river ecology. Proponent may share their view in this regard.	Section 06 (Proposed Conservation Measures) of the ESIA - Volume C.02: Biodiversity Action Plan provide measures to be adopted by the proponent for the protection of biodiversity and river ecology. The proponent is responsible to develop an environmentally friendly project by adopting and implementing the measures proposed and discussed in the ESIA - Volume C.02: Biodiversity Action Plan to meet the local legislations and international guidelines.

18	How many jobs are fixed for the locals? Moreover, Employment provides to the locals vs. total employment shall be shared with EPA.	There is no fixed number available for the jobs; however, the priority will be given to the locals to the extent possible and one person from each affected household will be given vocational training which will help them in their professional and economic growth. Moreover, the Community Development Program and Local Employment Strategy will be developed as part of the Project to support the economic growth of the locals. Section 09 (Relocation and Livelihood Restoration Plan) and Section 14 (Cost and Budget) of the ESIA - Volume D: Resettlement Action Plan provide details of the measures for the locals/affected households and corresponding budget for implementation, respectively. The proponent will also develop a Local Employment Strategy based on the guidelines provided in Section 9.6.4 (Local Employment Strategy) of the ESIA - Volume A: Environmental and Social Impact Assessment to support the locals in terms of employment.
19	Provide a plan for surface and ground water quality monitoring. Funds should be allocated for compensation if surface or ground water quality is contaminated by the project activities.	Table 9-13 in Section 9 (Monitoring Plan) of the ESIA - Volume A: Environmental and Social Impact Assessment provide monitoring program for underground (i.e., springs), and surface (i.e., tributaries, river) during pre-construction, construction and operation phases of the Project. Proponent will take necessary measures to make sure no contamination takes place in the nearby water bodies and will take necessary budgetary action as and when required to mitigate the impact of contamination if happened due to the Project. The required plans will be jointly elaborated by the Proponent and the EPC Contractor in a next Project design stage (i.e. during Project execution).
20	Is it possible for the company to donate funds to environmental improvement fund (EIF) for environmental improvement and monitoring purposes at the project site.	The Project Sponsors intend to donate funds to EIF in accordance with the best practices followed by other Hydro Power Projects in KPK province.

Environmental Protection Agency
Forestry, Environment & Wildlife Department
Govt. of Khyber Pakhtunkhwa

No.EPA/EIA/HPP/496 MW LSG/22/273-75

Date: 28/06/2022

To

Mr. Sangwoo Kim,
CEO LSG Hydro Power Limited,
Office No. 27, 28, 29, Executive Complex,
G-8, Markaz, Islamabad.

Subject: **PUBLIC HEARING ON THE EIA REPORT OF LOWER SPAT GAH HPP (496 MW) FOR APPROVAL**

Kindly refer to the subject cited above; you are hereby informed that under Rule-11 of the Khyber Pakhtunkhwa Environmental Assessment Rule, 2021 Public Hearing is a mandatory part of the EIA process and under sub Rule-1 the same shall be advertised with prior information to the District Administration.

Therefore, Public Hearing of the subject project has been fixed on 26/07/**2022**. In this connection you are requested to consult with concern District Administration as well as EPA Regional Directorate Abbottabad. Prior to the advertisement and submit the news papers cutting regarding the Public Hearing published in any two (02) national/local newspaper (in original) with minimum 15 days gap between the advertisement and Public Hearing date, mentioning the type of project, its exact location, the name, address of the proponent and the date, time and venue for Public Hearing under intimation to this Agency along with 150 copies of brief summary of the EIA Report (in Urdu) at earliest for distribution among the stake holders.

Furthermore, 03 number of banners/ panaflex of 5 x 8 feet size shall be displayed at the eve of the Public Hearing. Besides a video recording of the Public Hearing shall be arranged and two (02) soft copies of the same shall be provided to the Agency.

Moreover, the Public Hearing shall be arranged at the project area with sufficient space for the participants to attend, please.

Director General

Copy for information to:

- Deputy Commissioner, Upper Kohistan for the information and necessary action under Rule-11 (1) of the Khyber Pakhtunkhwa Environmental Assessment Rule-2021, please.
- Director (North), EPA Regional Office, Abbottabad.

F:\EIA Section\#Sectors\HPP,Spat Gah

3rd Floor, SDU Building, Khyber Road, Peshawar Cantt.
Tel: 92(91) 9210263-9210148, Fax: 92 (91) 9210280

[redacted]

LSG HYDRO
POWER LIMITED

Office 29, 3rd Floor, Executive Complex, G-8 Markaz, Islamabad Pakistan,
Tel: +92 51 8435288.
http://www.lsg-hydro.com

Date: July 15 2022
LSGHPP: EPA: 0013QL

Director General
KP Environmental Protection Agency (KP-EPA)
3rd Floor, SDU Building, Kyber Road,
Peshawar Cantt.
Khyber Pakhtunkhwa
Tel: +92 (92 (91) 9210263

Subject: **Public Hearing on the Environmental Impact Assessment (EIA) Report of Lower Spat Gah Hydropower Project for Approval**

Reference: **NO: EPA/EIA/HPP/496 MW/22/273-75**

Dear Sir,

Please find attached advertisement cutting in the following newspapers in response to your letter number EPA/EIA/HPP/496 MW/22/273-75. Also find the EIA report summary and Banners for advertisement as requested.

Thank you very much for your cooperation as always.

Regards

Sincerely.

LSG HYDRO POWER LIMITED
LSG

Chief Executive Officer
LSG Hydro Power limited.

C.C

1. Deputy Director EPA (Mr.Waheed)

Encl. 150 hard copies of Project summary, 8 Banners, and The news International, Jang Urdu and AJJ newspaper

Environmental Protection Agency
Forestry, Environment & Wildlife Department
Govt. of Khyber Pakhtunkhwa

No.EPA/EIA/HPP/496 MW LSG/22/ 588-589

Date: 24 / 08 /2022

To

Mr. Sangwoo Kim,
CEO LSG Hydro Power Limited,
Office No. 27, 28, 29, Executive Complex,
G-8, Markaz, Islamabad.

Subject: **PUBLIC HEARING ON THE EIA REPORT OF LOWER SPAT GAH HPP (496 MW)**

I am directed to refer to the public hearing on the subject EIA Report held on 26-07-2022 and to state that the following issues/observations were recorded during the public hearing which need clarification/justification.

1. The local of area demands for provision of health & education facilities and establishment of mini HPP for Energy provision in the area. Hence a comprehensive CSR document with year wise budget / activity detail keeping in view the demands of locals raised during public hearing and quantum of the project may be submitted to this Agency.
2. Non-technical jobs shall be offered to the locals while the locals should also be given preference in technical jobs on the basis of eligibility. Moreover, jobs to be provided for locals directly affected from the project.
3. The issues related to project land acquisition and structure / property compensation will be sorted out with locals Administration and a certificate in this regard duly signed by the concerned revenue officer be submitted to this Agency prior to commencement of construction activities.
4. Number and location of springs along with GPS coordinates located in the tunnel area shall be submitted to EPA along with protection / compensation plan. Moreover, submit detail of water supply schemes if any in the project area.
5. A grievance redressal committee comprising of representatives from the locals should be constituted to sort out the public concerns peacefully. All the public concerns shall be compensated before commencement of physical activities.
6. Submit detail of micro HPPs located downstream of the project site along with location GPS coordinates and water requirements of the same. Moreover, submit mitigation measure for protection of the same.

F:\EIA Section\Sectors\HPP.SpatGah

3rd Floor, SDU Building, Khyber Road, Peshawar Cantt.
Tel: 92(91) 9210263-9210148, Fax: 92 (91) 9210280

Received 25/8/20

7. Submit details of flood in parhusarNullah. What will be the project impacts in this connection and what mitigation measures can be adopted to lower the impacts of the flood?
8. Submit recordings of the public hearing as per requirements under the Khyber Pakhtunkhwa Environmental Assessment Rules, 2021.
9. The main concern of the locals is to carry out a fresh survey for the houses, land to be affected; hence the proponent will submit an updated survey for the same.
10. Details of down-riparian depending on the river water and mitigation measures for the same.

In view of the above, you are, therefore, requested to submit comprehensive reply and clarify the issues/observations at the earliest to proceed further in the case, please.

Deputy Director (EIA)

Copy for information to;

- PA to Director General, EPA Govt. of Khyber Pakhtunkhwa, Peshawar.

3rd Floor, SDU Building, Khyber Road, Peshawar Cantt.
Tel: 92(91) 9210263-9210148, Fax: 92 (91) 9210280

[redacted]

LSG HYDRO
POWER LIMITED

Office 29, 3rd Floor, Executive Complex, G-8 Markaz, Islamabad Pakistan
Tel: +92 51 8435288
http://www.lsg-hydro.com

LSGHPP: EPA: 0014QL
Date: September 19, 2022

Director General
KP Environmental Protection Agency (KP-EPA)
3rd Floor, SDU Building, Khyber Road,
Peshawar Cantt.
Khyber Pakhtunkhwa
Tel:+92 91 9210263

Subject: Response on Comments Received from EPA GoKPK on Public Hearing of Lower Spat Gah Hydropower Project;

Dear Sir.

With regards to the subject matter please refer to Appendices A for response to comments received from your office vide letter number EPA/EIA/HPP/496MW/22/588-589. We are also providing USB of Video Recording of Public Hearing.

Thank you very much for your cooperation as always.

Sincerely yours,

Sang-woo Kim
Chief Executive Officer
LSG Hydro Power Ltd.

CC:
1. Deputy Director EPA(Mr.Waheed)

Enclosed:

1. Appendices A: Response on EPA Comments on Public Hearing for Lower Spat Gah HPP
2. USB: Video Recording of Public Hearing

Appendices A: Response on EPA Comments on Public Hearing for Lower Spat Gah HPP

No.	KP EPA's issues_observations	LSG HYDRO POWER reply and clarification
1	The local of are demands for the provision of health & education facilities and the establishment of mini HPP for Energy provision in the area. Hence a comprehensive CSR document with year-wise budget / activity detail keeping in view the demands of locals raised during the public hearing and the quantum of the project may be submitted to this Agency.	A Community Development Program is proposed in the ESIA that will be implemented as part of the CSR activities. The program will include measures for employment enhancement and provision of on-site clinics/ambulances, medical camps, health awareness campaigns, school improvement initiatives, infrastructure development, and vocational training. Section 9.3 (Community Development Program) and Section 14 (Cost and Budget) of the ESIA - Volume D: Resettlement Action Plan provide details and budget of the program, respectively.
2	Non-technical jobs shall be offered to the locals while the locals should also be given preference in technical jobs on the basis of eligibility. Moreover, jobs are to be provided for locals directly affected by the project.	The priority will be given to the locals to the extent possible and one person from each affected household will be given vocational training which will help them in their professional and economic growth. Moreover, the Community Development Program and Local Employment Strategy will be developed as part of the Project to support the economic growth of the locals. Section 09 (Relocation and Livelihood Restoration Plan) and Section 14 (Cost and Budget) of the ESIA - Volume D: Resettlement Action Plan provide details of the measures for the locals/affected households and corresponding budget for implementation, respectively. The proponent will also develop a Local Employment Strategy based on the guidelines provided in Section 9.6.4 (Local Employment Strategy) of the ESIA - Volume A: Environmental and Social Impact Assessment to support the locals in terms of employment.
3	The issues related to project land acquisition and structure / property compensation will be sorted out with locals. Administration and a certificated in this regard duly signed by the connected revenue officer be submitted to this Agency prior to commencement of construction activities.	An experienced local Consultant will be hired who will carry out the land acquisition process with Revenue Department and in consultation with the locals on behalf of the Client.
4	Number and location of springs along with GPS coordinates located in the tunnel area shall be submitted to EPA along with a protection / compensation plan. Moreover, submit detail of water supply schemes if any in the project area.	The details of springs along with GPS coordinates are available in the ESIA report Volume A, Section 4, Table 4-6: Details of Mountain Springs. The details about impacts on springs and mitigation measures are provided in Section 7.1.7.1 Changes to Groundwater Patterns.
5	A grievance redressal committee comprising representatives from the locals should be constituted to sort out the public concerns peacefully. All public concerns shall be compensated before the commencement of physical activities.	The GRC will be established at two levels: 1.Village GRC, with the scope limited within the village, 2.Project GRC, covering all the Project affected villages. Section 8, Grievance Redress Mechanism of the ESIA Report Volume A provide details on the Grievance Redressal Committee.

6	Submit detail of micro HPPs located downstream of the project site along with location GPS coordinates and water requirements of the same. Moreover, submit mitigation measures for the protection of the same	There are 2 micro hydropower plants at Gabarband Gah. Coordinates are: a. 35°12'45.0"N, 73°15'41.0"E (Downstream Sachoi Settlement) b. 35°13'15.0"N, 73°16'49.0"E (Upstream Thoki Settlement) The proposed Project will not affect these micro hydropower plants and the recommended Eflow of 0.47 m3/s at Lower Gabarband Intake will meet the water requirements of these micro-hydropower plants.
7	Submit details of flood in parhusarNullah. What will be the project impacts in this connection and what mitigation measures can be adopted to lower the impacts of the flood?	The glaciers in the catchment above the Lower Spat Gah dam are small and few in number (relative to other regions in UIB). In addition, these are located far from the dam location. With potential increases in temperature and melting, the risk of GLOF will increase. However, the impact of a GLOF is very unlikely to extend down to the reservoir of the Lower Spat Gah HPP. No mitigation is required as GLOF formation is unlikely in the catchment area. Moreover, the dam design takes into account the potential of extreme precipitation events resulting in floods in the nearby tributaries and consider the findings of the flood assessment carried out as part of the Feasibility Study for Lower Spat Gah and Gabarband Intake.
8	Submit recordings of the public hearing as per requirements under the Khyber Pakhtunkhwa Environmental Assessment Rules, 2021.	The video recording of the public hearing has been submitted in USB to EPA.
9	The main concern of the locals is to carry out a fresh survey for the houses, and land to be affected; hence the proponent will submit an updated survey for the same.	The Client will hire a Consultant to carry out this exercise on his behalf. However, the Client hired Consultant will not be able to conduct the survey alone and will require Government assistance. It is because the Upper Kohistan District is one of the districts of KP where up-to-date land records are unavailable, and people who inhabit the land are considered land owners. At the time of the previous survey, AFRY/HBP surveyed the people who occupied the lands and houses. Now, as information about land acquisition is spread in the area, some people who do not have physical possession of the land may claim the ownership. In this scenario, if the latest survey is to be carried out by the Client hired Consultant only, there are chances of disputes in the area. Therefore, the Client will request the Revenue Department, a Government Department, to conduct a new survey at the time of land acquisition, prepare land records and decide on the ownership. The Client and its hired Consultant will provide any assistance required by the department for the smooth implementation of the survey, update the RAP after the survey is conducted by the Revenue Department, and make payments accordingly.

		Th above process of acquiring land is also explained in the ESIA Report – Volume D: Resettlement Action Plan.
10	Details of down-riparian depending on the river water and mitigation measures for the same.	Impact of Project related activities on riparian zone and mitigations proposed are discussed in ESIA Report Volume C.03: Cumulative Impact Assessment and in ESIA Report Volume A: Section 7.1 (Physical Impact Assessment and Mitigation Measures) and Section 7.2 (Ecological Impact Assessment and Mitigation Measures). A brief overview based on what has already been mentioned in ESIA is given below. The overall ecosystem integrity, which includes geomorphology, algae, macro-invertebrates, water quality and riparian vegetation is predicted to experience less change, as compared to the fish integrity. Even though there will be irreversible short-term harm to some ecological receptors (individuals), the species should not suffer as the area of habitat occupied by the Project infrastructure will be very small. Therefore, the magnitude of impact is considered as minor. Some mitigation measures from the ESIA Report are given below. 1. Temporary disposal sites shall be located out of wetlands, adjacent riparian corridors, and ordinary high-water areas as well as high-risk zones, such as 100-year floodplain and unstable slopes. 2. Minimize the Project footprint, clearly delineate and restrict access beyond work sites and other areas to be disturbed. 3. Minimize disturbance to, or movement of, soil and vegetation; prevent soil damage and erosion; retain as much natural vegetation as possible. 4. Maintain environmental flow as recommended in Project design.

Environmental Protection Agency
Forestry, Environment & Wildlife Department
Govt. of Khyber Pakhtunkhwa

No.EPA/EIA/HPP/496 MW LSG/22/209-210

Dated 07/11/2022

To

Mr. Sangwoo Kim,
CEO LSG Hydro Power Limited,
Office No. 27, 28, 29, Executive Complex,
G-8, Markaz, Islamabad.

Subject: **SUBMISSION OF ENVIRONMENTAL IMPACT ASSESSMENT REPORT OF LOWER SPAT GAH HPP 470 MW FOR APPROVAL**

I am directed to refer to your letter No. LSGHPP/EPA:003 on the subject noted above and to state that your replies have been thoroughly evaluated followed by a site visit conducted by the regional directorate North Abbottabad. In this context, the following issues/observations were recorded which need clarification/justification;

1. Submit comments of Fisheries Department that;
   a. Whether flow of 2.5 m3/s is sufficient for the survival of aquatic life or otherwise?
2. As per ESIA report there is no provision of fish ladder, no fish hatchery then what mitigation plan would be adopted by the proponent for aquatic life conservation and protection. Submit details of the same. (Comments / NOC from Fisheries Department shall be submitted to this Agency).
3. Detail of Budget allocation for the Biodiversity Action Plan. (EPA role and budget allocation for the same must be incorporated).
4. The proponent will carry out a cumulative impact assessment study to assess and mitigate the impacts of the project on the river morphology and ecology. Moreover, submit details of budget allocation in this regard. (The proponent shall allocate budget for cumulative impact assessment study of HPPs on the river ecology and morphology).

3rd Floor, SDU Building, Khyber Road, Peshawar Cantt
Telephone: 92 (91) 9210263, Fax: 92 (91) 9210280

5. The proponent will consult the Forest Department for clearance of the project activity in forest designated area and the cutting involved. Moreover, the proponent will share an updated KMZ file /boundary GPS coordinates of the project area. (The proponent must obtain NOC from the Forest Department and shall submit to this Agency).
6. Submit detail about composition of chemicals mixed effluents generated at tunnel site and treatment mechanism for the same.
7. The disposal area-1 at power house may block the natural flow of seasonal drain and will damage the nearby population in case of flooding. The same may be relocated and details of same will be shared with the agency. (The proponent shall select other suitable site for dumping muck material instead of previously selected disposal area 1).
8. Provide exact detail about main tunnel/access tunnel length, muck material generated, disposal area and detail of compaction and retention wall erection by observing safe engineering techniques for muck material. Moreover, as per GIS mapping the two disposal sites seems to fall in river RoW, hence provide exact Row of river duly approved by Irrigation department. (As per site visit report disposal area 1 & 5 fall into the RoW of freshwater streams/rainwater drain. Therefore, select other suitable sites for dumping of muck material instead of previously selected area 01 & 05. For disposal area 02 & 03 submit clearance certificate from Irrigation department).
9. The tunnel excavation via blasting will severely affects the nearby human settlement and surrounding environment. Hence the proponent will adopt environmentally sound safe tunnel excavation method and details of the same will be shared with the Agency. (The human settlement near to blasting site must be relocated before

3rd Floor, SDU Building, Khyber Road, Peshawar Cantt
Telephone: 92 (91) 9210263, Fax: 92 (91) 9210280

construction activity and controlled blasting techniques must be adopted not only to save human settlement but also the natural environment of the area).

In view of the above, you are, therefore, requested to submit comprehensive reply and clarify the issues/observations at the earliest to proceed further in the case, please.

Assistant Director (EIA)

Copy for information to;

- PA to Director General, EPA Govt. of Khyber Pakhtunkhwa, Peshawar.

3rd Floor, SDU Building, Khyber Road, Peshawar Cantt
Telephone: 92 (91) 9210263, Fax: 92 (91) 9210280

[redacted]

LSG HYDRO POWER LIMITED

LLI-LZP-23-087L

4th Floor, Emirates Tower, Jinnah Super, F-7,
Islamabad Pakistan
Tel: +92-51-6134782
http://www.lsg-hydro.com

August 02, 2023

Reply Required ☒ Yes ☐ No

Director General
KP Environmental Protection Agency (KP-EPA)
3rd Floor, SDU Building, Khyber Road, Peshawar Cantt.
Khyber Pakhtunkhwa

Subject: **SUBMISSION OF CLARIFICATIONS/JUSTIFICATIONS TO EPA'S COMMENTS FOR ESIA ON LOWER SPAT GAH HYDROPOWER PROJECT**

Reference: EPA Letter No. EPA/EIA/HPP/496MW LSG/22/209-210 dated 7 Nov. 2022

Dear Sir,

The LSG Hydro Power Limited, is planning to develop the Lower Spat Gah Hydropower Project ("Project") in Upper Kohistan District of Khyber Pakhtunkhwa Province of Pakistan. The Spat Gah valley is located on the left bank of the Indus River about 4km downstream of Dasu town. The installed capacity of the project will be 470MW.

Kindly find enclosed the response to Observations received by your esteemed office on Environmental Impact Assessment Report of Lower Spat Gah Hydro Power Project.

Sincerely yours,

For

Lim Seung Yeol
CEO
LSG Hydro Power Limited

Enclosures: ☒ Yes ☐ No

- Attachment: Clarification/Justification to Issues/Observation by KP-EPA

CC: 1. Director Renewable Energy, Private Power, PEDO, Peshawar

Document Delivery: ☐ Email ☒ Courier ☐ Fax ☐ Hand Delivered

Attachment. CLARIFICATION/JUSTIFICATION TO ISSUES/OBSERVATIONS BY KP-EPA

CLARIFICATION/JUSTIFICATION TO ISSUES/OBSERVATIONS BY KP-EPA

Issues/Observations by KP-EPA	Clarification/Justification by LSG Hydro Power Limited
1. Submit comments of Fisheries Department that; a. Whether flow of 2.5 m^3/s is sufficient for the survival of aquatic life or· otherwise?	The environmental flow of any project requires running multiple scenarios with different flows and monitoring indicators to find an optimal solution that balances economy and ecology. We consider this level of flow as a balance in the context of sustainable development between the need to protect the fish and river ecology, and the need to generate power to meet the economic needs of the country. The level of E-Flow proposed is comparable in terms of ratio of the environmental flow to the flow of river that has been accepted as reasonable for several other projects in the Himalayan region by international lenders as well as other environmental regulators in the region. Over and above, Fisheries Department is a member of Panel of Expert (PoE) of PEDO where Fisheries Department are already assimilated in the ESIA report. PoE has agreed with the project feasibility after substantial justification and technicalities discussed at the forum. Minutes of PoE supportive documents are provided at **Attachment 1.** Further, biodiversity action plant (BAP) is under consideration for the region with multiple indicators to know ecological impacts of the project on river. Recommendations and findings of the BAP would be considered for implementation including E. Flow proposed. KP EPA will also monitor the project activities and E. Flow. The E. Flow would be revised if recommended by KP EPA or BAP.
2. As per ESIA report there is no, provision of fish ladder, no fish hatchery then what mitigation plan would be adopted by the proponent for aquatic life conservation and protection. Submit details of the same. (Comments/NOC from Fisheries Department shall be submitted to this Agency).	The comments from the Fisheries Department were recorded at the time of ESIA consultation and incorporated in the ESIA report. Consultation log with Fisheries Department and other institutions are available in Annex M.2: Institutional Consultation Logs of ESIA - Volume B: Annexes for your kind consideration. As already explained in the report, fish hatchery and fish ladder are not technically feasible and will not mitigate the impacts of the Project. Snow trout has not as yet been bred in hatchery, and even if it is done in all likelihood, it will have an adverse impact on the genetics and

CLARIFICATION/JUSTIFICATION TO ISSUES/OBSERVATIONS BY KP-EPA

Issues/Observations by KP-EPA	Clarification/Justification by LSG Hydro Power Limited
	population of this fish in the river for reasons explained in the ESIA and its supporting studies on hatchery we have shared with you. Moreover, the fish ladder was not considered as a feasible option for this Project by the Fisheries Department, KP during consultation with them (see Section 3.2.1.2 of ESIA - Volume C.02: BAP for reference). In addition to maintaining an environmental flow, we have proposed several other mitigation measures in the Report in Section 06 of the ESIA-Volume C.02: BAP, including catch, truck and release of fish across the dam to maintain genetic diversity, investment in protection of the fish in the river under the Biodiversity Action Plan to prevent rapid depletion of fish by unregulated and open fishing by the local community which is a serious threat to survival of the fish in the river, and control of mining of stones and boulders in future to Protect the fish habitats and breeding areas. Section 06 also provides details of how fish passages will not be a feasible option for this Project. Detail consultation made with Fisheries Department is also elaborated above.
3. Detail of Budget allocation for the Biodiversity Action Plan. (EPA role and budget allocation for the same must be incorporated)	The budget for implementation of the Biodiversity Action Plan has been provided in Section 10 of ESIA-Volume C.02: Biodiversity Action Plan. Table 10-1 and Table 10-2, in Section 10 of ESIA-C.02: Biodiversity Action Plan, present budgets for capital/onetime costs and annual operating or recurring costs respectively, to implement protection in the Area of Management. The BAP Coordination Committee in KP will be established by the KP government through a notification which will include EPA as a member for the implementation of BAP. The details of the functions of the committee is in Section 7 (Institutional Arrangement) of ESIA-C.02: Biodiversity Action Plan. Additionally, the project is in the feasibility stage. EPA role can further be rationalized through mutual consultation with the department while finalizing the BAP.
4. The proponent will carry out a cumulative impact assessment study to assess and mitigate the impacts of the project on the river	A stand-alone CIA was carried out for the Project, for which Valued Environmental and Social Components were identified. No critical impacts due to the Project on river morphology were identified at a cumulative level as the flow of Spat Gah was assessed to be about 50 times less

CLARIFICATION/JUSTIFICATION TO ISSUES/OBSERVATIONS BY KP-EPA

Issues/Observations by KP-EPA	Clarification/Justification by LSG Hydro Power Limited
morphology and ecology. Moreover, submit details of budget allocation in this regard. (The proponent shall allocate budget for cumulative impact assessment study of HPPs on the river ecology and morphology).	than Indus River, therefore no significant impact on morphology was identified at a cumulative level. However, impacts on aquatic ecology were identified to be significant at a cumulative level. A management strategy at a basin level was discussed in the CIA report. Budgetary allocations were not explicitly provided to implement the management actions proposed, however a financial mechanism is provided in the Report, along with split of responsibilities between the Government and the Client. Budgetary allocations to manage the ecology, which includes the aquatic ecology were however, discussed in Section 10 (Budget for Implementation) of the ESIA - Volume C.02: Biodiversity Action Plan, which compliments the ecology aspects of the CIA. The environmental approval of the LSG project should not be linked with the budget allocation of CIA study of other HPPs. This should be a separate study and the consultant who will be hired for this will provide the estimates. However, the management of Spat Gah HPP is committed to add its share if EPA or any other government department ever planned a study on the river.
5. The proponent will consult the Forest Department for clearance of the project activity in forest designated area and the cutting involved. Moreover, the proponent will share an updated KMZ file / boundary GPS coordinates of the project area. (The proponent must obtain NOC from the Forest Department and shall submit to this Agency).	The consultation with Chief Conservator Office was made and Finally, both parties confirms that the project component are located beyond the designated forest. The Forest Department issued "NOC OF FOREST DEPARTMENT FOR CONSTRUCTION OF LOWER SPAT GAH(LSG) HPP UPPER KOHISTAN" (No.269/GB/D-XII-97/VoL-06, dated 24 / 07 / 2023). The NOC is provided at **Attachment 2.**

CLARIFICATION/JUSTIFICATION TO ISSUES/OBSERVATIONS BY KP-EPA

<table>
<tr><th>Issues/Observations by KP-EPA</th><th>Clarification/Justification by LSG Hydro Power Limited</th></tr>
<tr><td>6. Submit detail about composition of chemicals mixed effluents generated at tunnel site and treatment mechanism for the same.</td><td>We believe that tunnel excavation via blasting at depth will not result in generation of large wastewater. Requirements for sediments ponds and wastewater treatment at the portals locations will be included in the Project Technical Specifications for the EPC Contractor to comply during Project execution.</td></tr>
<tr><td>7. The disposal area-1 at powerhouse may block the natural flow of seasonal drain and will damage the nearby population in case of flooding. The same may be relocated and details of same will be shared with the agency. (The proponent shall select other suitable site for dumping muck material instead of previously selected disposal area 1).</td><td>We understand the point made. However, the Proponent will remain in coordination with the Irrigation Department and KP-EPA for an environmentally friendly development that balances the contractor's needs during the construction period. The site will not be utilized for dumping purposes without obtaining clearance from the Irrigation Department. As this is the feasibility stage of the project, disposal sites will be decided in consultation with related stakeholders.</td></tr>
<tr><td>8. Provide exact detail about main tunnel/ access tunnel length, muck material generated, disposal area and detail of compaction and retention wall erection by observing safe engineering g techniques for muck material. Moreover, as per GIS mapping the two disposal sites seems to fall in river RoW, hence provide exact Row of river duly approved by Irrigation department. (As per site visit report disposal area 1 & 5 fall into the RoW of freshwater streams/ rainwater drain. Therefore, select other suitable sites for dumping of muck material instead of previously selected area 01 &</td><td>Please see the details below for tunnel lengths and muck material. The details are also provided in the ESIA - Volume A.

• 2.4 km long Gabarband Intake Tunnel connecting to the Headrace Tunnel with free-flow section at the beginning and pressurized section after,
• 10.9 km long pressurized Headrace Tunnel,
• 0.5 km high Pressure Shaft,
• 0.2 km long High-Pressure Tunnel including penstock,
• 1.3 km long free-flow Tailrace Tunnel.
• 1.21 + 1.16 km long Main Access and Ventilation Tunnels

The total excavated material including underground and surface excavation will be 2.2 million m3 that shall be transported to the destinations. Assuming 30% may be used for the concrete production, about 1.54 million m3 shall be disposed of to the spoil disposal areas.</td></tr>
</table>

CLARIFICATION/JUSTIFICATION TO ISSUES/OBSERVATIONS BY KP-EPA

Issues/Observations by KP-EPA	Clarification/Justification by LSG Hydro Power Limited
05. For disposal area 02 & 03 submit clearance certificate from Irrigation department).	About 77,400 m3 of clay and filter are needed. Assuming a ratio of about 50% of unsuitable material, then about 155,000 m3 material need to be removed from the borrow areas. Half of this shall be disposed of to the spoil disposal areas (~77,400 m3), the rest shall be used. Of this, at least 100,000 m3 shall be taken from Dar Mose borrow area while the remaining 55,000 m3 shall be taken from the Jhul or Jalkot borrow areas. The total spoil quantity to be transported to the spoil dumping sites shall be 1.61 million m3. According to the technical drawings, no Project facility comes in river ROW and the proponent will make sure that no material is dumped into the river and no structure is built in river ROW. Such requirements including specifications for spoil management will be included in the Project Technical Specifications for the EPC Contractor to follow and submitted to KP-EPA for review and approval during construction. However, the possibility of seeing two disposal areas in river ROW may be due to the transformation or distortion caused while transferring the AutoCAD file to Google Earth to prepare an updated .KMZ file. Also, Google Earth show change in the river alignment with the time history. Therefore, proponent through its staff, contractors and sub-contractors will ensure that river ROW is not disturbed due to Project activities. Also, the disposal areas will be temporary facilities that will only in use during the active construction period. We believe operating in this manner would not result in the relocation of the disposal area, bearing in mind that the topography at the site is very unfavorable and only few flat areas are available for site installations. In particular, placing site installations as an attempt to mitigate the above concerns would result in more severe impacts on the environment. However, the Proponent will remain in coordination with the KP-EPA for an environmentally friendly development that balances the contractor's needs during the construction period.

CLARIFICATION/JUSTIFICATION TO ISSUES/OBSERVATIONS BY KP-EPA

Issues/Observations by KP-EPA	Clarification/Justification by LSG Hydro Power Limited
9. The tunnel excavation via blasting will severely affects the nearby human settlement and surrounding environment. Hence the proponent will adopt environmentally sound safe tunnel excavation method and details of the same will be shared with the Agency. (The human settlement near to blasting site must be relocated before construction activity and controlled blasting techniques must be adopted not only to save human settlement but also the natural environment of the area).	The Proponent aims to have minimum impact on the human settlement and focuses on generating clean power, providing employment opportunities, and improving the local economy. Given this, the ESIA assesses the impacts of blasting for the tunnel excavation on the nearby structures/houses and provides the appropriate measures to mitigate the impact. According to the assessment, there will be five structures only falling in the Structural Damage Zone that will be relocated and compensated as and when required. Moreover, there will be a pre-blasting survey that will assess the condition of the houses/structures and compensate accordingly. For clarity, it is worth mentioning that only D&B method will be used for the Project (i.e. no Tunnel Boring Machine).

Attachment 1. Minutes of PoE Supportive documents

Attachment 2. NOC of Forest Department for LSG HPP

PEDO

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION

Government of Khyber Pakhtunkhwa Peshawar

PEDO House, 38/B-2, Phase-V, Hayatabad, Peshawar. Tel: (+92-91) 9217246-186, Fax: (+92-91) 9217003

No. 509-10 /PEDO/DREPP/LSG/MoM
Dated: August 24, 2022

To

Mr. Sang-woo Kim
CEO, LSG Hydropower Ltd.
Korea Hydro & Nuclear Power Co. Ltd, (KHNP)

Subject: **MINUTES OF THE PANEL OF EXPERTS MEETINGS HELD ON APRIL 27-28, 2022 and JULY 28, 2022**

I am directed to refer to the subject noted above and to enclose herewith minutes of the Panel of Experts (PoE) meetings held on **April 27-28, 2022** and **July 28, 2022** for information and compliance please.

Deputy Director (RE-I)
PEDO, Peshawar

Copy for information to:-

- PS to CEO, PEDO, Peshawar.

Deputy Director (RE-I)
PEDO, Peshawar

		currently we have an example in under construction project designed by Koreans and vetted by Lahmyer consultant Germany to which the PoE advised to mention the reference in the feasibility study report. **ESIA Studies:** **xii.** The ESIA consultant briefed the forum about the environmental studies. EPA representative aggrieved that the consultant previous presentation to the EPA team was unsatisfactory. The consultant responded that the observations has been investigated in detail and addressed to the maximum possible extent and there are no serious environmental and social issues on the project site.	
		xiii. E-Flows of 20% and 30% of the minimum flow will have impact of 2% increase in tariff with the greater impact on fish species. The consultant responded that if we take E-flows for 50% or 60% of the minimum flow (as required by EPA and having less impacts on fish species) it will have 10% increase in tariff, hence, the consultant suggested that keeping under consideration the economic perspective, we along with EPA must make a combined decision on the matter.	**xiii.** PoE advised that an expert from the consultant shall investigate and study the issue in detail and come up with an optimized option to EPA so that they can best decide to go for the E-flows of 20% or 30% of the minimum flow. PoE further added that the project sponsor shall establish an office regionally and take onboard relevant experts to assess every project related activity in a professional manner. The project may also be registered to NEPRA for CSR activity.
		xiv. EPA representative observed that the disposal areas for mucking material have been planned inside the river and as an engineering practice these should be places alongside river, properly protected by gabion wall etc., that can be reclaimed and used for some social activity in future. Furthermore, mining of the river bed material and sand mining causes erosion of the river side banks which shall be avoided.	**xiv.** PoE advised to look in detail for the issues and avoid the same to the maximum possible. Furthermore, in all correspondence with EPA department, PEDO shall be taken in loop to which the project sponsor agreed.
		xv. PoE inquired about the mini micro plants of PEDO located in the project area. The consultant explained that two MHPs are in the project area which are under consideration and shall remain unaffected. **Feasibility Study Design:** **xvi.** E& M expert of PoE observed that rope type trash cleaning mechanism has been considered by the consultant which may not be	**xvi.** PoE suggested to look for the telescopic type hydraulic trash cleaning mechanism.

PEDO

PAKHTUNKHWA ENERGY DEVELOPMENT ORGANIZATION
Government of Khyber Pakhtunkhwa Peshawar
PEDO House, 38/B-2, Phase-V, Hayatabad, Peshawar. Tel: (+92-91) 9217246-186, Fax: (+92-91) 9217003

No. 509-10 /PEDO/DREPP/LSG/MoM
Dated: August 24, 2022

To

Mr. Sang-woo Kim
CEO, LSG Hydropower Ltd.
Korea Hydro & Nuclear Power Co. Ltd, (KHNP)

Subject: **MINUTES OF THE PANEL OF EXPERTS MEETINGS HELD ON APRIL 27-28, 2022 and JULY 28, 2022**

I am directed to refer to the subject noted above and to enclose herewith minutes of the Panel of Experts (PoE) meetings held on **April 27-28, 2022** and **July 28, 2022** for information and compliance please.

Deputy Director (RE-I)
PEDO, Peshawar

Copy for information to:-

- PS to CEO, PEDO, Peshawar.

Deputy Director (RE-I)
PEDO, Peshawar

Minutes of the Panel of Experts of PEDO

Dated: July 28, 2022 in PEDO House Peshawar

1. A meeting of the Panel of Experts (PoE) was held on July 28, 2022 at 11:00 AM in PEDO House, Peshawar to review the progress of feasibility study of 470 MW Lower Spat Gah HPP. The list of participants is attached as **Annex-I.**

2. Chief Engineer REP/PP, PEDO welcomed all participants of the meeting. Afterwards, the meeting progressed towards the following agenda items.

S. No	Project	Discussions/Reservations	Recommendations/Decisions
1	**470 MW Lower Spat Gah Hydro power Project**	The forum was informed that three meetings of the Panel of Experts (PoE) have been previously conducted wherein the inception report and further studies have been discussed in detail.	
		The NOC from the Environment department came under discussion with the commencement of the meeting. Representative of EPA asked for complete diversity plan of the river basin to be carried out by the project sponsor. PPIB representative suggested that at current EPA may give conditional approval of the EPA NOC with the advice that the project sponsor shall carry out the whole area study once the project get into the implementation stage.	PoE advised that EPA to give approval of environmental NOC with the condition that the project sponsor will carry out the complete diversity plan of the project river once the project get into the implementation phase, in order to avoid delays.
		NTDC representative was asked about the status of the project in IGCEP 2021-30 and any changes expected in the draft version submitted to Ministry of Energy (Power Division) in April 2022. They explained that we don't know the status of the project as it is a confidential document which is currently under discussion in the Ministry and we expect that there will be no drastic changes. The cost of transmission line was discussed and it was concluded to keep it as per policy responsibility of the NTDC at present as it is too early to decide and the same will further be fixed at the time of PPA. The consultant then presented the progress on the feasibility study and responses to the comments of the PoE made during the site visit;	

Attachment 2. NOC of Forest Department for LSG HPP

CHIEF CONSERVATOR OF FORESTS
CENTRAL SOUTHERN FOREST REGION-I
KHYBER PAKHTUNKHWA
(HAD)

SHAMI ROAD PESHAWAR
Ph: +92 91 9212177, Fax: +92 91 9211478
E-mail: ccfforests.pesh@gmail.com

No. 269 /GB/D-XII-97/Vol-06 Dated 24 / 07 / 2023

The Chief Executive Officer
LSG Hydro Power Limited Office 29,
3rd floor, Executive Complex, G-8 Markaz,
Islamabad.

Subject: - **NOC OF FOREST DEPARTMENT FOR CONSTRUCTION OF LOWER SPAT GAH (LSG) HPP UPPER KOHISTAN.**

Reference in continuation of this office letter No. 232-34/GB/D-XII-97/Vol-VI dated 19.07.2023.

Please refer to the subject cited above, it is intimated that **Conditional Approval** of the subject matter has been accorded by the Worthy Secretary Climate Change, Forestry, Environment and Wildlife Department Khyber Pakhtunkhwa Peshawar, vide his letter No. SO(Tech)/FE&WD/V-475/2023/PC/Towers/7045-47 dated 19.07.2023, **which is enclosed** herewith for favor for information and further necessary action as desired by Administrative Department.

Encl: as above.

Chief Conservator of Forests
Central Southern Forest Region-I
Khyber Pakhtunkhwa Peshawar.

No. ________________/GB/D-XII-97/Vol-06

Copy in continuation of this office letter cited above forwarded to: -

1. The Chief Conservator of Forest, Northern Forest Region-II Abbottabad for information and further necessary action as desired by Administrative Department.
2. The Section Officer (Technical) Forestry, Environment and Wildlife Department Khyber Pakhtunkhwa Peshawar for favor of information with reference to his letter cited above.

Chief Conservator of Forests
Central Southern Forest Region-I
Khyber Pakhtunkhwa Peshawar

GOVERNMENT OF KHYBER PAKHTUNKHWA
CLIMATE CHANGE, FORESTRY, ENVIRONMENT & WILDLIFE DEPARTMENT
No: So (TECH)/FE&WD/V-427/2022/PC/TOWERS
DATED PESHAWAR THE, 19-07-2023

To

The Chief Conservator of Forests,
Central Southern Forest Region-I,
Peshawar.

Subject: - **NOC OF FOREST DEPARTMENT FOR CONSTRUCTION OF LOWER SPAT GAH (LSG) HPP UPPER KOHISTAN.**

I am directed to refer to your letter No.231/GB dated 19-07-2023 on the subject cited above and to state that the competent authority i.e. Secretary CCFE&WD has agreed with the recommendations of the committee and accorded **conditional approval** for construction of Project camp at moose area located outside designated forests and 10.09 KM long and 3.9 Meter wide underground tunnel passing underneath Guzara Forest of Khel Baik Compartment No.1, Gujar bound Compartment No.2 and Toki Dader Compartment No.2, with entrance and exit of headrace tunnel outside forest area having minimum 700 Meter depth from the surface; **strictly as per the provisions of Forest Ordinance, 2002/rules made there-under and the consolidated criteria and SOPs duly approved by the Provincial Cabinet dated 05/01/2022 & 19/07/2022** subject to following formalities/conditions:

i. 2% income of project generation to be pledged and paid into Forest Development Fund in light of Provincial Cabinet decision dated 28-11-2017.
ii. Lower Spat Gah Hydro Power Project organization to acquire private land coming in the alignment of relocated project design.
iii. Environmental Protection Agency while issuing NOC shall ensure to include cost for eco-system and Biodiversity Restoration and conservation component in the EMP/ESMP in consultation with the Forest Department to be execute through Forest Department.

2. I am further directed to say that it may also be ensured fulfillment/observance of all codal formalities and instructions issued from time to time, please.

(Zafran Khan)
Section Officer (Tech)

Endst: No: & Date even

Copy is forwarded for information and further necessary action w/r to CCF-I letter No. quoted above:

1. Chief Conservator Forests-II, Northern Forest Region, Civil Line Forest Office, Abbottabad.
2. Section Officer (Environment), Climate Change, Forestry, Environment & Wildlife Department.
3. PS to Secretary, Climate Change, Forestry, Environment & Wildlife Department, Khyber Pakhtunkhwa for information.

Section Officer (Tech)

REPORT

LSG HYDRO POWER LIMITED

Lower Spat Gah Hydropower Project

Feasibility Study
Volume 9: Transmission Line Studies

127000588-002

04 November 2022

Final

AFRY
ÅF PÖYRY

Project
Lower Spat Gah Hydropower Project

Project No.
127000588-002

Revision
Final

Date
04 November 2022

Address
AFRY (Thailand) Ltd.
Vanit II Bldg., 22nd Floor, Room No. 2202-2204,
1126/2 New Petchburi Road, Makkasan,
Rajchthewi, Bangkok 10400, Thailand

Phone
+66 2 108 1000

Contact
Stephan Martin

Mobile
+66 92 264 0738

E-mail
stephan.martin@afry.com

Client
LSG Hydro Power Limited

Report
Feasibility Study, Volume 9: Transmission Line Studies

Structure of Feasibility Study

List of Abbreviations

Abbreviation	Meaning
GIS	gas-insulated switchgear
IGCEP	Indicative Generation Capacity Expansion Plan
LSG	Lower Spat Gah
NEPRA	National Electric Power Regulatory Authority
NTDC	National Transmission and Dispatch Company
PPI	Power Planners International
SPC	Special Purpose Company

List of Units

Symbol	Unit
kA	kiloampere
kV	kilovolt
MW	Megawatt

Table of Contents

1 General

This Volume 9 – Transmission Line Studies presents the power market study, power systems study and transmission line survey conducted as part of the Feasibility Study for the Lower Spat Gah Hydropower Project.

The power market study and the power systems study are the draft versions as submitted to the relevant Pakistani authorities in November 2022. The transmission route survey was still ongoing at the time of writing of this report and will be made available in due course.

2 Power Market Study

This chapter summarises the comprehensive power market study conducted to assess the feasibility of the Lower Spat Gah Project keeping the future perspective of generation and load demand as the key factors. The complete report is included in **Error! Reference source not found.** of this Feasibility Study Report volume.

The demand forecasts for the year 2031 were established for the three demand growth scenarios Low Demand Forecast, Medium Demand Forecast and High Demand Forecast in line with the Indicative Generation Capacity Expansion Plan (IGCEP).

The power generation capacities for the year 2031 were established for various energy generation technologies. This includes existing projects, committed projects as well as optimized projects picked from the candidates projects. The retirement of existing projects or those whose power purchase agreements expire have also been considered.

The projected demand and supply in the National Transmission and Dispatch Company (NTDC) system served as input for the power and energy balance simulations carried out for 2031, the year in which the Lower Spat Gah Project will be commissioned. The power and energy balances demonstrated that in 2031 there was enough demand in the NTDC system in all demand growth scenarios and capacity addition cases that could be met by the projected capacity offered by the must run plants, including the Lower Spat Gah Project. The addition of the Lower Spat Gah Project will not have any adverse impact on energy generated by any must run plant.

The development of the Lower Spat Gah Project will benefit the national grid in more ways than one. It will inject clean energy into the system from a climate change perspective, provide indigenously produced energy in meeting the energy security goals for the country and provide cheap energy compared to that of imported fuels such as RLNG, coal and RFO based thermal power plants.

3 Power Systems Study

This chapter summarises the power system studies conducted to evolve an interconnection scheme between the Lower Spat Gah HPP and the National Grid, for stable and reliable evacuation of electrical power generated from this Project. The complete report is included in Annex 1 of this Feasibility Study Report volume.

The study evaluated the loop in loop out connection to the nearby 765 kV Dasu-Mansehra transmission line in the summer 2030. Because the transmission network data beyond 2028 was not available from NTDC, PPI developed, in agreement with NTDC and to facilitate these power system studies, an interim Base Case for 2030 to be used for the studies based on i) assumptions agreed with NTDC and ii) the approved load forecast until 2030 and system data (NTDC Transmission Plan & IGCEP).

In order to connect to the 765 kV Dasu-Mansehra transmission line, the grid connection is planned as follows:

- Three 220 kV cables from the power cavern to the connection switchyard,
- 765/220 kV connection switchyard near the powerhouse access tunnel portals consisting of 220 kV GIS yard, auto transformer bank and 765 kV GIS yard,
- Two 765 kV overhead lines to the Dasu-Mansehra transmission line.

The results of the load flow studies carried out for peak and off-peak load scenarios of summer 2030 showed that the proposed interconnection scheme with all the proposed reinforcements and the protection schemes is adequate to evacuate the net 470 MW power of the Lower Spat Gah HPP under normal and contingency steady state conditions.

The maximum short circuit levels at Lower Spat Gah 765 kV are 12.65 kA and 11.17 kA for 3-phase and 1-phase faults, respectively, in the year 2030. Therefore, industry standard switchgear of a short circuit rating of 63 kA would be sufficient for installation at 765 kV switchyard of Lower Spat Gah HPP, as the maximum short circuit levels for the year 2030 were also found to be within this range, taking care of any future generation additions and system reinforcements in its electrical vicinity and also fulfilling the NEPRA Grid Code requirements specified for 765 kV switchgears. There are no violations of the power rating of the equipment in the vicinity of Lower Spat Gah HPP in the event of fault conditions.

The results of the dynamic stability carried out for summer 2030 show that the system is very strong and stable for the proposed scheme for the severest possible faults of 765 kV systems near the Lower Spat Gah HPP under all events of disturbances. Therefore, there is no problem of dynamic stability for interconnection of the Lower Spat Gah HPP, it fulfils all the criteria of dynamic stability. The system is found strong enough to stay stable and recovered with fast damping.

Overall it can be concluded that the proposed scheme of interconnection has no technical constraints or problems, it fulfils all the criteria of reliability and stability under steady state load flow, contingency load flows considered, short circuit currents and dynamic/transient conditions. It is therefore recommended to be adopted.

4. Transmission Line Survey Study Report

This chapter summarises Lower Spat Gah Project Grid Connection via 765 kV Dasu-Mansehra transmission line between the Dasu and Mansehra in Khyber Pakhtunkhwa Province. For this connection, a 765/220 kV Connection Switchyard located near the Powerhouse access tunnel portals will have to be constructed. The topography of the Project area is dominated by high mountains, which entails geological/environmental hazards of landslides (rock and/or soil), rock falls, snow drifts and avalanches, etc.

Annex 1 Power Market Study Report

REPORT

LSG HYDRO POWER LIMITED

Lower Spat Gah Hydropower Project

Feasibility Study

Transmission Line - Power Market Study

127000588-002
24 November 2022

Draft

AFRY
ÅF PÖYRY

Project
Lower Spat Gah Hydropower Project

Project No.
127000588-002

Revision
Draft

Date
24 November 2022

Address
AFRY (Thailand) Ltd.
Vanit II Bldg., 22nd Floor
1126/2 New Petchburi Road, Makkasan
Rajchthewi, Bangkok 10400, Thailand

Phone
+66 2 108 1000

Contact
Stephan Martin

Mobile
+66 92 264 0738

E-mail
stephan.martin@afry.com

Client
LSG Hydro Power Limited

Report

Feasibility Study, Transmission Line - Power Market Study

"This report has been prepared by AFRY (Thailand) Ltd. ("AFRY") together with Power Planners International (Pvt.) Ltd. ("PPI") for LSG Hydro Power Limited also called LSG SPC pursuant to the consultancy services agreement signed between AFRY and LSG Hydro Power Limited. This report is based in part on information not within AFRY's control. While the information provided in this report is believed to be accurate and reliable under the conditions and subject to the qualifications set forth herein, AFRY does not, without prejudice to AFRY's obligations towards the Recipient under the Agreement, make any representations or warranties, expressed or implied, as to the accuracy or completeness of such information.

Use of this report and any of the estimates contained herein by anyone else than the Recipient ("Third Party User") shall, therefore, be at the Third-Party User's sole risk. Any use by a Third-Party User shall constitute a release and agreement to defend and indemnify AFRY from and against any liability of AFRY towards the Third-Party User, whatsoever in type or nature, in connection with such use, whether liability is asserted to arise in contract, negligence, strict liability or other theory of law.

All information contained in this report is of confidential nature and may be used and disclosed by the Recipient solely in accordance with the terms and conditions set forth in the Agreement."

Table of Contents

Figures

Tables

List of Abbreviations

The following abbreviations have been used in this report.

Abbreviation	Meaning
ACGR	Annual Compound Growth Rate
COD	Commercial Operation Date
CPPA	Central Power Purchase Agency (Guarantee)
CTBCM	Competitive Traded Bilateral Contract Market
DISCO	Distribution Company
FY	Fiscal Year
G2G	government to government
GDP	gross domestic product
GENCO	Generation Company
GHG	greenhouse gas emission
HPP	Hydropower Project
IAA	Independent Auctions Administrator
IGCEP	Indicative Generation Capacity Expansion Plan
IPP	Independent Power Producer
KE	K-Electric
LOI	Letter of Intent
LOLP	Loss of Load Probability
LOS	Letter of Support
LSG	Lower Spat Gah
NEPRA	National Electric Power Regulatory Authority
NTDC	National Transmission and Dispatch Company
PESCO	Peshawar Electric Supply Company
PPI	Power Planners International
PV	photovoltaic
RFO	residual fuel oil
RLNG	Regasified Liquid Natural Gas
ROR	run of river
SPC	Special Purpose Company
SPT	Special Purpose Trader
VRE	variable renewable energy
WAPDA	Pakistan Water and Power Development Authority

The following units have been used in this report.

Symbol	Unit
%	percent
GWh	Gigawatt hour
kV	Kilovolt
MW	Megawatt

1 Introduction

1.1 General

The LSG Hydro Power Limited, also called LSG SPC ("Client") is planning to develop the Lower Spat Gah Hydropower Project ("Project") in Upper Kohistan District, in Khyber Pakhtunkhwa Province of Pakistan. The Spat Gah valley is located on the left bank of the Indus River about 4 km downstream of Dasu town. The Installed Capacity of the Project will be 470 MW. The Feasibility Study of the Project was carried out by AFRY Thailand.

AFRY Thailand has contracted Power Planners International ("PPI") to carry out transmission line studies, including a power market study, power systems studies and a transmission line survey for the Lower Spat Gah Hydropower Project. This report provides the power market study.

1.2 Objectives and Scope of Power Market Study

A comprehensive power market study was conducted to assess the feasibility of the Lower Spat Gah Project keeping the future perspective of generation and load demand as the key factors. This included all the planned / optimized generation additions in the IGCEP 2021 and IGCEP 2022 ("IGCEP") along with their technologies. The study also incorporated the retirement of existing power plants or those plants whose power purchase agreements expire over the respective years. The study reviewed the existing generation facilities, committed power projects and the corresponding existing and committed systems and appraised the range of generation addition options available to meet the future demand. In line with IGCEP methodology, three demand growth scenarios were included in the study:

- Low Demand Forecast
- Medium Demand Forecast
- High Demand Forecast

The analysis was carried out on a monthly basis for FY 2031 for which the monthly peak demand and energy generation factors of the NTDC system were used to estimate the monthly peak demand and energy generation requirements. Annual hourly power curves of all existing, committed and optimized hydropower (including Lower Spat Gah), wind, and solar projects were also converted to monthly maximum power generation in MW and monthly energy generation in GWh to simulate power and energy balances to see if the Lower Spat Gah Project can potentially form a part of IGCEP as per its planned commissioning schedule.

The analysis aimed at demonstrating that there was enough demand in the NTDC system in FY 2031 that can absorb the addition of the Lower Spat Gah Project consistently over the year without affecting the dispatch of any must run plant including hydroelectric, nuclear, variable renewable energy[1] (VRE) and bagasse, thereby clearly demarcating the project as a worthy hydel project for inclusion in IGCEP. The analysis took into account the installed hydroelectric projects and VRE projects that would be available in the FY 2031. Hydropower projects have long gestation periods and besides nuclear, require the highest capital investment on a per MW basis amongst the competing technologies, the two major challenges to overcome. Looking back at the history of the development of the power generation industry of the country through government's power generation policies[2] since 1994, shows a high rate of projects either facing long delays or dropping at various stages such as after receiving Letter of Intent (LOI) and Letter of Support (LOS) and never reaching construction stage. The majority of hydropower and other projects in the past have been delayed significantly or gone into obscurity owing to failures in securing financing, closing power purchase agreements and associated security package and management's failure where the sponsor lacked intent and ability to steer the projects to completion. It is hard to make any prediction at this stage to mark out projects that would be completed on schedule or drop down either to delays or to a complete halt.

---

1 Wind and solar PV technologies

2 Federal government's 1994 Power Policy, 1995 Power Policy, 1998 Power Policy, 2002 Power Policy, and 2006 Power Policy. In addition several power policies offered by provincial governments.

The study assumes that all the committed hydropower and other projects in IGCEP will be commissioned on time or with minor delays but will be available in the year 2031. The majority of the optimized hydropower project, however, are in their early stage of development. Besides completion of technical and commercial formalities and other critical steps for implementation, which adds to the uncertainty about their development timelines, many of the optimized hydropower project therefore, in high probability, may spill over beyond the horizon of the study. In order to capture this failure, two cases have been studied:

- Case 1: 100% completion of optimized hydropower projects as planned by FY 2031.
- Case 2: 50% completion of optimized hydropower project as planned with the other 50% spilling over the study horizon and therefore not available by year 2031.

In this report the year 2031 or FY 2031 are considered the same.

2 Pakistan Power Sector

Pakistan's power sector consists of two systems. One Ex-WAPDA that was desegregated in the late 1990s from a vertically integrated utility to smaller generation, transmission and distribution companies as publicly owned corporate entities. There are four generation companies (GENCOs), one transmission and dispatch company namely the National Transmission and Dispatch Company (NTDC) which is currently the transmission network operator and the system operator. There are ten distribution companies (DISCOs) that geographically cover all of Pakistan except the city of Karachi and its adjoining areas. The Ex-WAPDA system is also referred to as the NTDC system because of its system operator role. The other power system K-Electric (KE) is a privately owned vertically integrated power utility that serves the city of Karachi and its adjoining areas. The KE and NTDC networks are linked with each other through several interconnection lines ranging from 500 kV to 220 kV. The present combined transfer capacity of these interconnection facilities stands at 1,100 MW and KE has a contract with NTDC for import of 1,100 MW. With growing demand, KE is planning to enhance its interconnection facilities to 2,500 MW by FY 2030. By FY 2031, KE would be purchasing power from 300 MW Siddiqsons coal fired plant and 82 MW Turtonas Uzghor hydropower plant by using the NTDC network to wheel this power. In addition, KE will be importing 2,000 MW from the NTDC power pool around the same time. In this study, the 2,000 MW of KE demand has been added to the NTDC system demand for its captive market in FY 2031.

Besides the Ex-WAPDA power generation facilities, the NTDC system has over 90 Independent Private Power Producers (IPPs) consisting of thermal (17,160 MW), hydroelectric (1,205 MW), bagasse (364 MW), wind (1845 MW) and solar (500 MW) technologies totalling to over 21,000 MW of power generation capacity.

Over the past decade, the power generation wholesale market was operated as a single buyer in which the Central Power Purchasing Agency Guarantee Limited (CPPA-G) had been procuring power from all generators on behalf of the ten DISCOs under an agency arrangement. CPPA-G also provides the settlement function for payment to generators. Since 31 May 2022 however, the country has moved to a new wholesale power generation market model, a Competitive Traded Bilateral Contract Market (CTBCM) in which the large customers (load greater than 1 MW) are allowed to purchase electricity directly from the market. The current role of CPPA-G will continue as a Special Purpose Trader (SPT) until all legacy IPP contracts expire. DISCOs will also be allowed to procure new power capacity under competitive arrangements through the Independent Auctions Administrator (IAA). A market operator has been formed to cater for the market functions mainly the settlement and running the balancing mechanism to deal with variations and deviations in the market contracts and actual power flows between the contracting parties. Both the transmission and distribution networks will provide open access wheeling services to the electricity suppliers and traders and the large customers under the market operations. The Lower Spat Gah HPP, however, may get a power purchase agreement with CPPA-G under the government to government (G2G) project arrangements under the Federal Government's international (bilateral or multilateral) commitments subject to the signing of the project financing agreements.

The analysis in this report is restricted to the NTDC system of demand (including 2,000 MW of KE demand) and generation capacities as the Lower Spat Gah Project is envisaged to sell its energy into the NTDC system and may not have any direct linkage with KE.

This report has been prepared in light of the Indicative Generation Capacity Expansion Plan (IGCEP) 2021 and 2022 prepared by the NTDC Planning Department on a yearly basis to fulfil its obligations under the Grid Code. The IGCEP covers the future development of hydroelectric, thermal, nuclear and renewable energy resources to meet the anticipated load demand by the year 2031. It identifies new capacity requirements by taking into account capacity, technology, fuel and commissioning dates on a year-by-year basis by complying with the various regulatory requirements as set out through the provisions of the Grid Code, including Loss of Load Probability (LOLP), long-term load growth forecast and system reserve requirements. The IGCEP is submitted to the regulator (NEPRA) annually for its approval and it covers a period of 10 years, with the latest IGCEP 2022 offering analysis for the period 2022-2031.

3 Power Demand

This section briefly sets the perspective of the study from the NTDC system power demand and energy generation forecast. The IGCEP presented analysis for three demand forecast scenarios of low, medium and high growth, which were used in the study.

3.1 Current Demand

The computed peak demand in the NTDC system during 2022 is 23,746 MW with an annual energy generation requirement of 126,890 GWh.

3.2 Demand Forecast for FY 2031

The long-term demand forecast was developed by using econometric approaches mainly through multiple regression analysis. Electricity sales were regressed against the independent variables such as electricity prices, GDP, population, number of consumers, lag variables etc. by using time series data for the period 1970-2021.

The IGCEP demand forecast used in the study took into account the potential reduction in demand owing to demand side management, net metering and load management.

The monthly peak factors for demand and monthly energy were used to work out the monthly peak demand and energy generation requirements.

Table 3-1 presents the NTDC power demand projections under the three scenarios of Low, Medium and High Demand Growth.

3.2.1 Low Demand Forecast

The Low Demand Forecast assumed an overall GDP growth of 4.4% for the next 10 years and resulted in an annual peak demand of 39,039 MW as well as an energy generation requirement of 201,770 GWh in the year 2030-31, showing an ACGR of 5.32% and 5.71% respectively. As mentioned earlier, the KE import demand of 2,000 MW and energy requirement of 11,388 GWh have to be added into the NTDC demand to arrive at the power generation requirements for NTDC. The net NTDC demand with KE exports will become 41,039 MW and energy generation requirement of 213,158 GWh under the Low Demand Growth scenario.

3.2.2 Medium Demand Forecast

The Medium Demand Forecast also referred to as the normal forecast, assumed an overall GDP growth of 5.4% for the next 10 years and resulted in an annual peak demand of 42,081 MW as well as an energy generation requirement of 217,489 GWh in the year 2030-31, showing an ACGR of 6.17% and 6.56% respectively. Adding KE imports, the net NTDC demand under the Medium Demand Growth scenario is estimated to be 44,081 MW and energy generation requirements of 228,877 GWh.

3.2.3 High Demand Forecast

The High Demand Forecast assumed an overall GDP growth of 6.4% for the next 10 years and resulted in an annual peak demand of 45,328 MW as well as an energy generation requirement of 234,275 GWh in the year 2030-31, showing an ACGR of 7.02% and 7.42% respectively. Adding KE imports, the net NTDC demand under the High Demand Growth scenario is estimated to be 47,328 MW and energy generation requirements of 245,663 GWh.

Table 3-1: NTDC power demand projections

Years	Low Growth Scenario		Medium Growth Scenario		High Growth Scenario	
	Energy Demand (GWh)	Peak Demand (MW)	Energy Demand (GWh)	Peak Demand (MW)	Energy Demand (GWh)	Peak Demand (MW)
2021-22	126,574	23,687	126,890	23,746	127,203	23,805
2022-23	132,903	25,070	133,837	25,246	134,767	25,422
2023-24	140,033	26,627	141,874	26,977	143,721	27,329
2024-25	147,116	28,201	150,145	28,782	153,208	29,369
2025-26	154,938	29,943	159,429	30,811	164,002	31,695
2026-27	162,666	31,444	168,880	32,645	175,265	33,880
2027-28	171,296	33,120	179,496	34,706	187,999	36,350
2028-29	180,025	34,816	190,471	36,836	201,408	38,951
2029-30	189,492	36,655	202,439	39,160	216,126	41,807
2030-31	201,770	39,039	217,489	42,081	234,275	45,328
ACGR (2022-31)	5.32%	5.71%	6.17%	6.56%	7.02%	7.42%

4 Power Generation Capacity

This section provides the present installed generation capacity and the projected generation capacity in 2030-31 as per IGCEP. The IGCEP includes three types of projects: existing, committed, and candidates. The optimized projects were picked up by NTDC using PLEXOS, a generation planning software, from a long list of candidate projects on the basis of their competitiveness in comparison with those not picked.

4.1 Existing Generation Capacity

The present installed generation capacity in the NTDC system is 37,934 MW. However, the firm capacity is around 30,100 MW. Based on installed generation capacity, Figure 4-1 shows the fuel-wise generation mix as of March 2022. Annex A.1 present the plant-wise installed and firm capacity of existing plants.

Gas, RLNG and RFO based thermal plants are the largest contributor with a combined share of 41.5% in installed capacity whereas hydro is the next largest at 28%. Coal at 13.9%, nuclear 9.5%, wind 4.9%, solar 1.3% and Bagasse at 1% are the other contributors to the installed capacity.

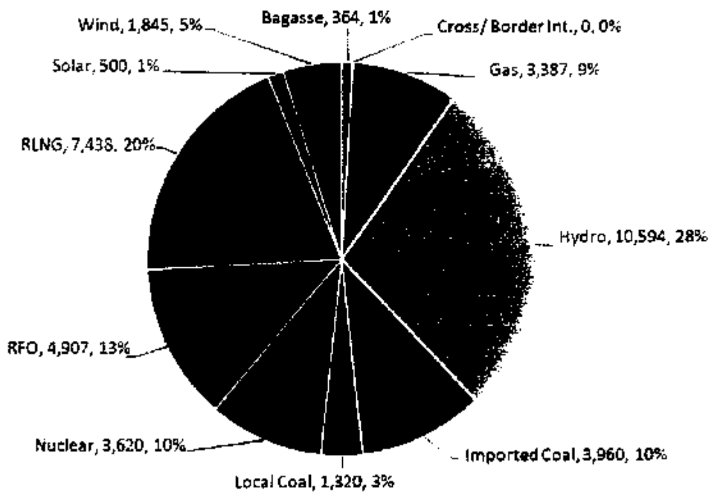


Figure 4-1: Existing generation mix based on installed generation capacity in 2022

In recent months, due to the dwindling economic situation of the country, the government could not generate enough foreign exchange to purchase petroleum and related fuels including RLNG and coal, which resulted in severe load shedding despite having enough capacity on ground. This raised the alarm from the energy security perspective of the country. Since the government found it difficult to procure imported fuels, the need to develop indigenous resources is imminent and paramount. Every hydro, wind and solar project will lead the country towards self-sufficiency and achieving the goal of energy security. From an economics perspective, once the debt repayment period of the initial 10-15 years is over, the cost of generation of hydropower significantly reduces to a level much less than the energy cost of imported RLNG and coal fired projects. Therefore, development of hydropower must be given priority over all the other power generation options.

At present the NTDC system has around 21,600 MW (57%) installed capacity based on indigenous fuels and resources.

Under the Power Policy 2021, it is one of the goals to develop projects that are either indigenous or based on indigenous fuels such as hydro, wind, solar, local coal, bagasse and domestic natural gas to ensure that country achieves the goal of energy security.

4.2 Committed Projects

As per IGCEP, there are 30 generation projects of various types and technologies with a cumulative installed capacity of 13,817 MW and firm capacity of 12,202 MW which form part of committed portfolio of the NTDC system. The committed portfolio is common to all the demand scenarios studied in the IGCEP. The list of committed projects is provided in Table 4-1.

Table 4-1: Committed projects in the IGCEP Plan 2022

Name of Power Plant	COD	Public/ Private	Agency	Fuel	Installed Capacity (MW)	Firm Capacity[3] (MW)
CASA	Aug-24	Public	NTDC	Cross/ Border Int.	1,000	1,000
Koto	Sep-22	Public	IPP	Hydro	41	38
Jagran-II	Jul-23	Public	IPP	Hydro	48	44
Lawi	Apr-24	Public	IPP	Hydro	69	63
Suki Kinari	Nov-24	Private	IPP	Hydro	884	813
Gorkin Matiltan	Jul-24	Public	IPP	Hydro	84	77
Tarbela_Ext_5	Sep-24	Public	WAPDA	Hydro	1,530	1,408
Dasu	May-27	Public	WAPDA	Hydro	2,160	1,987
Mohmand Dam	Nov-26	Public	WAPDA	Hydro	800	736
Keyal Khwar	Feb-27	Public	WAPDA	Hydro	128	118
Gabral Kalam	Nov-27	Public	IPP	Hydro	88	81
Madyan	Nov-27	Public	IPP	Hydro	157	144
Azad Pattan	Sep-28	Private	IPP	Hydro	701	645
Balakot	Dec-27	Public	IPP	Hydro	300	276
Kohala	Dec-28	Private	IPP	Hydro	1,124	1,034
Diamer Basha	Not available before 2032	Public	WAPDA	Hydro	xx	xx
Jamshoro Coal (U #1)	Dec-22	Private	GENCO-I	Imp Coal	660	574
Gwadar	Aug-25	Private	IPP	Imp Coal	300	261
Thar TEL	Jul-22	Private	IPP	Local Coal	330	287
Thal Nova	Sep-22	Private	IPP	Local Coal	330	304
Thar-I (SSRL)	Dec-22	Private	IPP	Local Coal	1,320	1,148
Trimmu	Jul-22	Private	IPP	RLNG	1,263	1,033
Helios	Nov-22	Private	IPP	Solar	50	12
HNDS	Nov-22	Private	IPP	Solar	50	12
Meridian	Nov-22	Private	IPP	Solar	50	12
Manjhand	Sep-23	Public	IPP	Solar	50	12
Siachen	Sep-23	Public	IPP	Solar	100	23
Zorlu	Dec-23	Private	IPP	Solar	100	20
Trans_Atlantic	Jun-24	Private	IPP	Wind	50	21
Western	Jun-24	Private	IPP	Wind	50	19
				Total Capacity of Committed Projects	**13,817**	**12,202**

3 Firm capacity is installed capacity minus auxiliary consumption minus plant outages.

4.3 Generation Capacity Retirements

A total of 20 power plants with cumulative installed capacity of 7,483 MW will retire over the study period of 2022-2031. The majority of the retiring GENCO plants have sub-optimal efficiencies, availability issues due to high outage rates as well as high fuel costs. Most of the IPP plants also operating on expensive fuels are being retired at the expiry of their power purchase agreements (PPA). From an economic point of view, it would therefore be wise to retire them once their economic life span is over and replace them with new more efficient technologies based on domestic resources. The plants along with their retirement dates, installed capacity, and fuel type are listed in Table 4-2.

Table 4-2: Power plant retirements assumed in the IGCEP Plan 2022

Name of Power Plant	Year of Retirement	Public/ Private	Agency	Fuel	Capacity (MW)
GTPS Block 4 U(5-9)	Jun-22	GENCOs	GENCO-III	RLNG	144
Guddu - II U(5-10)	Jun-23	GENCOs	GENCO-II	Gas	620
Jamshoro - I U1	Jun-23	GENCOs	GENCO-I	RFO	250
Jamshoro - II U4	Jun-23	GENCOs	GENCO-I	RFO	200
Muzaffargarh - I U1	Jun-23	GENCOs	GENCO-III	RFO	210
Muzaffargarh - I U2	Jun-23	GENCOs	GENCO-III	RFO	210
Muzaffargarh - I U3	Jun-23	GENCOs	GENCO-III	RFO	210
Muzaffargarh - II U4	Jun-23	GENCOs	GENCO-III	RFO	320
KAPCO 3	Jun-23	Private	IPP	RLNG	300
KAPCO 1	Jun-24	Private	IPP	RLNG	400
KAPCO 2	Jun-26	Private	IPP	RLNG	900
Liberty	Jun-27	Private	IPP	Gas	225
HUBCO	Jun-27	Private	IPP	RFO	1,292
Kohinoor	Jun-27	Private	IPP	RFO	131
Lalpir	Jun-29	Private	IPP	RFO	362
AES Pakgen	Jun-29	Private	IPP	RFO	365
Saba	Jun-30	Private	IPP	RFO	136
FKPCL	Jun-30	Private	IPP	RLNG	172
Uch	Jun-31	Private	IPP	Gas	586
Rousch	Jun-31	Private	IPP	RLNG	450
		Total Capacity Retired over 2022-2031			**7,483**

4.4 Optimized Generation

With a strong existing power generation base mainly consisting of new power plants topped with a large portfolio of committed projects basically left little room for new projects. However, with the retirement of around 7,483 MW of existing relatively inefficient and expensive plants, the NTDC system has been optimized to add around 43 projects having a total capacity of 14,819 MW, including the 6,328 MW coming from 40 optimized hydropower project. Special attention has been given to the selection criteria for inclusion into the plan by adding projects based on domestic resources, mainly hydropower, local coal, wind and solar PV. In line with government policies, there has been no planned / optimized project on residual fuel oil (RFO), Regasified Liquid Natural Gas (RLNG) or imported coal.

Table 4-3 presents the list of optimized projects under the Low Demand Growth scenario of the IGCEP 2022.

Table 4-3: Optimized generation projects capacity under the Low Demand Forecast of IGCEP

Name of Power Plant	Public/ Private	Agency	Fue	Capacity (MW)	Firm Capacity (MW)
Artistic-I	Private	IPP	Hydro	63	58
Artistic-II	Private	IPP	Hydro	55	51
Bankhwar	Private	IPP	Hydro	35	32
Bata Kundi	Private	IPP	Hydro	99	91
Chiniot_HPP	Private	IPP	Hydro	80	74
Chowkel Khwar	Private	IPP	Hydro	60	55
CJ	Private	IPP	Hydro	25	23
Gabral Utror	Private	IPP	Hydro	79	73
Ghorband	Private	IPP	Hydro	21	19
Harigehl-Majeedgala	Private	IPP	Hydro	40	37
Nila Da Katha	Private	IPP	Hydro	31	29
Tangar	Private	IPP	Hydro	26	24
Taunsa	Private	IPP	Hydro	135	124
Trappi	Private	IPP	Hydro	32	29
Arkari Gol	Private	IPP	Hydro	99	91
Asrit Kedam	Private	IPP	Hydro	215	198
Athmuqam	Private	IPP	Hydro	450	414
Dowarian	Private	IPP	Hydro	40	37
Gumat Nar	Private	IPP	Hydro	50	46
Jagran-III	Private	IPP	Hydro	35	32
Jagran-IV	Private	IPP	Hydro	22	20
Kaigah-II	Private	IPP	Hydro	40	36
Kaigah-III	Private	IPP	Hydro	21	19
Kalam Asrit	Private	IPP	Hydro	238	219
Kalkot Barikot	Private	IPP	Hydro	47	43
Kari Mashkur	Private	IPP	Hydro	495	455
Luat	Private	IPP	Hydro	49	45
Nagdar	Private	IPP	Hydro	35	32
Naran	Private	IPP	Hydro	188	173
Patrak Sheringhal	Private	IPP	Hydro	22	20
Rajdhani	Private	IPP	Hydro	132	121
Shalfalam	Private	IPP	Hydro	60	55
Sharmai	Private	IPP	Hydro	152	140
Shigo Kas	Private	IPP	Hydro	102	94
Shounter	Private	IPP	Hydro	48	44
Turtonas Uzghor	Private	IPP	Hydro	82	76
Ashkot	Private	IPP	Hydro	300	276
Mahl	Private	IPP	Hydro	640	589
Thakot-III	Private	IPP	Hydro	1,490	1,371
Lower Spat Gah	Private	IPP	Hydro	496	456

Name of Power Plant	Public/ Private	Agency	Fuel	Capacity (MW)	Firm Capacity (MW)
New_Local_Coal	Private	IPP	Local Coal	990	911
New_Solar	Private	IPP	Solar	4,000	1,148
New_Wind	Private	IPP	Wind	3,500	1,365
	Total Capacity of Optimized Projects			**14,819**	**9,245**

The Medium Demand Growth scenario has optimized 1,650 MW through new coal fired plants which resulted in the total installed capacity of 15,478 MW of optimized projects, and the High Demand scenario has new coal additions of 3,630 MW which makes the total optimized capacity at 17,458 MW.

4.5 Optimized Generation Mix in 2031

The committed and optimized hydro, thermal, bagasse, solar and wind projects are the same in the three demand forecast scenarios. The only difference in the three demand forecast scenarios is the optimized new local coal-based power generation which is 990 MW in the case of Low Demand scenario. The Medium or Normal Demand Forecast scenario has 1,650 MW capacity installed on local coal which increases to 3630 MW for the High Demand Forecast scenario.

The total optimized installed capacity in the NTDC system in the FY 2031 was worked out to be 60,573 MW under the Low Demand Forecast scenario. Figure 4-2 presents the optimized mix in 2031 based on installed generation capacity under Low Demand Forecast scenario. Annex A.2 presents the plant-wise installed and firm capacity for Low Demand Growth scenario in FY 2031.

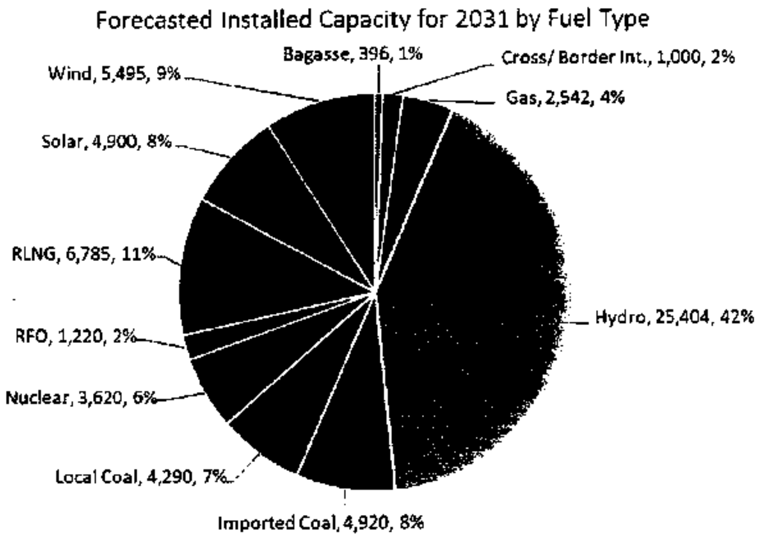


Figure 4-2: Optimized generation mix in FY 2031 under the Low Demand Forecast of IGCEP

The total installed capacity in the NTDC system in the FY 2031 was worked out to be 61,233 MW under the Medium (Normal) Demand Forecast Scenario. Figure 4-3 presents the optimized generation mix in 2031 based on installed generation capacity under Medium Demand Forecast scenario.

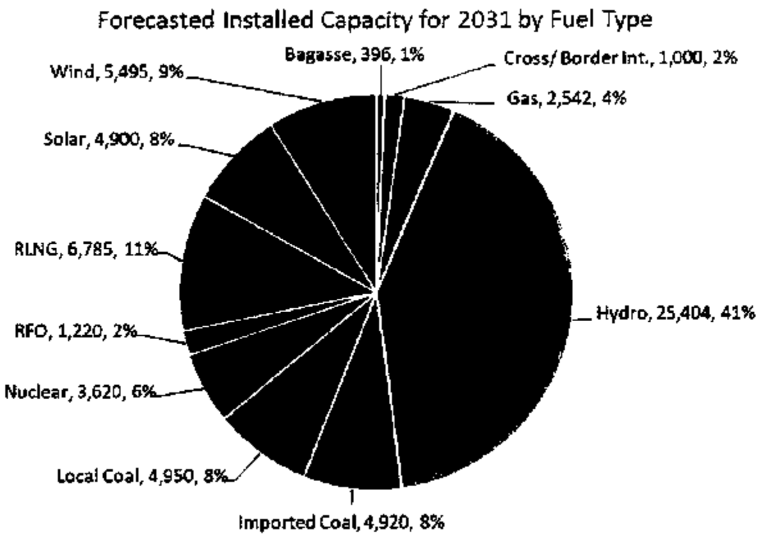


Figure 4-3: Optimized generation mix in FY 2031 under the Medium Demand Forecast of IGCEP

The total installed capacity in the FY 2031 was worked out to be 63,213 MW under the High Demand Forecast scenario. Figure 4-4 presents the optimized generation mix in 2031 based on installed generation capacity under High Demand Forecast scenario.

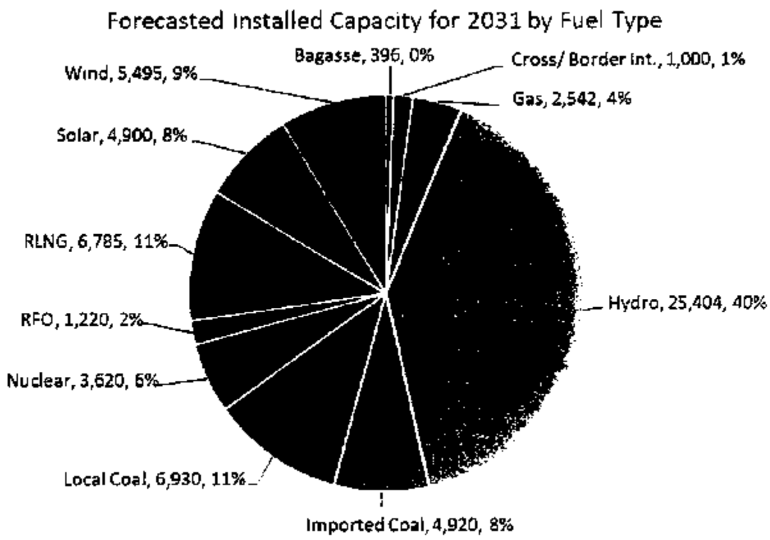


Figure 4-4: Optimized generation mix in FY 2031 under the High Demand Forecast of IGCEP

4.6 Indicative Power Generation Costs

An indicative costing analysis using annualized costs was carried out to draw the comparison between the Lower Spat Gah Project and other competing projects. The analysis has been limited to the options which are being implemented during the time window of 2023-2031 and for which the costing data was available. Figure 4-5 illustrates the indicative comparison between annualized costs of contemporary options as per IGCEP.

The figure shows that solar and wind costs are the lowest amongst all the options but they have high intermittency rates which require back-up generation capacity in the form of thermal or hydropower projects. Pakistan power system is projected to have sufficient back up cover to these projects. Several other hydropower projects included in the analysis are not far off in the cost comparison with Lower Spat Gah. Coal plants based on Thar coal are the expensive alternatives and on top of it, have a significant climate change impact so a penalty for GHG emissions could be added to their costs. The climate change penalty for coal[4] is about 4.68 US cents/kWh on top of its annualized cost making it a total of 14.46 US cents/kWh. Presently, only the energy cost component of RLNG[5] plants and imported coal plants are around 10.23 US cents/kWh and 15 US cents/kWh respectively. Adding the climate change penalty of 1.69 US cents/kWh for RLNG[6] and 4.86 US cents/kWh for coal, the RLNG and imported coal based plants' total energy costs become 11.92 US cents/kWh and 19.68 US cents/kWh respectively.

The capital costs of Lower Spat Gah HPP and other hydropower projects were taken from Annexure B3 of IGCEP 2022. PPI then calculated the annualized costs to compare the different projects. Lower Spat Gah appears economical when compared with only the energy costs of the RLNG and coal based thermal projects. Similar to wind and solar which have a much lower generation cost, hydropower plants can also displace thermal generation in the long run and save the country much-needed foreign exchange. The hydropower projects have lower intermittency and negligible GHG emissions. In fact, climate change objectives are achieved with every kWh generated through hydropower and the renewable energy from solar or wind resources.

It is therefore recommended to develop the hydropower potential of the country to meet the growing needs of economy at a minimum cost for sustainable growth and achieving energy security.

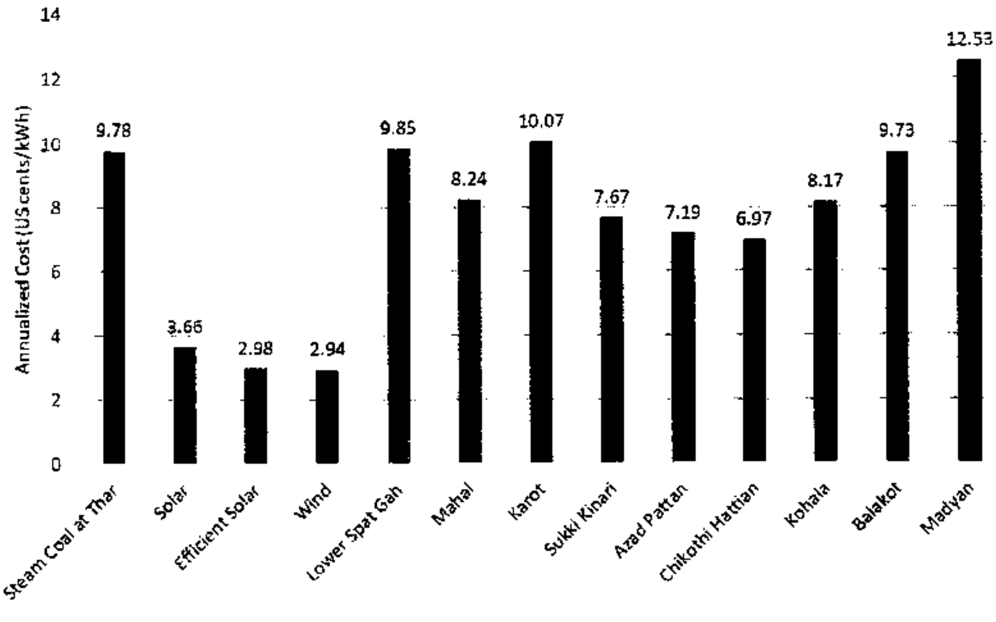


Figure 4-5: Annualized cost comparison of competing projects

4 Using an emission factor of 0.935 ton of CO_2/GWh of coal and multiplying it with CO_2 value of 50 USD/ton

5 Merit order notification of 16 August 2022

6 Using an emission factor of 0.337 ton of CO_2/GWh of natural gas and multiplying it with CO_2 value of 50 USD/ton

5 Power and Energy Balances

The power and energy balance simulations were carried out for 2031 projected demand and supply in the NTDC system. Monthly power and energy balances were carried out for the three demand forecast scenarios for the year 2031 coinciding with the expected commissioning date of the Lower Spat Gah Project. The basic premise of the power and energy balances were to show that there is enough power and energy demand in the NTDC system which can absorb Lower Spat Gah Project without affecting the dispatch of all must run power plants in the NTDC system. Some broad assumptions of the power demand and energy balances have been listed in Chapter 5.1.

5.1 Assumptions of the Power and Energy Balances

The following assumptions were made for the power and energy balances:

- In the NTDC system, the must run plants are dispatched ahead of the thermal plants. The thermal plants are dispatched in accordance with their economic merit order based on their energy cost which includes variable O&M, fuel cost and some other costs in case of gas fired Uch and Habibullah Coastal.
- The power and energy balances in the study have been considered only for the must run plants of the NTDC system. Any power or energy spillover beyond the must run plants will be met up with the thermal plants in accordance with the economic merit order dispatch.
- For existing hydropower plants, the simulations of power generation are assumed on the basis of average hydrological conditions which are based on 10 years of historical data. For committed and optimized projects, the average generation data from the Feasibility Studies were used. Similarly, simulations assumed average wind and solar resources for existing, committed and optimized projects.
- For power balances, the firm capacity of all must run generating options have been considered. Firm capacity of the plants is calculated as the installed capacity at the site minus auxiliary consumptions and then adjusted for the average plant availability over the month to capture the average outage rate of the respective generation technologies. Table 5-1 shows the plant availability data used in the study. For wind and solar plants, the availability of data for a number of plants is available which has been used. Where the availability of data was not available, the standard availability factors from Table 5-1 have been considered.
- The energy balances have been prepared based on hydro, wind and solar resources with no adjustments for auxiliary consumption and outage rates as these data streams have been considered to be the net output of the plants. The energy generation from nuclear and bagasse have been worked out by attributing the monthly load factor of 70% and 65% respectively.
- The VRE projects need back up that may come from the installed thermal plants in the system. There is enough thermal capacity in the NTDC system which can meet the reserve requirement as well as provide backup cover for the intermittency of the VRE.
- The simulations also assumed all committed and optimized projects to be commissioned as per their CODs indicated in IGCEP forming a conservative analysis. There is a high likelihood that many projects in these groups would either be delayed or stalled for various reasons, more so for the optimized hydro project. Additional scenarios have been simulated assuming a success ratio of 50% for the optimized hydro project to analyze the impact on the power and energy balances. The additional scenario will only strengthen the case for the Lower Spat Gah Project as the optimized hydro capacity not realized will have to be supplemented by other generation options such as solar or thermal plants operating on local coal. Two cases have been run on the generation side to capture the success rate of 100% and 50% of the optimized hydro project.

Table 5-1: Standard availability factors for power generation technologies

Plant Technology	Availability Factor
Hydro Reservoir	92.0%
Thermal	87.0%
Bagasse	92.0%
Nuclear	87.0%
Hydro ROR	92.0%
Wind	30.0%
Solar PV	22.0%

5.2 Results Case 1: 100% Planned Capacity Additions

100% completion of optimized hydropower project were assumed as planned. The case was analyzed for low, medium and high demand growth scenarios.

5.2.1 Low Demand Forecast

The power and energy balances were carried out for the year 2031. The tables containing the power and energy balances for the Low Growth Demand Forecast are attached as Annex B.1.

Power Balance

The power balances demonstrate that there was enough demand in the NTDC system that could be absorbed by the capacity offered by the must run plants, including the Lower Spat Gah Project. The spill over demand that would be supplied through thermal generation of around 18,767 MW capacity in 2031 is minimum at 2,400 MW during the months of March and a maximum of 12,214 MW during June. Figure 5-1 shows the power balances in 2031 under the Low Demand Forecast scenario.

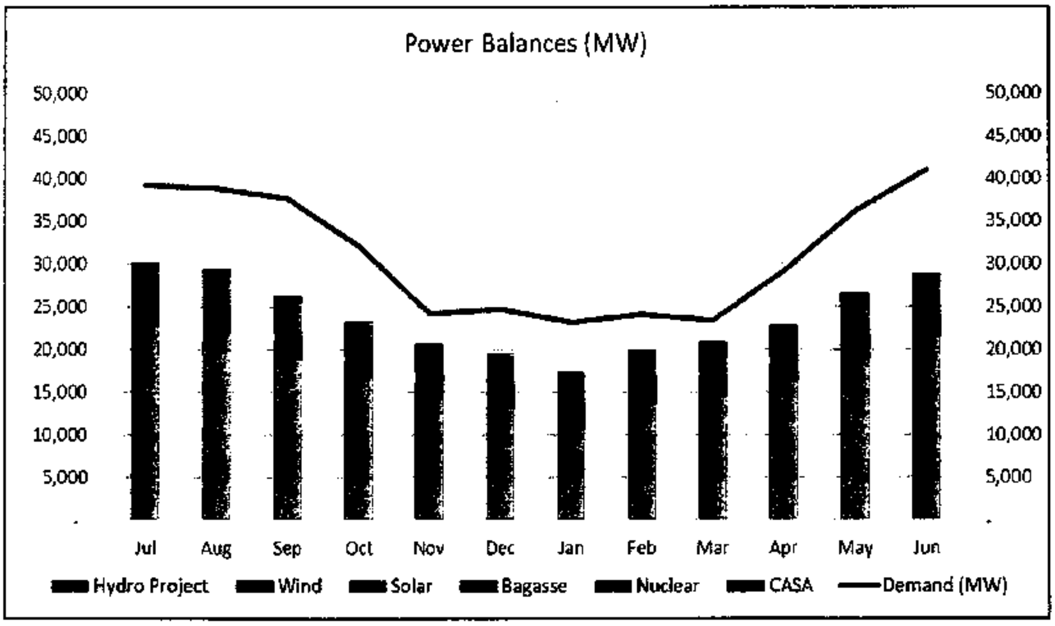


Figure 5-1: Power balances in 2031 under the Low Demand Forecast scenario

Energy Balance

The energy balances show that there was enough energy demand in the NTDC system that could be supplied by the must run plants, including the energy generated by the Lower Spat Gah Project. The spill over energy demand, almost 25% of the total energy demand, would be generated through thermal plants and would be minimum at 2,200 GWh during the months of June and a maximum of 6,480 GWh during October 2031. Here a project like Lower Spat Gah would actually be helping in reducing the generation cost by avoiding thermal generation from highly expensive RLNG (around 10.23 US cents/kWh) and imported coal-based (around 15 US cents/kWh) plants. Figure 5-2 shows the energy balances in 2031 under the Low Demand Forecast scenario.

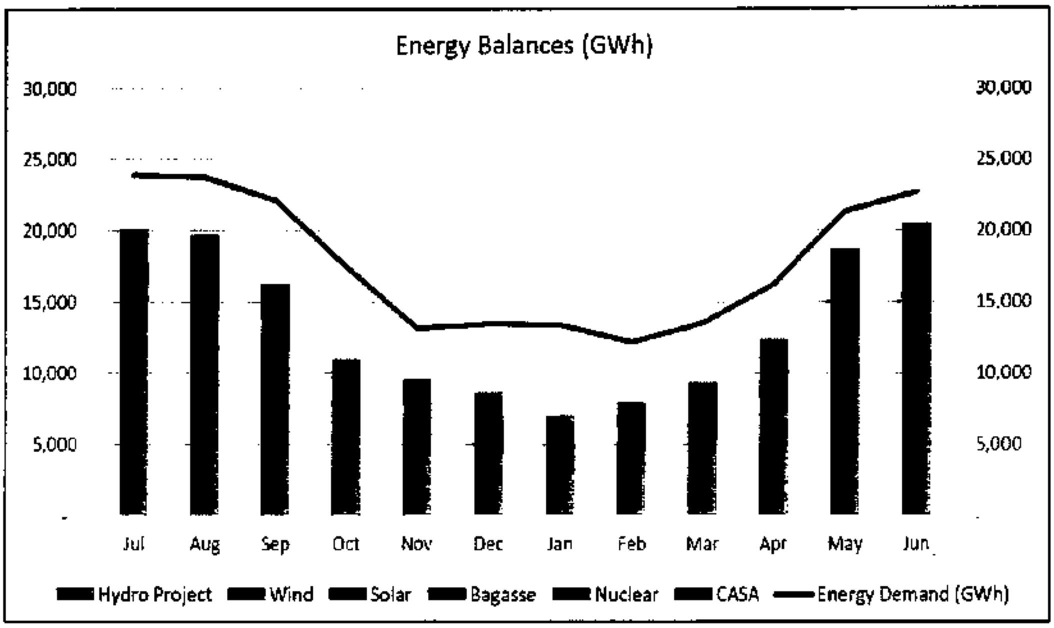


Figure 5-2: Energy balances in 2031 under the Low Demand Forecast scenario

5.2.2 Medium Demand Forecast

The power and energy balances were carried out for the year 2031. With medium demand, a capacity of 1,650 MW on local coal was added to meet the additional demand under the medium growth scenario.

The tables containing the power and energy balances for the Medium Growth Demand Forecast are attached as Annex B.1.

Power Balance

The power balances demonstrate that there was enough demand in the NTDC system that could be supplied by the capacity offered by the must run plants, including the Lower Spat Gah Project. The spill over demand would be generated through thermal generation of around 20,417 MW capacity. The demand for thermal plants is minimum at 4,131 MW during the months of March and a maximum of 15,256 MW during June. Figure 5-3 shows the power balances in 2031 under the Medium Demand Forecast scenario.

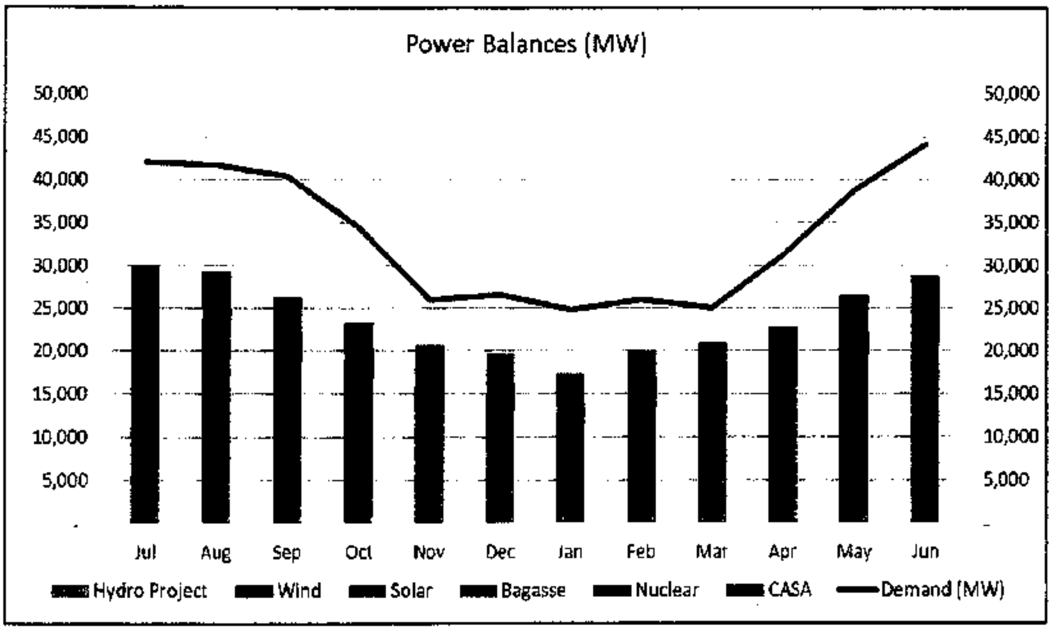


Figure 5-3: Power balances in 2031 under the Medium Demand Forecast scenario

Energy Balance

The energy balances show that there was enough energy demand in the NTDC system that could be met by the must run plants, including the energy generated by the Lower Spat Gah Project. The spill over energy demand, nearly 30% of the total energy required, would be generated through thermal plants and is minimum at 3,866 GWh during the months of June and a maximum of 7,768 GWh during October 2031. The Lower Spat Gah Project would be helping in reducing the generation cost by avoiding thermal generation from highly expensive RLNG (around 10.23 US cents/kWh) and imported coal-based (around 15 US cents/kWh) plants. Figure 5-4 shows the energy balances in 2031 under the Medium Demand Forecast scenario.

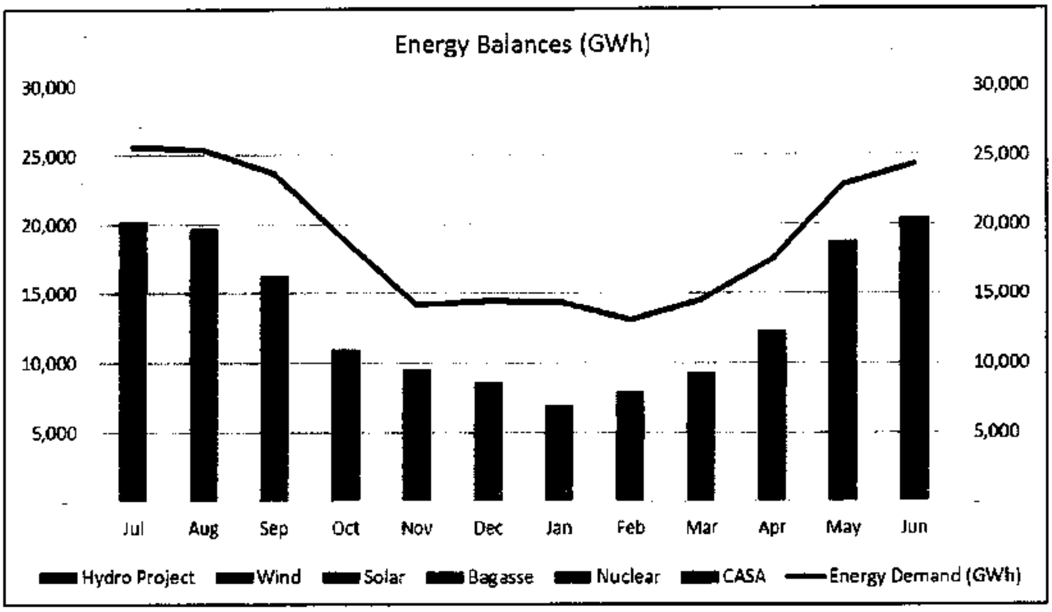


Figure 5-4: Energy balances in 2031 under the Medium Demand Forecast scenario

5.2.3 High Demand Forecast

The power and energy balances were carried out for the year 2031. With high demand, a capacity of 3,630 MW on local coal was added to meet the additional demand under the high growth scenario.

The tables containing the power and energy balances for the High Growth Demand Forecast are attached as Annex B.1.

Power Balance

The power balances demonstrate that there was enough demand in the NTDC system that could be supplied by the capacity offered by the must run plants, including the Lower Spat Gah Project. The spill over demand that would be generated through thermal generation of around 22,397 MW capacity is minimum at 5,982 MW during the months of March and a maximum of 18,500 MW during June. Figure 5-5 shows the power balances in 2031 under the High Demand Forecast scenario.

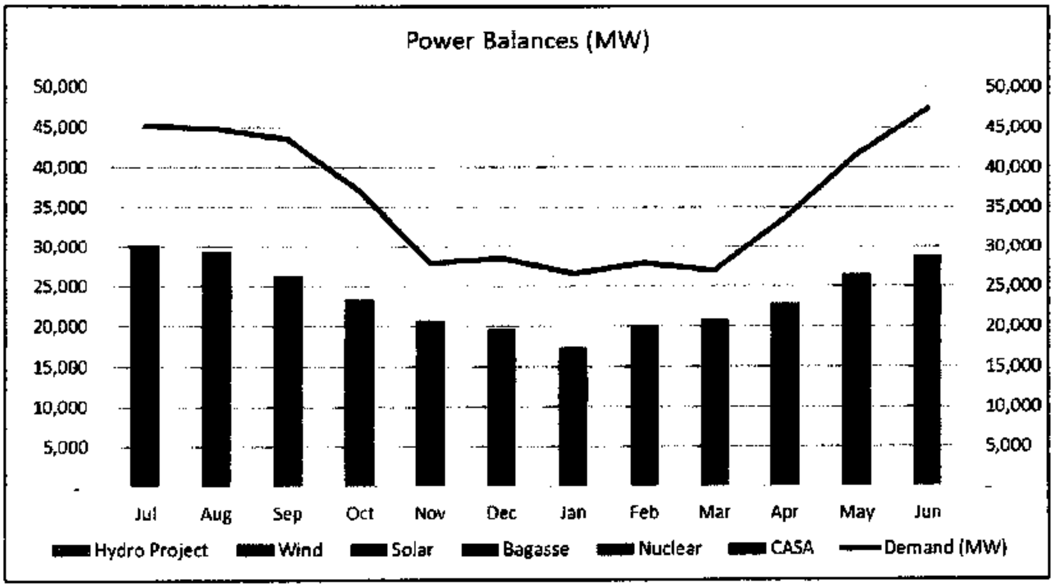


Figure 5-5: Power balances in 2031 under the High Demand Forecast scenario

Energy Balance

The energy balances show that there was enough energy demand in the NTDC system that could be supplied by the must run plants, including the Lower Spat Gah Project. The spill over energy demand, nearly 35% of the total energy demanded, would be generated through thermal plants and is minimum at 5,605 GWh during the months of November and a maximum of 9,154 GWh during September 2031. The Lower Spat Gah Project would be helping in reducing the generation cost by avoiding thermal generation from highly expensive RLNG and imported coal-based plants. Figure 5-6 shows the energy balances in 2031 under the High Demand Forecast scenario.

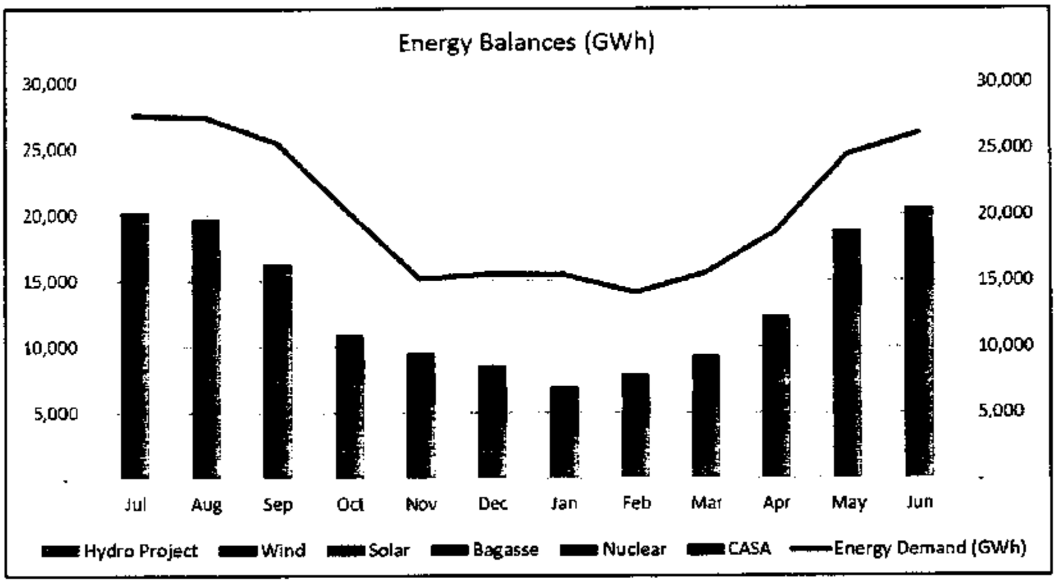


Figure 5-6: Energy balances in 2031 under the High Demand Forecast scenario

5.3 Results Case 2: 50% Optimized Capacity Additions of Hydropower Projects

Only half of the optimized hydropower projects or capacity were assumed as to be completed until the year 2031 and the remaining 50% were considered to be spilling over the study horizon. In all 3,164 MW, including the Lower Spat Gah Project, out of a total 6,328 MW of planned candidate hydropower capacity was assumed to be developed by 2031. The remaining optimized hydro project of 3,164 MW are presumed to be generally delayed beyond the study horizon, with some being abandoned by the sponsors or projects that fail to find sponsors. At the moment no substitute was added to replace these projects as it is difficult to make a prediction about the projects that would ultimately not see the light of day. These projects will likely be replaced at some stage either by other hydropower, VRE or local coal-based projects, but that might not happen within the study horizon. The 18,767 MW of the installed thermal capacity in 2031 will make up for the lost generation from the delayed or abandoned hydropower projects with some compromise on the reserve margins.

The case was also analyzed for low, medium and high demand growth scenarios.

5.3.1 Low Demand Forecast

The power and energy balances were carried out for the year 2031.

The tables containing the power and energy balances for the Low Growth Demand Forecast are attached as Annex B.2.

Power Balance

The power balances demonstrate that there was enough demand in the NTDC system that could be met by the capacity offered by the must run plants, including the Lower Spat Gah Project. The spill over demand that would be generated through thermal generation of around 18,767 MW capacity is minimum at 3,836 MW during the months of March and a maximum of 15,074 MW during June. Figure 5-7 shows the power balances in 2031 under the Low Demand Forecast scenario.

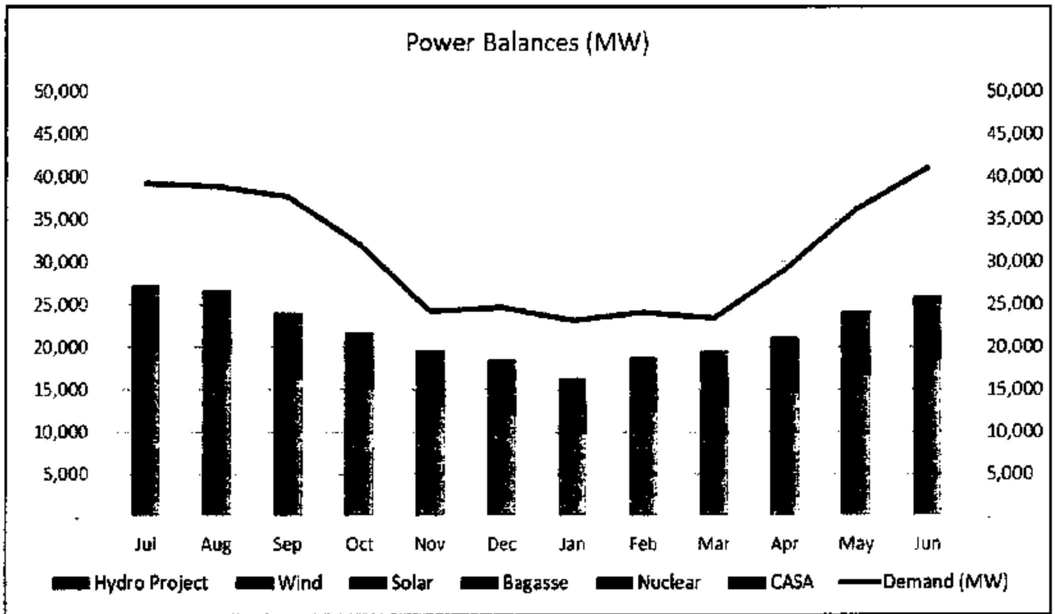


Figure 5-7: Power balances in 2031 under the Low Demand Forecast scenario

Energy Balance

The energy balances show that there was enough energy demand in the NTDC system that could be provided by the must run plants, including the Lower Spat Gah Project. The spill over energy demand, nearly 31% of the total energy demand, would be generated through thermal generation is minimum at 4,135 GWh during the months of November and a maximum of 7,450 GWh during October. Here a project like Lower Spat Gah would actually be helping in reducing the generation cost by avoiding thermal generation from highly expensive RLNG and imported coal-based generation. Figure 5-8 shows the energy balances in 2031 under the Low Demand Forecast scenario.

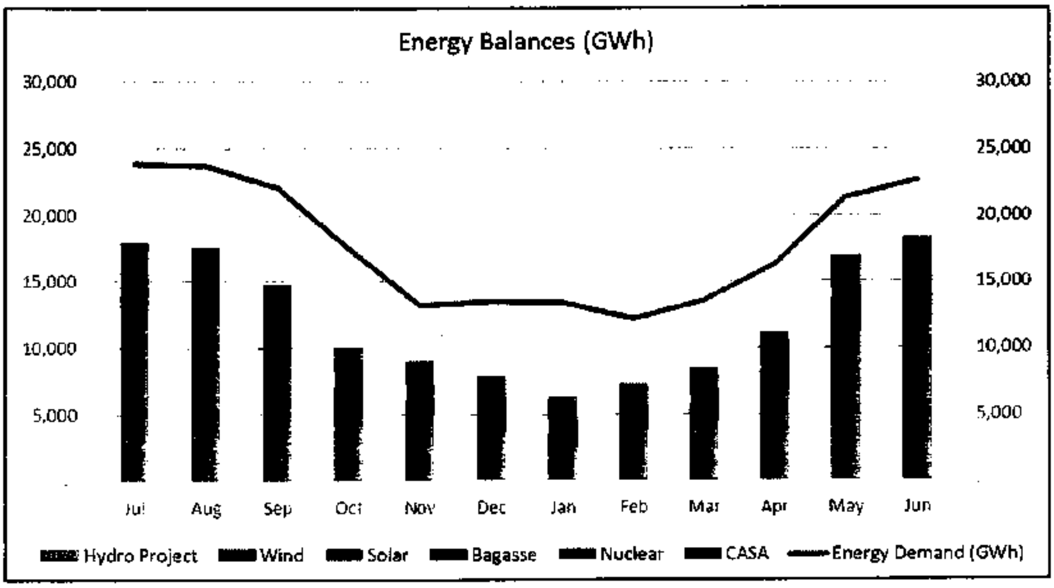


Figure 5-8: Energy balances in 2031 under the Low Demand Forecast scenario

5.3.2 Medium Demand Forecast

The power and energy balances were carried out for the year 2031. With medium demand, a capacity of 1,650 MW on local coal was added to meet the additional demand under the medium growth scenario.

The tables containing the power and energy balances for the Medium Growth Demand Forecast are attached as Annex B.2.

Power Balance

The power balances demonstrate that there was enough demand in the NTDC system that could be met by the capacity offered by the must run plants, including the Lower Spat Gah Project. The spill over demand that would be generated through thermal generation of around 20,417 MW capacity in 2031 is minimum at 5,569 MW during the months of March and a maximum of 18,116 MW during June. Figure 5-9 shows the power balances in 2031 under the Medium Demand Forecast scenario.

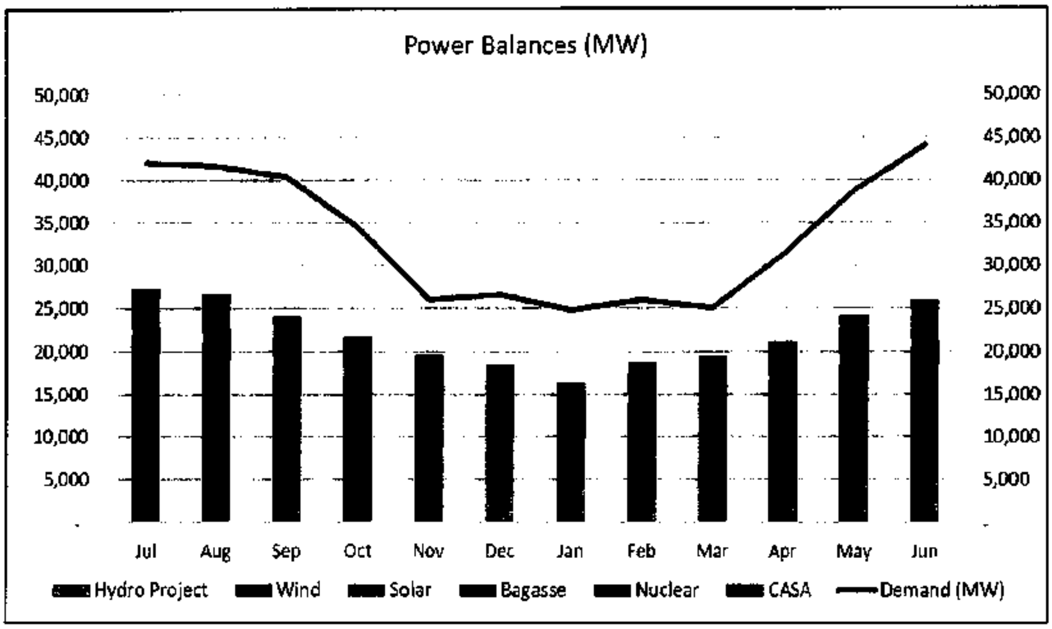


Figure 5-9: Power balances in 2031 under the Medium Demand Forecast scenario

Energy Balance

The energy balances show that there was enough energy demand in the NTDC system that could be supplied by the must run plants, including the Lower Spat Gah Project. The spill over energy demand, nearly 35% of the total energy demand, would be generated through thermal generation is minimum at 5,107 GWh during the months of November and a maximum of 8,892 GWh during September. The Lower Spat Gah Project would be helping in reducing the generation cost by avoiding thermal generation from highly expensive RLNG and imported coal-based generation. Figure 5-10 shows the energy balances in 2031 under the Medium Demand Forecast scenario.

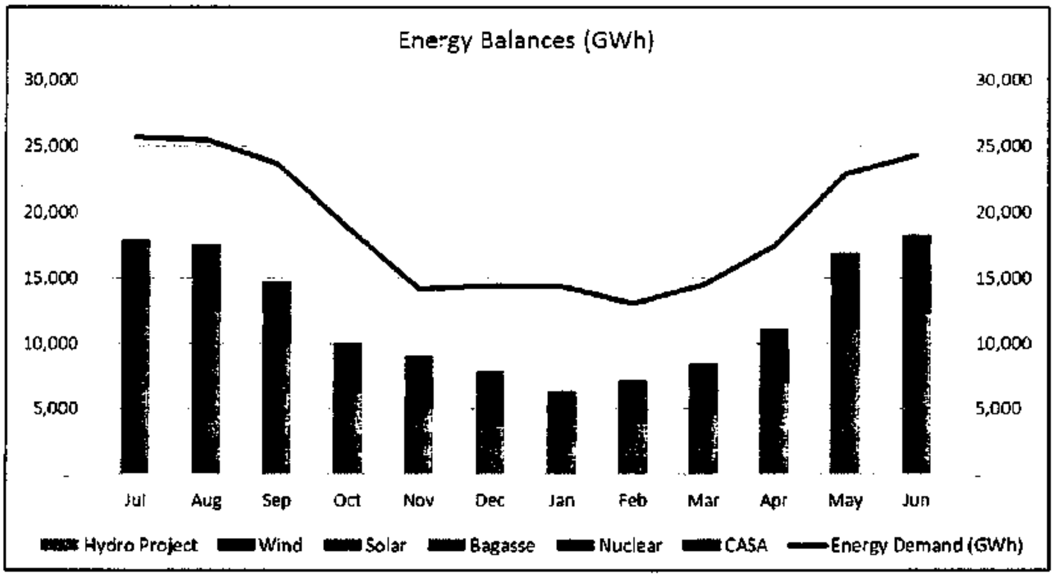


Figure 5-10: Energy balances in 2031 under the Medium Demand Forecast scenario

5.3.3 High Demand Forecast

The power and energy balances were carried out for the year 2031. With high demand, an capacity of 3,630 MW on local coal was added to meet the additional demand under the high growth scenario.

The tables containing the power and energy balances for the High Growth Demand Forecast are attached as Annex B.2.

Power Balance

The power balances demonstrate that there was enough demand in the NTDC system that could be met by the capacity offered by the must run plants, including the Lower Spat Gah Project. The spill over demand that would be generated through thermal plants of around 22,397 MW capacity in 2031 is minimum at 7,419 MW during the months of March and a maximum of 21,363 MW during June. With the absence of 50% capacity of the optimized hydropower projects, this scenario may face compromises on system reserve margins in the summer months of May to August. Figure 5-11 shows the power balances in 2031 under the High Demand Forecast scenario.

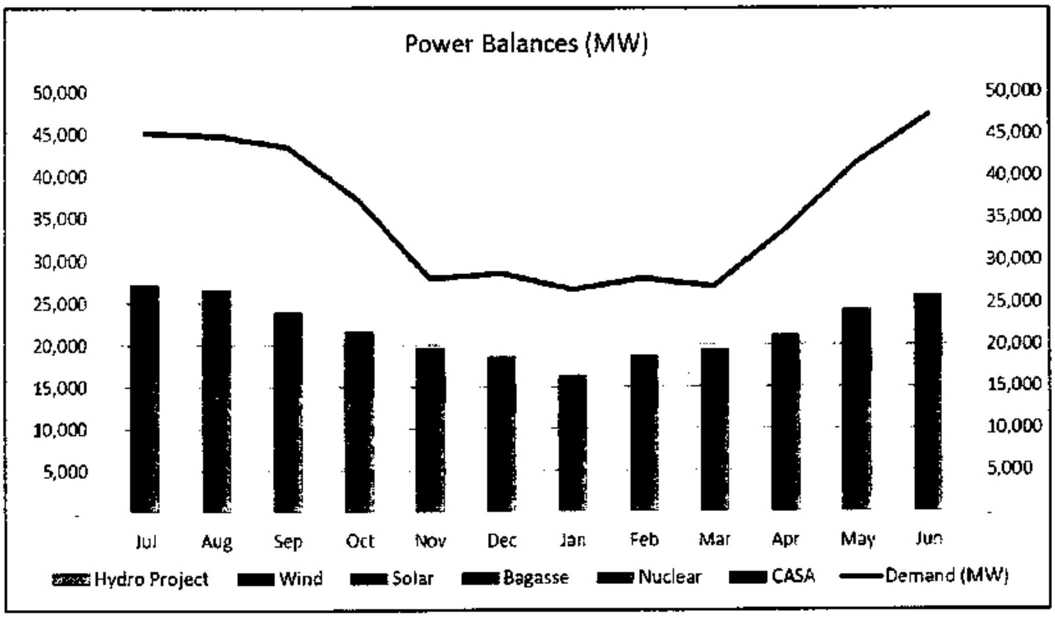


Figure 5-11: Powe balances in 2031 under the High Demand Forecast scenario

Energy Balance

The energy balances show that there was enough energy demand in the NTDC system that could be made up by the must run plants, including the Lower Spat Gah Project. The spill over energy demand, almost 40% of the total system demand, would be generated through thermal plants is minimum at 6,145 GWh during the months of November and a maximum of 10,630 GWh during September 2031. The Lower Spat Gah Project would be helping in reducing the generation cost by avoiding thermal generation from highly expensive RLNG and imported coal-based plants. Figure 5-12 shows the energy balances in 2031 under the High Demand Forecast scenario.

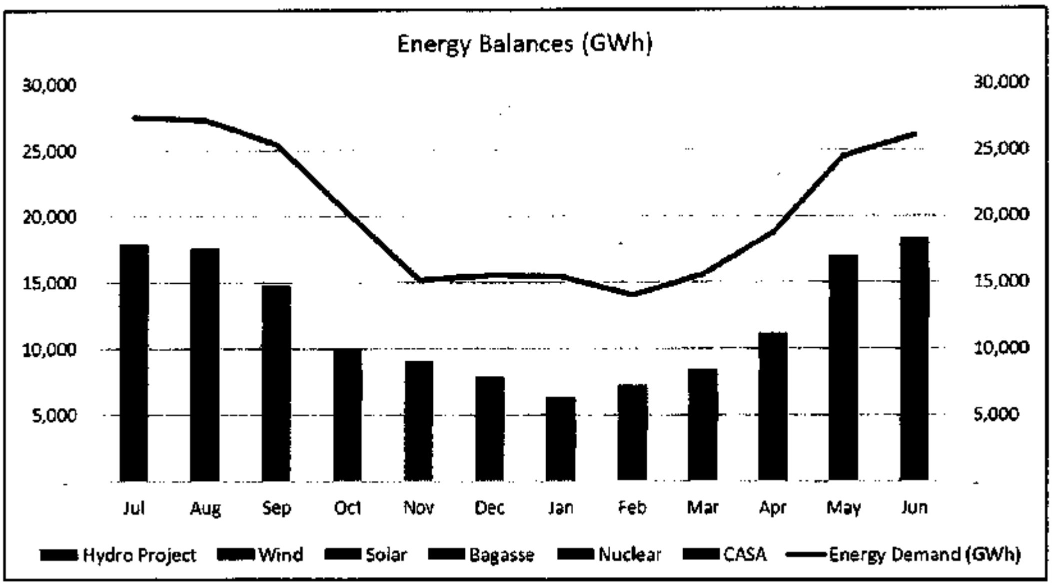


Figure 5-12: Energy balances in 2031 under the High Demand Forecast scenario

6 Conclusions

The IGCEP contains an optimistic assessment on development of hydropower and other renewable energy resources for the three demand growth scenarios low, medium and high. There is a likelihood that a number of committed and optimized hydropower plants may slip on their commissioning timelines, stall for a long duration or even be abandoned by their sponsors. Therefore, the NTDC system may not be having adequate capacity to meet the demand in FY 2031. Given the history of generation projects' development in the country, Case 2: 50% planned capacity additions of hydropower projects appears to be the most probable.

The power and energy balances demonstrate that in FY 2031 there was enough demand in the NTDC system in all demand growth scenarios and capacity addition cases that could be met by the projected capacity offered by the must run plants, including the Lower Spat Gah Project. The addition of the Lower Spat Gah Project will not have any adverse impact on energy generated by any must run plant.

Over the period 2023-2031, the NTDC system would have enough thermal generation capacity to take up the spill over energy and provide back up and reserve capacity.

The development of the Lower Spat Gah Project will benefit the national grid in more ways than one. It will inject clean energy into the system from a climate change perspective, provide indigenously produced energy in meeting the energy security goals for the country and provide cheap energy compared to that of imported fuels such as RLNG, coal and RFO based thermal power plants.

Annex A Installed Generation Capacity

A.1 Installed Generation Capacity in the NTDC System in March 2022

Name of Power Plant	Agency	Fuel	Installed Capacity (MW)	Firm Capability (MW)
Almoiz	IPP	Bagasse	36	33
Chanar	IPP	Bagasse	22	20
Chiniot	IPP	Bagasse	63	58
Fatima Energy (FEL)	IPP	Bagasse	120	110
Hamza	IPP	Bagasse	15	14
JDW - II	IPP	Bagasse	26	24
JDW - III	IPP	Bagasse	27	25
Ryk_Mills	IPP	Bagasse	30	28
Thal_Layyah	IPP	Bagasse	25	23
Guddu - I U(11-13)	GENCO-II	Gas	415	340
Guddu - II U(5-10)	GENCO-II	Gas	620	467
Guddu 747	GENCO-II	Gas	747	627
Engro	IPP	Gas	217	189
Foundation	IPP	Gas	184	140
Liberty	IPP	Gas	225	181
Uch	IPP	Gas	586	465
Uch-II	IPP	Gas	393	322
Allai Khwar	WAPDA	Hydro	121	111
Chashma	WAPDA	Hydro	184	169
Dubair Khwar	WAPDA	Hydro	130	120
Ghazi Brotha	WAPDA	Hydro	1,450	1,334
Golen Gol	WAPDA	Hydro	108	99
Jinnah	WAPDA	Hydro	96	88
Khan Khwar	WAPDA	Hydro	72	66
Mangla	WAPDA	Hydro	1,000	920
Nelum Jehlum	WAPDA	Hydro	969	891
Small Hydel	WAPDA	Hydro	128	118
Tarbela 1-14	WAPDA	Hydro	3,478	3,200
Tarbela_Ext_04	WAPDA	Hydro	1,410	1,297
Warsak	WAPDA	Hydro	243	224
Jagran - I	IPP	Hydro	30	28
Malakand - III	IPP	Hydro	81	75
New Bong	IPP	Hydro	84	77
Darwal Khwar	IPP	Hydro	37	34
Gul Pur	IPP	Hydro	103	95
Patrind	IPP	Hydro	150	138

Name of Power Plant	Agency	Fuel	Installed Capacity (MW)	Firm Capability (MW)
Karot	IPP	Hydro	720	662
China HUBCO	IPP	Imported Coal	1,320	1,087
Port Qasim	IPP	Imported Coal	1,320	1,081
Sahiwal Coal	IPP	Imported Coal	1,320	1,082
Engro Thar	IPP	Local Coal	660	474
Lucky Coal	IPP	Local Coal	660	527
CHASHNUPP – I	Nuclear	Nuclear	325	261
CHASHNUPP-II	Nuclear	Nuclear	325	261
CHASHNUPP-III	Nuclear	Nuclear	340	274
CHASHNUPP-IV	Nuclear	Nuclear	340	274
K-2	Nuclear	Nuclear	1,145	921
K-3	Nuclear	Nuclear	1,145	921
Jamshoro - I U1	GENCO-I	RFO	250	174
Jamshoro - II U4	GENCO-I	RFO	200	148
Muzaffargarh - I U1	GENCO-III	RFO	210	165
Muzaffargarh - I U2	GENCO-III	RFO	210	159
Muzaffargarh - I U3	GENCO-III	RFO	210	160
Muzaffargarh - II U4	GENCO-III	RFO	320	237
AGL	IPP	RFO	163	133
Atlas	IPP	RFO	219	181
HuB N	IPP	RFO	225	181
HUBCO	IPP	RFO	1,292	964
Kohinoor	IPP	RFO	131	101
Lalpir	IPP	RFO	362	294
Liberty Tech	IPP	RFO	202	167
Nishat C	IPP	RFO	209	167
Nishat P	IPP	RFO	202	166
Saba	IPP	RFO	136	98
AES Pakgen	IPP	RFO	365	291
GTPS Block 4 U(5-9)	GENCO-III	RLNG	144	99
Nandipur	GENCO-III	RLNG	525	427
Balloki	IPP	RLNG	1,223	998
Bhikki	IPP	RLNG	1,180	964
Davis	IPP	RLNG	14	9
FKPCL	IPP	RLNG	172	128
Halmore	IPP	RLNG	225	166
Haveli	IPP	RLNG	1,230	1,008
KAPCO 1	IPP	RLNG	400	299
KAPCO 2	IPP	RLNG	900	646
KAPCO 3	IPP	RLNG	300	224
Orient	IPP	RLNG	225	172

Name of Power Plant	Agency	Fuel	Installed Capacity (MW)	Firm Capability (MW)
Rousch	IPP	RLNG	450	338
Saif	IPP	RLNG	225	172
Sapphire	IPP	RLNG	225	171
Appolo Solar	IPP	Solar	100	22
Best	IPP	Solar	100	22
Crest	IPP	Solar	100	22
QA_Solar	IPP	Solar	100	22
Zhenfa	IPP	Solar	100	22
Act/Tapal Wind	IPP	Wind	30	9
Artistic_wind	IPP	Wind	50	11
Artistic_wind-2	IPP	Wind	50	11
FFC	IPP	Wind	50	11
FWEL-I	IPP	Wind	50	11
FWEL-II	IPP	Wind	50	11
Gul Ahmed	IPP	Wind	50	11
Gul Ahmed-II	IPP	Wind	50	11
Hawa	IPP	Wind	50	11
Indus	IPP	Wind	50	11
Jhimpir	IPP	Wind	50	11
LAKED SIDE WIND	IPP	Wind	50	11
LIBERTY WIND-I	IPP	Wind	50	11
Master	IPP	Wind	50	11
Metro_Wind	IPP	Wind	50	11
Metro_Wind-II	IPP	Wind	60	13
NASDA GREEN WIND	IPP	Wind	50	11
Sachal	IPP	Wind	50	11
Sapphire_Wind	IPP	Wind	50	11
TAPAL WIND-2	IPP	Wind	50	11
Three_Gorges_I	IPP	Wind	50	11
Three_Gorges_II	IPP	Wind	50	11
Three_Gorges_III	IPP	Wind	50	11
Tricon_A	IPP	Wind	50	11
Tricon_B	IPP	Wind	50	11
Tricon_C	IPP	Wind	50	11
UEP	IPP	Wind	99	22
Yunus	IPP	Wind	50	11
Zorlu_Wind	IPP	Wind	56	12
LIBERTY WIND-II	IPP	Wind	50	11
Dawood	IPP	Wind	50	11
DIN WIND ENERGY	IPP	Wind	50	11
Master Green	IPP	Wind	50	11

Name of Power Plant	Agency	Fuel	Installed Capacity (MW)	Firm Capability (MW)
Tenaga	IPP	Wind	50	11
Tricom	IPP	Wind	50	11
Zephyr	IPP	Wind	50	11
Total Installed Capacity (MW) in FY 2022			**37,934**	**30,100**

A.2 Installed Generation Capacity in the NTDC System in 2031 under Low Demand Scenario

Name of Power Plant	Agency	Fuel	Capacity (MW)	Firm Capacity (MW)
Almoiz	IPP	Bagasse	36	33
Chanar	IPP	Bagasse	22	20
Chiniot	IPP	Bagasse	63	58
Fatima Energy (FEL)	IPP	Bagasse	120	110
Hamza	IPP	Bagasse	15	14
JDW - II	IPP	Bagasse	26	24
JDW - III	IPP	Bagasse	27	25
Ryk_Mills	IPP	Bagasse	30	28
Shahtaj	IPP	Bagasse	32	29
Thal_Layyah	IPP	Bagasse	25	23
CASA	NTDC	Cross/Border Int.	1,000	1,000
Uch	IPP	Gas	586	465
Engro	IPP	Gas	217	189
Foundation	IPP	Gas	184	140
Guddu - I U (11-13)	GENCO-II	Gas	415	340
Guddu 747	GENCO-II	Gas	747	627
Uch-II	IPP	Gas	393	322
Allai Khwar	WAPDA	Hydro	121	111
Chashma	WAPDA	Hydro	184	169
Daral Khwar	IPP	Hydro	37	34
Dubair Khwar	WAPDA	Hydro	130	120
Ghazi Brotha	WAPDA	Hydro	1,450	1,334
Golen Gol	WAPDA	Hydro	108	99
Gulpur	IPP	Hydro	103	95
Jagran-I	IPP	Hydro	30	28
Jinnah	WAPDA	Hydro	96	88
Karot	IPP	Hydro	720	662
Khan Khwar	WAPDA	Hydro	72	66
Malakand-III	IPP	Hydro	81	75
Mangla	WAPDA	Hydro	1,350	1,242
Neelum Jehlum	WAPDA	Hydro	969	891
New Bong	IPP	Hydro	84	77
Patrind	IPP	Hydro	150	138
Small Hydel	WAPDA	Hydro	146	134
Tarbela 1-14	WAPDA	Hydro	3,478	3,200
Tarbela_Ext_4	WAPDA	Hydro	1,410	1,297
Warsak	WAPDA	Hydro	243	224
Artistic-I	IPP	Hydro	63	58
Koto	IPP	Hydro	41	38

Name of Power Plant	Agency	Fuel	Capacity (MW)	Firm Capacity (MW)
Jagran-II	IPP	Hydro	48	44
Lawi	IPP	Hydro	69	63
Suki Kinari	IPP	Hydro	884	813
Gorkin Matiltan	IPP	Hydro	84	77
Tarbela_Ext_5	WAPDA	Hydro	1,530	1,408
Dasu	WAPDA	Hydro	2,160	1,987
Mohmand Dam	WAPDA	Hydro	800	736
Keyal Khwar	WAPDA	Hydro	128	118
Gabral Kalam	IPP	Hydro	88	81
Madyan	IPP	Hydro	157	144
Azad Pattan	IPP	Hydro	701	645
Balakot	IPP	Hydro	300	276
Kohala	IPP	Hydro	1,124	1,034
Diamer Basha	WAPDA	Hydro	xx	xx
Artistic-II	IPP	Hydro	55	51
Bankhwar	IPP	Hydro	35	32
Bata Kundi	IPP	Hydro	99	91
Chiniot_HPP	IPP	Hydro	80	74
Chowkel Khwar	IPP	Hydro	60	55
CJ	IPP	Hydro	25	23
Gabral Utror	IPP	Hydro	79	73
Ghorband	IPP	Hydro	21	19
Harigehl-Majeedgala	IPP	Hydro	40	37
Nila Da Katha	IPP	Hydro	31	29
Tangar	IPP	Hydro	26	24
Taunsa	IPP	Hydro	135	124
Trappi	IPP	Hydro	32	29
Arkari Gol	IPP	Hydro	99	91
Asrit Kedam	IPP	Hydro	215	198
Athmuqam	IPP	Hydro	450	414
Dowarian	IPP	Hydro	40	37
Gumat Nar	IPP	Hydro	50	46
Jagran-III	IPP	Hydro	35	32
Jagran-IV	IPP	Hydro	22	20
Kaigah-II	IPP	Hydro	40	36
Kaigah-III	IPP	Hydro	21	19
Kalam Asrit	IPP	Hydro	238	219
Kalkot Barikot	IPP	Hydro	47	43
Kari Mashkur	IPP	Hydro	495	455
Luat	IPP	Hydro	49	45
Nagdar	IPP	Hydro	35	32

Name of Power Plant	Agency	Fue	Capacity (MW)	Firm Capacity (MW)
Naran	IPP	Hydro	188	173
Patrak Sheringhal	IPP	Hydro	22	20
Rajdhani	IPP	Hydro	132	121
Shalfalam	IPP	Hydro	60	55
Sharmai	IPP	Hydro	152	140
Shigo Kas	IPP	Hydro	102	94
Shounter	IPP	Hydro	48	44
Turtonas Uzghor	IPP	Hydro	82	76
Ashkot	IPP	Hydro	300	276
Mahl	IPP	Hydro	640	589
Thakot-III	IPP	Hydro	1,490	1,371
Lower Spat Gah	IPP	Hydro	496	456
China HUBCO	IPP	Imported Coal	1,320	1,087
Jamshoro Coal (U #1)	GENCO-I	Imported Coal	660	574
Gwadar	IPP	Imported Coal	300	261
Port Qasim	IPP	Imported Coal	1,320	1,081
Sahiwal Coal	IPP	Imported Coal	1,320	1,082
Engro Thar	IPP	Local Coal	660	474
Lucky Coal	IPP	Local Coal	660	527
Thar TEL	IPP	Local Coal	330	287
Thal Nova	IPP	Local Coal	330	304
Thar-I (SSRL)	IPP	Local Coal	1,320	1,148
New_Local_Coal	IPP	Local Coal	990	911
CHASHNUPP - I	Nuclear	Nuclear	325	283
CHASHNUPP-II	Nuclear	Nuclear	325	283
CHASHNUPP-III	Nuclear	Nuclear	340	296
CHASHNUPP-IV	Nuclear	Nuclear	340	296
K-2	Nuclear	Nuclear	1,145	996
K-3	Nuclear	Nuclear	1,145	996
AGL	IPP	RFO	163	133
Atlas	IPP	RFO	219	181
HuB N	IPP	RFO	225	181
Liberty Tech	IPP	RFO	202	167
Nishat C	IPP	RFO	209	167
Nishat P	IPP	RFO	202	166
Rousch	IPP	RLNG	450	338
Balloki	IPP	RLNG	1,223	998
Bhikki	IPP	RLNG	1,180	964
Davis	IPP	RLNG	14	9
Halmore	IPP	RLNG	225	166
Haveli	IPP	RLNG	1,230	1,008

Name of Power Plant	Agency	Fuel	Capacity (MW)	Firm Capacity (MW)
Nandipur	GENCO-III	RLNG	525	427
Orient	IPP	RLNG	225	172
Saif	IPP	RLNG	225	172
Sapphire	IPP	RLNG	225	171
Trimmu	IPP	RLNG	1,263	1,033
Appolo	IPP	Solar	100	19
Best	IPP	Solar	100	19
Crest	IPP	Solar	100	19
Helios	IPP	Solar	50	12
HNDS	IPP	Solar	50	12
Meridian	IPP	Solar	50	12
Manjhand	IPP	Solar	50	12
QA_Solar	IPP	Solar	100	19
Siachen	IPP	Solar	100	23
Zhenfa	IPP	Solar	100	22
Zorlu	IPP	Solar	100	20
New_Solar	IPP	Solar	4,000	1,148
Act	IPP	Wind	30	9
Artistic_wind	IPP	Wind	50	17
Artistic_Wind_2	IPP	Wind	50	19
Dawood	IPP	Wind	50	15
Din	IPP	Wind	50	19
FFC	IPP	Wind	50	17
FWEL-I	IPP	Wind	50	18
FWEL-II	IPP	Wind	50	16
Gul Ahmed	IPP	Wind	50	16
Gul_Electric	IPP	Wind	50	19
Hawa	IPP	Wind	50	17
Indus_Energy	IPP	Wind	50	19
Jhimpir	IPP	Wind	50	17
Lakeside	IPP	Wind	50	19
Liberty_Wind_1	IPP	Wind	50	19
Liberty_Wind_2	IPP	Wind	50	19
Liberty 2	IPP	Wind	50	19
Master	IPP	Wind	50	16
Master_Green	IPP	Wind	50	19
Metro_Wind	IPP	Wind	50	23
Metro_Wind	IPP	Wind	60	23
NASDA	IPP	Wind	50	19
Sachal	IPP	Wind	50	16
Sapphire_Wind	IPP	Wind	50	16

Name of Power Plant	Agency	Fuel	Capacity (MW)	Firm Capacity (MW)
Act_2	IPP	Wind	50	19
Tenaga	IPP	Wind	50	15
Three_Gorges_I	IPP	Wind	50	16
Three_Gorges_II	IPP	Wind	50	17
Three_Gorges_III	IPP	Wind	50	17
Trans_Atlantic	IPP	Wind	50	21
Tricom	IPP	Wind	50	19
Tricon_A	IPP	Wind	50	17
Tricon_B	IPP	Wind	50	17
Tricon_C	IPP	Wind	50	17
UEP	IPP	Wind	99	31
Western	IPP	Wind	50	19
Yunus	IPP	Wind	50	16
Zephyr	IPP	Wind	50	18
Zorlu_Wind	IPP	Wind	56	18
New_Wind	IPP	Wind	3,500	1,365
Total Installed Capacity (MW) in FY 2031			**60,573**	**47,560**

Annex B Power and Energy Balances

B.1 Power and Energy Balances of NTDC System – Case 1

Case 1A: Low Demand Forecast 100% Planned Hydro Electric Capacity Additions

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
[illegible]												
Demand	**39,161**	**38,840**	**37,654**	**32,120**	**24,241**	**24,717**	**23,107**	**24,163**	**23,383**	**29,103**	**36,063**	**41,039**
Hydro Project	22,582	21,794	18,686	16,677	14,034	12,956	10,778	13,441	14,364	16,263	18,958	21,371
Wind	2,038	2,038	1,996	2,041	2,058	2,045	2,026	1,985	2,019	2,049	2,034	2,030
Solar	935	1,062	1,101	1,125	1,128	1,113	1,104	1,091	1,089	1,070	988	910
Bagasse	364	364	364	364	364	364	364	364	364	364	364	364
Nuclear	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149
CASA	1,000	1,000	1,000	-	-	-	-	-	-	-	1,000	1,000
Total Must Run Generation	**30,068**	**29,407**	**26,297**	**23,357**	**20,734**	**19,628**	**17,423**	**20,031**	**20,985**	**22,895**	**26,494**	**28,825**
Demand for Thermal Plants	9,093	9,433	11,357	8,762	3,507	5,088	5,684	4,133	2,398	6,207	9,569	12,214
[illegible]												
Demand	**23,867**	**23,708**	**22,066**	**17,494**	**13,183**	**13,481**	**13,419**	**12,202**	**13,551**	**16,245**	**21,283**	**22,660**
Hydro Project	14,974	14,522	11,494	7,132	5,593	4,315	3,147	4,490	5,355	8,187	12,958	14,444
Wind	1,887	1,846	1,299	1,017	1,073	1,435	1,082	687	1,180	1,345	2,458	2,755
Solar	819	833	1,008	1,085	1,140	1,087	1,002	1,009	1,038	1,015	839	791
Bagasse	173	173	173	173	173	173	173	173	173	173	173	173
Nuclear	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609
CASA	694	694	694	-	-	-	-	-	-	-	694	694
Total Must Run Generation	**20,155**	**19,677**	**16,277**	**11,016**	**9,588**	**8,620**	**7,014**	**7,968**	**9,354**	**12,329**	**18,731**	**20,465**
Energy Demand for Thermal Plants	3,712	4,030	5,789	6,478	3,594	4,861	6,405	4,234	4,196	3,917	2,552	2,195

Case 1B: Medium Demand Forecast 100% Planned Hydro Electric Capacity Additions

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
[illegible]												
Demand	**42,064**	**41,719**	**40,446**	**34,500**	**26,038**	**26,549**	**24,820**	**25,954**	**25,117**	**31,260**	**38,736**	**44,081**
Hydro Project	22,582	21,794	18,686	16,677	14,034	12,956	10,778	13,441	14,364	16,263	18,958	21,371
Wind	2,038	2,038	1,996	2,041	2,058	2,045	2,026	1,985	2,019	2,049	2,034	2,030
Solar	935	1,062	1,101	1,125	1,128	1,113	1,104	1,091	1,089	1,070	988	910
Bagasse	364	364	364	364	364	364	364	364	364	364	364	364
Nuclear	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149
CASA	1,000	1,000	1,000	-	-	-	-	-	-	-	1,000	1,000
Total Must Run Generation	**30,068**	**29,407**	**26,297**	**23,357**	**20,734**	**19,628**	**17,423**	**20,031**	**20,985**	**22,895**	**26,494**	**28,825**
Demand for Thermal Plants	11,996	12,312	14,148	11,143	5,304	6,920	7,397	5,924	4,131	8,365	12,242	15,256
[illegible]												
Demand	**25,627**	**25,456**	**23,694**	**18,784**	**14,155**	**14,475**	**14,408**	**13,102**	**14,550**	**17,443**	**22,852**	**24,331**
Hydro Project	14,974	14,522	11,494	7,132	5,593	4,315	3,147	4,490	5,355	8,187	12,958	14,444
Wind	1,887	1,846	1,299	1,017	1,073	1,435	1,082	687	1,180	1,345	2,458	2,755
Solar	819	833	1,008	1,085	1,140	1,087	1,002	1,009	1,038	1,015	839	791
Bagasse	173	173	173	173	173	173	173	173	173	173	173	173
Nuclear	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609
CASA	694	694	694	-	-	-	-	-	-	-	694	694
Total Must Run Generation	**20,155**	**19,677**	**16,277**	**11,016**	**9,588**	**8,620**	**7,014**	**7,968**	**9,354**	**12,329**	**18,731**	**20,465**
Energy Demand for Thermal Plants	5,472	5,779	7,416	7,768	4,567	5,855	7,395	5,134	5,196	5,115	4,121	3,866

Case 1C: High Demand Forecast 100% Planned Hydro Electric Capacity Additions

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
[illegible]												
Demand	**45,163**	**44,792**	**43,425**	**37,042**	**27,956**	**28,504**	**26,648**	**27,866**	**26,967**	**33,563**	**41,589**	**47,328**
Hydro Project	22,582	21,794	18,686	16,677	14,034	12,956	10,778	13,441	14,364	16,263	18,958	21,371
Wind	2,038	2,038	1,996	2,041	2,058	2,045	2,026	1,985	2,019	2,049	2,034	2,030
Solar	935	1,062	1,101	1,125	1,128	1,113	1,104	1,091	1,089	1,070	988	910
Bagasse	364	364	364	364	364	364	364	364	364	364	364	364
Nuclear	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149
CASA	1,000	1,000	1,000	-	-	-	-	-	-	-	1,000	1,000
Total Must Run Generation	**30,068**	**29,407**	**26,297**	**23,357**	**20,734**	**19,628**	**17,423**	**20,031**	**20,985**	**22,895**	**26,494**	**28,825**
Demand for Thermal Plants	15,094	15,385	17,127	13,685	7,222	8,876	9,225	7,835	5,982	10,667	15,095	18,503
[illegible]												
Demand	**27,507**	**27,323**	**25,431**	**20,162**	**15,193**	**15,536**	**15,465**	**14,063**	**15,617**	**18,723**	**24,528**	**26,115**
Hydro Project	14,974	14,522	11,494	7,132	5,593	4,315	3,147	4,490	5,355	8,187	12,958	14,444
Wind	1,887	1,846	1,299	1,017	1,073	1,435	1,082	687	1,180	1,345	2,458	2,755
Solar	819	833	1,008	1,085	1,140	1,087	1,002	1,009	1,038	1,015	839	791
Bagasse	173	173	173	173	173	173	173	173	173	173	173	173
Nuclear	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609
CASA	694	694	694	-	-	-	-	-	-	-	694	694
Total Must Run Generation	**20,155**	**19,677**	**16,277**	**11,016**	**9,588**	**8,620**	**7,014**	**7,968**	**9,354**	**12,329**	**18,731**	**20,465**
Energy Demand for Thermal Plants	7,351	7,646	9,154	9,146	5,605	6,917	8,451	6,095	6,263	6,394	5,797	5,650

B.2 Power and Energy Balances of NTDC System – Case 2

Case 2A: Low Demand Forecast 50% Planned Hydro Electric Capacity Additions

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
[illegible]												
Demand	**39,161**	**38,840**	**37,654**	**32,120**	**24,241**	**24,717**	**23,107**	**24,163**	**23,383**	**29,103**	**36,063**	**41,039**
Hydro Project	19,739	19,044	16,452	15,062	12,948	11,892	9,782	12,233	12,926	14,543	16,575	18,511
Wind	2,038	2,038	1,996	2,041	2,058	2,045	2,026	1,985	2,019	2,049	2,034	2,030
Solar	935	1,062	1,101	1,125	1,128	1,113	1,104	1,091	1,089	1,070	988	910
Bagasse	364	364	364	364	364	364	364	364	364	364	364	364
Nuclear	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149
CASA	1,000	1,000	1,000	-	-	-	-	-	-	-	1,000	1,000
Total Must Run Generation	**27,225**	**26,658**	**24,063**	**21,741**	**19,647**	**18,564**	**16,426**	**18,823**	**19,548**	**21,176**	**24,111**	**25,965**
Demand for Thermal Plants	11,936	12,182	13,591	10,378	4,593	6,152	6,681	5,340	3,836	7,927	11,951	15,074
[illegible]												
Demand	**23,867**	**23,708**	**22,066**	**17,494**	**13,183**	**13,481**	**13,419**	**12,202**	**13,551**	**16,245**	**21,283**	**22,660**
Hydro Project	12,766	12,433	10,018	6,160	5,052	3,660	2,538	3,848	4,526	7,026	11,173	12,289
Wind	1,887	1,846	1,299	1,017	1,073	1,435	1,082	687	1,180	1,345	2,458	2,755
Solar	819	833	1,008	1,085	1,140	1,087	1,002	1,009	1,038	1,015	839	791
Bagasse	173	173	173	173	173	173	173	173	173	173	173	173
Nuclear	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609
CASA	694	694	694	-	-	-	-	-	-	-	694	694
Total Must Run Generation	**17,948**	**17,589**	**14,801**	**10,044**	**9,048**	**7,964**	**6,404**	**7,326**	**8,525**	**11,168**	**16,946**	**18,310**
Energy Demand for Thermal Plants	5,919	6,119	7,265	7,450	4,135	5,516	7,014	4,876	5,025	5,078	4,336	4,350

Case 2B: Medium Demand Forecast 50% Planned Hydro Electric Capacity Additions

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
[illegible]												
Demand	**42,064**	**41,719**	**40,446**	**34,500**	**26,038**	**26,549**	**24,820**	**25,954**	**25,117**	**31,260**	**38,736**	**44,081**
Hydro Project	19,739	19,044	16,452	15,062	12,948	11,892	9,782	12,233	12,926	14,543	16,575	18,511
Wind	2,038	2,038	1,996	2,041	2,058	2,045	2,026	1,985	2,019	2,049	2,034	2,030
Solar	935	1,062	1,101	1,125	1,128	1,113	1,104	1,091	1,089	1,070	988	910
Bagasse	364	364	364	364	364	364	364	364	364	364	364	364
Nuclear	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149
CASA	1,000	1,000	1,000	-	-	-	-	-	-	-	1,000	1,000
Total Must Run Generation	**27,225**	**26,658**	**24,063**	**21,741**	**19,647**	**18,564**	**16,426**	**18,823**	**19,548**	**21,176**	**24,111**	**25,965**
Demand for Thermal Plants	14,839	15,061	16,382	12,759	6,390	7,984	8,393	7,131	5,569	10,085	14,624	18,116
[illegible]												
Demand	**25,627**	**25,456**	**23,694**	**18,784**	**14,155**	**14,475**	**14,408**	**13,102**	**14,550**	**17,443**	**22,852**	**24,331**
Hydro Project	12,766	12,433	10,018	6,160	5,052	3,660	2,538	3,848	4,526	7,026	11,173	12,289
Wind	1,887	1,846	1,299	1,017	1,073	1,435	1,082	687	1,180	1,345	2,458	2,755
Solar	819	833	1,008	1,085	1,140	1,087	1,002	1,009	1,038	1,015	839	791
Bagasse	173	173	173	173	173	173	173	173	173	173	173	173
Nuclear	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609
CASA	694	694	694	-	-	-	-	-	-	-	694	694
Total Must Run Generation	**17,948**	**17,589**	**14,801**	**10,044**	**9,048**	**7,964**	**6,404**	**7,326**	**8,525**	**11,168**	**16,946**	**18,310**
Energy Demand for Thermal Plants	7,680	7,867	8,892	8,740	5,107	6,511	8,004	5,775	6,024	6,276	5,906	6,021

Case 2C: High Demand Forecast 50% Planned Hydro Electric Capacity Additions

	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
[illegible]												
Demand	**45,163**	**44,792**	**43,425**	**37,042**	**27,956**	**28,504**	**26,648**	**27,866**	**26,967**	**33,563**	**41,589**	**47,328**
Hydro Project	19,739	19,044	16,452	15,062	12,948	11,892	9,782	12,233	12,926	14,543	16,575	18,511
Wind	2,038	2,038	1,996	2,041	2,058	2,045	2,026	1,985	2,019	2,049	2,034	2,030
Solar	935	1,062	1,101	1,125	1,128	1,113	1,104	1,091	1,089	1,070	988	910
Bagasse	364	364	364	364	364	364	364	364	364	364	364	364
Nuclear	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149	3,149
CASA	1,000	1,000	1,000	-	-	-	-	-	-	-	1,000	1,000
Total Must Run Generation	**27,225**	**26,658**	**24,063**	**21,741**	**19,647**	**18,564**	**16,426**	**18,823**	**19,548**	**21,176**	**24,111**	**25,965**
Demand for Thermal Plants	17,938	18,134	19,362	15,300	8,308	9,940	10,222	9,043	7,419	12,387	17,478	21,363
[illegible]												
Demand	**27,507**	**27,323**	**25,431**	**20,162**	**15,193**	**15,536**	**15,465**	**14,063**	**15,617**	**18,723**	**24,528**	**26,115**
Hydro Project	12,766	12,433	10,018	6,160	5,052	3,660	2,538	3,848	4,526	7,026	11,173	12,289
Wind	1,887	1,846	1,299	1,017	1,073	1,435	1,082	687	1,180	1,345	2,458	2,755
Solar	819	833	1,008	1,085	1,140	1,087	1,002	1,009	1,038	1,015	839	791
Bagasse	173	173	173	173	173	173	173	173	173	173	173	173
Nuclear	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609	1,609
CASA	694	694	694	-	-	-	-	-	-	-	694	694
Total Must Run Generation	**17,948**	**17,589**	**14,801**	**10,044**	**9,048**	**7,964**	**6,404**	**7,326**	**8,525**	**11,168**	**16,946**	**18,310**
Energy Demand for Thermal Plants	9,559	9,734	10,630	10,117	6,145	7,572	9,061	6,736	7,091	7,555	7,582	7,805

Annex 2 Power Systems Study Report

REPORT

LSG HYDRO POWER LIMITED

Lower Spat Gah Hydropower Project

Feasibility Study

Transmission Line – Power System Studies

127000588-002
24 November 2022

Draft

AFRY
ÅF PÖYRY

Project
Lower Spat Gah Hydropower Project

Project No.
127000588-002

Revision
Draft

Date
24 November 2022

Address
AFRY (Thailand) Ltd.
Vanit II Bldg., 22nd Floor
1126/2 New Petchburi Road, Makkasan
Rajchthewi, Bangkok 10400, Thailand

Phone
+66 2 108 1000

Contact
Stephan Martin

Mobile
+66 92 264 0738

E-mail
stephan.martin@afry.com

Client
LSG HYDRO POWER Limited

Report

Feasibility Study, Transmission Line - Power System Studies

"This report has been prepared by AFRY (Thailand) Ltd. ("AFRY") together with Power Planners International (Pvt.) Ltd. ("PPI") for LSG Hydro Power Limited also called LSG SPC pursuant to the consultancy services agreement signed between AFRY and LSG Hydro Power Limited. This report is based in part on information not within AFRY's control. While the information provided in this report is believed to be accurate and reliable under the conditions and subject to the qualifications set forth herein, AFRY does not, without prejudice to AFRY's obligations towards the Recipient under the Agreement, make any representations or warranties, expressed or implied, as to the accuracy or completeness of such information.

Use of this report and any of the estimates contained herein by anyone else than the Recipient ("Third Party User") shall, therefore, be at the Third-Party User´s sole risk. Any use by a Third-Party User shall constitute a release and agreement to defend and indemnify AFRY from and against any liability of AFRY towards the Third-Party User, whatsoever in type or nature, in connection with such use, whether liability is asserted to arise in contract, negligence, strict liability or other theory of law.

All information contained in this report is of confidential nature and may be used and disclosed by the Recipient solely in accordance with the terms and conditions set forth in the Agreement."

Executive Summary

- The power system studies report of the hydropower plant of Lower Spat Gah with net power capacity of 470 MW, Upper Kohistan District is submitted herewith.
- The updated generation plan, transmission plan and load forecast from NTDC has been used for the study, vide data permission letter no. GMPSP/TRP-300/4365-71 dated 15-11-2021.
- The study objective, approach and methodology have been described and the plant's data received from the Lower Spat Gah Hydropower Project has been validated.
- The hydropower project, referred to as Lower Spat Gah HPP in the remainder of the report, is expected to start commercial operation by June 2030. Therefore, the scenario of summer 2030 has been selected to carry out the study as it is high water season and it will help to determine the maximum impact of the project.
- Lower Spat Gah HPP is located downstream of Dasu, on the Spat Gah River, a side river to the Indus River. The tunnel portal to the Lower Spat Gah powerhouse is south of Dasu.
- The grid system of NTDC in the vicinity of Lower Spat Gah HPP has been studied in detail by performing load flow, short circuit and dynamic analyses for the conditions prior to commissioning of Lower Spat Gah HPP and no bottlenecks or constraints have been found in the grid system.
- The hydropower plant comprises three turbine-generator generating units of 156.7 MW each. These three units are able to deliver a maximum net power of 470 MW.
- The Lower Spat Gah generators will be connected at a voltage level of 15.75 kV. This voltage will be stepped up to 765 kV within the switchyard of the power plant. This power will then be evacuated in the network of NTDC.
- The proposed interconnection scheme is to connect the Lower Spat Gah HPP in a Loop In Loop Out configuration on the proposed 765 kV line connecting Dasu and Mansehra with an assumed looping length of 10 km (to be confirmed after detailed survey).
- The following equipment will be required at the connection switchyard of Lower Spat Gah HPP:
  - Two Line Bays of 765 kV
  - Three cable bays of 220 kV for GSU 220/15.75
  - One Auto Transformer Bank of 570 MVA (3 x 190 MVA single phase)
  - Two transformer Bays for 765/220 kV at each of 765 kV and 220 kV
  - One Line Shunt Reactor at one 765 kV Line going to Mansehra
- 150 MVAR reactors have been proposed as per the detailed integrated study carried out by NTDC for this area. The reactor will initially be connected at both ends of the transmission line between Dasu and Mansehra to avoid Ferranti effect and absorb surplus VARs in light load conditions. After the interconnection of the Lower Spat Gah HPP, the reactor will be shifted on the line between Lower Spat Gah and Mansehra.
- Considering the COD targeted by the Lower Spat Gah HPP, load flow analysis has been carried out for peak and off-peak load scenarios of summer 2030 peak for the dispersal of power from Lower Spat Gah HPP into the NTDC system using the latest system data. The above-mentioned interconnection scheme has been evolved by performing the load flow studies testing the steady state performance for normal as well as N-1 contingency conditions fulfilling the Grid Code criteria.
- The maximum short circuit levels at Lower Spat Gah 765 kV are 12.65 kA and 11.17 kA for 3-phase and 1-phase faults, respectively, in the year 2030. Therefore, industry standard switchgear of a short circuit rating of 63 kA would be sufficient for installation at 765 kV switchyard of Lower Spat Gah HPP, as the maximum short circuit levels for the year 2030 were also found to be within this range, taking care of any future generation additions and system reinforcements in its electrical vicinity and also fulfilling the NEPRA Grid Code requirements specified for 765 kV switchgears. There are no violations of the

power rating of the equipment in the vicinity of Lower Spat Gah HPP in the event of fault conditions.

- The dynamic stability analysis of the proposed scheme of interconnection has been carried out. The stability has been tested for the worst cases, i.e. three phase fault right on the 765 kV bus bar of Lower Spat Gah substation followed by trip of a 765 kV single circuit from Lower Spat Gah to Mansehra has been performed for fault clearing of 5 cycles (100 ms), as understood to be the normal fault clearing time of 765 kV protection system. The system is stable for all the tested fault conditions.
- The proposed scheme of interconnection has no technical constraints or problems, it fulfils all the criteria of reliability and stability under steady state load flow, contingency load flows considered, short circuit currents and dynamic/transient conditions; and is therefore recommended to be adopted.

Table of Contents

Tables

List of Abbreviations

The following abbreviations have been used in this report.

Abbreviation	Meaning
COD	Commercial Operation Date
GSU	Generator Step-up Transformer
AT	Auto Transformer Bank
HPP	Hydropower Project
IEC	International Electrotechnical Commission
IGCEP	Indicative Generation Capacity Expansion Plan
LSG	Lower Spat Gah
NEPRA	National Electric Power Regulatory Authority
NTDC	National Transmission & Despatch Company
P.U.	Per unit
PMS	power market survey
PPI	Power Planners International
PSS/E	power system simulator for engineers
ROW	right of way
SPC	Special Purpose Company
WAPDA	Water and Power Development Authority

The following units have been used in this report.

Symbol	Unit
%	percent
Hz	Hertz
kA	kiloampere
km	kilometre
kV	Kilovolt
ms	millisecond
MVA	Megavolt amperes
MVAR	Mega volt amp of reactive power
MW	Megawatt
MWs	Megawatt second

1 Introduction

1.1 Background

The LSG Hydro Power Limited, also called LSG SPC ("Client") is planning to develop the Lower Spat Gah Hydropower Project ("Project") in Upper Kohistan District, in Khyber Pakhtunkhwa Province of Pakistan. The Spat Gah valley is located on the left bank of the Indus River about 4 km downstream of Dasu town. The electricity generated from this project would be supplied directly to the 765 kV Grid Station of NTDC available in the vicinity of this project. A general idea of the grid stations in the vicinity of the plant can be viewed in Annex B.1 attached.

Lower Spat Gah HPP aims to install three units with 156.66 MW each (total installed = 470 MW), as measured after the generator with the aim of exporting 444 MW power to the grid. The project is expected to start commercial operation by June 2030. The electricity generated from this project would be supplied to the grid system of NTDC through 765 kV transmission system in the vicinity of this project.

AFRY Thailand has contracted Power Planners International ("PPI") to carry out transmission line studies, including a power market study, power systems studies and a transmission line survey for the Lower Spat Gah Hydropower Project. This report provides the power systems studies.

1.2 Objectives

The overall objective of the study is to evolve an interconnection scheme between the Lower Spat Gah HPP and the National Grid, for stable and reliable evacuation of electrical power generated from this plant, fulfilling the N-1 reliability criteria. The specific objectives of this report are:

- To develop a scheme of interconnections at 765 kV for which right of way (ROW) and space at the terminal substations would be available.
- To determine the performance of interconnection scheme during steady state conditions of system, normal and N-1 contingency, through load-flow analysis.
- To check if the contribution of fault current from the plant unit increases the fault levels at the adjoining substations to be within the rating of equipment of these substations, and also determine the short circuit ratings of the proposed equipment of the substation at the Lower Spat Gah HPP.
- To check if the interconnection withstands dynamic stability criteria of post fault recovery with good damping.

1.3 Planning Criteria

The planning criteria required to be fulfilled by the proposed interconnection is as follows:

Steady State

Voltage	± 8%, Normal Operating Condition for 220 & 500 kV
	± 4%, Normal Operating Condition for 765 kV
	± 10%, Contingency Conditions for 220 & 500 kV
	-5% to +4.6%, Contingency Conditions for 765 kV
Frequency	50 Hz Nominal, continuous
	49.8 Hz to 50.2 Hz variation in steady state
	49.4 - 50.5 Hz, Min/Max Contingency Frequency Band
Power Factor	0.85 Lagging, 0.90 Leading

Short Circuit

765 kV substation equipment rating of 50 kA or 63 kA

Dynamic/Transient

The system should revert to normal condition after transients die out with good damping, without losing synchronism. The system is tested under the following fault conditions:

- Permanent three-phase fault on any primary transmission element, including: transmission circuit, substation bus section, transformer or circuit breaker. It is assumed that such a fault shall be cleared by the associated circuit breaker action in 5 cycles.

2 Assumptions of Data

2.1 Lower Spat Gah HPP Data

There will be three generating units at the Lower Spat Gah 15.75 kV. As per the data as defined in the Feasibility Study Report the following data has been modelled:

• Net capacity of generators	3 x 156.66 MW = 470 MW
• Power factor	0.85 lagging, 0.90 leading
• Inertia constant	3.2 MW-sec/MVA
• Generating voltage	15.75 kV
• GSU transformer 220/15.75 kV rating	3 x 190 MVA
• % Impedance of GSU	12.5%
• Auto Transformer 765/220 kV rating	3 x 190 MVA single phase (with 1x190 MVA single-phase as spare)
• % Impedance of AT	12.5%

2.2 Network Data

The 765 kV network in the area near Lower Spat Gah HPP is shown in the sketches in Annex B. This network has been proposed for the evacuation of power for Dasu and the downstream hydropower projects.

3 Study Approach and Methodology

3.1 Understanding the Problem

The Lower Spat Gah HPP intends to install hydropower generation with installed capacity of 470 MW . The difficult terrain, narrow corridor and right of way makes it difficult to lay new transmission lines. The site of the proposed project is located downstream of Dasu. The tunnel portal of the Lower Spat Gah is to the south of Dasu. The proposed Project is going to be embedded in the transmission network of NTDC through these nearest available 765 kV and 500 kV networks.

The adequacy of this 765 kV network in and around the proposed site of the Lower Spat Gah HPP has been investigated in this study for absorbing and transmitting this power fulfilling the reliability criteria.

3.2 Approach to the Problem

The following approach has been applied to the problem:

- The month of June 2030 has been selected for the study because it represents the high-water peak load conditions as per the COD June 2030 of the Lower Spat Gah HPP. Thus, lines in the vicinity of this plant will be loaded to the maximum extent, allowing to judge the complete impact of the plant on the transmission system in its vicinity.
- Load flow and short circuit studies have also been performed for summer 2030 to gauge the performance of the proposed plant in an extended term scenario.
- An interconnection scheme without any physical constraints, such as right of way or availability of space in the terminal substations, has been identified.
- Technical system studies have been conducted for peak load conditions, to confirm the technical feasibility of the interconnection. The scheme will be subjected to standard analyses such as load flow, short circuit, and transient stability to gauge the strength of the machines and the proposed interconnection under disturbed conditions.
- The relevant equipment for the proposed technically feasible scheme has been determined.

3.3 Base Case 2030

The transmission network data beyond 2028 is not available from NTDC. The power systems studies are however carried out for the year 2030 when the Lower Spat Gah Project delivers power to the grid after COD. The power system studies cannot be carried out without the system model for the year 2030. The availability of the NTDC transmission expansion plan for 2030 was unclear at the start of the studies.

In agreement with NTDC and to facilitate these power system studies; PPI developed an interim Base Case for 2030 based on

I. assumptions agreed with NTDC
II. the approved load forecast until 2030 and system data (NTDC Transmission Plan & IGCEP).

Once the NTDC transmission plan for 2030 is available, the power systems studies can be updated.

Preparation Methodology of Base Peak Case 2030:

The scenario was extended from 2028 to 2030 using the following methodology:

1. Load of each distribution company was modeled on the basis of DISCO wise demand forecast summary provided by NTDC. In this process, month factor and diversity factor as well as auxiliary loads of generation buses were taken into account. Since this study is performed for the summer season, the month factor

was taken as 1. The diversity factor for each DISCO was calculated by dividing the sum of individual loads of all grids by total load demand.

Diversity Factor = Sum of Individual Maximum Demands / Maximum Demand of the System

DISCO wise demand forecast summary provided by NTDC is attached in the Annex A.2.

2. The cumulative load demand of the system in the year 2028 and 2023 is tabulated below:

Case Year	Cumulative load demand in MW
2028	30912
2030	32550

3. New Grid Stations planned between the year 2028 and 2030 were added in the case. The transmission lines to be connected with each grid station and their loading was adjusted in consultation with the concerned DISCOs.
4. The generating units planned for 2030 were incorporated in the case scenario according to the Indicative Generation Capacity Expansion Plan added in the Annex A.1.
5. The 2030 case was then optimized by following methods
   a. The MVAR production of generating units was also adjusted such that no generator in the system is running on VAR absorption mode (leading power factor) as per usual practice to provide stability margin and avoid stress on end-regions of rotor. This is done by manually adjusting the terminal voltages and tap ratios of GSU and power transformers in the system.
   b. It was ensured that the bus bars in the system are within the acceptable voltage range. The admissible voltage ranges of DISCOs and NTDC are tabulated below:

	Lower Voltage limit (pu)	Upper Voltage Limit (pu)
DISCOs	0.95	1.05
NTDC	0.95	1.08

6. The steady state analysis was then performed using Fixed Slope Decoupled Newton Raphson Method. It was found that the case was running smoothly and the convergence criteria was met.
7. In the next step, the generating units of Lower Spat Gah were added in the system. It was found that the case was working properly after the integration of Lower Spat Gah.

Preparation Methodology of Off-Peak Case 2030:

1. PPI was also responsible for the preparation of Off-peak case scenario of the year 2030.
2. PPI has used the approach for making this case that was agreed upon by NTDC.
3. The loads of all distribution companies were scaled down to 85 percent of the load demand of peak case of 2030. The load comparison of peak and off-peak case is tabulated below:

Case	Cumulative load demand in MW
Peak 2030	32550
Off-Peak 2030	27647

A slightly higher value in the off-peak case is due to the fact that the auxiliary loads of some generators do not reduce even during off-peak season.

4. The generation capacity of hydel power generations was reduced because they do not generate to their full capacity during the off-peak timing. The methodology of this reduction has been agreed upon with NTDC.
5. Similarly, this case was also optimized to make sure that no generator was running on VAR absorption mode and voltage is within acceptable limits.
6. The steady state analysis was then performed using Fixed Slope Decoupled Newton Raphson Method. It was found that the case was running smoothly and the convergence criteria was met.
7. In the next step, the generating units of Lower Spat Gah were added in the system. It was found that the case was working properly after the integration of Lower Spat Gah.
8. The dynamic data of generators provided for 2028 by NTDC in the dynamic raw data file (*.dyr) was updated by adding the respective data of generators to be added between 2028 and 2030. Initial condition check was performed and it was found OK.

4 Development of Interconnection Scheme

4.1 Network around Proposed Site

The overall network in the area has been proposed on 765 kV level for Dasu HPP after extensive studies. The proposed Lower Spat Gah HPP will be interconnected in the same proposed network of Dasu 765 kV.

The power from these hydropower projects will be collected on 765 kV network and evacuated on 500 kV and 220 kV network of NTDC. The power is then sent towards load centres of distribution companies.

4.2 Interconnection Scheme of Lower Spat Gah HPP

The proposed interconnection scheme is to Loop In and Out Lower Spat Gah HPP on the proposed 765 kV line connecting Dasu and Mansehra with an assumed looping length of 10 km (to be confirmed after detailed survey).

The following equipment will be required at the connection switchyard of Lower Spat Gah HPP:

- Two Line Bays of 765 kV
- Three cable bays of 220 kV for GSU 220/15.75 kV
- One Auto Transformer Bank of 570 MVA (3 x 190 MVA single phase with 1x190 MVA single-phase as spare)
- Two transformer Bays for 765/220 kV each at 765 kV and 220 kV
- One Line Shunt Reactor at one 765 kV Line going to Mansehra

150 MVAR reactors have been proposed as per the detailed integrated study carried out by NTDC for this area. The reactor will initially be connected at both ends of the transmission line between Dasu and Mansehra to avoid Ferranti effect during energization, and avoid absorption of VARs under light load conditions. After the interconnection of the Lower Spat Gah HPP, the reactor will be shifted to switching station of Lower Spat Gah to be connected to the line end between Lower Spat Gah and Mansehra.

A few approximate sketches for the proposed scheme of interconnection are shown in Annex B.

5 Detailed Load Flow Studies

The base cases have been developed for the peak conditions of summer 2030 using the network data of NTDC available to PPI. The peak loads of the year 2030 have been modelled as per the latest PMS Demand forecast. Detailed load flow studies have been carried out for following scenarios:

- Peak load summer 2030
- Off-peak load summer 2030

5.1 Peak Load Case Summer 2030

The peak load case for summer 2030 has been studied in detail for both without and with the Lower Spat Gah HPP.

5.1.1 Without Lower Spat Gah HPP

The results of the load flow for this base case are plotted in Figure C.1-1 of Annex C.1. The system plotted in this figure shows the 765 kV and 500 kV network in the vicinity of the Lower Spat Gah HPP including the substations of Dasu, Mansehra and Islamabad West.

The load flow results show that the power flows on all circuits are within their specified normal current carrying rating. The voltages are also within the permissible limits.

N-1 contingency analysis has been carried out and the plotted results are attached in Annex C.1 as follows:

- Figure C.1-2 Dasu to Mansehra 765 kV Single Circuit Out
- Figure C.1-3 Mansehra to ISB-W 765 kV Single Circuit Out
- Figure C.1-4 ISB-W 765/500 kV Single Transformer Out
- Figure C.1-5 Tarbela to ISB-W 500 kV Single Circuit Out
- Figure C.1-6 ISB-W to G.Brotha 500 kV Single Circuit Out
- Figure C.1-7 ISB-W to Rewat-N 500 kV Single Circuit Out
- Figure C.1-8 Maira-S/S to ISBD-W 500 kV Single Circuit Out
- Figure C.1-9 Tarbela-5th to ISBD-W 500 kV Single Circuit Out

The power flows on all circuits remain within their ratings. Thus, it was found that there are no capacity constraints in terms of MW or MVA flow in the 765 kV network available in the vicinity of the Lower Spat Gah HPP for its connectivity under normal conditions and the N-1 contingency conditions considered.

5.1.2 With Lower Spat Gah HPP

The results of the load flow with the Lower Spat Gah HPP interconnected as per the proposed scheme are shown for each case. Lower Spat Gah HPP is delivering 444 MW power to the grid in peak summer season after deduction of auxiliary and load of the complex. The power flows on the circuits under normal conditions are seen well within the rated capacities. Also, the voltages on the bus bars are within the permissible operating range of ± 5% off the nominal.

No capacity constraints were found on the 765 kV circuits under normal conditions, i.e. without any outages of circuits.

N-1 contingency analysis has been carried out and the plotted results are attached in Annex C.2 as follows:

- Figure C.2-2 Lower Spat Gah to Mansehra 765 kV Single Circuit Out
- Figure C.2-3 Dasu to Lower Spat Gah 765 kV Single Circuit Out
- Figure C.2-4 Dasu to Mansehra 765 kV Single Circuit Out

- Figure C.2-5 Mansehra to ISB-W 765 kV Single Circuit Out
- Figure C.2-6 ISB-W 765/500 kV Single Transformer Out
- Figure C.2-7 Tarbela to ISB-W 500 kV Single Circuit Out
- Figure C.2-8 ISB-W to G.Brotha 500 kV Single Circuit Out
- Figure C.2-9 ISB-W to Rewat-N 500 kV Single Circuit Out
- Figure C.2-10 Maira-S/S to ISBD-W 500 kV Single Circuit Out
- Figure C.2-11 Tarbela-5th to ISBD-W 500 kV Single Circuit Out

The power flows on the circuits are seen well within the rated capacities and the voltages on the bus bars are also within the permissible operating range of ± 10% off the nominal for contingency conditions' criteria. No capacity constraints were found on the 765 kV circuits under normal and contingency conditions.

5.2 Off-Peak Load Case Summer 2030

The scenario of the Lower Spat Gah HPP with 85% loads in the system has been studied. Lower Spat Gah HPP is delivering 444 MW power to the grid in off-peak summer season. The results of load flows with the Lower Spat Gah HPP under normal conditions have been plotted in Figure C.3-1 in Annex C.3.

The power flows on the circuits are seen well within the rated capacities and the voltages on the bus bars are also within the permissible operating range of ± 5% off the nominal. No capacity constraints were found on the 765 kV circuits under normal conditions i.e. without any outages of circuits.

N-1 contingency analysis has been carried out and the plotted results are attached in Annex C.3 as follows:

- Figure C.3-2 Lower Spat Gah to Mansehra 765 kV Single Circuit Out
- Figure C.3-3 Dasu to Lower Spat Gah 765 kV Single Circuit Out
- Figure C.3-4 Dasu to Mansehra 765 kV Single Circuit Out
- Figure C.3-5 Mansehra to ISB-W 765 kV Single Circuit Out
- Figure C.3-6 ISB-W 765/500 kV Single Transformer Out
- Figure C.3-7 Tarbela to ISB-W 500 kV Single Circuit Out
- Figure C.3-8 ISB-W to G.Brotha 500 kV Single Circuit Out
- Figure C.3-9 ISB-W to Rewat-N 500 kV Single Circuit Out
- Figure C.3-10 Maira-S/S to ISBD-W 500 kV Single Circuit Out
- Figure C.3-11 Tarbela-5th to ISBD-W 500 kV Single Circuit Out

The power flows on the circuits are seen well within the rated capacities and the voltages on the bus bars are also within the permissible operating range of ± 10% off the nominal for contingency conditions' criteria. No capacity constraints were found on the 765 kV circuits under normal and contingency conditions.

5.3 Conclusion of Load Flow Analysis

From the analysis discussed above, it can be concluded that the proposed interconnection scheme with all the proposed reinforcements and the protection schemes is adequate to evacuate the net470 MW power of the Lower Spat Gah HPP under normal and contingency conditions. The interconnection ensures reliability and availability under all events of contingencies, i.e. planned or forced outages studied in this report for the base year. The bus bar voltages remain well within the permissible limits in all the contingency events.

6 Short Circuit Analysis

6.1 Methodology and Assumptions

The methodology of IEC 60909 has been applied in all short circuit analyses in this report for which provision is available in the PSS/E software used for these studies.

The maximum fault currents have been calculated with the following assumptions under IEC 60909:

- Set tap ratios and phase shift angles are left unchanged
- Set shunts and line charging is set to zero in positive and negative sequence
- Loads are left unchanged
- Sub-transient reactance is considered for the generator
- The breaker contact parting time is set to 0.05 s
- Desired voltage magnitude at bus bars set equal to 1.10 P.U., i.e. so voltage factor C is set to maximum fault currents

For the evaluation of maximum short circuit levels contribution in the fault currents were assumed from all the installed generation capacity of hydel, thermal and nuclear plants in the system in the year 2030, i.e. all the generating units have been assumed on-bar in the fault calculation's simulations.

The assumptions about the generator and the transformers data are the same as mentioned in Chapter 2 of this report.

6.2 Fault Current Calculations without Lower Spat Gah HPP Year 2030

In order to assess the short circuit strength of the 765 kV network without the Lower Spat Gah HPP, three-phase and single-phase fault currents have been calculated for the NTDC network in the vicinity of the Lower Spat Gah HPP site for the year 2030. These levels will give the information of the fault levels without the Lower Spat Gah HPP, which can be used to determine the impact of the addition of the plant later on. The results are shown in Figure D.1-1.

The short circuit levels have been calculated and plotted on the bus bars of 765 kV of substations lying in the electrical vicinity of the area of interest and are attached in Annex D.1. Both 3-phase and 1-phase fault currents are indicated in the Figure D.1-1 which are given in polar coordinates, i.e. the magnitude and the angle of the current. The total fault currents are shown below the bus bar.

The tabular output of the short circuit calculations is also attached in Annex D.1 for the 765 kV bus bars of interest. The total maximum fault currents for 3-phase and 1-phase short circuit at these substations are summarized in Table 6-1. The maximum fault currents seen do not exceed the short circuit ratings of the equipment at these 765 kV substations.

Table 6-1: Maximum short circuit levels without Lower Spat Gah HPP

Substation	3-Phase Fault Current (kA)	1-Phase Fault Current (kA)
Dasu 765 kV	11.35	12.06
Mansehra 765 kV	13.88	10.85
ISB-W 765 kV	15.12	13.39
ISBD-W 500 kV	47.92	40.53
Tarbela 500 kV	45.66	48.08
G. Brotha 500 kV	37.77	32.93
Gatti 500 kV	33.04	24.07

Substation	3-Phase Fault Current (kA)	1-Phase Fault Current (kA)
Rewat-N 500 kV	34.31	25.01
Gujranwala 500 kV	36.21	26.17
Maira-S/S 500 kV	33.26	27.97

6.3 Fault Current Calculations with Lower Spat Gah HPP Year 2030

Maximum fault currents have been calculated for the electrical interconnection of the proposed scheme. The fault types applied are three-phase and single-phase at the 765 kV bus bar of the Lower Spat Gah HPP itself and other bus bars of the 765 kV substations in the electrical vicinity of the Lower Spat Gah HPP. The graphic results are shown in Figure D.2-1.

The tabulated results of the short circuit analysis showing all the fault current contributions with short circuit impedances on 765 kV bus bars of the network in the electrical vicinity of the Lower Spat Gah HPP and the 765 kV bus bar of the Lower Spat Gah HPP itself are placed in Annex D.2. A brief summary of fault currents at significant bus bars of interest are tabulated in Table 6-2.

Table 6-2: Maximum short circuit levels with Lower Spat Gah HPP

Substation	3-Phase Fault Current (kA)	1-Phase Fault Current (kA)
Lower Spat Gah 765 kV	12.65	11.17
Dasu 765 kV	12.87	13.52
Mansehra 765 kV	15.08	11.42
ISB-W 765 kV	16.01	13.87
ISBD-W 500 kV	48.78	40.97
Tarbela 500 kV	46.07	48.38
G.Brotha 500 kV	37.96	33.06
Gatti 500 kV	33.01	24.05
Rewat-N 500 kV	34.59	25.12
Gujranwala 500 kV	36.12	26.08
Maira-S/S 500 kV	33.34	28.01

The comparison of Table 6-1 and Table 6-2 shows that results of short circuit levels for three-phase and single-phase faults improved due to the connection of the Lower Spat Gah HPP on the 765 kV bus bars, these fault levels are much below the rated short circuit values of the equipment installed at these substations.

6.4 Conclusion of Short Circuit Analysis

The maximum short circuit levels at the Lower Spat Gah HPP 765 kV are 12.65 kA and 11.17 kA for 3-phase and 1-phase faults, respectively, in the year 2030. However, as per the study of Dasu HPP, the short circuit levels will exceed by more than about 45 kA in the later stages when other power plants in the area will be interconnected. Therefore, industry standard switchgear of a short circuit rating of 63 kA is proposed to be installed at the 765 kV switchyard of the Lower Spat Gah HPP, taking care of any future generation additions and system reinforcements in its electrical vicinity. There are no violations of the power rating of the equipment in the vicinity of the Lower Spat Gah HPP in the event of fault conditions.

7 Dynamic Stability Analysis

7.1 Assumptions and Methodology

7.1.1 Dynamic Models

The assumptions about the generator and its parameters are the same as mentioned in Chapter 2 of this report.

The generic dynamic models available in the PSS/E model library for dynamic modelling of the generator, exciter and the governor were employed as follows:

- Generator GENSAL
- Excitation System EXST1
- Speed Governing System HYGOV
- Stabilizer PSS2A
- Inertia Constant H = 3.2 MWs/MVA

Power system stabilizer has also been proposed to be installed for the smooth and stable operation of the power plant.

7.1.2 System Conditions

The scenario of summer 2030 has been selected for the study because it represents the peak load season after the COD of the Lower Spat Gah HPP and thus the loading on the lines in the vicinity of the Lower Spat Gah HPP will be maximum, allowing to judge the full impact of the plant.

The proposed Lower Spat Gah HPP has been modelled in the dynamic simulation as per data as defined in the Feasibility Study Report of the Lower Spat Gah HPP. All the power plants of WAPDA/NTDC from Tarbela to Hubco have been dynamically represented in the simulation model.

7.1.3 Presentation of Results

The plotted results of the simulations runs are show in Annex E. Each simulation is run for its first one second for the steady state conditions of the system prior to fault or disturbance. This is to establish the pre fault/disturbance conditions of the network under study were smooth and steady. Post fault recovery has been monitored for nineteen seconds. Usually, all the transients due to non-linearity die out within a few seconds after disturbance is cleared in the system.

7.1.4 Worst Fault Cases

Three-phase faults are considered as the worst disturbance in the system. 3-phase fault was considered in the closest vicinity of the Lower Spat Gah HPP, i.e. right at the 765 kV bus bar of the Lower Spat Gah substation, cleared in 5 cycles, as normal clearing time for 765 kV, i.e. 100 ms, followed by a permanent trip of a 765 kV single circuit from the Lower Spat Gah to Mansehra.

7.2 Dynamic Stability Simulations' Results - Summer 2030

7.2.1 Fault at 765 kV Lower Spat Gah HPP to Mansehra

Table 7-1: Fault at 765 kV Lower Spat Gah HPP to Mansehra

Fault Type	3-Phase		
Fault Location	Lower Spat Gah 765 kV bus bar		
Fault Duration	5 cycles (100 ms)		
Line Tripping	Lower Spat Gah to Mansehra 765 kV single circuit		
Voltage	1. Lower Spat Gah 765 kV 2. Dasu 765 kV 3. Mansehra 765 kV 4. ISB-W 765 kV 5. ISBD-W 500 kV 6. Rewat-N 500 kV	The voltages of all the bus bars recover after fault clearance	E-1
Frequency	Lower Spat Gah 765 kV	Recovers after fault clearance	E-2
MW/MVAR Output of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-3
Speed and $P_{mechanical}$ of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-4
Line Flows (MW/MVAR)	Lower Spat Gah to Dasu 765 kV intact single circuit	Attains steady state value after damping of oscillations	E-5
Rotor Angles	1. Lower Spat Gah PP 15.75 kV 2. Dasu 16.5 kV 3. Karot 500 kV 4. Tarbela Unit # 5 13.8 kV 5. G.Brotha 500 kV 6. Guddu-New 500 kV (Reference angle)	Damps down quickly and attain a steady state value	E-6

7.2.2 Fault at 765 kV Lower Spat Gah HPP to Dasu

Table 7-2: Fault at 765 kV Lower Spat Gah HPP to Dasu

Fault Type	3-Phase		
Fault Location	Lower Spat Gah 765 kV bus bar		
Fault Duration	5 cycles (100 ms)		
Line Tripping	Lower Spat Gah to Dasu 765 kV single circuit		
Voltage	1. Lower Spat Gah 765 kV 2. Dasu 765 kV 3. Mansehra 765 kV 4. ISB-W 765 kV 5. ISBD-W 500 kV 6. Rewat-N 500 kV	The voltages of all the bus bars recover after fault clearance	E-7
Frequency	Lower Spat Gah 765 kV	Recovers after fault clearance	E-8
MW/MVAR Output of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-9
Speed and $P_{mechanical}$ of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-10
Line Flows (MW/MVAR)	Lower Spat Gah to Mansehra 765 kV intact single circuit	Attains steady state value after damping of oscillations	E-11
Rotor Angles	1. Lower Spat Gah PP 15.75 kV 2. Dasu 16.5 kV 3. Karot 500 kV 4. Tarbela Unit # 5 13.8 kV 5. G.Brotha 500 kV 6. Guddu-New 500 kV (reference angle)	Damps down quickly and attain a steady state value	E-12

7.2.3 Fault at 765 kV Dasu HPP to Lower Spat Gah

Table 7-3: Fault at 765 kV Dasu HPP to Lower Spat Gah

Fault Type	3-Phase		
Fault Location	Dasu 765 kV bus bar		
Fault Duration	5 cycles (100 ms)		
Line Tripping	Lower Spat Gah to Dasu 765 kV single circuit		
Voltage	1. Dasu765 kV 2. Lower Spat Gah 765 kV 3. Mansehra 765 kV 4. ISB-W 765 kV 5. ISBD-W 500 kV 6. Rewat-N 500 kV	The voltages of all the bus bars recover after fault clearance	E-13
Frequency	Lower Spat Gah 765 kV	Recovers after fault clearance	E-14
MW/MVAR Output of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-15
Speed and $P_{mechanical}$ of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-16
Line Flows (MW/MVAR)	Dasu to Mansehra 765 kV intact single circuit	Attains steady state value after damping of oscillations	E-17
Rotor Angles	1. Lower Spat Gah PP 15.75 kV 2. Dasu 16.5 kV 3. Karot 500 kV 4. Tarbela Unit # 5 13.8 kV 5. G.Brotha 500 kV 6. Guddu-New 500 kV (reference angle)	Damps down quickly and attain a steady state value	E-18

7.2.4 Fault at 765 Dasu HPP to Mashera

Table 7-4: Fault at 765 kV Dasu HPP to Mansehra

Fault Type	3-Phase		
Fault Location	Dasu 765 kV bus bar		
Fault Duration	5 cycles (100 ms)		
Line Tripping	Dasu to Mansehra 765 kV single circuit		
Voltage	1. Dasu 765 kV 2. Lower Spat Gah 765 kV 3. Mansehra 765 kV 4. ISB-W 765 kV 5. ISBD-W 500 kV 6. Rewat-N 500 kV	The voltages of all the bus bars recover after fault clearance	E-19
Frequency	Lower Spat Gah 765 kV	Recovers after fault clearance	E-20
MW/MVAR Output of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-21
Speed and $P_{mechanical}$ of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-22
Line Flows (MW/MVAR)	Lower Spat Gah to Dasu 500 kV intact single circuit	Attains steady state value after damping of oscillations	E-23
Rotor Angles	1. Lower Spat Gah PP 15.75 kV 2. Dasu 16.5 kV 3. Karot 500 kV 4. Tarbela Unit # 5 13.8 kV 5. G.Brotha 500 kV 6. Guddu-New 500 kV (reference angle)	Damps down quickly and attain a steady state value	E-24

7.2.5 Fault at 765 kV Mansehra HPP to Lower Spat Gah

Table 7-5: Fault at 765 kV Mansehra HPP to Lower Spat Gah

Fault Type	3-Phase		
Fault Location	Mansehra 765 kV bus bar		
Fault Duration	5 cycles (100 ms)		
Line Tripping	Mansehra to Lower Spat Gah 765 kV single circuit		
Voltage	1. Mansehra 765 kV 2. Lower Spat Gah765 kV 3. Dasu 765 kV 4. ISB-W 765 kV 5. ISBD-W 500 kV 6. Rewat-N 500 kV	The voltages of all the bus bars recover after fault clearance	E-25
Frequency	Lower Spat Gah 765 kV	Recovers after fault clearance	E-26
MW/MVAR Output of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-27
Speed and $P_{mechanical}$ of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-28
Line Flows (MW/MVAR)	Dasu to Mansehra 500 kV intact single circuit	Attains steady state value after damping of oscillations	E-29
Rotor Angles	1. Lower Spat Gah PP 15.75 kV 2. Dasu 16.5 kV 3. Karot 500 kV 4. Tarbela Unit # 5 13.8 kV 5. G.Brotha 500 kV 6. Guddu-New 500 kV (reference angle)	Damps down quickly and attain a steady state value	E-30

7.2.6 Fault at 765 kV Mansehra HPP to Dasu

Table 7-6: Fault at 765 kV Mansehra HPP to Dasu

Fault Type	3-Phase		
Fault Location	Mansehra 765 kV bus bar		
Fault Duration	5 cycles (100 ms)		
Line Tripping	Mansehra to Dasu 765 kV single circuit		
Voltage	1. Mansehra 765 kV 2. Dasu 765 kV 3. Lower Spat Gah 765 kV 4. ISB-W 765 kV 5. ISBD-W 500 kV 6. Rewat-N 500 kV	The voltages of all the bus bars recover after fault clearance	E-31
Frequency	Lower Spat Gah 765 kV	Recovers after fault clearance	E-32
MW/MVAR Output of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-33
Speed and $P_{mechanical}$ of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-34
Line Flows (MW/MVAR)	Lower Spat Gah to Mansehra 765 kV intact single circuit	Attains steady state value after damping of oscillations	E-35
Rotor Angles	1. Lower Spat Gah PP 15.75 kV 2. Dasu 16.5 kV 3. Karot 500 kV 4. Tarbela Unit # 5 13.8 kV 5. G.Brotha 500 kV 6. Guddu-New 500 kV (reference angle)	Damps down quickly and attain a steady state value	E-36

7.2.7 Fault at 765 kV ISBD-W to Mansehra

Table 7-7: Fault at 765 kV ISBD-W to Mansehra

Fault Type	3-Phase		
Fault Location	ISBD-W 765 kV bus bar		
Fault Duration	5 cycles (100 ms)		
Line Tripping	ISBD-W to Mansehra 765 kV single circuit		
Voltage	1. ISBD-W 765 kV 2. Mansehra 765 kV 3. Dasu 765 kV 4. Lower Spat Gah 765 kV 5. ISBD-W 500 kV 6. Rewat-N 500 kV	The voltages of all the bus bars recover after fault clearance	E-37
Frequency	Lower Spat Gah 765 kV	Recovers after fault clearance	E-38
MW/MVAR Output of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-39
Speed and $P_{mechanical}$ of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-40
Line Flows (MW/MVAR)	Mansehra to ISBD-W 765 kV intact single circuit	Attains steady state value after damping of oscillations	E-41
Rotor Angles	1. Lower Spat Gah PP 15.75 kV 2. Dasu 16.5 kV 3. Karot 500 kV 4. Tarbela Unit # 5 13.8 kV 5. G.Brotha 500 kV 6. Guddu-New 500 kV (reference angle)	Damps down quickly and attain a steady state value	E-42

7.2.8 Fault at 500 kV ISBD-W to Rewat

Table 7-8: Fault at 500 kV Mansehra HPP to Rewat

Fault Type	3-Phase		
Fault Location	ISBD-W 500 kV bus bar		
Fault Duration	5 cycles (100 ms)		
Line Tripping	ISBD-W to Rewat-N 500 kV single circuit		
Voltage	1. ISBD-W 500 kV 2. Rewat-N 500 kV 3. Lower Spat Gah 765 kV 4. Dasu 765 kV 5. Mansehra 765 kV 6. ISB-W 765 kV	The voltages of all the bus bars recover after fault clearance	E-43
Frequency	Lower Spat Gah 765 kV	Recovers after fault clearance	E-44
MW/MVAR Output of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-45
Speed and $P_{mechanical}$ of the Plant	Lower Spat Gah 765 kV	Recovers after damping down oscillations	E-46
Line Flows (MW/MVAR)	Mansehra to ISBD-W 765 kV intact single circuit	Attains steady state value after damping of oscillations	E-47
Rotor Angles	1. Lower Spat Gah PP 15.75 kV 2. Dasu 16.5 kV 3. Karot 500 kV 4. Tarbela Unit # 5 13.8 kV 5. G.Brotha 500 kV 6. Guddu-New 500 kV (reference angle)	Damps down quickly and attain a steady state value	E-48

7.3 Conclusion of Dynamic Stability Analysis

The results of the dynamic stability carried out for summer 2030 show that the system is very strong and stable for the proposed scheme for the severest possible faults of 765 kV systems near the Lower Spat Gah HPP under all events of disturbances. Therefore, there is no problem of dynamic stability for interconnection of the Lower Spat Gah HPP; it fulfils all the criteria of dynamic stability.

8 Conclusions

The following conclusions are drawn from these power system studies:

- Considering the COD targeted for the Lower Spat Gah HPP, load flow analysis has been carried out for peak and off-peak load scenarios of summer 2030 for the dispersal of power from the Lower Spat Gah HPP into the NTDC system using the latest system data. The proposed interconnection scheme with all the proposed reinforcements and the protection schemes is adequate to evacuate the net 444 MW spill over power of the Lower Spat Gah HPP under normal and contingency conditions.
- The maximum short circuit levels at the Lower Spat Gah HPP 765 kV are 12.65 kA and 11.17 kA for 3-phase and 1-phase faults, respectively, in the year 2030. Therefore, industry standard switchgear of a short circuit rating of 63 kA would be sufficient for installation at the 765 kV switchyard of the Lower Spat Gah HPP, as the maximum short circuit levels for the year 2030 were also found to be within this range, taking care of any future generation additions and system reinforcements in its electrical vicinity and also fulfilling the NEPRA Grid Code requirements specified for 765 kV switchgears. There are no violations of the power rating of the equipment in the vicinity of the Lower Spat Gah HPP in the event of fault conditions.
- The dynamic stability analysis of the proposed scheme of interconnection has been carried out. The stability has been tested for the worst cases, i.e. three-phase fault right on the 765 kV bus bar of the Lower Spat Gah substation followed by trip of a 765 kV single circuit from the Lower Spat Gah to Mansehra, has been performed for fault clearing of 5 cycles (100 ms), as understood to be the normal fault clearing time of 765 kV protection system. The system is stable for all the tested fault conditions.
- The system is found strong enough to stay stable and recovered with fast damping. The proposed scheme successfully passed the dynamic stability checks for the worst cases.
- The proposed scheme of interconnection has no technical constraints or problems, it fulfils all the criteria of reliability and stability under steady state load flow, contingency load flows considered, short circuit currents and dynamic/transient conditions. It is therefore recommended to be adopted.

Annex A NTDC Generation & Transmission Expansion Plan, NTDC Load Forecast

A.1: NTDC Generation & Transmission Expansion Plan

A.2: NTDC Load Forecast

A.1 NTDC Generation & Transmission Expansion Plan

A.2 NTDC Load Forecast

Annex B Sketches, Data as Defined in FS Report

B.1: Sketches

B.2: Data as Defined in FS Report

B.3: SLD and Layout of 765/220 kV Switching Station

B.1 Sketches

B.2 Data as Defined in FS Report

B.3 SLD and Layout of 765/220 kV Switching Station

Annex C Plotted Results of Load Flow

C.1: Peak Load Case Summer 2030 - without Lower Spat Gah HPP

C.2: Peak Load Case Summer 2030 - with Lower Spat Gah HPP

C.3: Off-Peak Load Case Summer 2030 - with Lower Spat Gah HPP

C.1 Peak Load Case Summer 2030 - without Lower Spat Gah HPP

C.2 Peak Load Case Summer 2030 - with Lower Spat Gah HPP

C.3 Off-Peak Load Case Summer 2030 - with Lower Spat Gah HPP

Annex D Results of Short Circuit Calculation

D.1: Results without Lower Spat Gah HPP

D.2: Results with Lower Spat Gah HPP

D.1 Results without Lower Spat Gah HPP

D.2 Results with Lower Spat Gah HPP

Annex E Plotted Results of Dynamic Stability Analysis

Annex F Dynamic Data for Stability

Generator Model: GENSAL

Con Description	Con Values
T'do (>0)	11.8
T"do (>0)	0.18
T"qo (>0)	0.31
Inertia H	3.2
Speed Damping D	0.0000
Xd	1
Xq	0.83
X'd	0.28
X"d = X"q	0.18
X1	0.12
S(1.0)	0.11
S(1.2)	0.363

Exciter Model: EXST1

Con Description	Con Values
TR	0.0100
VIMAX	99.0000
VIMIN	-99.0000
TC	1.0000
TB	4.0000
KA	500
TA	0.0000
VRMAX	5.0000
VRMIN	-5.0000
KC	0.1000
KF	0.0000
TF (>0)	1.0000

Governor Model: HYGOV

Con Description	Con Values
R, Permanent Droop	0.04
R, Temporary Droop	0.5000
Tr (>0) Governor Time Constant	6.0000
Tf (>0) Filter Time Constant	0.0500
Tg (>0) Servo Time Constant	0.5000
VELM, Grate Velocity Limit	0.1670
GMAX, Maximum Gate Limit	1.2
GMIN, Minimum Gate Limit	0.0000
TW (>0) Water Time Constant	2.0000
At, Turbine Gain	1.2000
Dturb, Turbine Damping	0.0000
qNL, No Load Flow	0.1000

Stabilizer Model: PSS2A

Con Description	Con Values
TW1 (>0) Washout Time Constant - Signal 1	2.0000
TW2 Washout Time Constant - Signal 1	2.0000
T6 Lag Time Constant - Signal 1	0.0000
TW3 (>0) Washout Time Constant - Signal 2	2.0000
TW4 Washout Time Constant - Signal 2	0.0000
T7 Lag Time Constant - Signal 2	2.0000
KS2 Gain - Signal 2	0.1900
KS3 Gain - Signal 2	1.0000
T8 Ramp Tracking Filter Lead Time Constant	0.5000
T9 (>0) Ramp Tracking Filter Lag Time Constant	0.1000
KS1 Stabilizer Gain	12.0000
T1 Lead Time Constant - Phase Comp. Block 1	0.2000
T2 Lead Time Constant - Phase Comp. Block 1	0.0300
T3 Lead Time Constant - Phase Comp. Block 2	0.1000
T4 Lead Time Constant - Phase Comp. Block 2	0.0200
VSTMAX Stabilizer Output Maximum	0.1000
VSTMIN Stabilizer Output Minimum	-0.1000

ANNEXES

Annex A

Annex A.1

NTDC Generation & Transmission Expansion Plan

PLEXOS final output comprising year-wise addition of all committed and candidate power plants is given below in Table 6-3.

Table 6-3: PLEXOS Annual Addition of Power Plants 2021-30

#	Name of Project	Fuel Type	Installed Capacity	Nominal Capacity	Agency	Status	Schedule of Commissioning
			2022				
1	Act_2	Wind	50	50	AEDB	Committed	Dec-21
2	Artistic_Wind_2	Wind	50	50	AEDB	Committed	Dec-21
3	Chianwali HPP	Hydro	5.38	5.38	PPDB	Committed	Dec-21
4	Din	Wind	50	50	AEDB	Committed	Dec-21
5	Gul_Electric	Wind	50	50	AEDB	Committed	Dec-21
6	Indus_Energy	Wind	50	50	AEDB	Committed	Dec-21
7	Jabori	Hydro	10.2	10.2	PEDO	Committed	Dec-21
8	Koto	Hydro	40.8	40.8	PEDO	Committed	Dec-21
9	Lakeside	Wind	50	50	AEDB	Committed	Dec-21
10	Liberty_Wind_1	Wind	50	50	AEDB	Committed	Dec-21
11	Liberty_Wind_2	Wind	50	50	AEDB	Committed	Dec-21
12	Metro_Wind	Wind	60	60	AEDB	Committed	Dec-21
13	NASDA	Wind	50	50	AEDB	Committed	Dec-21
14	Ranolia	Hydro	17	17	PEDO	Committed	Dec-21
15	Zhenfa	Solar	100	100	AEDB	Committed	Dec-21
16	Lucky	Local Coal	660	607	PPIB	Committed	Jan-22
17	Helios	Solar	50	50	AEDB	Committed	Mar-22
18	HNDS	Solar	50	50	AEDB	Committed	Mar-22
19	Karora	Hydro	11.8	11.8	PEDO	Committed	Mar-22
20	Meridian	Solar	50	50	AEDB	Committed	Mar-22
21	Thar TEL	Local Coal	330	300	PPIB	Committed	Mar-22
22	Chamfall	Hydro	3	3	AJK	Committed	Mar-22
23	K-3	Nuclear	1,145	1,059	PAEC	Committed	Apr-22

#	Name of Project	Fuel Type	Installed Capacity	Nominal Capacity	Agency	Status	Schedule of Commissioning
24	Trimmu	RLNG	1263	1243	PPIB	Committed	Apr-22
25	Jagran-II	Hydro	48	48	AJK	Committed	May-22
26	Thar-I (SSRL)	Local Coal	1,320	1,214	PPIB	Committed	May-22
27	Deg Outfall	Hydro	4	4	PPDB	Committed	Jun-22
28	Thal Nova	Local Coal	330	300	PPIB	Committed	Jun-22
	Generation Additions in 2022 (MW)		5,948	5,623			
	Cumulative Addition uptill 2022 (MW)		5,948	5,623			
			2023				
1	Access_Electric	Solar	11	11	AEDB	Committed	Aug-22
2	Access_Solar	Solar	12	12	AEDB	Committed	Aug-22
3	Jamshoro Coal (Unit-I)	Imported Coal	660	629	GENCO	Committed	Oct-22
4	Gwadar	Imported Coal	300	273	PPIB	Committed	Jun-23
5	Karot	Hydro	720	720	PPIB	Committed	Jun-23
6	Siachen	Solar	100	100	AEDB	Committed	Jun-23
7	Zorlu	Solar	100	100	PPDB	Committed	Jun-23
8	Siddiqsons	Local Coal	330	304	PPIB	Committed	Jun-23
	Generation Additions in 2023 (MW)		2,233	2,149			
	Cumulative Addition up till 2023 (MW)		8,181	7,772			
			2024				
1	Gorkin Matiltan	Hydro	84	84	PEDO	Committed	Jul-23
2	Riali-II	Hydro	7	7	PPIB	Committed	Jul-23
3	Suki Kinari	Hydro	884	884	PPIB	Committed	Jul-23
4	Manjhand	Solar	50	50	GOS	Committed	Sep-23
5	Safe	Solar	10	10	AEDB	Committed	Sep-23
6	Western	Wind	50	50	AEDB	Committed	Nov-23
7	Alliance	Bagasse	30	30	AEDB	Committed	Dec-23

#	Name of Project	Fuel Type	Installed Capacity	Nominal Capacity	Agency	Status	Schedule of Commissioning
8	Bahawalpur	Bagasse	31.2	31.2	AEDB	Committed	Dec-23
9	Faran	Bagasse	27	27	AEDB	Committed	Dec-23
10	Hamza-II	Bagasse	30	30	AEDB	Committed	Dec-23
11	HSM	Bagasse	26.5	26.5	AEDB	Committed	Dec-23
12	Hunza	Bagasse	50	50	AEDB	Committed	Dec-23
13	Indus	Bagasse	31	31	AEDB	Committed	Dec-23
14	Ittefaq	Bagasse	31	31	AEDB	Committed	Dec-23
15	Kashmir	Bagasse	40	40	AEDB	Committed	Dec-23
16	Mehran	Bagasse	27	27	AEDB	Committed	Dec-23
17	RYK_Energy	Bagasse	25	25	AEDB	Committed	Dec-23
18	Shahtaj	Bagasse	32	32	AEDB	Committed	Dec-23
19	Sheikhoo	Bagasse	30	30	AEDB	Committed	Dec-23
20	TAY	Bagasse	30	30	AEDB	Committed	Dec-23
21	Trans_Atlantic	Wind	48	48	AEDB	Committed	Dec-23
22	Two_Star	Bagasse	50	50	AEDB	Committed	Dec-23
23	Chapari Charkhel	Hydro	10.56	10.56	PEDO	Committed	Mar-24
24	Lawi	Hydro	69	69	PEDO	Committed	Apr-24
25	Tarbela_Ext_5	Hydro	1,530	1530	WAPDA	Committed	May-24
26	Candidate_Solar	Solar	1000	1000	To be Decided	Optimized	2024
27	Candidate_Wind	Wind	1000	1000	To be Decided	Optimized	2024
	Generation Additions in 2024 (MW)		5,233	5,233			
	Cumulative Addition up till 2024 (MW)		13,415	13,006			
			2025				
1	CASA	Cross Border Interconnection	1,000	1,000	GOP	Committed	Aug-24
2	Kathai-II	Hydro	8	8	PPIB	Committed	Dec-24
3	Dasu_1 Unit 1-3	Hydro	1,080	1,080	WAPDA	Committed	Apr-25

#	Name of Project	Fuel Type	Installed Capacity	Nominal Capacity	Agency	Status	Schedule of Commissioning
4	Candidate_Solar	Solar	1000	1000	To be Decided	Optimized	2025
5	Candidate_Wind	Wind	1000	1000	To be Decided	Optimized	2025
	Generation Additions in 2025 (MW)		4,088	4,088			
	Cumulative Addition up till 2025 (MW)		17,503	17,094			
			2026				
1	Mohmand	Hydro	800	800	WAPDA	Committed	Apr-26
2	Dasu_1 Unit 4-6	Hydro	1,080	1,080	WAPDA	Committed	Nov-25
3	Candidate_Solar	Solar	1000	1000	To be Decided	Optimized	2026
4	Candidate_Wind	Wind	1000	1000	To be Decided	Optimized	2026
	Generation Additions in 2026 (MW)		3,880	3,880			
	Cumulative Addition up till 2026 (MW)		21,383	20,974			
			2027				
1	Keyal Khwar	Hydro	128	128	WAPDA	Committed	Feb-27
2	Harpo	Hydro	34.5	34.5	WAPDA	Committed	Apr-27
3	Candidate_Solar	Solar	1000	1000	To be Decided	Optimized	2027
4	Candidate_Wind	Wind	62	62	To be Decided	Optimized	2027
	Generation Additions in 2027 (MW)		1224.5	1224.5			
	Cumulative Addition up till 2027 (MW)		22,607	22,198			
			2028				
1	Azad Pattan	Hydro	700.7	700.7	PPIB	Committed	Sep-27
2	Gabral Kalam	Hydro	88	88	PEDO	Committed	Oct-27
3	Madyan	Hydro	157	157	PEDO	Committed	Oct-27
4	Balakot	Hydro	300	300	PEDO	Committed	Nov-27
5	Candidate_Solar	Solar	1000	1000	To be Decided	Optimized	2028
	Generation Additions in 2028 (MW)		2,246	2,246			
	Cumulative Addition up till 2028 (MW)		24,853	24,444			

#	Name of Project	Fuel Type	Installed Capacity	Nominal Capacity	Agency	Status	Schedule of Commissioning
			2029				
1	Kohala	Hydro	1,124	1,124	PPIB	Committed	Dec-28
2	Diamer Bhasha	Hydro	4,500	4,500	WAPDA	Committed	Feb-29
3	Candidate_Solar	Solar	1000	1000	To be Decided	Optimized	2029
	Generation Additions in 2029 (MW)		6,624	6,624			
	Cumulative Addition up till 2029 (MW)		31,477	31,068			
			2030				
1	Candidate_Solar	Solar	1000	1000	To be Decided	Optimized	2030
	Generation Additions in 2030 (MW)		1,000	1,000			
	Cumulative Addition up till 2030 (MW)		32,477	32,068			

Draft NTDC Transmission Expansion Plan upto 2025-26

500 kV Expansion Plan

Sr. No.	New Substation	500/220 kV Transformer Description	No. of S/C line	Length of Each Line	Transformer Capacity (MVA)	Expected Completion Date
1		Domeli – Nokhar (Phase-II of Neelum Jhelum HPP)	2	125		15/10/2021
2		In/Out of Neelum Jhelum HPP – Nokhar S/C at Karot HPP	2	5		15/10/2021
3		In/Out of Port Qasim CFPP – Matiari S/C at Lucky Electric CFPP	2	12		15/11/2021
4	Faisalabad West				2 x 750	1st Quarter of 2022
5		Replacement of 1x450 MVA, 500/220 kV T/F at Gatti with new one			1 x 450	28/02/2022
6		In/Out of Port Qasim CFPP – Matiari S/C at K-2/K-3	2	102		30/04/2022
7		Extension of 3rd 600 MVA, 500/220 kV T/F at Nokhar			1 x 600	30/04/2022
8		Extension of 1x450 MVA, 500/220 kV T/F at Multan as an Interim Arrangement			1 x 450	30/04/2022
9		Extension of 1x450 MVA, 500/220 kV T/F at Lahore (Sheikhupura) as an Interim Arrangement			1 x 450	31/05/2022
10		Shangai Electric CFPP – Matiari	2	220		31/08/2022
11		In/Out of Thal Nova CFPP – Matiari S/C at Siddique Sons CFPP	2	1		31/08/2022
12		In/Out of Port Qasim CFPP – K-2/K-3 NPP S/C at KKI	2	4		2022-23
13		Suki Kinari HPP for looping In/Out on one circuit of the existing Neelum Jhelum HPP – Nokhar (Gujranwala) 500 kV D/C T/Line	2	75		30/04/2023

14		Extension of 4th 600 MVA, 500/220 kV T/F at Nokhar			1 x 600	15/08/2023
15		Extension of 4th 450 MVA , 500/220 kV T/F at Sheikh Muhammadi			1 x 450	15/08/2023
16	Lahore North	Lahore North – Lahore South CS	2	105	3 x 750	11/09/2023
		Lahore North – Nokhar	2	45		

17	Nowshera (Azakhel)	In/Out of existing 500 kV Tarbela – Peshawar S/C at Nowshera Azakhel	2	12	2 x 750	28/02/2024
18	Islamabad West	In/Out of Ghazi Barotha HPP – Rewat S/C at Islamabad West	2	15	3 x 750	T/L: 31/12/2023 G/S: 30/06/2024
		In/Out of Tarbela HPP – Rewat S/C at Islamabad West	2	12		
19		Tarbela 5th Ext. HPP – Islamabad West	2	55		30/06/2024
20		Tarbela 5th Ext. HPP - Tarbela	1	2		30/06/2024
21		Replacement of 1x450 MVA, 500/220 kV T/F with 1x600 MVA at Lahore (Sheikhupura) (Final Arrangement)			1 x 600	2023-24
22		Extension of 3rd 750 MVA, 500/220 kV T/F at Faisalabad West			1 x 750	2023-24
23		Replacement of 1x450 MVA, 500/220 kV T/F at Multan with new one (Final Arrangement)			1 x 450	2023-24
24		Extension of 3rd 450 MVA, 500/220 kV T/F at Dadu			1 x 450	2023-24
25	Allama Iqbal Industrial City (AIIC)-FIEDMC	In/Out of Gatti - Ghazi Barotha S/C at AIIC	2	2	2 x 750	30/06/2024
26	HVDC Convertor Station at Nowshera (Azakhel)	±500 kV HVDC Bi-pole Line from Tajikistan to Nowshera Azakhel (CASA-1000)		113		31/10/2024
27	Maira Switching Station	Suki Kinari HPP – Maira	2	165 (75 + Remaining 90 km)		2024-25
28		Maira – Islamabad West	2	130		2024-25
29		Karot – Maira	2	15		2024-25
30	Chakwal New	In/Out of AIIC – Ghazi Barotha S/C at Chakwal New	2	3	2 x 500 (500/132 kV T/F)	2024-25

30	Chakwal New	In/Out of Gujranwala – Rewat S/C at Chakwal New	2	30		2024-25
31		Extension of 4th 750 MVA, 500/220 kV T/F at Lahore North			1 x 750	2024-25
32	Sialkot New	Sialkot New – Lahore North	2	55	2 x 750	2025-26
33	Vehari	In/Out of Multan – Sahiwal S/C at Vehari	2	15	2 x 750	2025-26

34		Ghazi Barotha – Faisalabad West	2	330		2025-26
35	Ludewala	Ludewala Nowshera	2	325	2 x 600	2025-26
		Ludewala Faisalabad West	2	100		

220 kV Expansion Plan

Sr. No.	New Substation	220 kV Transmission Line Description	No of D/C line	Length of Each Line	Transformer Capacity (MVA)	Expected Year of Completion
1	Jhimpir-2	Extension of 4th 250 MVA, 220/132 kV T/F at Jhimpir-1			1 x 250	31/12/2021
		In/Out of Jhimpir New (Jhimpir-1) – Gharo S/C at Jhimpir-2	1	2.2	4 x 250	T/L: 30-11-2021 G/S: 31-12-2021
		In/Out of Jamshoro – KDA 33 D/C at Jhimpir-2	2	20		
2		Faisalabad West – T.T. Singh	1	45	3 x 250	T/L: 30/11/2021 G/S: 1st Quarter of 2022
3		Augmentation of 1x160 MVA 220/132 kV T/F with 1x250 MVA at 500 kV Rewat (4th 160 MVA 220/132 kV T/F has been installed at Rawat, whereas, 250 MVA T/F was originally proposed by PSP department.)			1 x 250	31/01/2022
4		Extension of 1x250 MVA, 220/132 kV T/F at Kassowal			1 x 250	31/03/2022
5		Extension of 3rd 160 MVA, 220/132 kV T/F at Chishtian			1 x 160	31/03/2022
6		Augmentation of 1x160 MVA, 220/132 kV T/F with 1x250 MVA at Wapda Town			1 x 250	30/04/2022

Sr. No.	New Substation	220 kV Transmission Line Description	No of D/C line	Length of Each Line	Transformer Capacity (MVA)	Expected Year of Completion
7		Extension of 1x250 MVA, 220/132 kV T/F at Nokhar			1 x 250	30/04/2022
8		Extension of 5th 160 MVA, 220/132 kV T/F at ISPR (Sangjani)			1 x 160	30/04/2022
9	Lalian New	Gatti – Ludewala D/C In/Out at Lalian New.	2	4	3 x 250	31/05/2022

Sr. No.	New Substation	220 kV Transmission Line Description	No of D/C line	Length of Each Line	Transformer Capacity (MVA)	Expected Year of Completion
10		Guddu - Shikarpur - Uch - Sibbi		360		30/06/2022
11	Zhob	Zhob – D.I Khan	1	220	2 x 160	30/06/2022
12		Extension of 1x250 MVA, 220/132 kV T/F at NGPS (Piranghaib)			1 x 250	30/06/2022
13		Augmentation of 07 No. 220/132 kV T/Fs from 160 MVA to 250 MVA (at Shikarpur (02 No.), Vehari (02 No.) and Multan (03 No.))			630	Multan and Vehari 31/08/2022 Shikarpur 15/01/2023
14		Augmentation of 20 No. 220/132 kV T/Fs from 160 MVA with 250 MVA (at Bahawalpur (01 No.), Sheikhupura (04 No.), Daharki (01 No.), Bannu (02 No.), Ghakar (02 No.), T.M.Khan (02 No.), Sammundari Road (02 No.), Hala Road (02 No.), Quetta Industrial (02 No.), Wapda Town (02 No.)) + Extension of 03 No. 220/132 kV T/Fs (1x160 MVA each at Daud Khel & Jamshoro and 1x 250 MVA MVA at Rohri)			2370	Quetta Industrial 15/01/2023 Sammundari Road, Gakkhar, Bannu, Daud Khel, Rohri, Daharki and Bahawalpur 15/02/2023 Sheikhupra, T.M. Khan, Hala Road, Wapda Town and Jamshoro 31/03/2023

Sr. No.	New Substation	220 kV Transmission Line Description	No of D/C line	Length of Each Line	Transformer Capacity (MVA)	Expected Year of Completion
15		Augmentation of 08 No. 220/132kV T/Fs from 160 MVA with 250 MVA (at Nokhar (03 No.), Ludewala (01 No.) & Kala Shah Kaku (04 No.)) + Extension of 04 No. 220/132kV T/Fs (1x250 MVA each at Loralai, ISB University & NKLP and 1x160 MVA at Sibbi)			1630	Sibbi and Loralai 30/04/2023 Ludewala, ISB University, NKLP and Nokhar 15/08/2023 Kala Shah Kaku 31/01/2024
16		Extension of 3rd 160 MVA, 220/132 kV T/F at Khuzdar			1 x 160	28/02/2023
17		Reconductoring of 220 kV Tarbela – ISPR D/C on twin bundled Rail conductor	1	62.5		31/05/2023
18		Extension of 1x160 MVA, 220/132 kV T/F at Guddu			2 x 160	30/06/2023

Sr. No.	New Substation	220 kV Transmission Line Description	No of D/C line	Length of Each Line	Transformer Capacity (MVA)	Expected Year of Completion
19	Mirpurkhas New	In/Out of the Hala Road – Jamshoro S/C at Mirpurkhas New	1	70	2 x 250	30/06/2023
20	Quaid-e-Azam Business Park (QABP)	In/Out of Bandala - KSK D/C at QABP (T/L has been completed on cost deposit basis and its cost is not included in PC-I)	2	3	2 x 250	30/06/2023
21	Sunder Industrial	In/Out of Kot Lakhpat Sarfraz Nagar S/C at Sunder Industrial	1	2	2 x 250	30/06/2023
22		In/Out of T.T Singh - FBD West S/C at Sammundari Road	1	35		30/06/2023
		220 kV Sammundari Road to Jaranwala Road (Including 2 km U/G cable)	1	23		31/12/2023
23	Haripur New	In/Out of Mansehra ISPR S/C at Haripur New	1	2	3 x 250	31/08/2023
24		In/Out of Ghazi Road/Ravi – K.S.K D/C at Lahore North	2	15	3 x 250	11/09/2023
25		In/Out of Lahore Old – Ravi S/C at Lahore North	1	14		11/09/2023
26		In/Out of Jamshoro – T.M. Khan S/C at Hala Road (2nd Source of Supply to 220 kV Hala Road)	1	10		15/11/2023
27	Jauharabad	In/Out of C-1/C-2/C-3/C-4 – Ludewala D/C at Jauharabad	2	6	2 x 250	31/12/2023
28	Swabi	Swabi Nowshera	1	55	3 x 250	31/12/2023
29	Dhabeji SEZ	In/Out of Gharo Jhimpir S/C at Dhabeji SEZ	1	10	2 x 160	31/12/2023
30		In/Out of Dhabeji SEZ Jhimpir S/C at Dhabeji (K-Electric)	1	3		
31		In/Out of Tarbela – ISPR S/C at Islamabad West	1	12	3 x 250	31/12/2023
32		In/Out of Haripur – ISPR S/C at Islamabad West	1	15		

Sr. No.	New Substation	220 kV Transmission Line Description	No of D/C line	Length of Each Line	Transformer Capacity (MVA)	Expected Year of Completion
33	Pilot Battery Energy Storage System (BESS) at Jhimpir-I					2023-24
34	Gharo				2 x 250	2023-24
35	Conversion of 4 No. of AIS Grid Station to GIS	Ravi, Bund Road, Nishatabad, Kala Shah Kaku				Nishatabad project dropped Ravi and Bund Road 31/08/2023 Kala Shah Kaku 31/01/2024
36		In/out of Shahibagh – Chakdara S/C at Nowshera	1	6		28/02/2024
37		In/out of Shahibagh – Nowshera Industrial S/C at Nowshera	1	12		
38		Faisalabad West – Lalian New	1	80		31/03/2024
39		Reconductoring of Bund Road – Kot Lakhpat D/C T/L (Partially on U/G cable)	1	17		31/03/2024
40	H.Faqirian	H.Faqirian – Ludewala	1	88	2 x 250	2023-24
41		Augmentation of 2x160 MVA, 220/132 kV T/Fs with 2x250 MVA at Guddu			2 x 250	2023-24

Sr. No.	New Substation	220 kV Transmission Line Description	No of D/C line	Length of Each Line	Transformer Capacity (MVA)	Expected Year of Completion
42		Extension of 3rd 250 MVA, 220/132 kV T/F at Rahim Yar Khan			1 x 250	2023-24
43		Extension of 4th 250 MVA, 220/132 kV T/F at Nokhar			1 x 250	2023-24
44		Extension of 4th 250 MVA, 220/132 kV T/F at Ravi			1 x 250	2023-24
45	Installation of SVS at Quetta Industrial	600 MVAR SVS (300 MVAR SVC & 300 MVAR Switched Capacitor) at Quetta Industrial				2024-25
46	Punjab University	In/Out of Bund Road – New Kotlakhpat D/C at Punjab University	2	1	3 x 250	2024-25
47	Mastung	Mastung – Sibbi	1	120	3 x 250	2024-25
48	Arifwala	In/Out of Yousafwala – Kassowal D/C at Arifwala	2	25	2 x 250	2024-25
49	Jamrud	Jamrud - Peshawar	1	20	2 x 250	2024-25
50	Gujranwala-II	In/Out of Mangla – KSK S/C at Gujranwala-II	1	30	2 x 250	2024-25
		500 kV Nokhar – Gujranwala-II	1	80		2024-25
51		Dharki – Rahim Yar Khan	1	105		2024-25
52		Rahim Yar Khan – Bahawalpur	1	150		2024-25
53		In/Out of Chishtian – Vehari S/C at Lal Sohanra	1	80		2024-25
54	Larkana	Larkana – Sikarpur	1	65	3 x 250	2024-25

Sr. No.	New Substation	220 kV Transmission Line Description	No of D/C line	Length of Each Line	Transformer Capacity (MVA)	Expected Year of Completion
55		Sialkot New – Sialkot (Sahuwala)	1	12	3 x 250	2025-26
56		Sialkot New – Gujranwala-II	1	36		2025-26
57	Nagshah	In/Out of Multan – M.garh New S/C at Nagshah	1	5	3 x 250	2025-26
		In/Out of Multan – M.garh-II at S/C Nagshah	1	5		2025-26
58	Qasimpur	Qasimpur – Multan	1	12	3 x 250	2025-26
					Subtotal 220 kV	

765 kV Expansion Plan

Sr. No.	New Substation	765 kV Transmission Line Dscription	No. of S/C line	Length of Each Line	Transformer Capacity (MVA)	Expected Completion Date
1	Islamabad West	Upgradtion of 500 kV Islamabad West to 765 kV Voltage Level			3 x 1200	Dec-24
2	Mansehra	Dasu HPP (Phase-1: 2160 MW) – Manshera	2	157	2 x 1200	Jun-25
		Mansehra – Islamabad West	2	97		

REPORT

LSG HYDRO POWER LIMITED

Lower Spat Gah Hydropower Project

Feasibility Study

Volume 0: Executive Summary and Salient Features

127000588-002

04 November 2022

Final

Project
Lower Spat Gah Hydropower Project

Project No.
127000588-002

Revision
Final

Date
04 November 2022

Address
AFRY (Thailand) Ltd.
Vanit II Bldg., 22nd Floor, Room No. 2202-2204,
1126/2 New Petchburi Road, Makkasan,
Rajchthewi, Bangkok 10400, Thailand

Phone
+66 2 108 1000

Contact
Stephan Martin

Mobile
+66 92 264 0738

E-mail
stephan.martin@afry.com

Client
LSG Hydro Power Limited

Report
Feasibility Study, Volume 0: Executive Summary and Salient Features

"This report has been prepared by AFRY (Thailand) Ltd. ("AFRY") for LSG Hydro Power Limited also called LSG SPC pursuant to the consultancy services agreement signed between the Parties. This report is based in part on information not within AFRY's control. While the information provided in this report is believed to be accurate and reliable under the conditions and subject to the qualifications set forth herein, AFRY does not, without prejudice to AFRY's obligations towards the Recipient under the Agreement, make any representations or warranties, expressed or implied, as to the accuracy or completeness of such information.

Use of this report and any of the estimates contained herein by anyone else than the Client ("Third Party User") shall therefore be at the Third Party User's sole risk. Any use by a Third Party User shall constitute a release and agreement by the Third Party User to defend and indemnify AFRY from and against any liability of AFRY, whatsoever in type or nature, in connection with such use, whether liability is asserted to arise in contract, negligence, strict liability or other theory of law.

All information contained in this report is of confidential nature and may be used and disclosed by the Client solely in accordance with the terms and conditions set forth in the Agreement."

Structure of Feasibility Study

List of Abbreviations

Abbreviation	Meaning
AASHTO	American Association of State Highway and Transportation Officials
CPP	Capacity Purchase Price
D&B	Drill and Blast
DBE	Design Basis Earthquake
DSM	Digital Surface Model
DTM	Digital Terrain Model
E	east
E&M	electro-mechanical
EPC	Engineering, procurement, and construction
EPP	Energy Purchase Price
ESIA	Environmental and Social Impact Assessment
FSL	Full Supply Level
GCP	ground control points
GIS	gas-insulated switchgear
GRP	glass-reinforced plastic
H	height
HPP	Hydropower Project
HVAC	heating, ventilation and air conditioning
i.e.	that means
ICOLD	International Commission on Large Dams
IDC	Interest During Construction
L	length
LSG	Lower Spat Gah
MOL	Minimum Operating Level
N	north
NEPRA	National Electric Power Regulatory Authority
NOL	Normal Operating Level
NPV	Net Present Value
OBE	Operating Basis Design Earthquake
O&M	Operation & Maintenance
PGA	peak ground acceleration
PMF	Probable Maximum Flood
PSHA	Probabilistic Seismic Hazard Analysis
SEE	Safety Evaluation Earthquake
SoP	Survey of Pakistan
SPC	Special Purpose Company
USACE	United States Army Corps of Engineers
W	width
WGS	World Geodetic System

List of Units

Symbol	Unit
%	percent
g	gravitational constant (9.81 m/s^2)
GWh	Gigawatt hour
km	kilometre
km^2	square kilometre
kV	kilovolt
kWh	kilowatt hour
m	metre
m asl	metre above sea level
m^3	cubic metre
m^3/s	cubic metre per second
MVA	Megavolt amperes
MW	Megawatt
PKR	Pakistani Rupees
rpm	revolutions per minute
t	ton
USc	United States Cent (1 USc = 0.01 USD)
USD	United States Dollar
yr	year

Table of Contents

Figures

Tables

1 Executive Summary

1.1 Introduction

The purpose of this Lower Spat Gah HPP Feasibility Study Report is to describe its key components by indicating how its physical components interrelate with the main project parameters such as hydrology, topography and geology. This Volume 0 - Executive Summary and Salient Features provides a summary and the salient features of the Feasibility Study results for the Lower Spat Gah HPP.

1.2 Project Location

The Lower Spat Gah Project is located in the Kohistan District, in the Khyber Pakhtunkhwa Province of Pakistan. The Lower Spat Gah Headworks are located at the Spat Gah River, the Lower Gabarband Intake is located at the Gabarband River and the Powerhouse Tailrace Outlet Structure is at the Indus River. The Spat Gah valley is located on the left bank of the Indus River and starts about 4 km downstream of Dasu town.

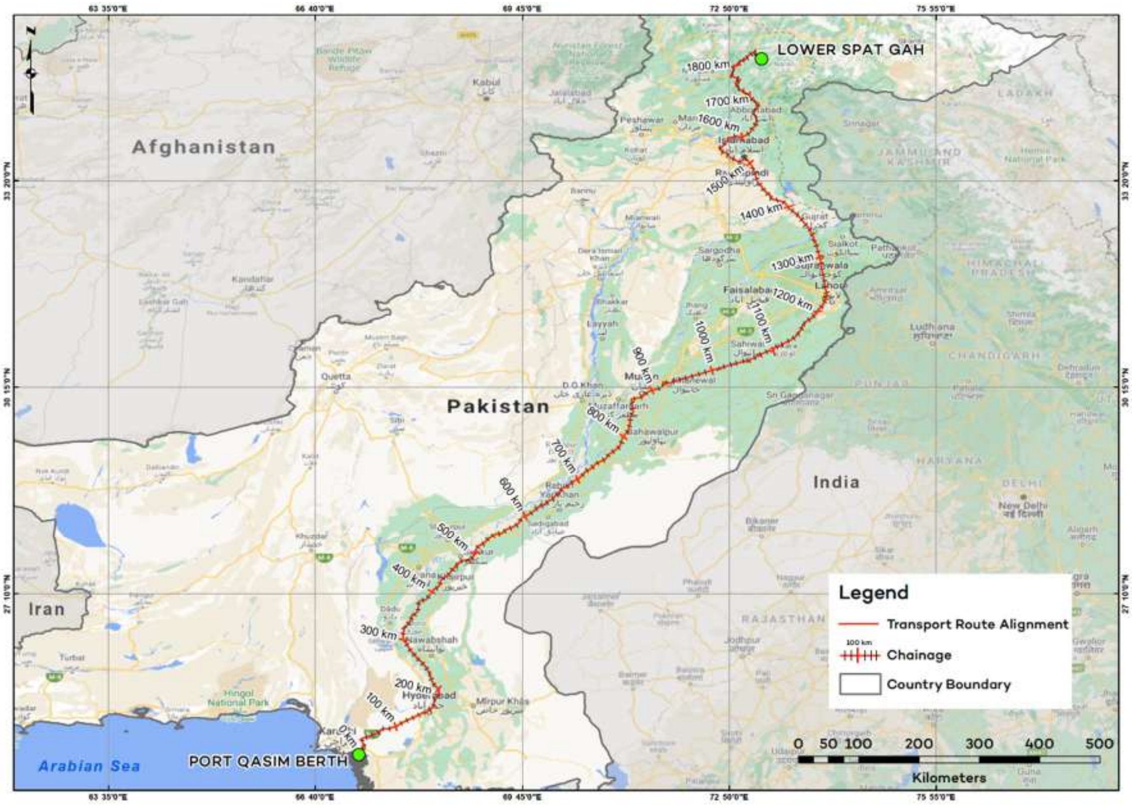


Figure 1-1: Lower Spat Gah Project location in the area

1.3 Cascade

The Lower Spat Gah Project is part of a hydropower cascade in the Spat Gah and Gabarband valleys, which includes the three stages Upper Spat Gah, Middle Gabarband and Lower Spat Gah HPPs. The Project has previously been developed and optimised as part of that cascade. The status and future development of the upper two stages is unknown at the time of this study. It has to be assumed that the Lower Spat Gah Project will be operated as a stand-alone project for at least a few years.

1.4 Access Roads

The existing access to the project is from Dasu via existing one-lane roads to about 900 m downstream of the Lower Spat Gah Headworks. The rest of the Project, including the Gabarband valley, can currently only be accessed by foot path. The existing access road in the Spat Gah valley will have to be upgraded and additional access roads will have to be built in order to reach the relevant Project structures. It has been assumed that the road construction will start prior to the EPC Contract commencement as they are on the critical path.

The roads were designed to allow for two-way heavy traffic during construction and operation according to Pakistani specifications and using USACE And AASHTO standards. Culvert, bridges, galleries and tunnels were designed where required. A new bridge will be built across the Indus River north of the Tailrace Outlet Structure, which will be the main access point of the Project area. This shortens the access and new bridge guarantees sufficient loading capacity for the transport of the heavy and valuable E&M equipment. The road from Dasu to the Powerhouse area will only be used during the early stages of the access road construction until the new Indus bridge is ready.

The following permanent and construction roads will have to be either upgraded or built to meet the Project needs:

- The access roads between the new Indus bridge and the main access road to the Lower Spat Gah Headworks as well as to the Tailrace Outlet Structure and the Power Cavern access tunnel portals will be 1.1 km long,
- The access road to the Upper Erection and Gate Chamber will be 3.7 km long from the junction with the main access road,
- The temporary construction road to the surge shaft chamber access tunnel at the top of the Surge Shaft will be 3.7 km long from the junction with the Upper Erection and Gate Chamber access road,
- The access road from the junction with the Upper Erection and Gate Chamber access road to the Lower Spat Gah Headworks will be 18.1 km long,
- The temporary construction road to the Lower Spat Gah Headworks right bank will be 0.5 km long between the Lower Spat Gah Headworks access road and the bridge to the right bank,
- The road in the Gabarband valley to the Gabarband Crossing will be 2.8 km long from the junction with the Lower Spat Gah Headworks access road.

1.5 Power Market Study

A comprehensive power market study has been conducted to assess the feasibility of the Lower Spat Gah Project keeping the future perspective of generation and load demand as the key factors.

The demand forecasts for the year 2031 were established for the three demand growth scenarios Low Demand Forecast, Medium Demand Forecast and High Demand Forecast in line with the Indicative Generation Capacity Expansion Plan (IGCEP).

The power generation capacities for the year 2031 were established for various energy generation technologies. This includes existing projects, committed projects as well as optimized projects picked from the candidates projects. The retirement of existing projects or those whose power purchase agreements expire have also been considered.

The projected demand and supply in the National Transmission and Dispatch Company (NTDC) system served as input for the power and energy balance simulations carried out for 2031, the year in which the Lower Spat Gah Project will be commissioned. The power and energy balances demonstrated that in 2031 there was enough demand in the NTDC system in all demand growth scenarios and capacity addition cases that could be met by the projected capacity offered by the must run plants, including the Lower Spat Gah Project. The study also demonstrated that the addition of the Lower Spat Gah Project will not have any adverse impact on energy generated by any must run plant.

The development of the Lower Spat Gah Project will benefit the national grid in more ways than one. It will inject clean energy into the system from a climate change perspective, provide indigenously produced energy in meeting the energy security goals for the country and provide cheap energy compared to that of imported fuels such as RLNG, coal and RFO based thermal power plants.

1.6 Topography

Detailed terrestrial surveys were conducted in the Survey of Pakistan (SoP) system during the 2010 Feasibility Study at the Lower Spat Gah Headworks, Lower Gabarband Intake, Powerhouse and Spat Gah access road areas. New topographic data with sufficiently good accuracy was however needed at the Gabarband Crossing, along the road in the Gabarband valley and for the dam break analysis.

Therefore, topographic data based on satellite images was acquired from Airbus Defence & Space in the WGS84 system. Ground control points (GCP) were surveyed throughout the Project area in order to achieve horizontal and vertical resolutions < 2 m. The satellite imagery data was processed by Airbus to create a Digital Terrain Model (DTM) from the Digital Surface Model (DSM).

The transformation parameters from the 2010 Feasibility Study were used to transform the WGS84 Airbus topography into the SoP system, but the transformed topography showed a large horizontal and vertical offset compared to the detailed terrestrial topographies. An additional field survey with new ground control points was required to be able to establish a reliable transformation and confirm the reliability of the different topographies in itself.

The new GCPs were identified on the detailed SoP topographies and measured with long exposure in the field in the WGS84 system. With this data, new and reliable transformation parameters with a good accuracy and reliability between the two systems could be established.

The comparison between the transformed Airbus topography and the detailed terrestrial topographies showed a good match, with some local discrepancies mainly in areas forests, shaded areas and steep slopes which was not surprising due to the known limitation of satellite images in steep/narrow valleys and presumably an overestimation of vegetation cover when establishing the DTM from the DSM.

Because the detailed terrestrial topographies are considered preferable (e.g. more reliable in itself) to the Airbus topography, the detailed terrestrial topographies were used wherever available for the design, that means at the Lower Spat Gah Headworks, Lower Gabarband Intake, Powerhouse area and along the Spat Gah road. The Airbus DTM topography was used for all other areas, thus mainly the Power Waterway in general (where the topography is mainly used to estimate the ground cover), the Gabarband Crossing and the Gabarband access road.

1.7 Hydrology

The Spat Gah River and the Gabarband River have an unexploited catchment area of about 1,066 km^2 and 307 km^2 at the Lower Spat Gah Headworks site and the Lower Gabarband Intake respectively.

The meteorological and hydrological data from the 2010 Feasibility Study has been extended with additional data covering the time period since the previous study. A 54-year discharge series was scaled from the daily observations at Talhata and calibrated to the 2007-2009 data at Goshali station. The mean natural annual reservoir inflow is estimated to 40.7 m^3/s and 8.1 m^3/s at the Lower Spat Gah Headworks and the Lower Gabarband Intake, respectively. The inflow data shows a strong seasonality with the low-flow season in the Project area being assumed from October to March and the high-flow season from April to September. The flow duration curve at the two weir locations is shown in Figure 1-2.

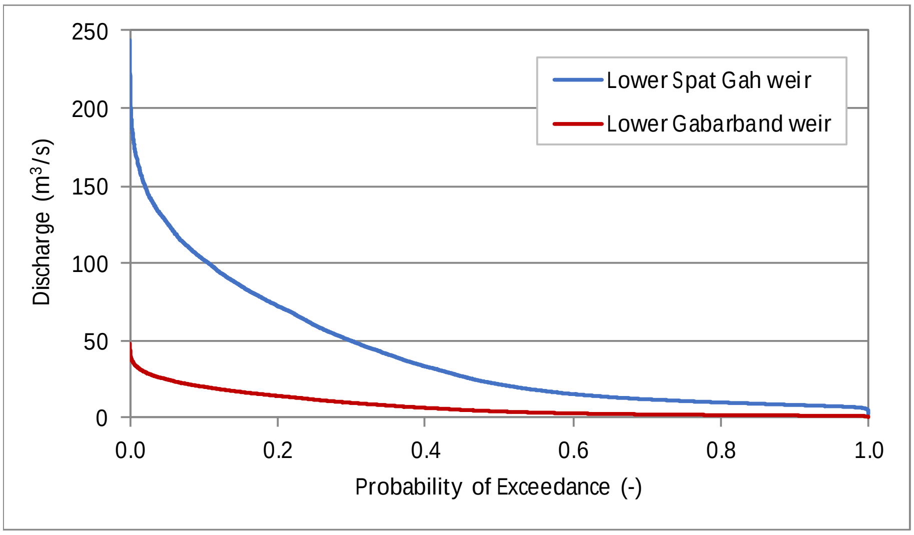


Figure 1-2: Flow duration curves of natural inflows of Lower Spat Gah and Lower Gabarband weir sites

One water level and one rain gauge was installed near the Lower Spat Gah Headworks in April 2021 as well near Goshali Bridge in May 2021. The water levels are measured in 15 min intervals while the rain is logged hourly. Discharge measurements are taken regularly and a preliminary stage-discharge rating curve was established with bathymetry sections taken at the stations after a year of water level and discharge measurements.

The annual maximum floods for different return periods were updated and the values from the regional flood frequency analysis selected. The 10,000-year flood at the Lower Spat Gah Headworks corresponds to about 2,595 m^3/s and the PMF was selected at 3,625 m^3/s. The 10,000-year flood at the Lower Gabarband Intake corresponds to about 850 m^3/s.

Sediment data from neighbouring catchments including Talhata bridge as well as data collected from the site 2007 - 2009 have been available to estimate sediment loads in the Project area. The average sediment suspended sediment yield at the Lower Spat Gah Headworks is proposed at 200 t/km^2/year.

In order to improve the data from the Project site, a sediment monitoring and analysis campaign was started in parallel to this Feasibility Study in September 2020 at the Lower Spat Gah Headworks, Lower Gabarband Intake and Goshali Bridge and continued until June 2021. It consisted of suspended sediment sampling and bed material sampling, for which the particle size distribution was analysed in the laboratory. In addition the grain density and mineralogy of a few samples in the high-flow season were also determined.

The required (preliminary) annual reservoir flushing has been theoretically estimated based on the estimated bedload and suspended sediment influx and assumed flushed volumes per flushing event. Four to nine annual flushing events would be required in order to maintain the active storage at the Lower Spat Gah Headworks. Due to the limited Lower Gabarband Intake reservoir, the flushing channel will have to be operated more frequently and diligently during larger inflows when most of the material is transported.

Preliminary flushing cycles have also been estimated for the desanders and showed that the sediment would need to be flushed once every 14 weeks at the Lower Spat Gah desander based on the settled material. A more frequent flushing does however seem to be more applicable based on experience from existing desanders in similar areas characterised by high sediment transport.

Preliminary water losses of 0.5% to 1.1% have been estimated at the Lower Spat Gah Headworks under design flow conditions if the desander is flushed once to twice a week. Because the sediment samples taken during the low-flow season showed show that the particle sizes are below the desander design grain size, a minimum flushing frequency for the low-flow season will have to be defined based on a trial during operation.

The preliminary water losses at the Lower Gabarband Intake desander have been estimated in the range of 0.1% to 0.2% for once to twice-weekly flushing due to the run-of-river operation of the reservoir.

1.8 Geology

The available geological data consists of the results of the investigations carried out during the 2010 Feasibility Study and the 2020/2021 Update of the Feasibility Study as well as information from the additional study in 2013.

The 2010 Feasibility Study investigations included mapping, boreholes, test pits and laboratory tests while the 2013 investigation included one borehole, laboratory tests and geophysical surveys.

The 2020/2021 investigation campaign included geological mapping in the Gabarband valley, boreholes at the Lower Spat Gah Headworks, Lower Gabarband Intake, Gabarband Crossing and Powerhouse area, soil penetration tests at the borrow areas, test pits as well as an electric resistivity survey along part of the Tailrace Tunnel alignment. With those investigations data could be gathered at the structures of the updated Feasibility Study to serve as the design basis.

The Lower Spat Gah Headworks and Lower Gabarband Intake sites are mainly located on top of alluvial sediments, slope wash and scree deposits while the bedrock is mainly amphibolite.

The bedrock is close to the surface on the left bank at the headworks while the rock surface on the right abutment is several tens of metres deep. Therefore only the rockfill dam at the left abutment and the desander near the Headrace Tunnel intake will be founded on rock while the rest of the structures will be founded on sediments. The alluvium consists of poorly stratified rounded coarse-grained material with a high content of boulders and cobbles (up to a diameter of several meters). The right bank scree is an angular material and has no or very little fine material, the coarse blocks accumulate at the foot of slopes at the valley bottom.

Rock outcrops along the upper part of the left river bank and along the right river bank can be observed at the Lower Gabarband Intake. The spillway right abutment will be founded on rock while the flushing channel and weir will be founded on sediments. Very coarse grained alluvium with a high content of boulders and cobbles (up to a diameter of several meters) is found in the riverbed. An old rockfall area has been recognised at the left bank of the Lower Gabarband Intake area but the site inspection and investigation did not evidence any recent movements or rockfalls. The fallen blocks are large to very large (several cubic metres).

At the Gabarband Crossing area the river flows in a 300 m long narrow valley section characterised by very steep slopes and outcropping rocks mainly. Only at the base of the slopes small scree and slope wash deposits are found, while very coarse grained alluvium with a high content of boulders and cobbles (up to a diameter of several meters) is found in the riverbed. Large and active scree deposits are found upstream and downstream of this narrow valley section along the right bank, while only local small scree or slope wash deposits cover the amphibolite along the left bank. The Headrace Tunnel alignment has been shifted to avoid the active scree areas.

The power waterway will mainly run through amphibolitic and magmatic rock of mainly good quality. The upstream part of the Headrace Tunnel between the intake and the Gabarband Crossing as well as the Gabarband Intake Tunnel are in amphibolitic rock. Downstream of the Gabarband Crossing the Headrace Tunnel will be in amphibolites with massive gabbro and diorites intrusions. Close to the Indus River, that means the downstream end of the Headrace Tunnel as well as the Pressure Shaft, High Pressure Tunnel and Tailrace Tunnel will be excavated in a large granitic intrusion.

The geological information at the Powerhouse area is based upon geological surface mapping in and 5 short boreholes at the foot of a steep slope, west of the actual Powerhouse location. The geological map shows that amphibolitic lenses are thrusted within the granite body and that the contact between the granite and amphibolite is generally faulted and of low rock quality. Based on the good rock quality observed on the granite outcrops, favourable rock mass conditions can be reasonably expected at depth, east of the drilled boreholes, where the tunnels and the Powerhouse are located.

Based on the available information, the concrete aggregates and the rock fill for the construction of the Lower Spat Gah Headworks, Lower Gabarband Intake, Powerhouse and Power Waterway are intended to be won from the rock excavation material of the weirs/desanders as well as tunnel excavation material.

The total volume of suitable silty clay material that can be won from the Dar Mose borrow area next to the Lower Spat Gah Headworks is estimated at about 50,000 m^3, which would provide sufficient material for the clay core of the rockfill dam. If needed, additional material can be sources from the two borrow areas in the Powerhouse area.

Recommendations for additional investigations are given in Volume 4 - Geology, including an exploratory adit towards the Powerhouse.

1.9 Seismicity

A probabilistic and deterministic seismic hazard assessment has been performed for the Lower Spat Gah HPP site based on the available earthquake catalogues and in accordance with ICOLD Bulletin 148.

The nearest major faults are the Indus Suture with extension to the Panjal Thrust and Main Mantle Thrust towards the south. Towards the west there is Duber Kale strike slip fault with branches towards the Project site. Branch no. 2 of the Duber Kale fault is passing with a distance of about 5 km towards the north of the Lower Spat Gah Headworks site.

To the present knowledge based on site inspections, regional seismicity data and geological tectonic documentation, there is no active tectonic fault in the Lower Spat Gah Headworks foundation and close vicinity of the selected dam axis.

The peak ground acceleration (PGA), acceleration response spectra and acceleration time histories at the rock surface were derived from the Probabilistic Seismic Hazard Analysis (PSHA) for the Safety Evaluation Earthquake (SEE) at safety level, Operating Basis Design Earthquake (OBE) at serviceability level and Design Basis Earthquake (DBE) for the seismic design of the appurtenant structures.

The recommended annual probability of exceedance for the SEE for large dams (> 15 m) and high risk category dams is often 1/10,000 as recommended by ICOLD. Lower values of ground shaking, for example not less than 3,000 years for moderate consequence and not less than 1,000 years for low consequence of a dam failure, are only recommended if a risk assessment for the downstream area shows only marginal risks in case of a dam failure as confirmed by the dam break analysis performed for the Lower Spat Gah HPP presented in Volume 11.

In view of the size, importance and risk classification of the main structures and components of the Lower Spat Gah HPP based on the results of the dam break analysis, the following design earthquakes have been selected with the corresponding PGA shown in Table 1-1:

- Safety Evaluation Earthquake (SEE) for the Lower Spat Gah Headworks with a return period of 3,000 years:

  Lower Spat Gah dam (no failure) and flushing channels (structural reinforcement) including safety relevant hydro-mechanical works such as flushing channel gates under the assumption of no uncontrolled water releases in accordance with international standards.

- Safety Evaluation Earthquake (SEE) for the Lower Gabarband Intake with a return period of 1,000 years:

  Lower Gabarband Intake spillway (no failure) and flushing channels (structural reinforcement) including safety relevant hydro-mechanical works such as flushing channel gates under the assumption of no uncontrolled water releases in accordance with international standards.

- Design Basis Earthquake (DBE) with return period of 475 years:

  Powerhouse, desanders, Waterway, hydro-mechanical and electro-mechanical equipment.

- Operating Basis Earthquake (OBE) with return period of 145 years:

  Selected structures such as the Lower Spat Gah dam (slopes stability analysis) and Lower Spat Gah and Lower Gabarband Intake flushing channels (structural stability against sliding, overturning, bearing capacity).

Table 1-1: Site-specific peak ground acceleration (PGA) for rock site for the different design earthquakes for the Lower Spat Gah and Lower Gabarband Intake dams

Design Earthquake	Analysis Method	Return Period (years)	Peak Ground Acceleration (g)	
			Horizontal	Vertical
OBE	Probabilistic	145	0.23	0.16
DBE	Probabilistic	475	0.35	0.23
SEE (Lower Gabarband Intake)	Probabilistic	1,000	0.44	0.29
SEE (Lower Spat Gah Headworks)	Probabilistic	3,000	0.61	0.41

1.10 Alternatives and Optimisation Studies

During the Project Alternatives Study different arrangements for the Lower Spat Gah Headworks, Power Waterway, Lower Gabarband Intake and Powerhouse were studied and evaluated. The basis of the studies was the 2010 Feasibility Study Report and its design.

Lower Spat Gah Headworks:

A small run-of-river weir option was developed at the Lower Spat Gah Headworks to alleviate the sediment handling issues of the 2010 large dam. The small weir was also moved upstream to avoid the right bank scree as much as possible.

Lower Gabarband Intake:

A diversion discharge study at the Lower Gabarband Intake showed that having a larger Gabarband diversion flow results in the highest IRR. Not diverting any water at the Lower Gabarband Intake was only found beneficial if the cascade operation starts in the first Lower Spat Gah concession year which is considered as very unlikely.

It was therefore recommended to design the Lower Gabarband Intake and Intake Tunnel for a diversion discharge of 10 m^3/s as the optimum at higher discharges was very flat with small extra benefits but with higher risks and costs involved.

Power Waterway and Powerhouse:

A comparison of the pressure shaft layout resulted in the recommendation to forego the previous inclined shaft and use a vertical shaft because of the advantageous construction risks.

The excavation methods were also compared and the risk of getting stuck in squeezing or rockburst conditions as a result of the high overburden was evaluated to be much higher for a Tunnel Boring Machine than for Drill & Blast (D&B). Considering the construction risks it was therefore recommended to excavate the Headrace Tunnel with D&B.

Different powerhouse locations were assessed and an underground Powerhouse location at the bottom of the Pressure Shaft was favoured due to economic reasons.

For the optimisation of the Power Waterway alignment, several alternatives were developed. As a result of the internal pressure limit especially at the emergency gate at the top of the Pressure Shaft, some alternatives were pre-excluded due to their longitudinal profile. Alternatives involving the construction of a bridge to cross the Gabarband River were also excluded for economic and safety/access reasons. It was also recommended to not pursue other alternatives due to their high construction costs and geological risks. The preferred alternative of the remaining alternatives had the lowest geological risk and was therefore recommended.

Optimisation:

Based on the recommended alternatives from the Alternatives Studies, the Optimisation Study studied different design discharges. Preliminary cost estimates and energy generation estimates were prepared and their impact on the economic IRR evaluated.

The results showed the highest IRR for the stand-alone operation for a design discharge of 90 m^3/s with no overload. The variation of IRR around the optimum was however fairly small and a design discharge of 75 m^3/s was recommended and subsequently selected. The FSL could not be further increased due to the cascade elevation restrictions and was also not lowered.

1.11 Initial Feasibility Study Studies

Several design criteria were studied at the beginning of the Feasibility Study based on the Alternatives Study and used as an input for the design works.

Desander grain size:

Due to the high head and the composition of the sediment, sediments particles should be removed in the desander to the extent possible to reduce the abrasion of the turbines.

A preliminary comparison between desander construction costs and turbine O&M costs over the Concession Period showed that the lower desander construction costs of the 0.3 mm grain size outweigh the slightly higher O&M costs during the Concession Period. Therefore the design grain size was preliminarily set as 0.3 mm. It has however to be noted that such a study was based on sediment data mainly available during the low-flow season where very little sediment is being transported. Thus, it cannot be excluded that a lower design grain size may be proposed after the results of the high-flow seasons 2021 campaign have become available.

Headrace Tunnel sizing:

The tunnel cross sections of the Headrace Tunnel, Pressure Shaft and High Pressure Tunnel were economically optimised in a cost vs energy production loss comparison.

Gabarband Intake Tunnel:

The access conditions to the Lower Gabarband Intake are particularly challenging if not unfavourable. This has been confirmed by the repeated landslides faced during the 2020-2021 geological investigations campaign. This led to an underground access design to the Lower Gabarband Intake from the Gabarband Crossing.

Several options were studied for the tunnel profile to accommodate the design vehicle and the glass-reinforced plastic (GRP) pipe during construction and operation. As the construction costs were very similar for all options, the option with the GRP pipe mounted on supports on one side of the tunnel and the vehicles on the other side of the tunnel was selected due to its shorter construction time, reduced planning interfaces during construction and high maintenance flexibility during Project operation.

Powerhouse characteristics:

A comparison of a 2-unit and 3-unit layout of the Power Cavern was conducted to select the most suitable number of turbines for the Project. Because there was no significant cost advantage for a 2-unit layout and because a 3-unit layout is more beneficial regarding transportation, installation, operation and maintenance, it was recommended to select the 3-unit layout.

The Indus River in its natural flow condition has water levels below the Tailrace Tunnel Outlet Structure and does not impact the design of the Project. The future Patan reservoir will however impact the operation of the Project with its assumed FSL at 760.00 m asl. A water level of 1 m above the Patan FSL has been assumed as the downstream boundary condition to calculate the water level in the Tailrace Tunnel directly below the turbines in order to determine the turbine centreline with an appropriate freeboard.

Single-phase and three-phase transformers were compared to select the best suited type for the Lower Spat Gah HPP. Because the single-phase transformers do not offer a significant advantage in terms of transport size or weight and because of the non-negligible price advantage of the three-phase transformers, the three-phase transformers were selected for this Project.

1.12 Project Layout

The Lower Spat Gah Project is a high head run-of-river scheme with limited peaking capabilities located on the Spat Gah and Gabarband Rivers. The water is conveyed from the Lower Spat Gah Headworks to the Powerhouse for power generation, with a secondary intake on the Gabarband River connecting to the Headrace Tunnel. Excess water will be spilled back into the rivers. The water is released from the Powerhouse to the Indus River about 1.2 km upstream of the confluence with the Spat Gah River.

The Lower Spat Gah HPP consists of the following main structures:

- Lower Spat Gah Headworks with rockfill dam, flushing channels, intake on the right bank, surface desander and forebay,
- Lower Gabarband Intake with weir structure, intake on the left bank, surface desander and forebay,
- 2.4 km long Gabarband Intake Tunnel connecting to the Headrace Tunnel with free-flow section at the beginning and pressurised section after,
- 10.9 km long pressurised Headrace Tunnel,
- 0.5 km high Pressure Shaft,
- 0.2 km long High Pressure Tunnel including penstock,
- Power Cavern with 3 Pelton turbines,
- 1.3 km long free-flow Tailrace Tunnel.

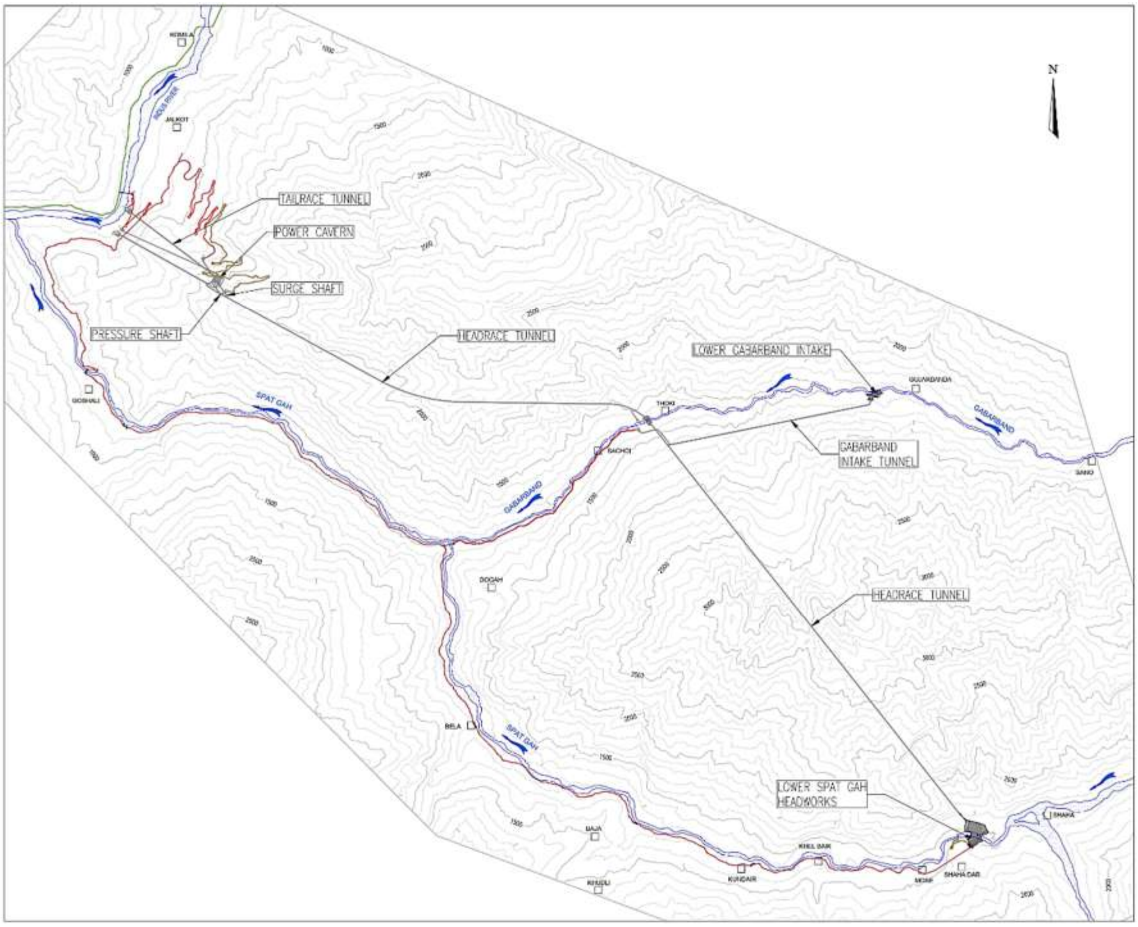


Figure 1-3: Project overview

Lower Spat Gah Headworks:

The Lower Spat Gah Headworks comprises a clay core rockfill dam on the left bank, three flushing channel bays also serving as spillway, a desander intake and desander as well as the forebay at the inlet to the Headrace Tunnel.

Dam and flushing channel:

The 34 m high dam and 39 m high gated flushing channel are designed with a 1,000-year design flood, 10,000-year check flood and a 10,000-year n-1 and PMF safety flood.

The dam is located on the left river bank. The flushing channel is located next to the right bank desander intake and allows for effective flushing of sediments in front of the intake area. The flushing channel radial gates are used for sediment flushing, ideally during flood conditions, passing of debris as well as reservoir water level regulation for normal conditions and floods.

Residual flow:

The residual flow will be released through a valve-controlled pipe from the desander intake through the flushing channel No. 3 right wall. The residual flow consists of the environmental flow and the irrigation flow.

The environmental flow was calculated according to the CEMAGREF method while the irrigation flow was determined by the ESIA. The residual flow ranges from 1.2 m^3/s to 4.0 m^3/s.

Intake and desander:

The intake to the Power Waterway system and desander is located on the right river bank. The intake has a separate opening for each two desander basins and is protected with a trash rack to prevent the inflow of large debris. A trash rack cleaning machine will be provided to remove accumulated debris which could not be flushed downstream.

Each of the three intakes consists of a sluice gate, which can be closed to isolate the desander and Power Waterway system from the river flow as well as enable the desander flushing process for each basin pair without stopping the power plant operation. The diverted water is then conveyed through the intake channels into the 3 x 2 desander basins. The purpose of the six desander basins with a length of 110 m is to deposit particles exceeding a size of 0.3 mm and thus removing them from the water being conveyed to the Powerhouse. The sediment can be flushed back to the Spat Gah River by a flushing channel. Each basin has a sluice gate at the bottom and slide gates on top of the end sill to be flushed separately. The total applied design discharge equals the plant design discharge of 75 m^3/s.

Forebay:

The inflow into the forebay downstream of the desander is over the end sill crest at the downstream end of the desander basins. The reservoir, desander and forebay are designed to operate with communicating water levels, resulting in a continuous and corresponding water level between the forebay and reservoir. The water level above the end sill and in the forebay for the design discharge at Full Supply conditions is at 1,509.98 m asl. This is the FSL for the forebay.

The Lower Spat Gah Headworks reservoir is used for water storage between the Full Supply Level (FSL) and Minimum Operating Level (MOL) with which peaking energy is generated during two 2-hour periods in the morning and evening and the desander was sized to work efficiently for all water levels between the FSL and the MOL. The MOL in the forebay is 1,499.65 m asl and corresponds to the MOL in the reservoir minus the head losses in between.

Construction sequence:

The Lower Spat Gah Headworks are planned to be constructed in two stages. After some initial works, the flushing channels No. 2 and 3, desander intake and desander on the right bank will be constructed in Stage 1 while the flushing channel No. 1 and the clay core rockfill dam on the left bank will be constructed in Stage 2. Prior to the river diversion, the intermediate pier separating the flushing channels No. 1 and No. 2 will have to be constructed. The construction of this intermediate pier should be started in the beginning of the low-flow season (October to March).

Stage 1 works will be carried out along the right bank and the river will be allowed to follow its natural course at the dam site, i.e. along the main channel and left bank. The Stage 2 works will be carried out at the river main channel and the left bank, and the river will be diverted to flow through the flushing channels No. 2 and 3 constructed in Stage 1. The cofferdams are designed to offer protection for the 10-year flood.

Lower Gabarband Intake:

The Lower Gabarband Intake consists of a concrete weir with spillway and flushing channel, desander intake, desander and forebay at the inlet to the Gabarband Intake Tunnel.

Spillway and flushing channel:

The 20.9 m high weir has an ungated spillway bay and a gated flushing channel and is designed with a 1,000-year design flood, 10,000-year check flood and a 1,000-year n-1 safety flood.

The flushing channel is located next to the left bank desander intake and allows for effective flushing of sediments in front of the intake area. The flushing channel radial gate is used for sediment flushing while the debris and floods will mainly pass over the spillway. The radial gate will also be used for reservoir water level regulation for normal conditions and small floods.

Residual flow:

The residual flow is released through a valve-controlled pipe from the desander intake through the flushing channel left wall, and ranges from 0.23 m^3/s to 0.33 m^3/s.

The residual flow comprises the environmental flow and the irrigation flow. The environmental flow was calculated according to the CEMAGREF method while the irrigation flow was determined by the ESIA.

Intake and desander:

The desander intake is protected by a trash rack while the two 39 m long desander basins are designed to remove particles larger than 0.3 mm. The design discharge of the desander and subsequent tunnel equals the design diversion discharge of 10 m^3/s. The reservoir is very minimal and water is only diverted into the Power Waterway when the Powerhouse is operating.

Reservoir:

The Normal Operating Level (NOL) at the Lower Gabarband Intake is at 1,553.00 m asl and the MOL at 1,552.06 m asl, which corresponds to the desander end sill level. Up to the maximum diversion discharge the reservoir regulates itself as a result of the desander end sill overflow. Up to the discharge capacity of the radial gate the flushing channel gate regulates the reservoir to be at the NOL. For larger inflows water starts flowing over the spillway and the reservoir level rises.

Construction sequence:

The construction of the Lower Gabarband Intake is also carried out in two stages. In the first stage, starting at the beginning of a low-flow season, the flushing channel, intake and desander on the left bank are built. During the second stage the spillway on the right bank will be constructed during one low-flow season.

Power Waterway:

The Power Waterway comprises the pressurised system between the Lower Spat Gah Headworks and the Power Cavern, the Gabarband Intake Tunnel, a Surge Shaft and a free-flow Tailrace Tunnel. The 11.7 km long pressurised system has a Headrace Tunnel, Pressure Shaft and High Pressure Tunnel including penstock and conveys the flow from the Lower Spat Gah forebay to the Powerhouse.

The Headrace Tunnel, High-Pressure Tunnel and Tailrace Tunnel are all excavated with the Drill & Blast method as horseshoe sections while the Pressure Shaft and Surge Shaft have a circular profile excavated by the raise drilling method.

Headrace Tunnel:

The Headrace Tunnel conveys the flow from the forebay to the Pressure Shaft under pressurised flow conditions. The size of the tunnel has been determined with an economic optimisation. The Headrace Tunnel is systematically lined with an internal diameter of 5.30 m in the concrete lined tunnel sections and 4.00 m in the steel lined section. The steel lining will be required at the Gabarband Crossing over a length of about 760 m based on hydraulic confinement requirements.

Gabarband Intake Tunnel:

Additional water diverted at the Lower Gabarband Intake is conveyed with a 2.4 km long glass-reinforced plastic (GRP) pipe on one side of Gabarband Intake Tunnel which connects to the Headrace Tunnel.

The elevation of the intake is above the Full Supply Level of the Lower Spat Gah Headworks and the water is flowing in free-flow conditions in the upper part of the pipe while it flows under pressurised conditions in the lower part.

A butterfly valve is installed at the downstream end of the GRP pipe to allow for emergency closure as well as maintenance closure such that the pipe can be inspected independently of the Headrace Tunnel.

Surge Shaft:

At the downstream end of the Headrace Tunnel, just upstream of the Upper Erection and Gate Chamber, is the 0.4 km high vertical Surge Shaft. The Surge Shaft is systematically concrete lined as water level oscillations will occur. The throttle connecting the Headrace Tunnel to the Surge Shaft itself will be steel lined.

Upper Erection and Gate Chamber:

The Upper Erection and Gate Chamber is located at the downstream end of the Headrace Tunnel and houses the emergency and maintenance butterfly valve as well as the concrete-encased bend at the upper end of the Pressure Shaft.

The butterfly valve will serve as one of the emergency closing systems and also allows for inspection of the Pressure Shaft and High Pressure Tunnel without having to dewater the Headrace Tunnel. The access is through the access tunnel to the Upper Erection and Maintenance Gate Chamber. The erection crane in the chamber will be used for the erection and the maintenance of the of the butterfly valve and a temporary erection crane/winch (not shown on the drawings) will be used for the installation of the Pressure Shaft steel liner.

Pressure Shaft:

Downstream of the gate chamber is the 0.5 km high vertical Pressure Shaft with a systematic steel lining. The size of the lining is based on a cost optimum between construction costs and generation losses due to head losses.

High Pressure Tunnel and Penstock:

The High Pressure Tunnel connects the Pressure Shaft with the penstocks to the three turbines of the Powerhouse and includes a Lower Erection Chamber for installation of the steel cans. The tunnel is excavated as a horseshoe profile and is systematically steel lined with the same inner diameter as all the other steel lined sections of the Power Waterway.

Tailrace Tunnel:

The 1.4 km long Tailrace Tunnel conveys the turbined flow from the Powerhouse to the Tailrace Outlet Structure into the Indus River under free-flow conditions. The tunnel is excavated as a modified horseshoe profile and is systematically concrete lined.

Powerhouse:

The Powerhouse is located in a cavern at the bottom of the Pressure Shaft about 800 m below natural ground and has two access tunnels from the left bank of the Indus River as shown in Figure 1-4.

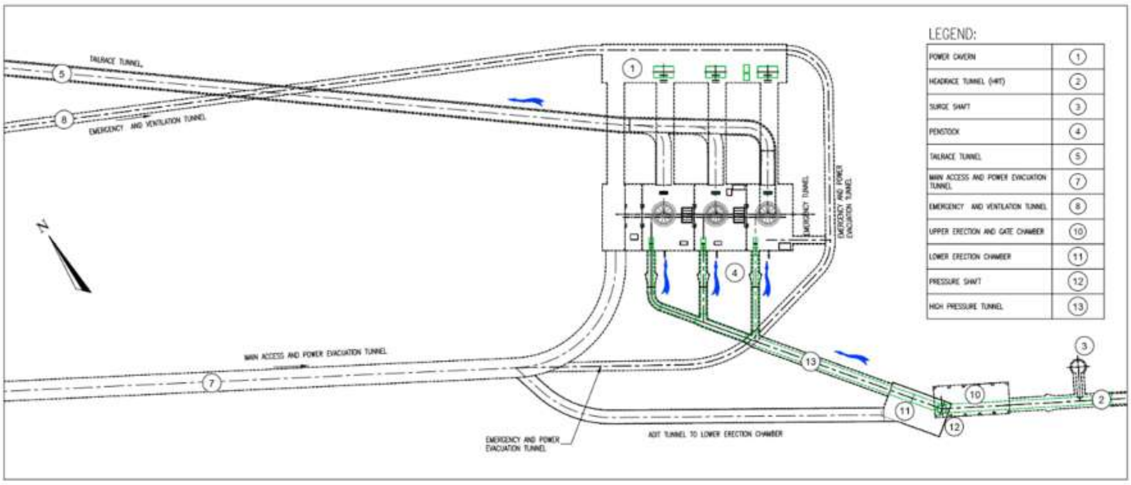


Figure 1-4: Powerhouse layout and plan view

The Powerhouse complex includes the following structures:

- Machine hall with dimensions of 91.2 m length, 45.1 m height and 31.9 m span housing three machine bays, one erection and unloading bay and one dewatering pit,
- Transformer Cavern with dimensions of 88.7 m length, 17.1 m height and 17.95 m span housing three three-phase transformer and a gas-insulated switchyard (GIS),

- Three Insulated Phase Busbar galleries with dimensions of 48.0 m length, 7.70 m height and 8.20 m span each and three Tailrace Tunnels merging into one tunnel.

Power Evacuation

The switchyard of the Lower Spat Gah HPP will be located in the Transformer Cavern next to the Powerhouse Cavern and consists of a 220 kV gas-insulated switchgear (GIS). The voltage has been assumed due to the unknown grid connection requirements from NTDC.

The power will be evacuated through the 0.3 km long Emergency and Power Evacuation Tunnel and the 1.2 km long Main Access and Power Evacuation Tunnel to the surface. Based on the power systems study, the NTDC Connection Switchyard will be located near the Power Cavern access tunnel portals at which the voltage is stepped up from 220 kV to 765 kV. From there a 765 kV transmission line built by NTDC will connect to the 765 kV Dasu - Mansehra transmission line.

The exact final grid connection point is unknown at the time of writing of this Feasibility Study Report and the main characteristics of the connection switchyards and power line will have to be defined once the power system study and transmission line survey have been discussed and approved by NTDC.

1.13 Hydro-Mechanical Equipment

The hydro-mechanical equipment of the project is as follows:

- Lower Spat Gah Headworks:
  - Flushing channels: 9.50 m wide and 23.71 m high radial gate at each channel, the gate closest to the intake will be equipped with a flap gate on top,
  - Flushing channels: Stoplog set for upstream and downstream of radial gates,
  - Flushing channels: Gantry crane with 25 ton lifting capacity and 23 m span,
  - Residual flow: Steel pipe of 0.8 m diameter with service and maintenance valves,
  - Desander intake: 14.10 m wide and 6.6 m high trashrack at each intake,
  - Desander intake: Trashrack cleaning machine for the intake,
  - Desander intake: 7.00 m wide and 6.60 m high fixed-wheel gate at each intake,
  - Desander intake: Stoplog set for fixed-wheel gate,
  - Desander basin: Three rows of calming racks at transition zone upstream of each basin,
  - Desander basin: Two 5.10 m wide and 6.15 m high roller gates on top of the end sill of each basin,
  - Desander basin: 1.30 m wide and 1.00 m high sliding gates at the downstream end of each basin for flushing.
- Lower Gabarband Intake:
  - Flushing channel: 4.00 m wide and 7.08 m high radial gate,
  - Flushing channel: Stoplog set for upstream of radial gate,
  - Residual flow: Steel pipe of 0.3 m diameter with service and maintenance valves,
  - Desander intake: 4.20 m wide and 2.0 m high trashrack at each intake,
  - Desander intake: Trashrack cleaning machine for the intake,
  - Desander intake: 1.40 m wide and 2.00 m high fixed-wheel gate at each intake,
  - Desander intake: Stoplog set for fixed-wheel gate,
  - Desander basin: Three rows of calming racks at transition zone upstream of each basin,
  - Desander basin: 1.00 m wide and 1.00 m high sliding gates at the downstream end of each basin for flushing,
  - Forebay: 2.10 m wide and 2.10 m high fixed-wheel gate at intake to GRP pipe.
- Power Waterway:
  - Lower Spat Gah forebay: Stoplog set for emergency gate,

- Lower Spat Gah forebay: 5.30 m wide and 5.30 m high fixed-wheel gate for emergency closure,
- Headrace Tunnel at the Gabarband Crossing: 524 ton steel lining,
- Headrace Tunnel: Butterfly valve upstream of pressure shaft for emergency and maintenance purposes,
- Upper Erection and Gate Chamber: Crane with 60 ton capacity,
- Pressure Shaft: 673 ton steel lining,
- High Pressure Tunnel: 401 ton steel lining,
- Penstock: 422 ton steel lining,
- Gabarband Intake Tunnel: 10 ton steel pipe at downstream end of GRP pipe,
- Gabarband Intake Tunnel: Butterfly valve just upstream of Headrace Tunnel for emergency and maintenance purposes,
- Gabarband Intake Tunnel: Chain hoist in junction chamber.

1.14 Electro-Mechanical Equipment

The main purpose of the Powerhouse is to house the mechanical and electrical equipment required for the three Pelton turbine sets with a spacing of 25 m between units.

The Powerhouse is equipped with three six-nozzle vertical Pelton turbine/generator units with a total design discharge of 75 m^3/s and a total Installed Capacity of 470 MW after the generator. The maximum gross head of the scheme is 744.58 m, and the net head at design discharge is 722.08 m. The turbine speed has been selected at 428.57 rpm based on the prevailing hydraulic conditions. The centreline of the turbine is at 765.40 m asl with a freeboard of 2.5 m to the maximum tailwater level.

A spherical valve is installed upstream of each turbine for turbine isolation and as a secondary turbine shut-off device in case of failure of the deflector or failure of the Pelton nozzle-needle

The main electrical equipment consists of the three 190 MVA generators with excitation system, generator switchgear and the three 220 kV three-phase transformers connected via isolated phase busbars. On the high-voltage side the transformers will be connected to the 220 kV gas-insulated switchgear (GIS) in the Transformer Cavern.

A 220 kV cable will connect the GIS with the 200/765kV Connection Switchyard via the Emergency and Power Evacuation Tunnel as well as the Main Access and Power Evacuation Tunnel.

1.15 Transmission Line and Grid Connection

Power Systems Study and Connection Switchyard:

The power systems study's objective was to evolve an interconnection scheme between the Lower Spat Gah HPP and the National Grid, for stable and reliable evacuation of electrical power generated from this Project.

The study evaluated the loop in loop out connection to the nearby 765 kV Dasu-Mansehra transmission line in the summer 2030. Because the transmission network data beyond 2028 was not available from NTDC, PPI developed, in agreement with NTDC and to facilitate these power system studies, an interim Base Case for 2030 to be used for the studies based on i) assumptions agreed with NTDC and ii) the approved load forecast until 2030 and system data (NTDC Transmission Plan & IGCEP).

In order to connect to the 765 kV Dasu-Mansehra transmission line, the grid connection is planned as follows:

- Three 220 kV cables from the power cavern to the Connection Switchyard by the Client,
- 765/220 kV Connection Switchyard near the Powerhouse access tunnel portals consisting of 220 kV GIS yard, auto transformer bank and 765 kV GIS yard with final allocation to be determined,
- Two 765 kV overhead lines to the Dasu-Mansehra transmission line by NTDC.

The results of the load flow studies carried out for peak and off-peak load scenarios of summer 2030 showed that the proposed interconnection scheme with all the proposed reinforcements and the protection schemes is adequate to evacuate the net 470 MW power of the Lower Spat Gah HPP under normal and contingency steady state conditions.

The maximum short circuit levels at Lower Spat Gah 765 kV are 12.65 kA and 11.17 kA for 3-phase and 1-phase faults, respectively, in the year 2030. Therefore, industry standard switchgear of a short circuit rating of 63 kA would be sufficient for installation at the 765 kV Connection Switchyard of Lower Spat Gah HPP, as the maximum short circuit levels for the year 2030 were also found to be within this range, taking care of any future generation additions and system reinforcements in its electrical vicinity and also fulfilling the NEPRA Grid Code requirements specified for 765 kV switchgears. There are no violations of the power rating of the equipment in the vicinity of Lower Spat Gah HPP in the event of fault conditions.

The results of the dynamic stability carried out for summer 2030 show that the system is strong and stable for the proposed scheme for the severest possible faults of 765 kV systems near the Lower Spat Gah HPP under all events of disturbances. Therefore, there is no problem of dynamic stability for interconnection of the Lower Spat Gah HPP, it fulfils all the criteria of dynamic stability. The system is found strong enough to stay stable and recovered with fast damping.

Overall it can be concluded that the proposed scheme of interconnection has no technical constraints or problems, it fulfils all the criteria of reliability and stability under steady state load flow, contingency load flows considered, short circuit currents and dynamic/transient conditions. It is therefore recommended to be adopted.

Transmission Line Survey:

The transmission line survey is still ongoing at the time of writing of this report and will be made available in due course.

1.16 Environmental and Social Impact Assessment

The overall purpose of the ESIA is to identify the potential environmental and social impacts of the Project and evaluate them following a process which is acceptable to regulatory authorities in Pakistan and the Project Lenders. In this process, the ESIA identified measures to minimize any anticipated adverse impact of the Project, at least to the level that it meets the national and good international industry practice criteria for evaluation of environmental and social impacts, in particular the International Finance Corporation's (IFC) Standards and the Equator Principles.

Besides the standard evaluations and consultations, the ESIA also assessed whether:

- The project would trigger Critical Habitat for any impacted flora or fauna species and to what extent modified and natural habitats are impacted. This assessment resulted together with the environmental flow assessment's conclusions in the preparation of a Biodiversity Action Plan,
- The Project would cause, reduce or increase cumulative impacts in combination with other existing and proposed large infrastructure in the region.

Stakeholder Consultations and Grievance Procedure:

Consultations with Project stakeholders were undertaken in late October, November, and December 2020. A procedure will be adopted to resolve grievances received by the Grievance Redress Committees. The grievance mechanism will be made public through public consultations by the Environment and Social Unit of the Power Management Unit and the Consultant.

Baseline Studies and Project Impacts:

During the scoping stage of the ESIA process, several potential environmental and social impacts of the Project were identified. The physical environment, ecology and socioeconomic environment baseline surveys were conducted keeping in consideration the potential impacts. A total of 29 relevant project impacts were assessed. After the proposed mitigation measures no negative impact remained as highly significant. From the impacts which are considered being positive, two are expected to achieve a *high* (positive) impact significance after implementation of the proposed measures, as presented in Table 1-2.

Table 1-2: Summary of the most significant environmental and social impacts

ID	Aspect	Impact	Phase	Stage	Magnitude	Timeframe	Spatial Scale	Consequence	Probability	Significance	+/-	Confidence
24	Employment	Direct, indirect and induced employment at the local levels, resulting in increased prosperity and wellbeing due to higher and stable incomes of people.	C, O	Res.	Moderate	Long term	Inter-mediate	High	Definite	High	+	Medium
25	Training and Skill Development	Increase in the stock of skilled human capital due to transfer of knowledge and skill under the Project resulting in enhanced productivity of the local labour.	C, O	Res.	Moderate	Long term	Inter-mediate	High	Possible	High	+	Low

C: Construction (and pre-Construction); O: Operation; Res: Residual; Duration: Long (beyond the life of the Project)

Environmental Flow Assessment:

An environmental flow assessment for the Spat Gah and Gabarband Rivers, upstream and downstream of the Project was carried out as part of the ESIA. The objectives of the EFlow assessment were to assess the environmental (ecological and social) implications of the operation of Lower Spat Gah HPP on the Spat Gah and Gabarband Rivers, provide stakeholders with the above information to facilitate informed decision making for Project operation, and support the development of the Biodiversity Action Plan.

The EFlow assessment paid particular attention to the impacts on the vulnerable and migratory Snow Trout which is a fish species of concern in regard of conservation significance. The impact of different flow scenarios on the fish population compared to the baseline was determined so that the final decision on the environmental flow can be taken by considering the trade-off to power generation and the survival of the species present in the river.

Cumulative Impact Assessment:

This Cumulative Impact Assessment was prepared as part of the ESIA, with the assessment following the methodology of IFC. The Valued Environmental and Social Components river ecology, flow regime and fish fauna were prioritized during the assessment of the fifteen hydropower projects currently in various development stages in the Spat Gah and Upper Indus Basin. Climate change, seismicity, unregulated fishing, and waste generation were the three external stressors impacting the VECs.

Based on the assessment under full development scenario, the main stem of the Indus River will be highly modified after completion of all 15 hydropower projects. However, relative contribution of Lower Spat Gah HPP in the cumulative impacts is considered low.

Biodiversity Action Plan:

A Habitat Assessment for the Project site and vicinity was carried out as part of the ESIA of the Lower Spat Gah Hydropower Project according to the IFC's Performance Standard 6. It was determined that the Project lies in a Natural Habitat both for aquatic and terrestrial environment. This is because the water of the river is not regulated by any dams, reservoirs, or barrages. Anthropogenic impacts such as sediment extraction from riverbed and banks (for construction) is limited, primarily because the Spat Gah Valley is difficult to access and demand for sediment is low.

In Natural Habitats, 'no net loss where feasible' is required for those values for which Natural Habitat has been designated under IFC PS6. The Biodiversity Action Plan (BAP) was prepared to meet the requirements of IFC's PS6. The strategy and approach used for protecting the biodiversity included the following:

- Setting up an effective protection system that will help to reduce the existing anthropogenic pressures in the Area of Management which is central to keeping the integrity of the Area of Management of the BAP intact. This will:
    - Curtail illegal fishing including non-selective fishing, fishing in breeding season of fish, fishing in river tributaries,
    - Regulate sediment mining to maintain it at sustainable levels and prevent sediment mining from ecologically sensitive locations.
- Promote environmental awareness among the local communities and engage them in protecting the ecological resources,
- Institutional strengthening of custodian government departments.

Resettlement Action Plan:

A Resettlement Action Plan has been prepared for the Project to undertake the resettlement in a fair and open manner and to minimise social or economic impacts. The basic principles used for resettlement are derived from Pakistani laws, IFC Performance Standards and ADB's Safeguard Policy Statement 2009 so that the livelihoods and standards of living for all affected households are improved or at least restored.

A total of 90 households will be affected by the execution of the Project based on the resettlement field survey conducted in October and November 2020. Out of 90 households, 25 households' residences will be affected, 25 households' cultivated lands and crops will be affected, 82 households' uncultivated lands will be affected, 21 households will lose their fruit trees, and 74 households will lose their non–fruit trees. All the affected households losing any asset will be compensated according to the replacement cost. Every Project Affected Person losing their livelihood resources or places of income generation because of Project interventions will be supported with income and livelihood restoration assistance. Moreover, eligible PAPs will also receive resettlement allowances like relocation allowance, vulnerability allowance, severe impact allowance etc.

The Resettlement Action Plan also provides a grievance redress mechanism and a monitoring and evaluation system. It is also anticipated that the Project development will significantly contribute to the betterment of the socio-economic conditions in the Project area besides better connectivity and overall improvement of local and regional infrastructure.

1.17 Transportation Survey

A route survey was carried out to identify the best suited transportation route of the heavy and large equipment brought to Pakistan at Port Qasim in Karachi. The cargo transport with the railway infrastructure is based on standard containers, thus transportation for non-standard equipment is via the road network. The heaviest and largest equipment to be transported to the Project site is the transformer without oil at 125 t and 8.5 (L) x 4.0 (W) x 4.0 m (H).

The selected route from the port via Hyderabad-Lahore-Islamabad-Abbottabad-Manshera-Thakot to Dasu as shown in Figure 1-1 has been selected because it is the route used for the majority of heavy cargo transports in Pakistan. It is the most optimal, feasible and safe route as indicated by the many past heavy cargo transports using the presented road.

The survey documented the obstacles such as bridges and overhead structures along the route as observed during the survey in October 2020. As much information as possible about the minimum dimensions and maximum weight capacity of roads and bridges has been collected from the relevant authorities for this survey. However, information is often not available to the general public or firms for bridges located in the Northern Region.

To the Consultant's knowledge, there is only one obstacle with a road width and clearance smaller than the largest equipment and civil works may be required in the form of road extension / expansion over a length of 49 m. All other obstacles on the route to Dasu have a road clearance of at least 4.6 m.

Possible civil work due to minimum road height and bridge capacity will have to be evaluated by the logistics subcontractor during the Project execution when the final dimensions are known and the route feasibility is evaluated.

It is expected that the transformers of the Dasu HPP, which are heavier and larger, will be using the same route. It is recommended to approach the Project Owners about their transportation concept and using synergies to be able to transport the Lower Spat Gah HPP equipment with minor or no adjustments to be borne by the Client for the Lower Spat Gah HPP.

1.18 Energy Calculation

The mean energy generation of the Project with an Installed Capacity of 470 MW is 1,925 GWh/year at the Connection Switchyard if operated as a stand-alone project and 1,931 GWh/year if operated as part of the cascade. The load factor of the plant is 49%.

Two hours of peaking in the morning and evening have been assumed for the energy generation in the energy model without any restrictions regarding annual peaking availability. This results in the highest possible peaking energy which can be generated. A 90% annual peaking availability criterion was applied to back-calculate the peaking design discharge. The criterion means that 90% of the maximum possible annual peaking energy at a specified peaking discharge needs to be generated.

If the Lower Spat Gah Project is operated within the Spat Gah cascade then the Project design discharge of 75 m^3/s is also the peaking design discharge due to the storage of inflows in the upper reservoirs during the high-flow season and release during the low-flow season. The generated peaking energy results to 652 GWh/yr and the peaking availability is 98.9%.

If the Lower Spat Gah Project is operated as a stand-alone scheme, which has to be expected until the operation of the upstream plants, then the peaking design discharge is 65.5 m^3/s to guarantee a 90% availability. The generated peaking energy amounts to 518 GWh/yr.

1.19 Construction Schedule

The construction of the Lower Spat Gah Project involves several different and independent construction sites spreading over a wide area. Therefore, as far as the construction schedule is concerned, the construction of access roads and access tunnels to the different sites becomes an important and critical part of the construction works.

It has been assumed to start construction of the main access roads in January of Year 1 after the approval of the Feasibility Study by the Korean and Pakistani governments. The finalisation of the access road to the Powerhouse portal together with the mobilisation of the EPC Contractor in the first half of Year 2 will allow for the start of the main works for the Powerhouse complex in the second half of Year 2.

The Lower Spat Gah Headworks and Lower Gabarband Intake works are dependent on the season as the initial cut-off wall and intermediate pier construction as well as the cofferdams have to be constructed during the low-flow season. The Gabarband Crossing of the Headrace Tunnel is equally dependent on the seasonality of the flows. The construction of the tunnels, shafts and caverns are independent of the seasons.

Assuming working times of seven (7) days per week and 365 days per year as well the listed progress rates, the total construction time is calculated to 7.5 years with 2 years of early works and 5.5 years of main construction and commissioning works. The following milestones are calculated:

- Commencement date of access road construction: January Year 1
- Commencement Date of EPC Contract: January Year 2
- Lower Gabarband intake ready for operation: March Year 7
- Lower Spat Gah reservoir ready for impounding: June Year 7
- Waterway ready for filling: October Year 7
- Date of completion: April Year 8
- Commercial Operation Date: June year 8

The construction of the Powerhouse and subsequent installation and commissioning of the units is on the critical path. However should there be any delay for the access roads, the Headrace Tunnel, or Lower Spat Gah Headworks, then the critical path also could be for any of those structures.

1.20 Cost Estimate

An estimate for the direct costs has been prepared with quantities derived from the Feasibility Study drawings and unit rates based on current hydro IPP market construction costs for the civil works and budgetary proposals for the E&M equipment.

The EPC costs including contingencies are 814.7 million USD. The indirect costs have been considered as a percentage of the direct costs (20.4%) and amount to 165.6 million USD. The total costs without the Interest during Construction (IDC) are thus estimated to 980.3 million USD. The IDC is based on the equity & loan drawdown pattern as a result of the disbursement schedule in the given financial analysis and amounts to 104.8 million USD, resulting in total project costs including IDC of 1,085.2 million USD.

Table 1-3: Cost estimate summary

	Item	Amount (million USD)
Direct Costs		
	Infrastructure and Road Works	93.7
	Civil Works	405.0
	Hydro-Mechanical and Electro-Mechanical	299.5
	Design Studies and Field Investigations	15.0
	Total EPC Cost	814.7
Indirect Costs		
	Non-EPC Costs	165.6
	Base Project Cost (without IDC)	980.3
	Interest during Construction (IDC)	104.8
	Total Project Costs (incl. IDC)	1,085.2

1.21 Financial Analysis

The financial analysis evaluates the Project from the viewpoint of an investor and has been carried out with the financial model provided by the Client. The financial model has been run with a 30 year operation period, 25%/75% equity/debt ratio, 10% NPV discount rate, 4.9% loan interest, 0% price inflation and an exchange rate of 1 USD = 178.25 PKR. With an equity IRR of 17% as granted for hydropower project by NEPRA, the equity NPV results to 256 million USD while the project IRR and NPV are 9.6% and 112 million USD, respectively.

One of the main indicators of the financial analysis are the corresponding energy tariffs based on the equity IRR of 17%. The energy tariff comprises the Energy Purchase Price (EPP) and the Capacity Purchase Price (CPP) according to the Power Generation Policy 2015 by the Government of Pakistan as shown in Table 1-4. The energy tariff resulted to 9.87 US cent/kWh for years 1-12 and 5.31 US cent/kWh for years 13-30, with a levelized tariff of 8.61 US cent/kWh.

Table 1-4: Proposed energy tariff

Tariff Component			
Energy Purchase Price (EPP)		US cent/kWh	PKR/kWh
	Water Use Charge	0.2384	0.4250
	Variable O&M	0.1006	0.1793
	Subtotal EPP	0.3399	0.6043
Capacity Purchase Price (CPP)		US cent/kW/month	PKR/kW/month
	Fixed O&M - Foreign	158.3931	282.3356
	Fixed O&M - Local	105.5954	188.2237
	Insurance	144.4562	257.4932
	Return on Equity during development	252.0455	449.2712
	Return on Equity during construction	168.3605	300.1026
	Return on Equity	817.7132	1,457.5737
	Debt Service - Principle (average year 1-12)	1,202.5194	2,143.4908
	Debt Service - Interest (average year 1-12)	406.0618	723.8052
Subtotal CPP		3,255.1451	5,802.2961
Energy Tariff		US cent/kWh	PKR/kWh
	Levelized	8.6094	15.3462
	Year 1-12	9.8737	17.5999
	Year 13-30	5.3128	9.4701

Several sensitivity analyses have been carried out based on the financial model by varying numerous parameters and determining the impact on the financial results and energy tariffs. The varied parameters include the hydrological inflow, head loss, construction costs and OPEX costs. Special attention should be paid if the change in costs can result in a tariff adjustment or not.

2 Salient Features

Location	
Country	Pakistan
Province	Khyber Pakhtunkhwa
Lower Spat Gah Headworks	Spat Gah River 73°18'41" E, 35°10'35" N (WGS84) 3226780 E, 1223092 N (SoP)
Lower Gabarband Intake	Gabarband River 73°18'06" E, 35°13'18" N (WGS84) 3225632 E, 1228075 N (SoP)
Headrace Tunnel Gabarband Crossing	Gabarband River 73°16'24" E, 35°13'12" N (WGS84) 3223036 E, 1227771 N (SoP)
Powerhouse	Indus River 73°13'14" E, 35°14'11" N (WGS84) 3218178 E, 1229334 N (SoP)
Tailrace Tunnel Outlet Structure	Indus River 73°12'37" E, 35°14'38" N (WGS84) 3217191 E, 1230131 N (SoP)
Hydrology	
Catchment area	Lower Spat Gah Headworks: 1,066 km^2 Lower Gabarband Intake: 307 km^2
Average annual discharge	Lower Spat Gah Headworks: 40.7 m^3/s Lower Gabarband Intake: 8.1 m^3/s
Floods – Lower Spat Gah Headworks	Design flood: 1,622 m^3/s (1,000-year) Check flood: 2,595 m^3/s (10,000-year) Safety flood: 2,595 m^3/s (10,000-year, n-1)
Floods – Lower Gabarband Intake	Design flood: 530 m^3/s (1,000-year) Check flood: 850 m^3/s (10,000-year) Safety flood: 530 m^3/s (1,000-year, n-1)
Lower Spat Gah Reservoir	
Full Supply Level (FSL)	1,510.00 m asl
Minimum Operating Level (MOL)	1,500.00 m asl
Flood level – Design flood	1,498.98 m asl
Flood level – Check flood	1,503.46 m asl
Flood level – Safety flood (check flood, n-1)	1,510.74 m asl
Reservoir volume at FSL	0.41 million m^3
Surface area at FSL	0.044 km^2
Backwater length at FSL	0.2 km
Spat Gah Dam and Flushing Channels	
Type	Clay core rockfill dam Gated flushing channel concrete structure
River bed level	~1,487 m asl
Crest elevation	1,512.00 / 1,513.00 m asl

Maximum height	39 m
Crest length	Dam: 124.4 m Flushing channels: 43.0 m
Gates	3 radial gates
Gate dimensions	9.50 m wide x 23.71 m high
Channel sill level	1,488.00 m asl
Residual flow	1.22 - 3.97 m^3/s
Lower Spat Gah Headworks Intake	
Type	Lateral
Inlet sill level	1,497.80 m asl
Number of intakes	Three
Inlet size (W x H)	14.10 m x 6.60 m (each)
Lower Spat Gah Headworks Desander	
Number of basins	6
Design grain size	0.3 mm
Main dimensions of basins (L x W x H)	110 m x 13.7 m x 17.2 m
Flushing gate	Sluice
Headrace Tunnel	
Type	Pressurised
Length	10.9 km (start after inlet to upper erection chamber)
Shape	Horseshoe
Excavation size	4.90 m wide x 6.55 m high
Inner diameter	5.30 m concrete / 4.00 m steel lining
Slope	1.5% / 12.0% / 0.75%
Lower Gabarband Intake Reservoir	
Normal Operating Level (NOL)	1,553.00 m asl
Flood level – Design flood	1,556.77 m asl
Flood level – Check flood	1,558.28 m asl
Flood level – Safety flood (design flood, n-1)	1,557.66 m asl
Reservoir volume at NOL	4,000 m^3
Surface area at NOL	1,700 m^2
Backwater length at NOL	65 m
Lower Gabarband Intake	
Type	Concrete gravity with ungated spillway and gated flushing outlet
River bed level	~1,548 m asl
Crest elevation	1,559.40 m asl
Maximum height	20.9 m
Weir width	31.0 m
Gates	1 radial gate (flushing channel) Ungated spillway
Gate dimensions	Flushing gate: 4.00 m wide x 7.08 m high

Weir sill level	Spillway: 1,553.00 m asl Flushing: 1,548.00 m asl
Residual flow	0.23 – 0.33 m³/s
Gabarband Intake Tunnel	
Length	2.36 km (portal to chamber)
Slope	9.2%
Flow conditions	Free-flow in upstream part and pressurised flow in downstream part in GRP pipe
Excavation method	Drill and Blast
Tunnel profile	Horseshoe
Lining type	Shotcrete
Pipe diameter	2.10 / 1.90 / 1.70 m
Pipe invert level at forebay	1,548.50 m asl
Pipe invert level at start chamber	1,335.11 m asl
Pressure Shaft	
Type	Pressurised
Length	0.46 km (bottom upper chamber to top lower chamber)
Shape	Circular
Excavation diameter	5.30 m
Inner diameter	4.00 m
High Pressure Tunnel	
Type	Pressurised
Length	69 m (lower erection chamber to first bifurcation)
Shape	Horseshoe
Excavation size	4.90 m wide x 6.55 m high
Inner diameter	4.00 m
Slope	0.5%
Surge Shaft	
Type	Vertical shaft
Length	0.39 km (bottom to invert adit)
Excavation diameter	7.70 m
Inner diameter	6.50 m
Powerhouse	
Type	Cavern
Flood level – Design flood	762.40 m asl
Turbine unit type	Vertical Pelton
Number of units	3
Design discharge	3 x 25 m^3/s = 75 m^3/s with no overload
Turbine level	765.40 m asl
Gross head at FSL	744.58 m
Net head (at design flow and FSL)	722.08 m
Maximum turbine capacity	3 x 159.3 MW = 478.0 MW

Installed Capacity (after generator)	470 MW
Rated Capacity	3 x 190 MVA = 570 MVA
Synchronous unit speed	428.57 rpm
Tailrace Tunnel	
Type	Free-flow
Length	1.31 km
Shape	Horseshoe
Excavation size	5.85 m wide x 8.25 m high
Slope	0.1%
Invert outlet structure	756.32 m asl
FSL Patan Reservoir (future)	760.00 m asl
Switchyard	
Type	GIS
Voltage level	220 kV
Energy Production	
Average annual energy output	Stand-alone 1,925 GWh Cascade 1,931 GWh
Load factor	0.49

REPORT

LSG HYDRO POWER LIMITED

Lower Spat Gah Hydropower Project

Feasibility Study
Volume 1: Main Report

127000588-002

04 November 2022

Final

AFRY
ÅF PÖYRY

Project
Lower Spat Gah Hydropower Project

Project No.
127000588-002

Revision
Final

Date
04 November 2022

Address
AFRY (Thailand) Ltd.
Vanit II Bldg., 22nd Floor, Room No. 2202-2204,
1126/2 New Petchburi Road, Makkasan,
Rajchthewi, Bangkok 10400, Thailand

Phone
+66 2 108 1000

Contact
Stephan Martin

Mobile
+66 92 264 0738

E-mail
stephan.martin@afry.com

Client
LSG Hydro Power Limited

Report
Feasibility Study, Volume 1: Main Report

Structure of Feasibility Study

Volume 0:	Executive Summary and Salient Features
Volume 1:	Main Report
Volume 2:	Topography
Volume 3:	Hydrology
Volume 4:	Geology
Volume 5:	Seismicity
Volume 6:	Alternatives and Optimisation Studies
Volume 7:	Project Design
Volume 8:	Mechanical and Electrical Equipment
Volume 9:	Transmission Line Studies
Volume 10:	Transportation and Infrastructure Survey
Volume 11:	Environmental and Social Impact Assessment
Volume 12:	Project Schedule and Cost Estimate
Volume 13:	Financial Analysis
Volume 14:	Drawings

List of Abbreviations

Abbreviation	Meaning
2D	two-dimensional
AC	alternate current
ADB	Asian Development Bank
AIS	air-insulated switchgear
ASR	Alkali-Silica Reaction
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTM	American Society for Testing and Materials International
BAP	Biodiversity Action Plan
BID	Background Information Document
BoP	Balance of Plant
BoQ	Bill of Quantities
BS	British Standard
CAPEX	Capital expenditure
CCRD	Clay Core Rockfill Dam
CCTV	Closed Circuit TV
CE	Construction Earthquake
CFRD	Concrete Faced Rockfill Dam
CMTL	Central Material Testing Laboratory
COD	Commercial Operation Date
CPP	Capacity Purchase Price
CPT	Cone Penetration Test
CVC	Conventional Vibrated Concrete
D	diameter
D&B	Drill and Blast
d/s	downstream
DBE	Design Basis Earthquake
DC	direct current
DEM	Digital Elevation Model
Dh	hydraulic diameter
DIN	German Institute for Standardization (Deutsches Institut für Normung)
DN	Diameter Nominal
DSCR	Debt Service Coverage Ratio
DSHA	Deterministic Seismic Hazard Analysis
E	east
E&M	electro-mechanical
e.g.	for example
ENE	east-northeast
EOT	electric overhead traveling
EMME	Earthquake Model of the Middle East
EPC	Engineering, procurement, and construction

EPP	Energy Purchase Price
ESIA	Environmental and Social Impact Assessment
FCFE	Free Cash Flow to Equity
FFA	flood frequency analysis
FS	factor of safety
FS	Feasibility Study
FSL	Full Supply Level
GCB	generator circuit breaker
GRP	glass-reinforced plastic
GIS	gas-insulated switchgear
GLIMS	Global Land Ice Measurements from Space
GPCC	Global Precipitation Climatology Centre
GSI	Geological Strength Index
GSW	Galvanized Steel Wire
H	height
HM	hydro-mechanical
HPP	Hydropower Project
HPU	hydraulic power unit
HQ xx	Flood with a return period of xx years
HRT	Headrace Tunnel
HV	high voltage
HVAC	heating, ventilation and air conditioning
i.e.	that means
IC	Installed Capacity
ICOLD	International Commission on Large Dams
IDC	Interest During Construction
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IGCEP	Indicative Generation Capacity Expansion Plan
IPB	Insulated Phase Busbar
IRR	Internal Rate of Return
KKH	Karakoram Highway
KP EPA	Khyber Pakhtunkhwa Environmental Protection Agency
KPK	Khyber Pakhtunkhwa
L	length
LAA	Los Angeles Abrasion
LAN	local area network
LC	load case
LCC	load case combination
LG	Lower Gabarband
LIBOR	London Inter-bank Offered Rate
LK	Lahmeyer & Knight Piesold
LLCR	Loan Life Coverage Ratio

LS	lump sum
LSDH	Lower Spat Gah drillhole
LSG	Lower Spat Gah
LSTP	Lower Spat Gah test pit
LV	low voltage
MAPET	Main Access and Power Evacuation Tunnel
MCE	Maximum Credible Earthquake
MDE	Maximum Design Earthquake
MG	Middle Gabarband
MIV	main inlet valve
MOL	Minimum Operating Level
MoU	Memorandum of Understanding
MS	Middle Spat Gah
MV	medium voltage
N	north
N/A	Not applicable, not available
NATM	New Austrian Tunnelling Method
NE	northeast
NEPRA	National Electric Power Regulatory Authority
NHA	National Highway Authority
NOL	Normal Operating Level
NPV	Net Present Value
NTDC	National Transmission & Despatch Company
NW	northwest
O&M	Operation & Maintenance
OBE	Operating Basis Earthquake
ODWF	Oil Directed Water Forced
OFWF	Oil Forced Water Forced
ÖGG	Austrian Society for Geomechanics (Österreichische Gesellschaft für Geomechanik)
OPC	Ordinary Portland Cement
OPEX	operating expense
OPGW	Optical Ground Wire
PAP	Project Affected Person
Pcs	pieces
PEDO	Pakhtunkhwa Energy Development Organization
PGA	peak ground acceleration
PH	Powerhouse
PID	Proportional-integral-derivative
PIRR	Project Internal Rate of Return
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
PS	Performance Standards

PSHA	Probabilistic Seismic Hazard Assessment
Q	discharge
Q_D	design discharge
RAP	Resettlement Action Plan
RD	raise drilling
R_h	hydraulic radius
RMR	rock mass rating
RMT	rock mass type
ROE	Return on Equity
RQD	Rock Quality Designation
S	south
SE	southeast
SEE	Safety Evaluation Earthquake
SF	safety factor
SPC	Special Purpose Company
SPT	Standard Penetration Test
SPV	Special Purpose Vehicle
SWHP	Surface Water Hydrology Project
T	time
TBM	Tunnel Boring Machine
TL	Transmission line
TRCM	trash rack cleaning machine
TRMM	Tropical Rainfall Measuring Mission
TRT	tailrace tunnel
u/s	upstream
UCS	unconfined compressive strength
UG	Upper Gabarband
UPS	uninterruptable power supply
US	Upper Spat Gah
USACE	U.S. Army Corps of Engineers
USBR	United States Bureau of Reclamation
V:H	vertical to horizontal
VAT	value-added tax
VSS	Video Surveillance System
W	west
W	width
w x h	width by height
WAPDA	Water and Power Development Authority
WC	Water column
WGS	World Geodetic System

List of Units

Symbol	Unit
%	percent
°	degree
°C	degree Celsius
Ah	amp hour
cm	centimetre
cm/s	centimetre per second
d	day
d50	diameter at which 50% of a sample's mass is comprised of smaller particles
dm	mean diameter
g	gravitational constant (9.81 m/s^2)
GPa	Gigapascal
GWh	Gigawatt hour
h	Hour
ha	hectare
Hz	Hertz
K	Kelvin
kA	kiloampere
kg/m^3	kilogram per cubic metre
km	kilometre
km^2	square kilometre
kN	kilonewton
kN/m^2	Kilonewton per square metre
kN/m^3	Kilonewton per cubic metre
kNm	Kilonewton metre
kPa	kilopascal
k_{st}	Strickler value
kV	kilovolt
kWh	kilowatt hour
l	litre
lbs	pounds
m	metre
m asl	metre above sea level
m/s	metre per second
m^2	square metre
m^3	cubic metre

m^3/s	cubic metre per second
Ma	million year
mbar	millibar
min	minute
mm	millimetre
mm^2	square millimetre
MN/m^3	Meganewton per cubic metre
MPa	Megapascal
mUSD	million USD
MVA	Megavolt amperes
MW	Megawatt
Pa	Pascal
PKR	Pakistani Rupees
rpm	revolutions per minute
s	second
t	ton
USc	United States Cent (1 USc = 0.01 USD)
USD	United States Dollar
USD/m	United States Dollar per metre
USD/m^3	United States Dollar per cubic metre
V	volt
VA	volt-ampere
yr	year

Table of Contents

Figures

Tables

1 Introduction

1.1 General

AFRY Thailand (AFRY or "the Consultant"), which was formerly operating under the name of Pöyry Thailand, has been contracted by the KHNP-Consortium (or the "Client") to carry out a Feasibility Study for the Lower Spat Gah Hydropower Project, herein called Lower Spat Gah HPP, in the Khyber Pakhtunkhwa Province (KPK) of Pakistan.

In addition to KHNP, the following companies are part of the KHNP-Consortium and will also participate in the Project as Construction Investors:

- KEPCO Plant Service & Engineering Co., Ltd.,
- Korea Overseas Infrastructure & Urban Development Corporation,
- Sambu Engineering & Construction Co., Ltd.
- Lotte Engineering & Construction Co., Ltd.,
- Daelim Industrial Engineering & Construction Co., Ltd.,
- Doosan Heavy Industry & Construction Co., Ltd.,

The KHNP-Consortium has established the Special Purpose Company (SPC) LSG Hydro Power Limited (or the "LSG SPC") in Pakistan in March 2021.

AFRY's services for the Inception Phase commenced on 01 February 2019 with the Letter for Notice of Awarding the Contract. The Inception Report from May 2019 contained the recommendations for the preferred arrangement for the Lower Spat Gah Headworks, waterway, Gabarband Intake and Powerhouse which were studied in the Alternatives Study as well as the recommendation for the design discharge and Installed Capacity from the Optimisation Study (see Volume 6). The preferred layout and design discharge were selected as the basis for the Feasibility Study.

The preferred layout was then designed as a desktop study at Feasibility level to serve as a basis for the field investigation of the Feasibility Study.

AFRY's services of the Feasibility Study Phase commenced on 09 September 2020 with the Letter for Notice of Awarding the Contract. The main purpose of this Feasibility Study is to present the findings of this Feasibility Study as well as a short summary of the previous Project phases. The report includes the Project technical descriptions and drawings. The goal is to assess the Project's technical feasibility and the bankability, and to provide the Client all necessary information to make a fully informed decision on whether to proceed with the implementation of the Project.

To achieve this goal, the following specific and complementary services were performed as basis for this Feasibility Study:

- Complementary geological and geotechnical investigations,
- Seismic hazard assessment study,
- Complementary topographic survey and investigations,
- Sediment monitoring, analysis and investigations,
- Access roads study,
- Installation and operation of two new gauging and rainfall stations,
- Transmission line study, power system study and transmission line survey,
- ESIA,
- Road and infrastructure survey.

1.2 The Project

The Lower Spat Gah Project is located in the Kohistan District, in the Khyber Pakhtunkhwa Province of Pakistan. The Spat Gah valley is located on the left bank of the Indus River and starts about 4 km downstream of Dasu town. The access to the Lower Spat Gah Headworks site is from Dasu and includes about 18 km of drivable roads and tracks as well as footpath sections.

The Spat Gah and Gabarband Rivers have an unexploited catchment area of about 1,066 km^2 and 307 km^2 at the Lower Spat Gah Headworks site and the Lower Gabarband Intake respectively.

The Project area has a very rugged topography ranging from undulating terraces on the relatively narrow valley floor of Spat Gah having a slight to moderate slope to very high mountains with steep to precipitous slopes. The Lower Spat Gah Headworks and reservoir will be located in the valley occupying the terraces and steep slopes of the mountains bounding the valley on the north and south sides. The entrance to the Power Cavern will be located in a steep slope of a high mountain facing the Indus River.

The Lower Spat Gah Project is part of a hydropower cascade in the Spat Gah and Gabarband valleys, which includes the three stages Upper Spat Gah, Middle Gabarband and Lower Spat Gah. The Project has been developed as part of that cascade in the 2008 Pre-Feasibility Study and the 2010 Feasibility Study. The characteristics of the three cascade stages are described in Chapter 1.4.

1.3 Project History

A reconnaissance study prepared by Knight Piesold and Lahmeyer International in 1997 investigated the hydropower development for the Spat Gah valley on a very preliminary level.

A Pre-Feasibility Study for the Palas valley and Spat Gah valley was carried out for the Pakistan Water and Power Development Authority (WAPDA) in 2006 and 2007 by a Joint Venture of Pöyry, ILF and ACE. The study investigated the hydropower potential in both valleys and developed conceptual designs of the schemes. Their overall ranking and recommendation for further development of the lower stages is documented in the final 2008 Pre-Feasibility Study Report [2].

A Feasibility Study including staff gauge installation, terrestrial surveys, extensive geological site investigations and ESIA was conducted for WAPDA by the same Joint Venture following the Pre-Feasibility Study and is documented in the final 2010 Report [3].

In December 2012 a Memorandum of Understanding (MoU) was signed between WAPDA, the government of Khyber-Pakhtunkhwa and Korea Midland Power Company to develop the Project in a public-private partnership. The partnership included the Pakistani government, Korea Midland Power, Daelim, Lotte Engineering & Construction, and POSCO Engineering.

Additional site investigations including a drillhole at the Powerhouse area were carried out for Daelim by Geotech Consultant in 2013 as part of a geological due diligence [4]. Technical advisory services were provided for Daelim by Mott MacDonald and included a review of the existing Feasibility Study [5] and proposed Project alterations [6].

KHNP signed a MoU with the Khyber-Pakhtunkhwa government in November 2018 to develop the Lower Spat Gah Project in a public-private partnership and in February 2019 KHNP appointed AFRY to conduct the update of the Feasibility Study (herein called Feasibility Study) including the Alternatives Study and Optimisation Study as a desktop study mainly.

The Inception Report [8] was submitted with a recommended Project layout and design discharge. Based on economic indicators and risk assessments, a layout with a Lower Spat Gah weir, Lower Gabarband diversion discharge of 10 m^3/s, Headrace Tunnel alignment 3 with 10.7 km length, vertical Pressure Shaft and Underground Powerhouse with a design discharge of 75 m^3/s with no overload was selected for the Feasibility Study of the Lower Spat Gah Project.

The KHNP-Consortium also appointed AFRY to conduct a new ESIA and a number of complementary studies including field investigations as part of the Feasibility Study services with the objective to comply with the applicable terms of reference (ToR) for a Feasibility Study in Pakistan. This Report is the final outcome of AFRY's services summarizing the findings of the Feasibility Study and is for the Pakistani government.

1.4 Projects in the Spat Gah Valley

The cascade on the Spat Gah and Gabarband Rivers was developed during the 2008 Pre-Feasibility Study [2] for a cascade operation of peaking plants, with the Lower Spat Gah Project further developed during the 2010 Feasibility Study [3]. During the Feasibility Study, the Full Supply Level of the Upper Spat Gah and the Installed Capacity of all projects were adjusted. The cascade consists of the following projects (Figure 1-1) and salient features as a result of the 2010 Feasibility Study:

- Upper Spat Gah (uppermost project):
    - Upper Spat Gah dam and reservoir: reservoir with 40 million m^3 live storage (33 times the live storage of the Lower Spat Gah reservoir),
    - Upper Gabarband weir and intake: diversion from Gabarband into waterway,
    - Catchment area: 759 km^2 at dam and 226 km^2 at weir,
    - Mean annual inflow: 29 m^3/s at dam (75% of the inflow reaching Lower Spat Gah dam site) and 6 m^3/s at weir (15% of the inflow reaching Lower Spat Gah dam site),
    - Powerhouse with 3 Pelton turbines, 60 m^3/s total design discharge and 199 MW total Installed Capacity.
- Middle Gabarband:
    - Middle Gabarband dam and reservoir: reservoir with 12.2 million m^3 live storage (10 times the live storage of the Lower Spat Gah reservoir),
    - Middle Spat Gah weir and intake: diversion from Spat Gah into Middle Gabarband reservoir,
    - Catchment area: total catchment 280 km^2 at dam (54 km^2 intermediate catchment downstream of Upper Gabarband weir) and total catchment 831 km2 at weir (72 km^2 intermediate catchment downstream of Upper Spat Gah dam),
    - Mean annual inflow: 7.2 m^3/s at dam from total catchment (1.2 m^3/s from intermediate catchment downstream of Upper Gabarband weir) and 30.9 m^3/s at weir from total catchment (1.9 m^3/s from intermediate catchment downstream of Upper Spat Gah dam),
    - Powerhouse with 3 Pelton turbines, 66 m^3/s total design discharge and 424 MW total Installed Capacity.
- Lower Spat Gah (lowermost project):
    - Lower Spat Gah dam and reservoir: 57 m high concrete face rockfill dam impounding a reservoir with 1.2 million m^3 live storage,
    - Lower Gabarband weir and intake: Tyrolean weir with 0.2 km long diversion and 0.5 km long shaft feeding the headrace tunnel,
    - Catchment area: total catchment 1,066 km^2 at dam (235 km^2 intermediate catchment downstream of Middle Spat Gah weir) and total catchment 307 km^2 at weir (27 km^2 intermediate catchment downstream of Middle Gabarband dam),
    - Mean annual inflow: 38.8 m^3/s at dam from total catchment (7.9 m^3/s from intermediate catchment downstream of Middle Spat Gah weir) and 7.7 m^3/s at weir from total catchment (0.7 m^3/s from intermediate catchment downstream of Middle Gabarband dam),
    - Pressurised headrace system with 12.6 km long tunnel, 1.1 km long inclined shaft and surge tank,
    - Underground Powerhouse with 3 Pelton turbines, 81 m^3/s total design discharge, 496 MW total Installed Capacity and 0.5 km long free-flow tailrace tunnel.

Figure 1-1: Spat Gah cascade with Upper Spat Gah HPP, Middle Gabarband HPP and Lower Spat Gah HPP (from [3])

The Middle Gabarband HPP and Upper Spat Gah HPP have not been further developed since the 2008 Pre-Feasibility Study according to the Consultant's knowledge. The main benefits of a cascade of hydropower projects from the Lower Spat Gah perspective are:

- Natural inflow into the reservoir controlled by the two upstream reservoirs,
- Increased plant availability for peaking / plant utilization / installed capacity & firm energy,
- Reduced spillage / increased power output,
- Upstream reservoirs used as sediments traps / reduced sediments load.

The Lower Spat Gah HPP is designed as the lowermost scheme of the cascade of hydropower projects. The turbine level of Middle Gabarband HPP, located upstream of Lower Spat Gah HPP, and the maximum Full Supply Level of Lower Spat Gah HPP were set during the cascade development in the 2008 Pre-Feasibility Study. The Middle Gabarband HPP turbine level is at 1,515 m asl.

A Full Supply Level of 1,510 m asl was set in the Pre-Feasibility Study for the Lower Spat Gah Headworks, thus not impacting the turbine operation and the power generation of the planned Middle Gabarband HPP.

During the 2021 Feasibility Study the cascade was not re-optimized and the Full Supply Level at Lower Spat Gah Headworks was kept at 1,510 m asl to avoid a reduction of the available head of the Middle Gabarband HPP. Lower Spat Gah HPP does therefore not disturb the concession limits of the upstream cascade project Middle Gabarband HPP.

1.5 Projects on the Indus River

Pakistan plans to develop the five hydropower projects Bunji, Diamer-Basha, Dasu, Patan and Thakot as part of the North Indus River Cascade (Figure 1-2). The construction of the Dasu HPP with its dam located 7 km upstream of Dasu has started in June 2017 with the mobilisation of the main Civil Works Contractor. The completion of Stage 1 with 6 turbine-generator units is scheduled for 2023.

The Lower Spat Gah Tailrace Outlet Structure is located downstream of the tailrace of Dasu HPP, thus Lower Spat Gah HPP does not impact the concession limits of Dasu HPP.

The Patan HPP dam is located about 3 km upstream of the village Patan and the reservoir extends 35 km upstream to the Dasu HPP dam. The planned Full Supply Level of 760 m asl of the reservoir as provided in a former study sets the tailwater level of the Lower Spat Gah Project.

The Lower Spat Gah turbine centreline has been determined using the Patan flood water level as downstream boundary condition with sufficient freeboard. Thus Patan HPP does not impact the Lower Spat Gah turbine centreline and power generation, and Lower Spat Gah HPP does not disturb the concession limits of Patan HPP.

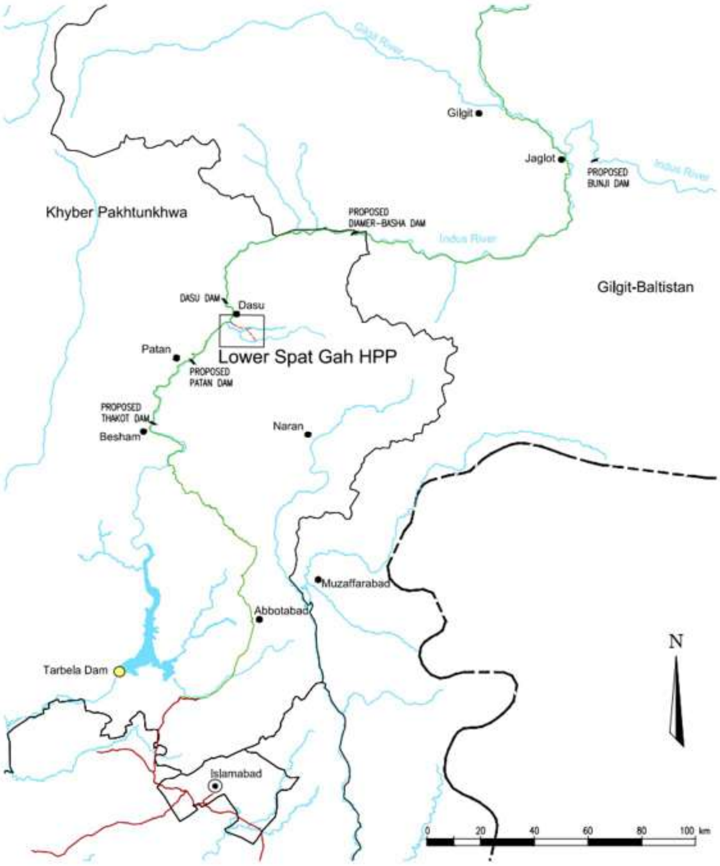


Figure 1-2: Location of North Indus River hydropower projects

1.6 Organisation of the Studies

1.6.1 General

The Lower Spat Gah Feasibility Study services were divided into two main phases as follows:

- Inception Phase:
  - Hydrology update,
  - Seismic Hazard Assessment Study,
  - Project Review,
  - Alternatives and Optimisation Studies,
  - Inception Report.
- Feasibility Study:
  - Sediment monitoring, analysis and investigations (started in September 2020 - ongoing),
  - Complementary topographic survey and investigations (October 2020 and April 2021),
  - Route survey (April 2021),
  - Complementary geological and geotechnical investigations (May 2021),
  - Installation (April and May 2021) and ongoing operation of the gauging and rainfall stations,

  - Access roads study (October 2021),
  - ESIA (Draft March 2022),
  - Transmission line study, power system study and transmission line survey (ongoing).

The Inception phase consisted of the update of the hydrological study and the identification of the most promising concept of the main Project features Lower Spat Gah Headworks, Lower Gabarband Intake, Headrace Tunnel, Pressure Shaft and Powerhouse. The subsequent Optimisation Study resulted in the selection of the design discharge as basis for the Feasibility Study Phase design.

The Feasibility Study consisted of a new ESIA, several field surveys and specific studies as required in the ToR issued by the Pakistani government for a Feasibility Study as basis for a full update of the previous Feasibility Study.

1.6.2 Feasibility Study Report

The Feasibility Study Report is divided into the following fourteen (14) volumes:

- Volume 0: Executive Summary and Salient Features
- Volume 1: Main Report
- Volume 2: Topography
- Volume 3: Hydrology
- Volume 4: Geology
- Volume 5: Seismicity
- Volume 6: Alternatives and Optimisation Studies
- Volume 7: Project Design
- Volume 8: Mechanical and Electrical Equipment
- Volume 9: Transmission Line Studies
- Volume 10: Transportation and Infrastructure Survey
- Volume 11: Environmental and Social Impact Assessment
- Volume 12: Project Schedule and Cost Estimate
- Volume 13: Financial Analysis
- Volume 14: Drawings

This Volume 1 provides the main report of the Feasibility Study.

1.7 Objectives of this Report

The objectives of this Feasibility Study are as follows:

i) To conduct a technically feasible Feasibility Study based on the previous Project phase's input as well as the results of the updated hydrology, seismic and field studies with the goal to optimise the costs and the power energy revenues.

ii) To make an economic evaluation with a cost estimate based on the budgetary proposals and energy calculations based on the design, and providing the evaluation of the bankability to the Client to proceed with the implementation of the Project.

iii) To prepare this Feasibility Study Report.

1.8 Available Information

The following data was reviewed for this Feasibility Study:

[1] Chor Nala Hydel Development Conceptual Study Final Report, Volume 4, Lahmeyer International & Knight Piesold Consulting Engineers, July 1998

[2] Pre-Feasibility Study Report, Palas Valley / Spat Gah Hydropower Complex, Volumes 1-13, Palas Valley – Spat Gah Hydropower Consultants (PHSC), a Joint Venture of Pöyry, ILF and ACE, 29 February 2008

[3] Feasibility Study Report, Lower Spat Gah Hydropower Project, Volumes 1-10 and Executive Summary, Palas Valley – Spat Gah Hydropower Consultants (PHSC), a Joint Venture of Pöyry, ILF and ACE, 26 March 2010

[4] Feasibility Study Due Diligence, Confirmation of Feasibility Study and Appendix, Lower Spat Gah HPP, Geotech Consultant, June 2013

[5] Phase 1 – Review of Feasibility Study, Lower Spat Gah Hydroelectric Project, Mott MacDonald, April 2013

[6] Phase 2 – Project Enhancements, Lower Spat Gah Hydroelectric Project, Mott MacDonald, March 2014

[7] Alternatives Study Memo, Lower Spat Gah Hydropower Project, Pakistan, Pöyry Energy Ltd., 5 April 2019

[8] Final Inception Report, Lower Spat Gah Hydropower Project, Pakistan, Pöyry Energy Ltd., 24 May 2019

[9] Probabilistic Seismic Hazard Assessment Report, Lower Spat Gah HPP, Pakistan, Studer Engineering, 21 June 2019

[10] Access Roads - Design Criteria Memorandum, Final, Lower Spat Gah Hydropower Project, Pakistan, AFRY Thailand Ltd., 06 November 2020

[11] Airbus Topography - Memorandum, Revision Final, Lower Spat Gah Hydropower Project, Pakistan, AFRY Thailand Ltd., 08 January 2021

[12] Topography - Satellite DEM, Spatiotriangulation Report EL1-TR1-PAKISTAN-SO20204282, Final Rev 1, Lower Spat Gah Hydropower Project, Pakistan, Airbus Defence & Space and AFRY Thailand Ltd., 05 January 2021

[13] Topography - Ground Control Points, Final Rev 2, Lower Spat Gah Hydropower Project, Pakistan, Country Survey & Mapping Services PLC and AFRY Thailand Ltd., 19 April 2021

[14] Topography - GPS Survey - Memorandum, Final Rev 2, Lower Spat Gah Hydropower Project, Pakistan, AFRY Thailand Ltd., 22 April 2021

[15] Route Survey Report, Final Rev 3, Lower Spat Gah Hydropower Project, Pakistan, deugro and AFRY Thailand Ltd., 22 April 2021

[16] Geotechnical Investigation Report, Lower Spat Gah Hydropower Project, District Kohistan, KPK, Pakistan, IVCC Engineering, June 2021

[17] Gauging Station - Installation Report, Final, Lower Spat Gah Hydropower Project, Pakistan, Engineering Axis and AFRY Thailand Ltd., 07 July 2021

[18] ESIA - Dam Break Analysis Report, Final, Lower Spat Gah Hydropower Project, Pakistan, AFRY Thailand Ltd., 29 September 2021

[19] Access Road Study Design Report, Final, Lower Spat Gah Hydropower Project, Pakistan, AFRY Thailand Ltd., 21 October 2021

[20] ESIA, Draft for KP EPA, Lower Spat Gah Hydropower Project, Pakistan, AFRY Thailand Ltd., 23 February 2022

[21] Sediment Monitoring and Interpretation Report, Final, Lower Spat Gah Hydropower Project, Pakistan, AFRY Thailand Ltd., 21 March 2022

[22] Gauging Station –Rating Curve Report, Final, Lower Spat Gah Hydropower Project, Pakistan, AFRY Thailand Ltd., 28 June 2022

[23] Transmission Line - Power Market Study, Draft Report, Lower Spat Gah Hydropower Project, Pakistan, AFRY Thailand Ltd., 02 November 2022

[24] Transmission Line – Power System Studies, Draft Report, Lower Spat Gah Hydropower Project, Pakistan, AFRY Thailand Ltd., 02 Novemberr 2022

2 Location and Access

Corresponding Drawings

LSG-FS-000-001	Project Overview, Project Location, Overview Map
LSG-FS-000-002	Project Overview, Project Overview, General Arrangement
LSG-FS-050-001 to 031	Project Access Roads

2.1 Project Location

The Lower Spat Gah Project is located in Northern Pakistan in the Kohistan District in the Khyber Pakhtunkhwa Province. The Lower Spat Gah Headworks are located at the Spat Gah River, the Lower Gabarband Intake is located at the Gabarband River and the Powerhouse Tailrace Outlet Structure is at the Indus River.

The Spat Gah valley is accessible from Dasu and located about 4 km south of Dasu.

Figure 2-1: Lower Spat Gah Project location in the area

2.2 Access

2.2.1 Airport

The nearest international airport to the Project site is the Islamabad International Airport, which is located about 350 km from Dasu.

2.2.2 Road to Dasu

The main access point for the Lower Spat Gah Project from Islamabad is via the Islamabad - Peshawar highway for about 60 km to the Hasan Abdal intersection, and from Hasan Abdal on the main Karakoram Highway (KKH) for about 295 km to the Komila bridge just south of Dasu.

2.2.3 Existing Roads from Dasu to Project Site

During the site visit in April 2019 the different access roads from the Komila bridge south of Dasu to the Project sites and their current road conditions were documented as shown in Figure 2-2 and this chapter.

The current one-lane site access road starts at the Komila bridge which crosses the Indus River south of Dasu. From this bridge until shortly before the Goshali bridge (section 1) the road is asphalt paved, afterwards a gravel road continues. The unpaved road section from the Goshali bridge to the confluence of the Spat Gah and Gabarband Rivers (section 2) can only be accessed by vehicles like pick-ups, jeeps or smaller vehicles. The unpaved road section in the Spat Gah valley from the confluence of the Spat Gah and Gabarband Rivers until Baja village (section 3) is manageable by pick-ups and jeeps but at the limit of the vehicle capabilities. The narrow road in the Spat Gah valley between Baja village and 900 m downstream of the Lower Spat Gah Headworks axis (section 4) is accessible for small jeeps but not for pick-ups. The section between the avalanche and the Lower Spat Gah Headworks (section 5) as well as the section in the Gabarband valley from the confluence of the Spat Gah and the Gabarband up to the Lower Gabarband Intake (section 6) is only accessible on foot. The recorded average driving speed in sections 1 to 4 was 8 - 10 km/h.

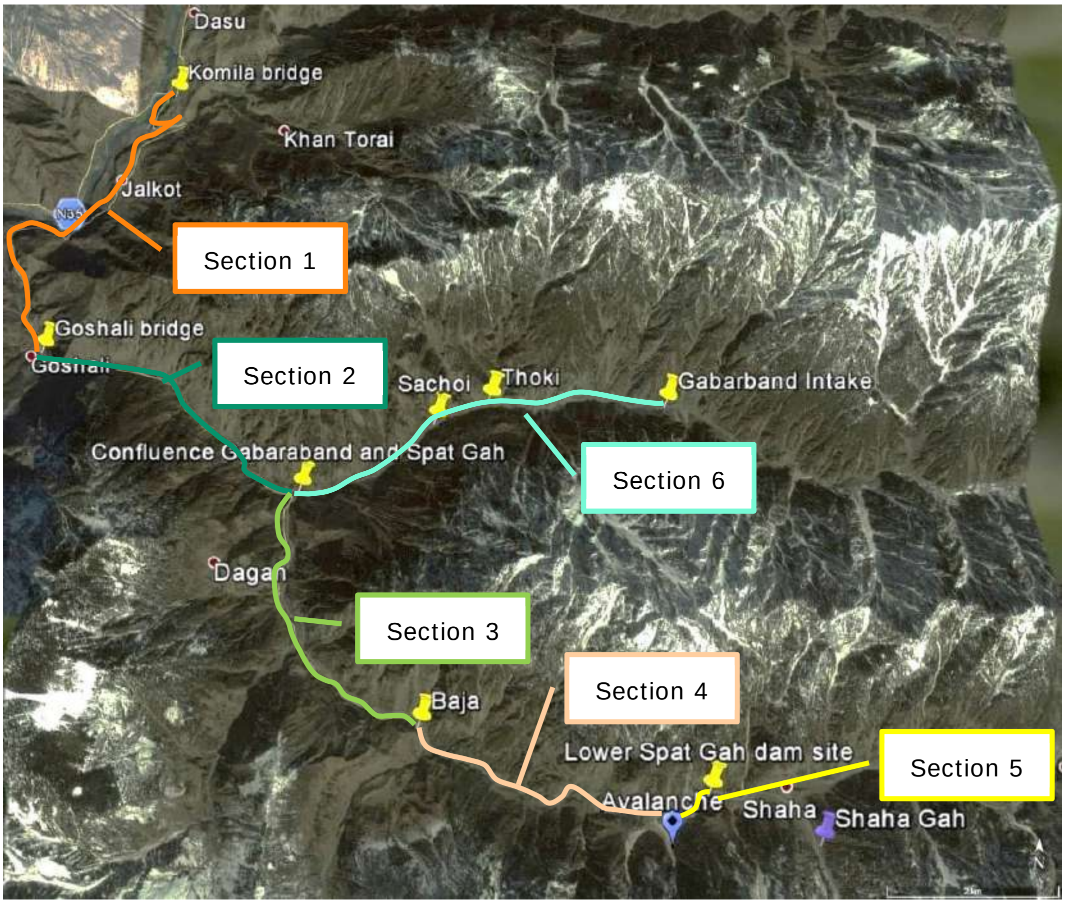


Figure 2-2: Sections of access roads and conditions

Section 1

Compared to the previous investigation phase a decade ago the access conditions seem to be without major changes.

Section 1: Asphalt paved road

Section 1: Asphalt paved road:

partly steep descent to Goshali bridge

Goshali bridge, crossable with pick-ups but not with heavy load vehicles

Figure 2-3: Access road section 1 (Komila to Goshali bridge)

Section 2

The unpaved road section 2 starting from Goshali shows differing conditions. Very narrow, overhanging rock slopes alternate with flatter and wider sections (Figure 2-4).

Section 2: alternate inclined gravel road

Section 2: narrow road section with overhanging rock slopes

Section 2: wider gravel road section

Figure 2-4: Access road section 2 (Goshali bridge to confluence Spat Gah/ Gabarband)

Section 3

The third road section in the Spat Gah valley from the confluence of the Spat Gah and Gabarband Rivers until Baja village still shows alternate road sections. Compared to section 2 the accessibility is more challenging. The ride in section 3 is manageable by pick-ups and jeeps but at the limit of the vehicle capabilities (Figure 2-5).

Section 3: wide and more favourable road section

Section 3: narrow road section

Section 3: wide and more favourable road section

Section 3: narrow road with overhanging rocks (limitation for vehicle height)

Figure 2-5: Access road section 3 (Spat Gah valley from Gabarband confluence to Baja village)

Section 4

The fourth road section in the Spat Gah valley between Baja village and 900 m downstream of the Lower Spat Gah Headworks axis is accessible for small jeeps but not for pick-ups (Figure 2-6). During the site visit this section could not be accessed by vehicle, especially due to the reduced width of the road.

Section 4: alternate road surface (gravel and rock surface)

Section 4: favourable gravel road section

Section 4: end of the road section which is accessible with a jeep. Avalanche reaches down to Spat Gah, can be seen in the background of the jeep.

Figure 2-6: Access road section 4 (Spat Gah valley from Baja village to avalanche)

Section 5

The fifth section (starting approximately 900 m downstream of the headworks site) between the avalanche and the headworks site is only accessible on foot (Figure 2-7).

Section 5

Section 5: Footpath blasted in rock

Figure 2-7: Access road section 5 (Spat Gah valley from avalanche to dam site)

Section 6

The road section 6 in the Gabarband valley from the confluence of the Spat Gah and the Gabarband up to the Lower Gabarband Intake is only accessible on foot (Figure 2-8). The formerly existing hanging bridge at the entrance of the Gabarband valley is destroyed and replaced by a small wooden bridge only for pedestrians.

Section 6: Footpath Gabarband valley

Section 6: Footpath Gabarband valley

Figure 2-8: Access road section 6 (Gabarband valley from Spat Gah confluence to intake)

2.2.4 New Access Roads

A new bridge will be built across the Indus River north of the Tailrace Outlet Structure. This shortens the access and new bridge guarantees sufficient loading capacity for the transport of the heavy and valuable E&M equipment. The existing road in the Spat Gah valley will have to be upgraded and new roads will have to be built in order to reach the different project structures as shown in Figure 2-9.

The roads have been designed for two-way heavy traffic during construction and operation. The following permanent and construction roads will have to be either upgraded or built to meet the Project needs:

- The access roads between the new Indus bridge (No. 10 in Figure 2-9) and the main access road to the Lower Spat Gah Headworks as well as to the Tailrace Outlet Structure and the Power Cavern access tunnel portals will be 1.1 km long.
- The access road to the Upper Erection and Gate Chamber (No. 12 in Figure 2-9) will be 3.7 km long from the junction with the main access road.
- The temporary construction road to the surge shaft chamber access tunnel at the top of the Surge Shaft (No. 13 in Figure 2-9) will be 3.7 km long from the junction with the Upper Erection and Gate Chamber access road.
- The access road within the Spat Gah valley (No. 14 in Figure 2-9) from the junction with the Upper Erection and Gate Chamber access road (No. 12 in Figure 2-9) to the Lower Spat Gah Headworks (No. 1 in Figure 2-9) will be 18.1 km long.

- The temporary construction road to the Lower Spat Gah Headworks right bank will be 0.5 km long between the Lower Spat Gah Headworks access road (No. 14 in Figure 2-9) and the bridge to the right bank.
- The access road in the Gabarband valley (No. 16 in Figure 2-9) to the Gabarband Crossing (No. 5 in Figure 2-9) will be 2.8 km long from the junction with the Lower Spat Gah Headworks access road.

The access to the Lower Gabarband Intake is through the adit tunnel left bank at the Gabarband Crossing and the Gabarband Intake Tunnel. A surface road between the Gabarband Crossing and the Lower Gabarband Intake has not been considered due to geological risks as described in Volume 4 - Geology, Chapter 7.3 The existing road between Dasu and the Project will only be used for the construction of the road at the beginning of the Project. The new bridge and the roads from the bridge will be used during the construction and operation of the Project when they are available. Table 2-1 shows the classification of the road conditions based on the existing access conditions as presented during the April 2019 site visit.

Table 2-1: Estimated road conditions

Road Section	Description	Length (km)
Existing main road up to Goshali bridge	Medium geotechnical effort (rock support)	4.1
Existing road between Goshali bridge and Spat Gah and Gabarband Rivers confluence	High geotechnical effort (rock support, retaining walls, gabions)	5.1
Other road sections (excluding tunnel near Lower Spat Gah Headworks)	High geotechnical effort including avalanche galleries and bridges	20.7

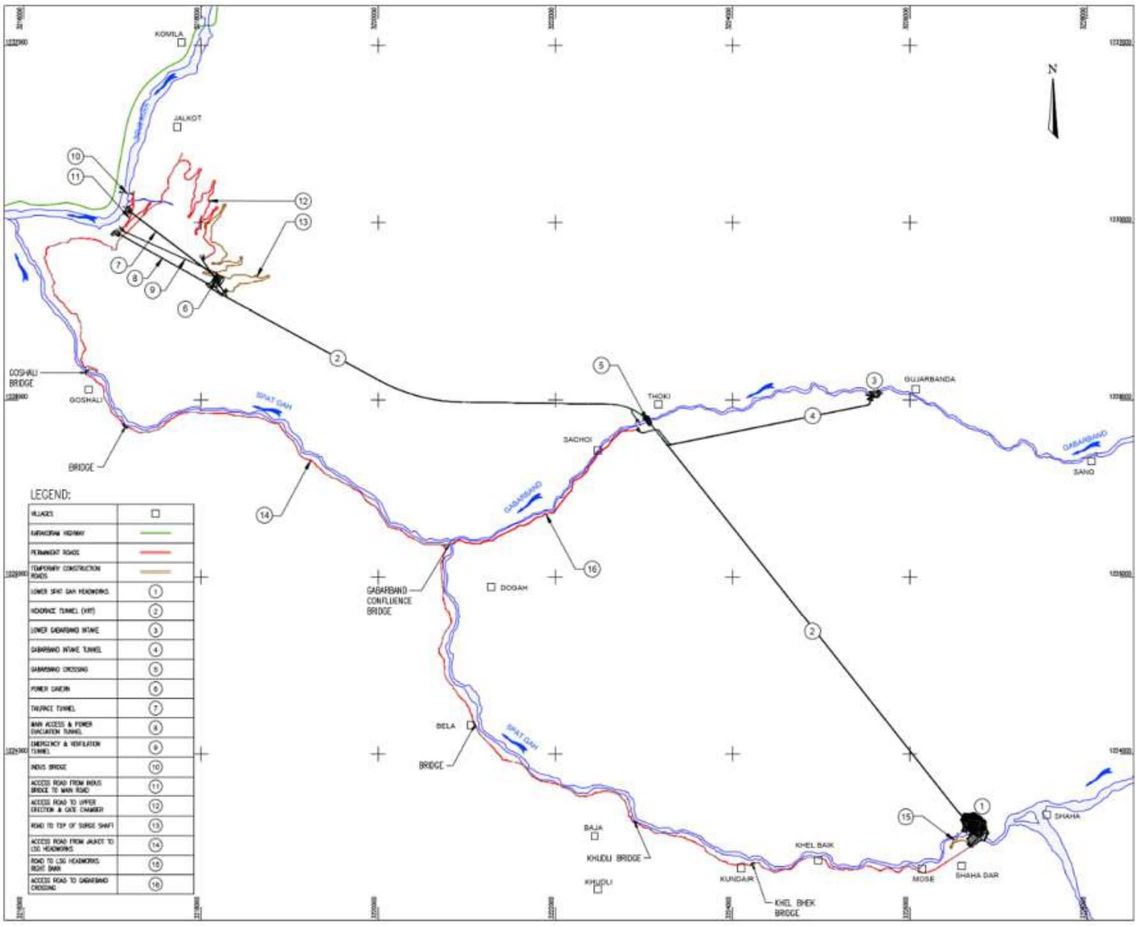


Figure 2-9: Access roads of Lower Spat Gah Project

An access concept to catch and release snow trout based on the findings of the ESIA will have to be determined in the next Project phase.

A specific and detailed access road study has been performed for the current Feasibility Study to accurately define the alignment, prepare a design, estimate the quantities for the cost estimate and establish construction progress rates of the Project.

The roads will first be built with as a simple gravel road to be used during construction and the final road surface pavement will be added at the end of the construction to increase the access roads durability and avoid costly repair works during construction.

The design vehicle for the design of the permanent access roads to the Lower Spat Gah Headworks and Lower Gabarband Intake is the WB15 / WB 50 intermediate semitrailer taken from AASHTO. All roads to the surge shaft chamber access tunnel (temporary) or to the Upper Gate and Erection Chamber (permanent) need to enable the safe transport of earth / rock moving equipment and the equipment needed for the raise boring method that will be shipped in 12.95 m overseas containers. The 125 ton transformers shall be shipped on trailers not exceeding a maximum axle load of 14.5 tons.

The most important geometric parameters for the two lane road alignments are as follows:

- Passing width: 5.0 m
- Width of unpaved shoulders (verge): 0.5 m
- Total road width: 6.0 m

Natural hazards such as snow fall, rockfall, flash water and flooding, avalanches and mud flows have been taken into account for the access road design as the terrain in the Lower Spat Gah Project area is extremely steep. Different measures such as rockfall protection netting, sufficient distance to rivers to adhere to respective flood return periods, avalanche galleries, bridges and tunnels are foreseen based on the expected conditions. The existing bridges along the access road to the Lower Spat Gah Headworks and the bridge at the Gabarband confluence have been re-designed to suit the Project’s requirements. In additional 4 avalanche galleries are foreseen along the access road to the Lower Spat Gah Headworks. One tunnel directly next to the Lower Spat Gah Headworks and two tunnels along the access road to the Gabarband Crossing provide easier and safer access.

The new Indus Bridge will be a steel arch bridge with one span of 108 m. On the left river bank a comparatively high abutment will be built to reduce the bridge span and thus result in an overall economical solution. The underside of the bridge has been designed with 10 m freeboard to the Patan reservoir Full Supply Level, allowing for a vessel to pass underneath in case of flood conditions.

The design of the access roads is given in Annex 5 of Volume 7 - Project Design of this Feasibility Study.

The upstream Middle Gabarband and Upper Spat Gah HPPs would also benefit from the new Indus Bridge and the newly constructed access roads of the Lower Spat Gah Project.

3 Power Market Study

3.1 Introduction

This chapter summarises the comprehensive power market study conducted to assess the feasibility of the Lower Spat Gah Project keeping the future perspective of generation and load demand as the key factors. The complete report is attached in Volume 9 – Transmission Line Studies.

3.2 Power Demand

The demand forecasts for the year 2031 were established for the three demand growth scenarios Low Demand Forecast, Medium Demand Forecast and High Demand Forecast in line with the Indicative Generation Capacity Expansion Plan (IGCEP). The results of the forecasted demand are listed in Table 3-1. The demand includes the K-Electric import demand.

Table 3-1: Demand forecast for year 2031

	Current Demand	Low Demand Forecast 2031	Medium Demand Forecast	High Demand Forecast
GDP growth assumption	-	4.4%	5.4%	6.4%
NTDC power demand (MW)	23,746	41,039	44,081	47,328
NTDC energy generation requirement (GWh)	126,890	213,158	228,877	245,663

3.3 Power Generation Capacity

The present installed generation capacity in the National Transmission and Dispatch Company (NTDC) system is 37,934 MW and the fuel-wise generation mix as of March 2022 is shown in Figure 3-1.

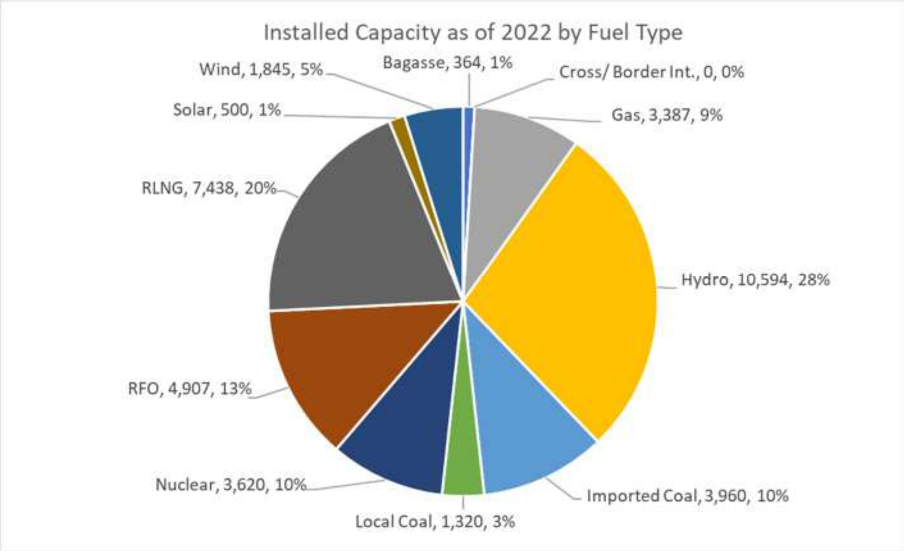


Figure 3-1: Existing generation mix based on installed generation capacity in 2022

The power generation capacities for the year 2031 were established for various energy generation technologies. This includes existing projects, committed projects as well as optimized projects picked from the candidates projects. The retirement of existing projects or those whose power purchase agreements expire have also been considered.

The committed and optimized hydro, thermal, bagasse, solar and wind projects are the same in the three demand forecast scenarios. The only difference in the three demand forecast scenarios is the optimized new local coal-based power generation. The Lower Spat Gah Project was assumed to be part of the optimized projects.

For the Low Demand Forecast scenario, the total optimized installed capacity in the NTDC system in year 2031 was worked out to be 60,573 MW. Figure 3-2 presents the optimized mix in 2031 based on installed generation capacity.

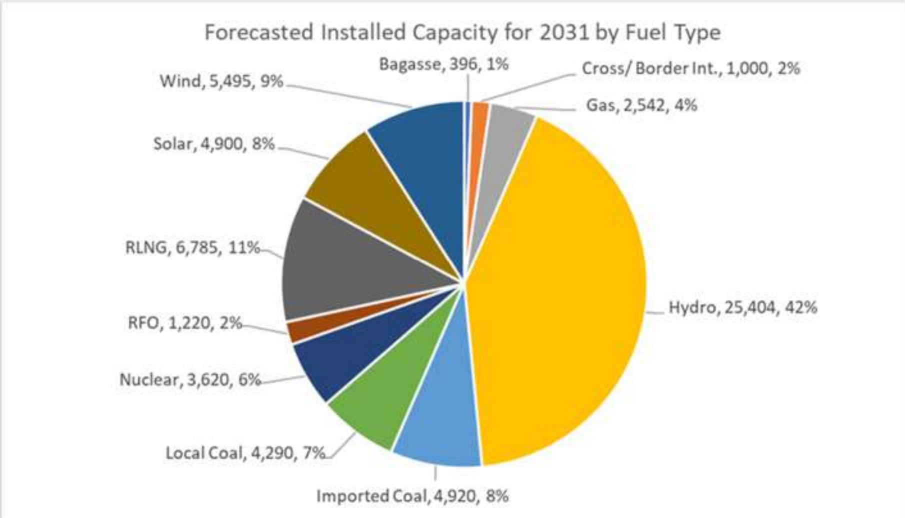


Figure 3-2: Optimized generation mix in 2031 under the Low Demand Forecast of IGCEP

3.4 Power and Energy Balances

The power and energy balance simulations were carried out for 2031 projected demand and supply in the NTDC system. Monthly power and energy balances were carried out for the three demand forecast scenarios for the year 2031 coinciding with the expected commissioning date of the Lower Spat Gah Project. The basic premise of the power and energy balances were to show that there is enough power and energy demand in the NTDC system which can absorb Lower Spat Gah Project without affecting the dispatch of all must run power plants in the NTDC system.

To account for uncertainties in the completion of the optimized hydropower project due to technical and commercial formalities and other critical steps for implementation, which would lead to a delay beyond the horizon of the study, two cases have been studied:

- Case 1: 100% completion of optimized hydropower projects as planned by 2031.
- Case 2: 50% completion of optimized hydropower project as planned with the other 50% spilling over the study horizon and therefore not available by year 2031.

For the power and energy balances it was assumed that the must run plants are dispatched ahead of the thermal plants in the NTDC system. The thermal plants are dispatched in accordance with their economic merit order based on their energy cost.

The power balances of the Case 2 with Low Demand Forecast scenario, as shown in Figure 3-3, demonstrate that there was enough demand in the NTDC system that could be absorbed by the capacity offered by the must run plants, including the Lower Spat Gah Project. The spill over demand that would be supplied through thermal generation. The energy balances show the same result. In fact, the same conclusion is reached for the combination of the two cases and three demand scenarios.

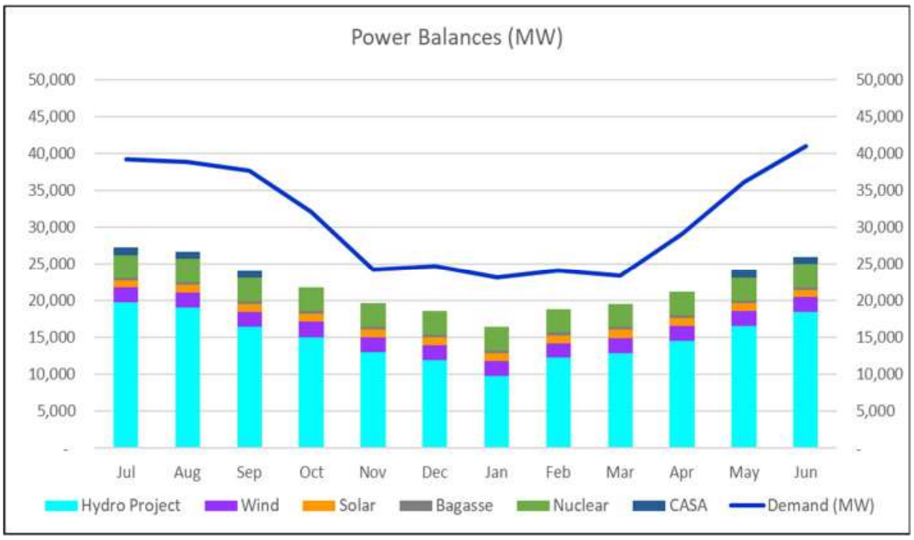


Figure 3-3: Power balances in 2031 under the Low Demand Forecast scenario for Case 2

3.5 Conclusion

The IGCEP contains an optimistic assessment on development of hydropower and other renewable energy resources for the three demand growth scenarios low, medium and high. There is a likelihood that a number of committed and optimized hydropower plants may slip on their commissioning timelines, stall for a long duration or even be abandoned by their sponsors. Therefore, the NTDC system may not be having adequate capacity to meet the demand in 2031. Given the history of generation projects' development in the country, Case 2: 50% planned capacity additions of hydropower projects appears to be the most probable.

The power and energy balances demonstrate that in 2031 there was enough demand in the NTDC system in all demand growth scenarios and capacity addition cases that could be met by the projected capacity offered by the must run plants, including the Lower Spat Gah Project. The addition of the Lower Spat Gah Project will not have any adverse impact on energy generated by any must run plant.

Over the period 2023-2031, the NTDC system would have enough thermal generation capacity to take up the spill over energy and provide back up and reserve capacity.

The development of the Lower Spat Gah Project will benefit the national grid in more ways than one. It will inject clean energy into the system from a climate change perspective, provide indigenously produced energy in meeting the energy security goals for the country and provide cheap energy compared to that of imported fuels such as RLNG, coal and RFO based thermal power plants.

4 Topography

Corresponding Drawings

LSG-FS-010-001 Topography, Overview of Available Data, Topographic Surveys

4.1 Introduction

This chapter summarises Volume 2 – Topography which presents the topographic data of the Lower Spat Gah Project.

4.2 Available Topography 2008 and 2010

4.2.1 Overview Map of Project Area

A Digital Elevation Model (DEM) of the Spat Gah cascade area based on the 20 m pixel spacing SPOT-5 satellite data has been purchased during the Pre-Feasibility Study [2]. The topographic data is available in 100 m contour intervals.

4.2.2 Detailed Topography

The following detailed topographic surveys were conducted by ARCO during the 2008 Pre-Feasibility Study and 2010 Feasibility Study at the Lower Spat Gah Headworks, Lower Gabarband Intake, Powerhouse and access road areas (Figure 4-1) in the SOP coordinate system:

- Lower Spat Gah Headworks and reservoir area:

  Preliminary terrestrial survey, AutoCAD file contains measured points and generated 5 m contour intervals.

- Lower Spat Gah Headworks area:

  Terrestrial survey, AutoCAD file contains measured points and generated 2 m contour intervals.

- Lower Gabarband Intake area:

  Terrestrial survey, AutoCAD file contains measured points and generated 2 m contour intervals.

- Surge Shaft and Powerhouse area:

  Terrestrial survey, AutoCAD file contains measured points and generated 5 m contour intervals.

- Access road in Spat Gah valley:

  Terrestrial survey, AutoCAD file contains measured points and generated 1 m contour intervals.

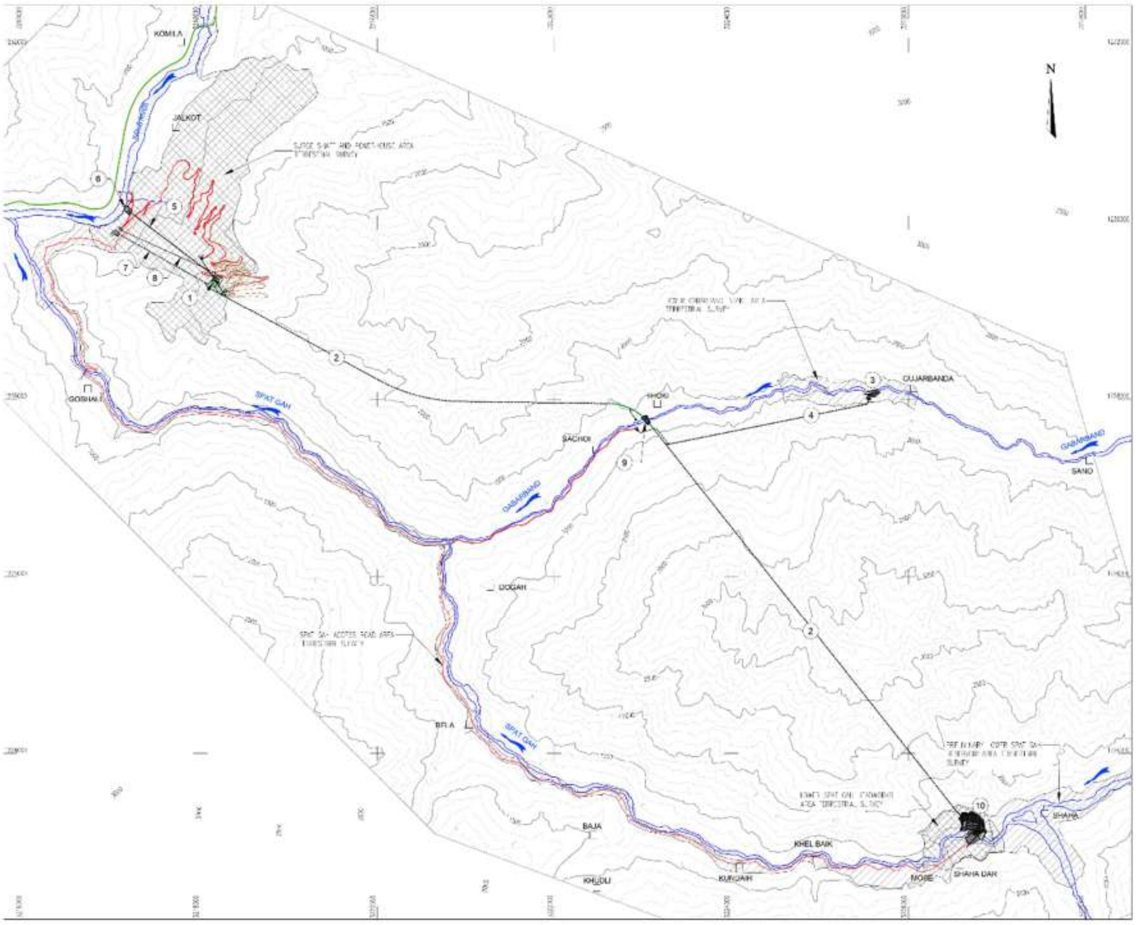


Figure 4-1: Location and extent of overall and detailed topographic surveys of Lower Spat Gah Project (from [3]), overall topography is Airbus topography

4.3 Airbus Topography

4.3.1 Ground Control Point Survey and Airbus Topography

Good topographic data was needed for the dam break study, Gabarband Crossing design and access road design because the overall DEM from 2008 as described in Chapter 4.2.1 is not sufficiently accurate. Therefore, a topographic survey based on satellite images was undertaken by Airbus Defence & Space. A Digital Surface Model (DSM) and Digital Terrain Model (DTM) of the whole Project area have been generated from a high resolution Pleiades stereo imagery. The Airbus deliverables have been produced using the WGS84 UTM 43N projection and EGM2008 vertical datum.

In order to achieve horizontal and vertical resolutions < 2 m, 12 ground control points (GCP) throughout the Project area were surveyed by Country Survey & Mapping Services (CSMS) in October 2020.

4.3.2 Post-Processing of Airbus Topography

The transformation parameters from the 2010 Feasibility Study [3] were used to transform the WGS84 Airbus topography into the SoP system, but the transformed topography showed a large horizontal and vertical offset compared to the ARCO topography. Because the Airbus topography could not be matched with the ARCO topography using the 2010 transformation parameters, an additional field survey as documented in Chapter 4.3.3 was conducted. New ground control points were required to establish a reliable transformation.

4.3.3 GPS Survey 2021

The Global Position System (GPS) survey consisted of Differential Global Positioning System (DGPS) observations, in order to determine firm and accurate transformation parameters between WGS84 and SoP. The following Differential Global Positioning System (DGPS) observations at the Lower Gabarband Intake and in the Spat Gah valley between the Lower Spat Gah Headworks and Indus River were performed:

- Observation of 5 control points in DGPS static mode,
- Observation of 21 control points in DGPS Real-Time-Kinematic (RTK) mode,
- Observation of 5 benchmarks from 2009 ARCO topography survey in DGPS RTK mode.

The five (5) control points were measured in WGS84 in two independent measurements over six hours on two different days in DGPS static mode. The resulting coordinates and elevations then served as a basis for the other control point and benchmark observations. The results shall also be used for future surveys, including the data for the Dasu benchmark as shown in Table 4-1. The WGS84 geodetic coordinates and elevations of all the observations are shown in Volume 2.

Table 4-1: Results of static DGPS survey (WGS84 geodetic coordinates)

Location	ID	Latitude	Longitude	Elevation (m asl)	
		N	E	Orthometric	Ellipsoid
Dasu	BM Dassu	35° 16' 14.90023"	73° 13' 23.02529"	777.994	750.331

4.3.4 Transformation Parameters

The following map projection system of Survey of Pakistan (SoP) were used for the transformation process:

- Projection type: Lambert Conformal Conic Two Parallel
- Origin latitude: 32°30'00.00000" N
- Origin longitude: 68°00'00.00000" E
- False Easting: 2’743’196.400 m
- False Northing: 914’398.800 m
- First Standard Parallel: 30° 05‘ 54.56000‘‘ N
- Second Standard Parallel: 35° 31‘ 42.94000‘‘ N
- South azimuth system: No

The SoP system is using the India/Everest 1956 Ellipsoid:

- Semi-major Axis a: 6’377’301.243 m
- Inverse flattening 1/f: 300.8017255000

Geoid model:

- No geoid model is applied in the SoP system

Using the WGS84 coordinates of the 2021 GPS survey (Chapter 4.3.3) and the corresponding SoP coordinates as determined from the ARCO topography, the transformation parameters between the global and local coordinate system were established. Points with residuals which were too large were discarded from the calculation.

The transformation parameters were established for two different transformation models, the Bursa Wolf model as shown in Figure 4-2 and the Molodensky-Badekas model as shown in Figure 4-3.

- The translation vectors (Δx, Δy, Δz) and the corresponding standard deviations (RMS Δx, RMS Δy, RMS Δz) of the Bursa Wolf model refer to the coordinates of the numerical zero point of the start system (WGS84).
- The translation vectors (Δx, Δy, Δz) and the corresponding standard deviations (RMS Δx, RMS Δy, RMS Δz) of the Molodensky-Badekas model refer to the coordinates of the centre of gravity of all control points of the starting system.
- The transformed coordinates, the angles of rotation (Rx, Ry, Rz), the scale factor and the residuals in the control points are completely identical in both models.

The Molodensky-Badekas transformation was performed in addition to the Bursa Wolf transformation in order to proof the accuracy and reliability of the transformation parameters. Figure 4-3 shows the accuracy which is in the range of ±0.15 m. These small residuals show the good quality of the DGPS survey as well as the reliability of the ARCO's topography at the control point locations. The complete transformation reports of both models are given in Volume 2 - Annex 7 and show that the residuals of the points used for the transformations are within 1.18 m for East/North and within 1.56 m for the height.

Protocol created: 06.04.2021 20:39:49

Transformation: WGS84 to SoP - Classic 3D

Parameter

Height Mode:	Orthometric		
Model:	Bursa Wolf		
Common Points:	19		
Δx:	51.85018 m	RMS Δx:	366.37424 m
Δy:	-2'442.12508 m	RMS Δy:	209.42685 m
Δz:	-2'272.33792 m	RMS Δz:	330.67563 m
Rx:	-72.00418 "	RMS Rx:	10.60389 "
Ry:	-163.36291 "	RMS Ry:	10.56001 "
Rz:	-159.40469 "	RMS Rz:	8.85809 "
Scale:	1.000386251248	RMS Scale:	0.000027466032
x0:	0.00000 m		
y0:	0.00000 m		
z0:	0.00000 m		

Figure 4-2: Transformation parameters with Bursa Wolf model

Protocol created: 06.04.2021 20:56:55

Transformation: WGS84 to SoP - Classic 3D

Parameter

Height Mode:	Orthometric		
Model:	Molodensky		
Common Points:	19		
Δx:	-328.80633 m	RMS Δx:	0.14590 m
Δy:	-628.01265 m	RMS Δy:	0.14202 m
Δz:	-306.72371 m	RMS Δz:	0.14778 m
Rx:	-72.00418 "	RMS Rx:	10.60389 "
Ry:	-163.36291 "	RMS Ry:	10.56001 "
Rz:	-159.40469 "	RMS Rz:	8.85809 "
Scale:	1.000386251248	RMS Scale:	0.000027466032
x0:	1'503'138.22448 m		
y0:	4'995'434.08520 m		
z0:	3'659'352.84402 m		

Figure 4-3: Transformation parameters with Molodensky model

4.3.5 Comparison of the Topography

After the transformation parameters between the WGS84 and SoP system were established, the Airbus topography was transformed from the WGS84 to the SoP system. The transformed topography was then compared with the ARCO topography to determine if the transformation can be considered successful for the intended purpose.

The comparison showed a good match between the Airbus and ARCO topographies. Some discrepancies were however noted, mainly in areas covered with forests, shaded areas and steep slopes as originally anticipated by AFRY. Some of the areas showed elevation differences of up to 10 m and more. In general it seems that the algorithm establishing the DTM from the DSM overestimated the vegetation cover.

The following conclusions can be drawn from the topography comparison:

- The transformed Airbus topography matches pretty well with the ARCO topography. The intended purpose of the transformation is achieved,
- In steep areas, shaded areas and areas with dense vegetation the differences can reach up to 10-20 m,
- The ARCO topography is considered more precise/detailed than the Airbus topography because the Airbus DTM is established using photogrammetry,
- It is acknowledged that the ARCO topography shows some local inaccuracies, for example in the riverbed (which may also be partly explained by some changes due to flood events) and at the right abutment at the Headworks (which can be attributed to small landslides based on satellite images over time).

Because the ARCO topography is considered preferable to the Airbus topography, the ARCO topography is used wherever available for the design, that means at the Lower Spat Gah Headworks, Lower Gabarband Intake, Powerhouse area and along the Spat Gah road. The Airbus DTM topography will be used for all other areas, thus mainly the Power Waterway in general, the Gabarband Crossing and the Gabarband access road.

4.4 Recommendations

A new terrestrial survey of the relevant Project areas is recommended before Project execution as basis for the Detailed Design.

5 Hydrology

Corresponding Drawings

LSG-FS-020-001	Hydrology, Catchment Areas & Gauging Stations, Overview Map
LSG-FS-020-002	Hydrology, Hydrological Information, Inflow Curves, Flood & Temperature Data & LSG Reservoir Curves

5.1 Introduction

This chapter summarises Volume 3 - Hydrology, which covers the main results of the 2008 Pre-Feasibility Study [2] and the 2010 Feasibility Study [3] and includes updates based on additional data covering the time period since the 2010 Feasibility Study.

5.2 Hydro-Meteorological Data

5.2.1 Data Collection and Processing

Data has already been collected and used during the Pre-Feasibility Study [2] and Feasibility Study [3]. New data was requested and received for the current study. Table 5-1 and Table 5-2 give an overview of all the available data for this study, which was received with daily data values.

It is noted that the station Garhi Habibullah was severely damaged in 1992 and subsequently shifted to downstream location (Talhata Bridge) after 1993. Only the name Talhata is used for the gauge for the complete period from 1960-2016 in this report.

The discharge gauges are displayed in Figure 5-1.

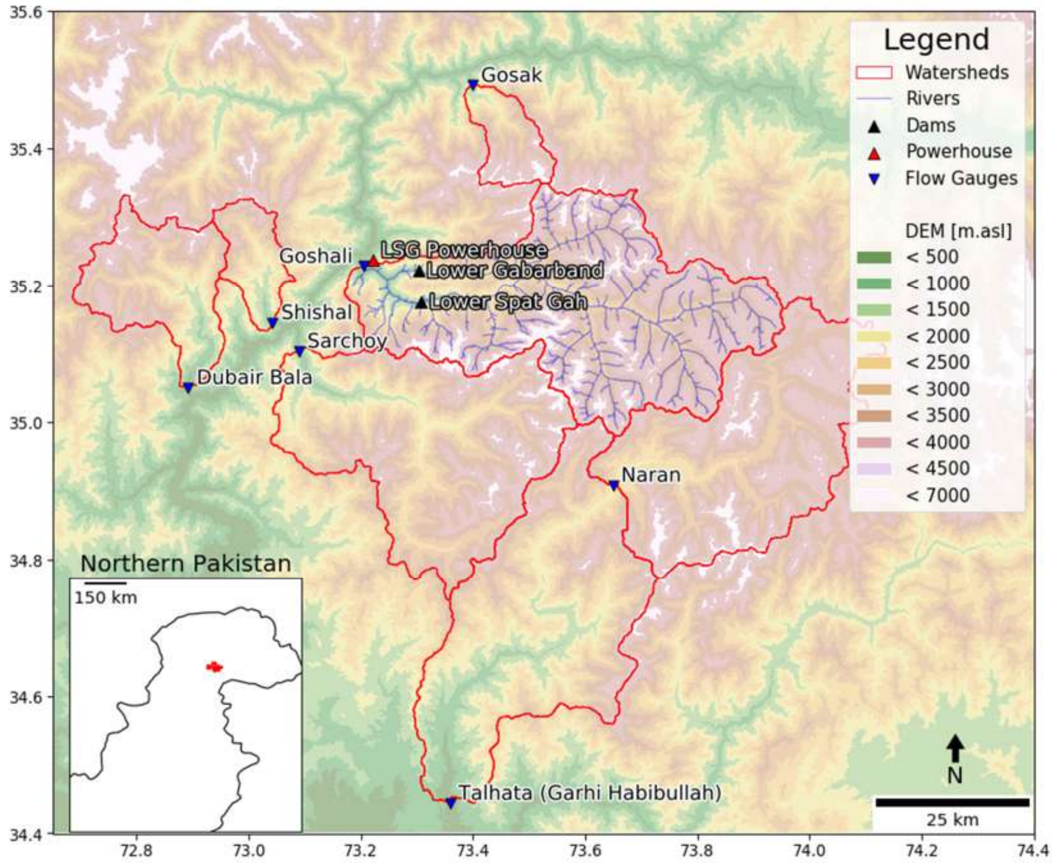


Figure 5-1: Discharge gauges around the Project area

Table 5-1: Discharge data

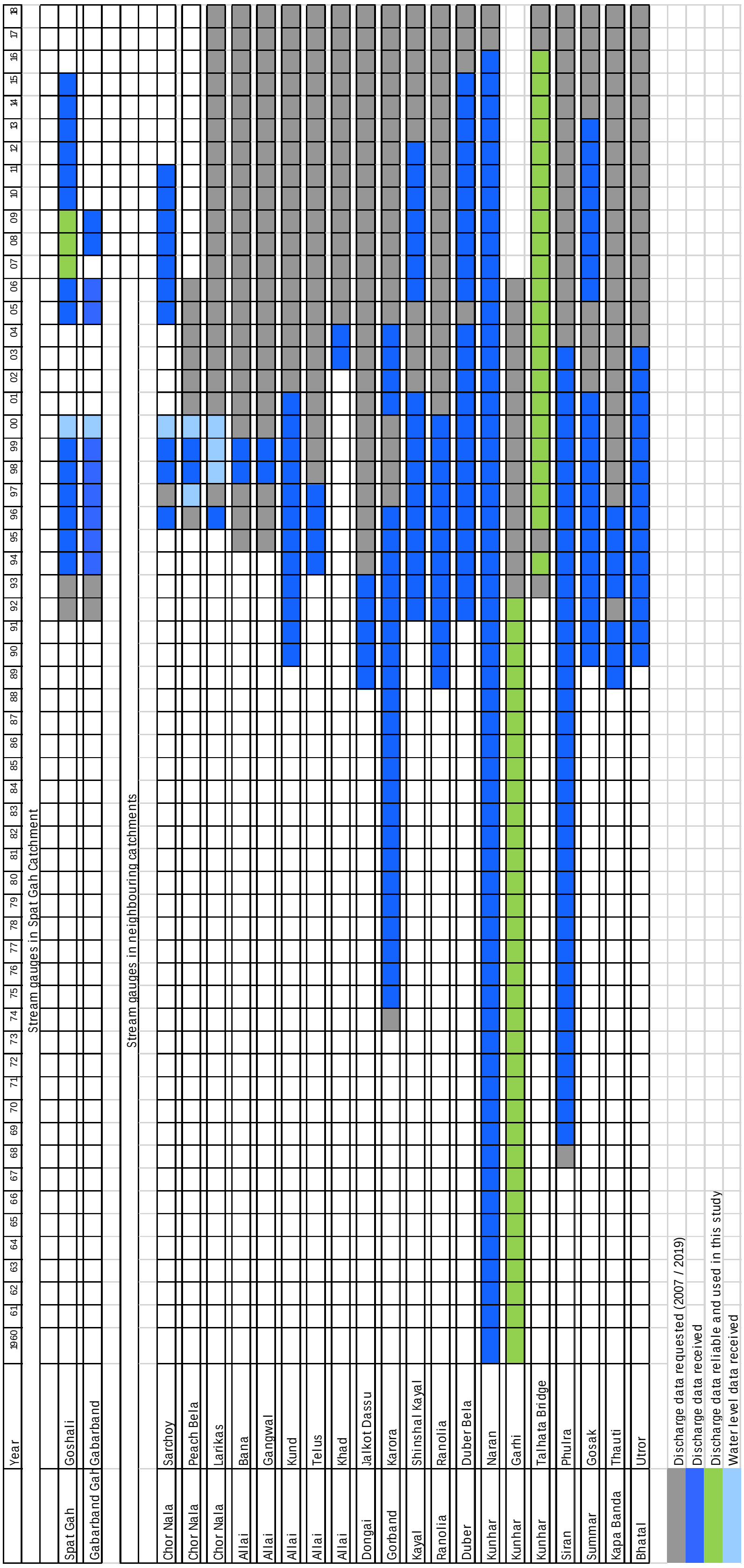
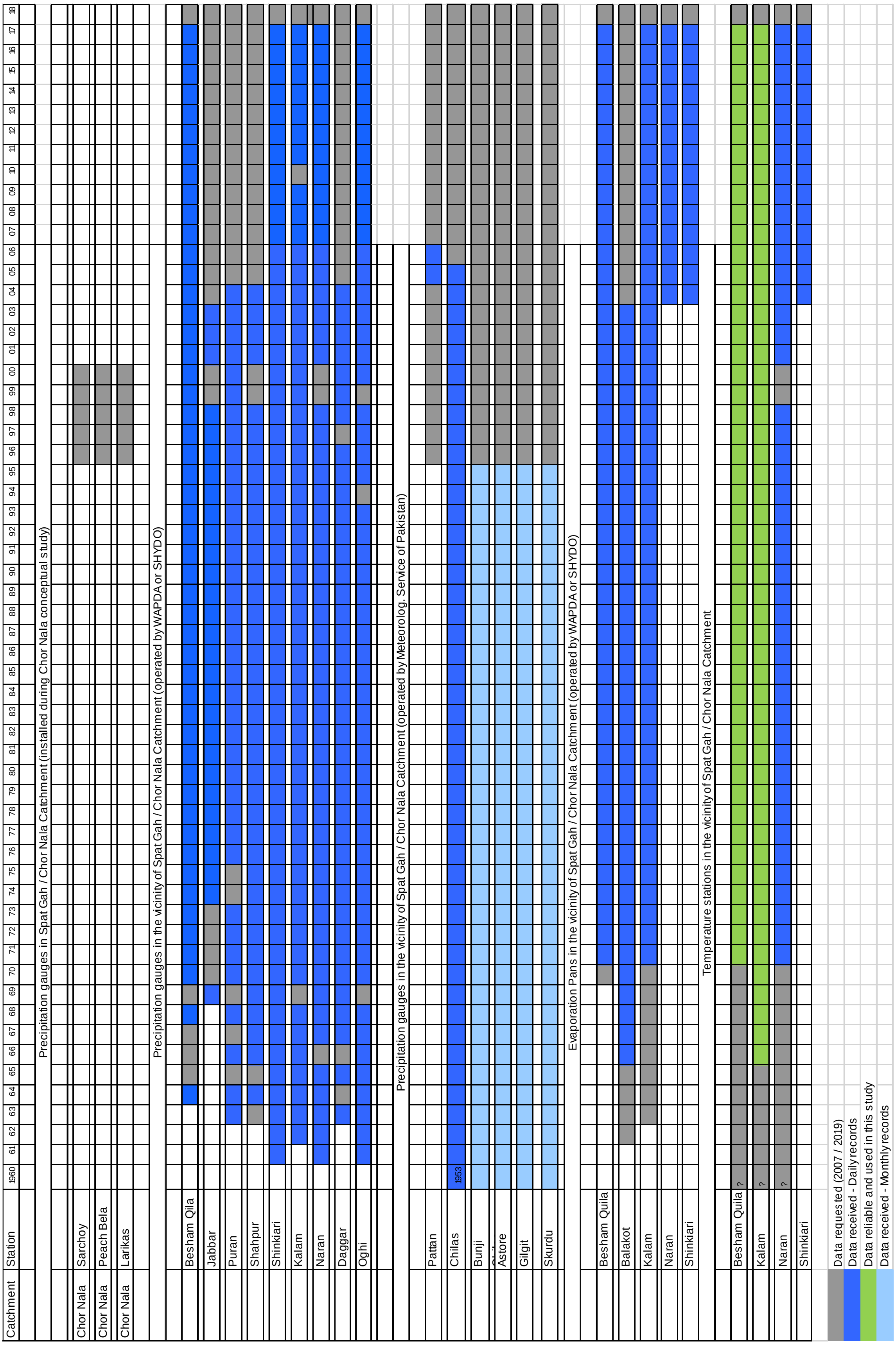


Table 5-2: Meteorological data



5.2.2 New Discharge and Rainfall Gauging Stations in Project Area

Within the Lower Spat Gah Project area, no current discharge or rainfall measurements were available as the existing WAPDA Goshali station is not operated. Therefore one water level and one rain gauge was installed near the Lower Spat Gah Headworks in April 2021 as well near Goshali Bridge in May 2021 by Engineering Axis. The location of both stations has been selected based on hydrological conditions and adjusted on site due to land availability. The water levels are measured in 15 min intervals while the rain is logged hourly. Discharge measurements are taken regularly and a preliminary stage-discharge rating curve has been established in April 2022 with bathymetry sections taken at the stations. Longer period of water level measurements, especially in the high-flow season, and more discharge measurements, are necessary to improve the quality and accuracy of the newly developed rating curves (ongoing activity).

5.2.3 Data Evaluation

5.2.3.1 Discharge

Only one gauging station is currently operated in the Lower Spat Gah catchment, which is the Goshali gauge. It is situated around 2 km upstream of the confluence of the Spat Gah and Indus Rivers. Discharge data for this gauge is available from 1994-1999, April 2007 to July 2010, and January 2011 to December 2016 (Figure 5-2).

The discharge data from 1994 – 1999 shows very high peaks in the first years and very low discharge during the year 1999 and is therefore considered as doubtful.

The discharge data from April 2007 to September 2009 are considered as the most reliable, since this new gauge was installed by Pöyry during the 2010 Feasibility Study including a significant number of discharge measurements and detailed analyses as a basis for rating curve development.

During this period observations were recorded manually on a daily basis (3 readings per day) as well as automatically every 15 minutes. In 2009 the gauge was handed over to WAPDA. In 2010 an extreme flood event occurred at the end of July, obviously damaging the station and resulting in a data gap until the beginning of 2011. However, no explicit information on the damage that occurred during the flood event and the measurement method that was applied after 2011 is available. Figure 5-2 shows that the periods of daily discharge measurements at Goshali show a significant difference between the periods of 2007-2009 and 2011-2016. Especially the years from 2013 onwards show much less inter-daily variations and are also considered to be doubtful.

Therefore only the data from 2007 to 2009 was used as a basis for estimation of long-term inflow series (see Chapter 5.4.2)

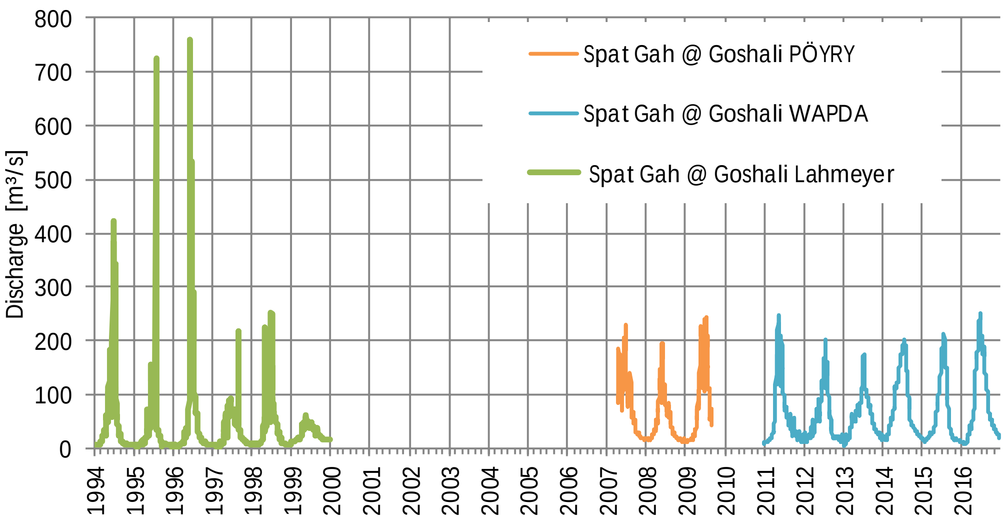


Figure 5-2: Discharge measurements at Goshali between 2007 and 2016

Naran and Talhata show the best data quality and long-time series without gaps, hence the following discharge analyses were mainly based on the data of these two gauges.

5.2.3.2 Double Mass Curves

Double mass curves of the new gauge data and TRMM precipitation are plotted. Based on the experience of the Consultant, TRMM series can be considered quite homogenous, however it is appreciated that they may be affected by considerable systematic errors, but not so much by data instationarities. They were therefore used as a reference series in the double mass curve analyses.

Generally it was found that the data from Talhata can be considered to be the most homogenous.

5.3 Catchment Characteristics

5.3.1 Catchment

The Project area is located in Upper Kohistan District (Khyber Pakhtunkhwa Province) approximately 160 km north of Islamabad. The location of the Lower Spat Gah Headworks and the Lower Gabarband Intake, and their catchment areas are shown in Figure 5-3 and Table 5-3.

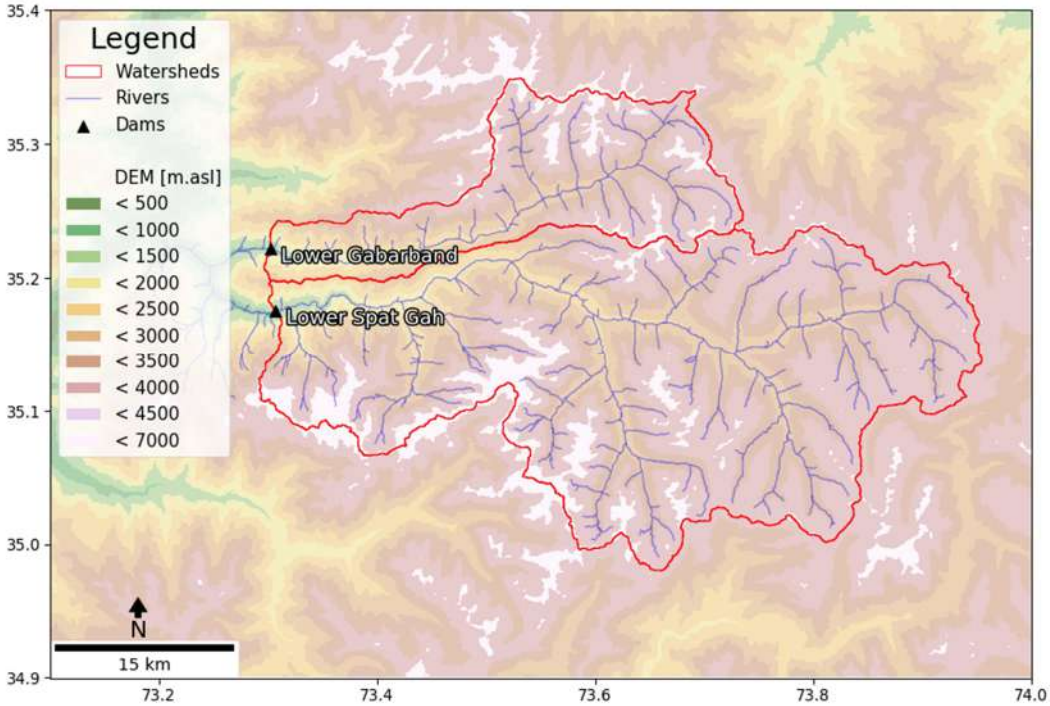


Figure 5-3: Catchment areas of the Lower Spat Gah Project

The catchment areas of Lower Spat Gah Headworks and Lower Gabarband Intake were adopted from the previous studies and verified with the ASTER digital elevation model.

Table 5-3: Catchment areas of Lower Spat Gah Project

Location	Latitude (°)	Longitude (°)	Catchment Area (km²)
Lower Spat Gah Headworks	35.1799	73.3280	1,066
Lower Gabarband Intake	35.2217	73.3019	307

5.3.2 Precipitation

During the 2008 Pre-Feasibility Study [2] and 2010 Feasibility Study [3] detailed analyses on the precipitation characteristics were carried out. Generally it was challenging to define the detailed characteristics as no rainfall stations are located within the Lower Spat Gah catchment.

Rainfall stations situated in the west and east of the Project location show only one precipitation maximum in the winter months which is caused by the westerlies. Stations located further south show high precipitation during July and August which is caused by the monsoon. Stations in the north are very dry.

Generally it can be derived from the station data that the south of the Spat Gah catchment gets more precipitation than the north but it remains partly unclear to which extent the monsoon reaches up to the Spat Gah valley.

5.4 Inflow Hydrology

5.4.1 Water Balance Analyses

The runoff at the Spat Gah cascade weir/dam locations had been previously determined by the Consultant with a water balance analysis in the 2010 Feasibility Study. This sub-chapter is adopted from the 2010 Feasibility Study. The runoff results were used as scaling factors for the calculation of the inflow series of the cascade locations (see chapter 5.4.2).

5.4.2 Construction of Long Discharge Time Series

The regression model that was used for the calculation of the long time series at the Project sites in the 2008 Pre-Feasibility Study [2] and 2010 Feasibility Study [3] had been set up on a monthly basis.

In the current study the energy simulations are modelled on an hourly basis to reproduce the influence of the intra-daily operation of the reservoirs more accurately. Therefore the previous regression model could no longer be used to derive the inflow time series for the energy simulations.

For the generation of a long daily inflow time series, daily observations at the neighbouring Talhata gauge - which is located 88 km away from Goshali - were used, based on a formula proposed by Andréassian et al. (2012). The parameters were calibrated in an iterative way to fit the resulting simulated discharge series well to the observed discharge data of Goshali during the period April 2007 to September 2009 (Figure 5-4). This period is considered to have the best data quality (see Chapter 5.2.3.1).

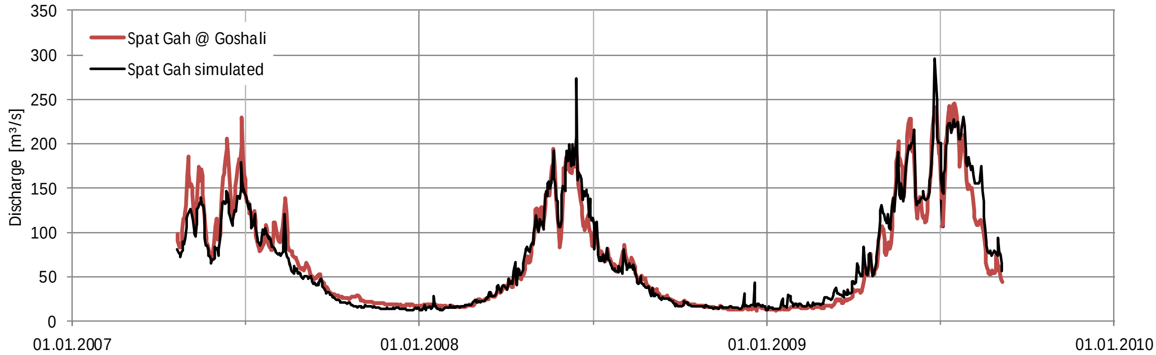


Figure 5-4: Observed and simulated natural discharge at Goshali

The calibrated formula was then applied to the discharge data of Talhata from 1960 – 1992 and 1996 to 2016 (the observed values were used for the period April 2007 to September 2009) to get an inflow time series at Goshali. This was then reduced by the relation of the catchment areas of Goshali and Lower Spat Gah to derive the Lower Spat Gah inflow series (Figure 5-5).

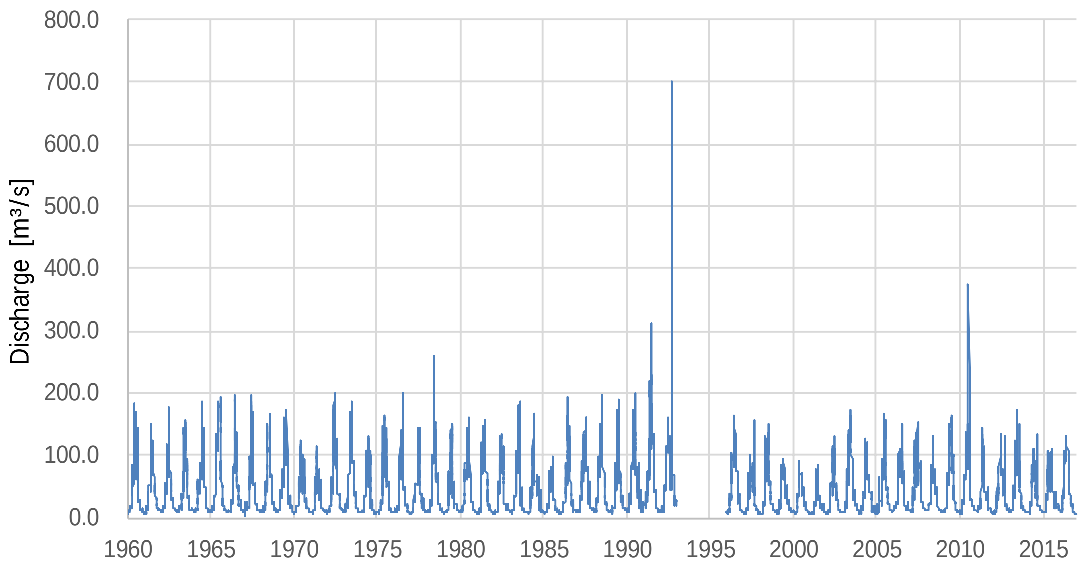


Figure 5-5: Inflow series at Lower Spat Gah Headworks

This approach led to a mean annual discharge at the Lower Spat Gah Headworks which is slightly higher than the one derived with the water balance considerations in the 2010 Feasibility Study (see also Chapter 5.4.1). In the absence of long-term inflow series within the catchment area and considering the fact that the (doubtful) flow records collected at Goshali before 2007 and after 2011 showed considerably lower values than estimated for the long-term mean in the 2010 Feasibility Study, it was decided not to directly use the Goshali flow series derived from the Talhata records based on the formula of Andréassian. Instead some conservativism was applied and the Goshali flow series derived from the Talhata records were reduced by 2% based on the Consultant's experience and engineering judgement.

The mean annual flow of the discharge time series including information of 1996 to 2003 is however still higher than the mean annual flow considered in the 2010 Feasibility Study. This goes well in line with the Mott MacDonald review [5] which states that the Goshali inflow time series calculated in the 2010 Feasibility Study [3] might have been underestimated, since there was a moderate increase of the discharges compared to the ones calculated in the 2010 Feasibility Study.

The mean annual discharges resulting from the runoff calculation (Chapter 5.4.1) were used as a scaling factor to calculate the inflow time series of all Spat Gah and Gabarband dam and weir location from the Lower Spat Gah inflow series.

5.4.3 Mean Inflow and Flow Duration Curves

The updated mean annual runoff and discharge values are listed in Table 5-4 for all dam and weir locations of the cascade. The annual distribution of natural inflow and the flow duration curves of the Lower Spat Gah Project are shown in Figure 5-6, Table 5-5 and Figure 5-7.

Table 5-4: Mean natural annual runoff and discharge of the cascade locations

Location	Catchment Area (km^2)	Runoff (mm)	Mean Discharge (m^3/s)	2010 Mean Discharge (from [3]) (m^3/s)
Upper Spat Gah	759	1,267	30.5	29.0
Middle Spat Gah	831	1,233	32.5	30.9
Lower Spat Gah	1,066	1,204	40.7	38.8
Upper Gabarband	226	878	6.3	6.0
Middle Gabarband	280	856	7.6	7.2
Lower Gabarband	307	828	8.1	7.7

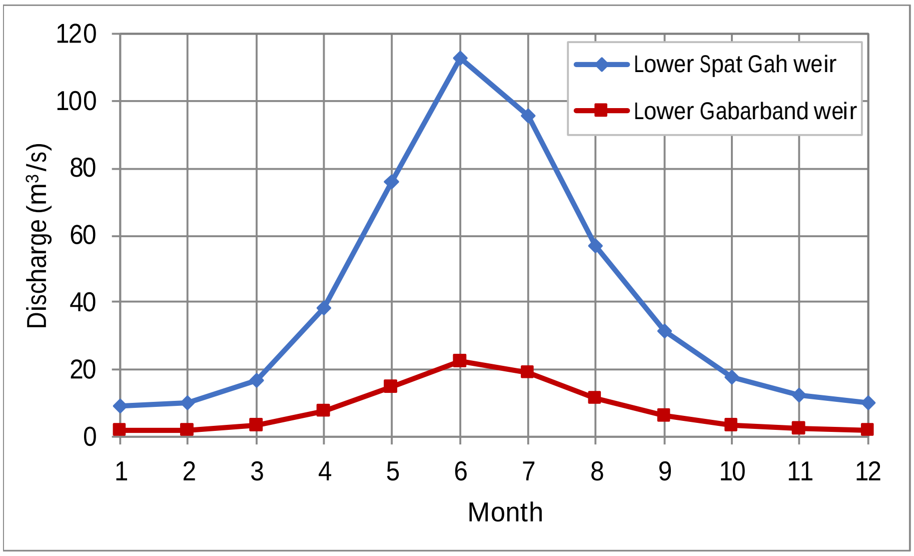


Figure 5-6: Mean monthly natural inflow of Lower Spat Gah and Lower Gabarband weir sites

Table 5-5: Mean monthly streamflow

Month		1	2	3	4	5	6	7	8	9	10	11	12
Discharge (m^3/s)	Lower Spat Gah Headworks	8.9	9.9	17	38	76	113	96	57	32	18	13	10
	Lower Gabarband Intake	1.8	2.0	3.4	7.6	15	22	19	11	6.3	3.5	2.5	2.0

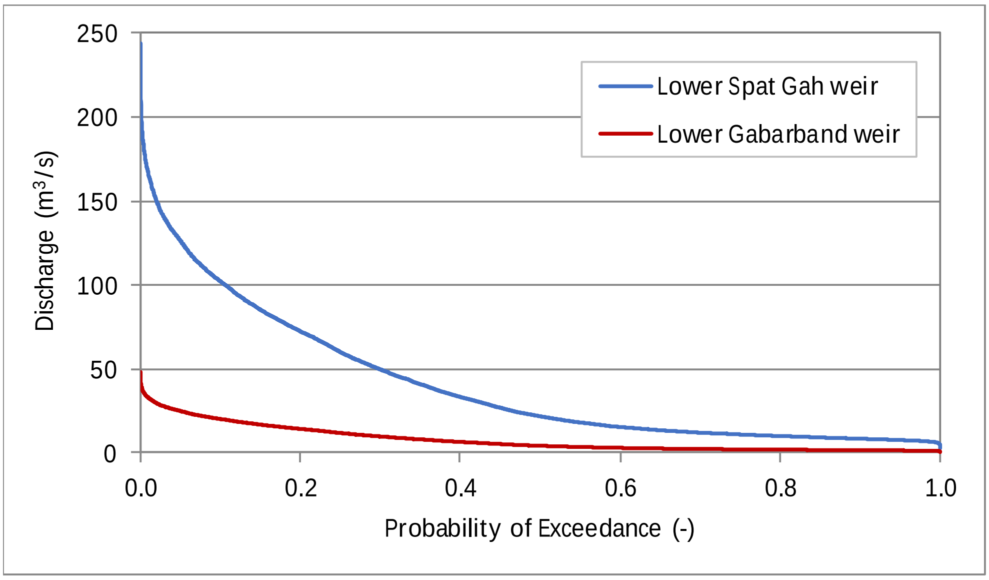


Figure 5-7: Flow duration curves of natural inflows of Lower Spat Gah and Lower Gabarband weir sites

5.5 Flood Estimates

5.5.1 Flood Design Values for Lower Spat Gah Headworks

Flood design values up to the 10,000-year flood were in two ways:

- Regional flood frequency analysis (FFA) approach based on statistical analyses of flood events in neighbouring catchments
- Observations from the Goshali gauging station

The flood values using the flood frequency analysis were calculated via the specific flood peak discharge and a correction factor of 1.15 which accounts for the difference in monsoon exposure, as applied in the Pre-Feasibility Study. The median of the best fitting probability distributions for the extended Talhata series were used.

The analysis of the observation data at Goshali did not include data from 2011 onwards as the newly available data is doubtful (Chapter 5.2.3.1). The extreme flood in July 2010 was however included in this updated analysis. The flood peak on 29 July 2010 can only be estimated based on proxy data. The calculation from the discharge at Talhata gauge leads to a peak value of 720 m^3/s, which still seems to underestimate the real peak value. Therefore a value of 800 m^3/s was chosen. This value is also close to the discharge level at which severe damage of the gauging station was expected when the station was designed and installed by Pöyry in 2007.

Table 5-6 shows the results of the updated regional FFA and the updated results from the observations at Goshali. Since the regional FFA is based on a much longer time series, the values of this analysis are recommended as the design values to be used.

Table 5-6: Results of different flood estimation approaches and updated design flood values

Recurrence Interval (years)	Flood Discharge (m^3/s)	
	Goshali Observation Update	Recommended Design Values - Regional FFA Update
1	195	195
2	265	261
5	390	388
10	505	494
20	605	614

Recurrence Interval (years)	Flood Discharge (m^3/s)	
	Goshali Observation Update	Recommended Design Values - Regional FFA Update
30	690	694
50	825	797
100	960	950
200	1,100	1,125
500	1,290	1,391
1,000	1,435	1,622
5,000	2,220	2,299
10,000	2,460	2,595

5.5.2 Design Floods for Lower Gabarband Intake

Table 5-7 shows the updated results with both applied methods for the Lower Gabarband Intake, as in Table 5-6 for the Lower Spat Gah Headworks. As for the Lower Spat Gah Headworks, the recommended design values are based on the regional FFA due to the very long available time series used for this analysis.

Table 5-7: Updated design flood values for Lower Gabarband Intake

Recurrence Interval (years)	Flood Discharge (m^3/s)	
	Goshali Observation Update	Recommended Design Values - Regional FFA Update
1	-	65
2	140	85
5	205	125
10	270	160
20	320	200
30	365	225
50	435	260
100	510	310
200	585	365
500	685	455
1,000	760	530
5,000	1,175	750
10,000	1,300	850

5.5.3 Estimation of Probable Maximum Flood

In the 2008 Pre-Feasibility Study a heavy rain-on-snow event occurring at the beginning of the monsoon period, when large parts of the catchment are still snow-covered, has been identified as most critical situation causing floods in the Project area.

The general scenario as it was applied in the Pre-Feasibility Study has also been adopted for PMF calculations in the 2010 Feasibility Study. However, the detailed analyses of the snow cover based on satellite images revealed that the assumption on the extent of the snow cover at the beginning of the monsoon period had been too conservative. Furthermore some of the meteorological parameters relevant for snowmelt computations had to be adjusted in order to be within a plausible range. This applies first of all to the temperature data. The observations of air temperature at Goshali showed that for a precipitation event in June a temperature of 25°C at an elevation of 1,000 m asl is not a realistic assumption. Also the assumed wind speed has been reduced slightly.

Precipitation-runoff computations for the Lower Spat Gah dam site have been carried out using precipitation events (PMP+Melt) of different durations as input data. The duration of the precipitation resulting in the maximum flood peak was considered to determine the PMF event. In case of the Lower Spat Gah dam site this was the 12 hour rainfall event. The calculated PMF values are listed in Table 5-8.

Table 5-8: PMF computed for Lower Spat Gah Headworks (from [3])

	Lower Spat Gah
Critical duration t (h)	12
PMF (m^3/s)	3,625

5.6 Sediments

An analysis of sediment transport in the Lower Spat Gah catchment was already carried out in the Pre-Feasibility Report [2], based on the following data:

- Review of earlier studies,
- Findings in the literature,
- Data from neighbouring catchments,
- Data collected during site visits.

This analysis was further refined during the 2010 Feasibility Study with the following additional data taken into account and tasks performed.

- Analyses of regular sampling of suspended sediment at Goshali Bridge,
- Numerical simulation of bed load transport in the Lower Spat Gah reservoir area.

For this new Feasibility Study the suspended sediment data from Talhata Bridge was available for the period from January 2007 to December 2016.

5.6.1 Suspended Load

As part of the 2010 Feasibility Study a sediment sampling programme was started in April 2007. Samples of suspended sediment were taken in regular intervals at the gauging stations Goshali (Spat Gah valley) and Sarchoy (Palas valley). Besides that a few samples were also collected at the Lower Spat Gah and Lower Palas dam sites.

The samples showed a concentration of suspended load in the range between 2 ppm (low flow period in autumn and winter) and 100 ppm (snow melt and summer floods). The concentration of the samples are widely scattered but show a clear trend towards higher concentrations at higher discharges.

Generally the concentrations of suspended sediments observed at Goshali were significantly lower than expected. Two possible sediment rating curves were derived from the sampled data and results based on the upper envelope curve were considered as conservative estimates.

Besides the grain size distribution also a petrographic analysis was carried out for a selected sample. The content of Quartz is in the range of 40%, which is rather high. This will be taken into account when designing the electromechanical equipment (turbines).

The annual sediment yields for Goshali have been derived from the discharge records 1994-2000 and 2007-2009 using the two sediment rating curves (upper envelope curve and regression curve) described above. At the Lower Spat Gah dam site the total annual yields of suspended sediment derived from the envelope curve range from 25,000 t/year to 270,000 t/ year with an average of

105,000 t/year. The average specific sediment yield is 99 t/km²/year and varies between 22 t/km²/year and 250 t/km²/ year. If the regression curve is used as sediment rating curve, the computed yields are significantly smaller (only 20 to 25% of above values).

These results were then compared with suspended sediment data from neighbouring areas. The sediment data clearly indicate that the monsoon is the main factor determining the suspended sediment loads in the rivers of Khyber Pakhtunkhwa Pakistan. Specific sediment yields in the catchments exposed to monsoon rainfalls (Kunhar at Garhi Habibullah, Gorband, Siran and Allai Khwar) are approximately 10 times higher than in the catchments not affected by monsoon (Kunhar at Naran, Swat). Besides high rainfall and runoff intensity during the monsoon period, probably also the availability of erodable soils explain the high loads of suspended loads observed at Garhi Habibullah, Phulra and other gauges.

A comparison of specific sediment yields found for different basins in the world indicates that sediment yields in the upper tributaries of the Indus basin (Hunza) are also extremely high, which can probably be linked to glacier phenomena.

For the verification of the suspended sediment yields estimated for the Lower Spat Gah dam site, probably the most representative stations are Larikas and Sarchoy (Palas valley), Kalam (Swat valley) and Naran (Kunhar valley). They are hardly influenced by the monsoon and drain catchments of similar characteristics. The specific sediment yields estimated for these catchments range from 170 to 780 t/km²/ year.

In the 2010 Feasibility Study [3] an average sediment yield of 20 t/km²/year was derived from the regression curve. A value of 100 t/km²/year estimated for the Lower Spat Gah dam site (sediment rating based on the upper envelope curve) also seems to be too low because the measurements at Goshali were done in years without high discharge peaks. Therefore it is now proposed that the value be increased to 200 t/km²/year to be on the conservative side.

5.6.2 Bed Load

Bed load samples were taken during the Pre-Feasibility Study at the Lower Spat Gah dam site using the line-by-number method. Generally the samples were taken as close to the river as possible. However, since snowmelt season had started and water levels were already rising when the site visit was carried out in April 2007, it was hardly possible to take samples directly from the river bed. The samples were therefore generally considered as being a mixture of bed material and coarse sediments deposited during previous floods, with the characteristic grain size dm being somewhat coarser than the dm of a sample taken from the subsurface layer of the river bed. The graduation curves generally range from 1 to 100 cm with the characteristic grain size d50 being in the order of 15 to 30 cm.

Besides rock slides and earth movements, which were a basin-wide phenomenon during the 2005 Kashmir earthquake, big floods, occurring during the monsoon season, are considered the main factors for sediment generation and transport. Sediment generated at higher elevations is transported to the main rivers by numerous tributaries, most of them being very steep creeks and consequently having a significant transport capacity during floods.

The Shaha Gah River, which is a left bank tributary to the Spat Gah joining the main river directly at the Lower Spat Gah dam site, is considered as the most problematic with respect to sediment transport. Probably most of the sediment which will reach the reservoir of the Lower Spat Gah dam will originate from this tributary. It is not clear whether there is also a potential for glacial lake outbursts, but definitely the transport capacity and also the actual bed load transport of the Shaha Gah are extremely high.

5.6.3 Bed Load Transport in the Main Rivers to the Dam Sites (Meso Scale)

Sediments transported by tributaries or directly by rockfall or avalanches to the main rivers are first deposited and later moved further downstream by floods. The transport capacity of the main rivers is therefore crucial for the amount of bed load reaching the reservoir areas.

In order to get estimates of this transport capacity, bed load transport capacity was computed for all dam sites using the formula of Meyer-Peter-Müller. In the computations it was assumed that the transport capacity of a river reach would be limited by the sections with the minimum transport capacity. The results of the bed load transport capacity estimate are 0.36 million t/year.

The values should be understood as a first estimate of an upper limit for bed load transport, which is possible in the main river upstream of the dam site. The actual bed load transport is probably lower. As a rule of thumb the actual rate of bed load transport is frequently assumed to be in the order of 20% of the transport rate for suspended load. Applying this rule to the suspended sediment data estimated in the previous section, the actual bed load transport in Spat Gah (0.04 million t/year) would be significantly below the transport capacities computed by the Meyer-Peter Müller formula. The transport rates estimated by applying the 20%-rule could therefore be understood as lower limits of bed load transport to be expected for the dam sites.

Similar to the suspended load the total yields of bed load which have to be expected for the dam sites mainly depend on the magnitude and frequency of floods occurring during the monsoon season. The monsoon influence is probably different for the upper and lower reaches of the Project area. However, the regional differences of the monsoon impact are currently uncertain due to the very limited precipitation and runoff data observed in the catchment. Long-term monitoring of the hydro-meteorological conditions within the Project area is therefore considered a precondition for more accurate estimation of sediment transport to the dam sites.

Especially at the Lower Spat Gah dam site the major bed load transport into the reservoir area will not be determined by the transport capacity of the main river (Spat Gah) but by the tributary Shaha Gah. Especially during summer floods torrents might transport enormous amounts of sediments to the main valley, which will be deposited only a few 100 m upstream of the reservoir.

A retention structure on the Shaha Gah is not foreseen in the design as its construction would be a very expensive measure to retain only a small part of the transported boulders and to be maintained. Should all boulders of an event need to be captured on the Shaha Gah, then an extremely expensive structure would have to be foreseen. However, boulders coming from the Shaha Gah will be mainly mobilised during large to very large floods and storm events. During those events, and when the material is transported to the reservoir, the radial gates of the Lower Spat Gah Headworks are open and the material will be transported through the reservoir to the downstream area. Smaller sediments will be transported through the reservoir and released to the downstream via recirculation current and venting effect due to the very large capacity of the flushing channels and the very short length of the reservoir.

Should boulders and other deposited sediments become an impediment to the normal operation of the plant, then it is foreseen that these will be mechanically removed using large excavators and dump trucks and sent to disposal areas.

5.6.4 Sediment Sampling Campaign 2020-2021

Suspended sediment and bed material sampling has started in September 2020 in order to obtain the sediment concentration and particle size distribution at the Lower Spat Gah Headworks, Lower Gabarband Intake and Goshali Bridge and continued until July 2021. The grain density and mineralogy was determined for a few samples in the high-inflow season.

The required preliminary annual reservoir flushing has been theoretically estimated based on the estimated bedload and suspended sediment influx and assumed flushed volumes per flushing event. Four to nine annual flushing events would be required in order to maintain the active storage at the Lower Spat Gah Headworks. Due to the limited Lower Gabarband Intake reservoir, the flushing channel will have to be operated more frequently and diligently during larger inflows when most of the material is transported.

Preliminary flushing cycles have also been estimated for the desanders and showed that the sediment would need to be flushed once every 14 weeks at the Lower Spat Gah desander based on the settled material. A more frequent flushing does however seem to be more applicable based on experience from existing desanders in similar areas characterised by high sediment transport.

Preliminary water losses of 0.5% to 1.1% have been estimated at the Lower Spat Gah Headworks under design flow conditions if the desander is flushed once to twice a week. Because the sediment samples taken during the low-flow season showed show that the particle sizes are below the desander design grain size, a minimum flushing frequency for the low-flow season will have to be defined based on a trial during operation.

The preliminary water losses at the Lower Gabarband Intake desander have been estimated in the range of 0.1% to 0.2% for once to twice-weekly flushing due to the run-of-river operation of the reservoir.

5.7 Recommendations

It is recommended to conduct the following further investigations for a minimum of one full hydrological year:

- Pursue and improve ongoing water level and discharge measurements:
    - Collect further inter-daily measurements to be able to observe the snow melt and get even more reliable on floods;
- Rainfall measurements in the Project area:
    - Collect further inter-daily rainfall data;
- Pursue ongoing sediment sampling and testing campaign with emphasis on the high-inflow season to confirm the design grain size of the desanders and the electro-mechanical design that is sensitive to sediments abrasion. In addition, investigate the shape of quartz as a further input for the turbine supplier.

Numerical modelling of the sediment in the Lower Spat Gah Headworks and Lower Gabarband Intake reservoir is recommended in a next Project phase to evaluate the effectiveness and efficiency of the sediment flushing and potential impact on active reservoir storage and develop operation Flood and Sediment Management Plans.

6 Geology

Corresponding Drawings

LSG-FS-030-001	Geology, Project Area, Overview Map
LSG-FS-030-002	Geology, Lower Spat Gah Headworks, Plan View
LSG-FS-030-003	Geology, Lower Spat Gah Headworks, Sections A-A & B-B
LSG-FS-030-004	Geology, Lower Gabarband Intake, Plan View
LSG-FS-030-005	Geology, Lower Gabarband Intake, Sections A-A & B-B
LSG-FS-030-006	Geology, Gabarband Crossing, Plan View
LSG-FS-030-007	Geology, Gabarband Crossing, Section A-A
LSG-FS-030-008	Geology, Headrace Tunnel & Pressure Shaft, Longitudinal Profile
LSG-FS-030-009	Geology, Powerhouse & Tailrace Tunnel, Plan View
LSG-FS-030-010	Geology, Powerhouse & Tailrace Tunnel, Longitudinal Profile
LSG-FS-030-011	Geology, Gabarband Intake Tunnel, Longitudinal Profile

6.1 Introduction and Overview

This geological chapter is a summary of Volume 4 – Geology which presents the results of the geological and geotechnical investigations carried out during the 2008 Pre-Feasibility [2], 2010 Feasibility [3] stage as well as this Feasibility Study for the Lower Spat Gah Project. Volume 4 also includes information from the 2013 Geotechnical Due Diligence [4] and has been updated to the new alignment where possible.

6.2 Executed Investigations

6.2.1 Investigations 2008-2010

The following investigations had already been carried out in the Pre-Feasibility stage:

- Geological mapping at scale 1:10,000 along the entire Spat Gah valley,
- Geological mapping at scale 1:2,500 at dam site and Powerhouse locations,
- Petrographical investigations on rock samples of entire Spat Gah valley,

The following investigations have been carried out at Feasibility stage:

- Geological mapping of natural hazards of access road to Lower Spat Gah Headworks at scale 1:1,000,
- Geological mapping of Lower Spat Gah reservoir scale at scale 1:2,500,
- Geological mapping of Lower Spat Gah Headworks area at scale 1:1,000,
- Geological mapping of Lower Gabarband Intake at scale 1:1,000,
- Geological mapping of Lower Spat Gah Powerhouse area at scale 1:2,500 (final location).

Drilling Works

An overview of the drilling depths is presented in Table 6-1.

Table 6-1: List of drillholes performed in 2008 and 2009

Borehole	Total Drilling Depth (m)	Length in Overburden (m)	Length in Bedrock (m)
Lower Spat Gah dam site			
LSDH-1	115.0	4.5	110.5
LSDH-2	70.0	51.3	18.7
LSDH-3	68.3	68.3	0.0
LSDH-4	1.5	1.5	0.0
LSDH-5	30.3	9.5	20.5
LSDH-6	31.0	6.0	25.0
LSDH-9	60.0	60.0	0.0
LSDH-10	60.3	60.0	0.0
Total Dam	435.8	261.1	174.7
Powerhouse			
LSDH-11	115.0	0.3	114.7
Total Dam + PH	550.8	261.4	289.4

Test Pits

Test pits have been carried out for the investigation of alluvium and scree in the dam site area as well as for construction material purposes in borrow areas.

Geophysical Investigations

Geophysical investigations have been carried out at the Lower Spat Gah dam site and in the Indus valley at the 2010 Feasibility Study Powerhouse location which was not selected as final location, so that these investigation results are not representative for the present location of Powerhouse.

Geological Mapping

Geological mapping was carried out at the Lower Spat Gah Headworks, Powerhouse site and Lower Gabarband Intake. Furthermore geological mapping was done in side valleys close to the proposed Power Waterway. Due to limited budget and the steepness and remoteness of the terrain it was not possible to carry out drillholes along the Power Waterway alignment, therefore the geological mapping was carried out with the intention to obtain surface information and to gain knowledge as far as possible regarding thickness of faults.

6.2.2 Investigations 2013

In 2013 an additional study was carried out by Geotech Consultant. One borehole was drilled at the 2010 Powerhouse area and geophysical investigations were carried out at the major engineering facility areas. Geological investigations confirmed the pre-existing data but additional small intrusive bodies have been observed. In addition a classification and more detailed investigations along lineaments have been carried out.

In addition geoelectrical investigations have been carried out in the Lower Spat Gah, Powerhouse area and Lower Gabarband Intake areas with a total length of 5.4 km.

6.2.3 Investigations 2020-2021

The following investigations have been carried out as part of the 2020-2021 geological investigation for the update of the existing Feasibility Study:

- Geological mapping of natural hazards of the Gabarband Crossing and Gabarband valley access road at scale 1:1,000,
- Drilling works at the Lower Spat Gah Headworks, Lower Gabarband Intake, Gabarband Crossing and Indus/Tailrace areas,
- Soil penetration tests (short boreholes) at the Jhul, Jalkot and Dar Mose borrow areas,
- Test pits at the Lower Spat Gah Headworks, Lower Gabarband Intake and Gabarband Crossing areas,
- Electric resistivity survey along part of the Tailrace Tunnel alignment,
- Laboratory tests on soil rocks and aggregates material.

Drilling Works

An overview of the drilling depths of the 15 executed boreholes is presented in Table 6-2.

Table 6-2: 2020-2021 boreholes campaign information

Borehole	Depth (m)	Length in Overburden (m)	Length in Bedrock (m)
Lower Spat Gah Headworks			
LSG20-HW-01	Cancelled by Client due to time issues		
LSG20-HW-02	55.00	32.50	22.50
LSG20-HW-03	52.00	52.00	0.00
LSG20-HW-04	82	70	12.00
LSG20-HW-05	35	27.6	7.4
Total Headworks	224	182.1	41.9
Lower Gabarband Intake			
LSG20-GI-01	50	50	0
LSG20-GI-02	42	42	
LSG20-GI-03	30	30	
LSG20-GI-04	15	5.30	9.7
Total Intake	137	127.3	9.7
Gabarband Crossing			
LSG20-GC-01	30	7	23
LSG20-GC-02	32.90	10	22.90
LSG20-GC-03	39.80	39.80	-
LSG20-GC-04	40	29.35	10.65
Total Crossing	142.7	86.15	56.55
Tailrace Powerhouse Access Tunnels			
LSG20-IT-01	22.8	9.70	13.10
LSG20-IT-02	40	33.6	6.4

Borehole	Depth (m)	Length in Overburden (m)	Length in Bedrock (m)
LSG20-IT-03	Not drilled because all necessary information have been obtained by other boreholes and seismic survey		
LSG20-IT-04	60	42.17	17.83
Total Tailrace	122.8	85.47	37.33
Total all Boreholes	626.5	481.02	145.48

Test Pits and Soil Penetration Tests

Additional test pits have been carried out for the investigation of alluvium and scree in the Lower Spat Gah Headworks, Lower Gabarband Intake and Gabarband Crossing areas as well as for construction material purposes in borrow areas close to the Lower Spat Gah Headworks and Powerhouse sites.

Laboratory Tests

Numerous laboratory tests have been carried out for the purpose of the Feasibility Study during the period 2020-2021 study to check the overburden and rock mass properties and to proof availability and quality of construction materials.

Geophysical Investigations

Geophysical investigations have been carried out in the Powerhouse area in the Indus valley to investigate the presence of potentially active faults along the Tailrace Tunnel alignment.

Geological Mapping

A complementary geological mapping was carried out within the Gabarband Valley. The main objective of the mapping was to collect important additional geological information as required for the design of the new access road along the Gabarband River and for the design of the Gabarband Crossing area including the portals of the adits to the Headrace Tunnel.

6.3 Project Site Geomorphology

The morphological conditions at the Lower Spat Gah Headworks are shown in Figure 6-1. The mountain slopes are stable and uncovered, but at right bank downstream of the newly selected dam site a thick scree cover resulting from rock fall has developed. Due to the lack of fine soil particles and therefore missing water retention capacity of the soil these zones are uncovered.

The unvegetated most active scree cone can be seen in Figure 6-1 at the right bank (approximately in the middle of the photo) including the white coloured rock fall zone at the rock slope above. Slope wash deposits, generally encountered at the lower parts of the slopes are covered by forest.

Figure 6-1: Morphological overview of Lower Spat Gah Headworks site with arrow indicating rock fall zone (view in downstream direction)

6.4 Project Area Tectonic Setting

6.4.1 Active Faults

According to literature the weir site is not influenced by active faults.

But there are different views concerning Waterway and Indus area. The active fault map of Erdik shows the end of an active fault in the Project area. The fault map of Zeilinger shows a "major fault" but is not describing it as active.

According to the 2013 Geotech Consultant study there are active faults in the proximity of the Indus valley, namely the lineament 0 and Jhul nullah (located in close distance to the tunnel portal of the Powerhouse access). Lineament 0 runs parallel to the Indus (NE-SW) or partly within the Indus river bed and crosses the Tailrace Tunnel (Figure 6-2). The judgement concerning activity of faults is based mainly on the evaluation of satellite images and topographic features.

It is noted that the orientation of lineament 0 is not coinciding with the main faults sketched in the literature, but Jhul nullah lineament would match with the "major" fault of Zeilinger et al. 2000.

In the course of the 2010 and 2020 – 2021 studies no evidence for ground-breaking zones have been found. The geological mapping and the analysis of aerial photographs did not evidence the presence of any active fault in the project area but no special investigations have been carried out.

Due to travel restrictions related to the Covid pandemic a field inspection of the Indus area where potential active faults are present was not possible. These lineaments (Figure 6-2) shall be inspected in the field during the next project phases.

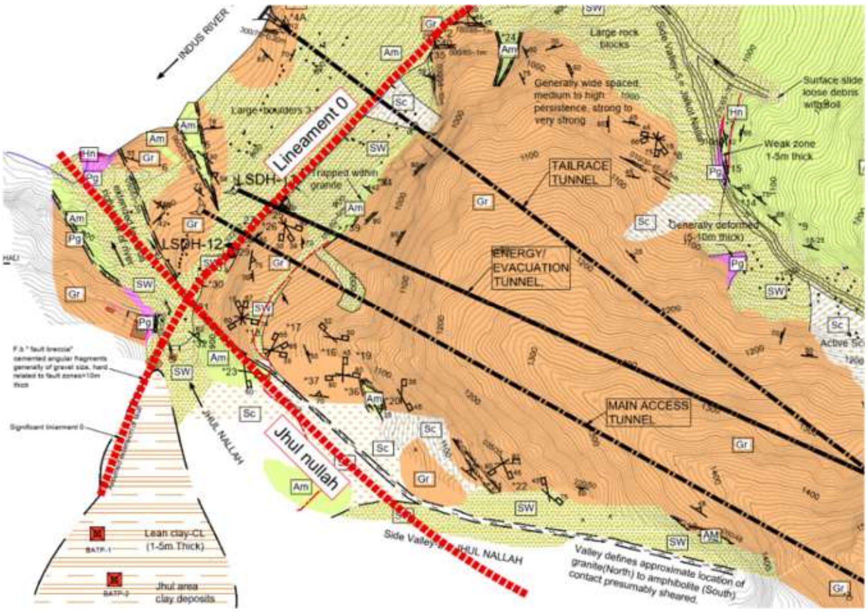


Figure 6-2: Lineament 0 and Jhul nullah lineament, active faults (Geotech Consultant 2013)

6.5 Project Site Geology

6.5.1 Lower Spat Gah Headworks Area

Dam Location

During the Alternatives Study of this Feasibility Study, the dam axis was shifted upstream and the new dam axis is located downstream of the confluence of the Spat Gah and Shaha Gah Rivers some 300 m upstream of the dam axis that has been previously selected in the 2010 Feasibility Study (Figure 6-3).

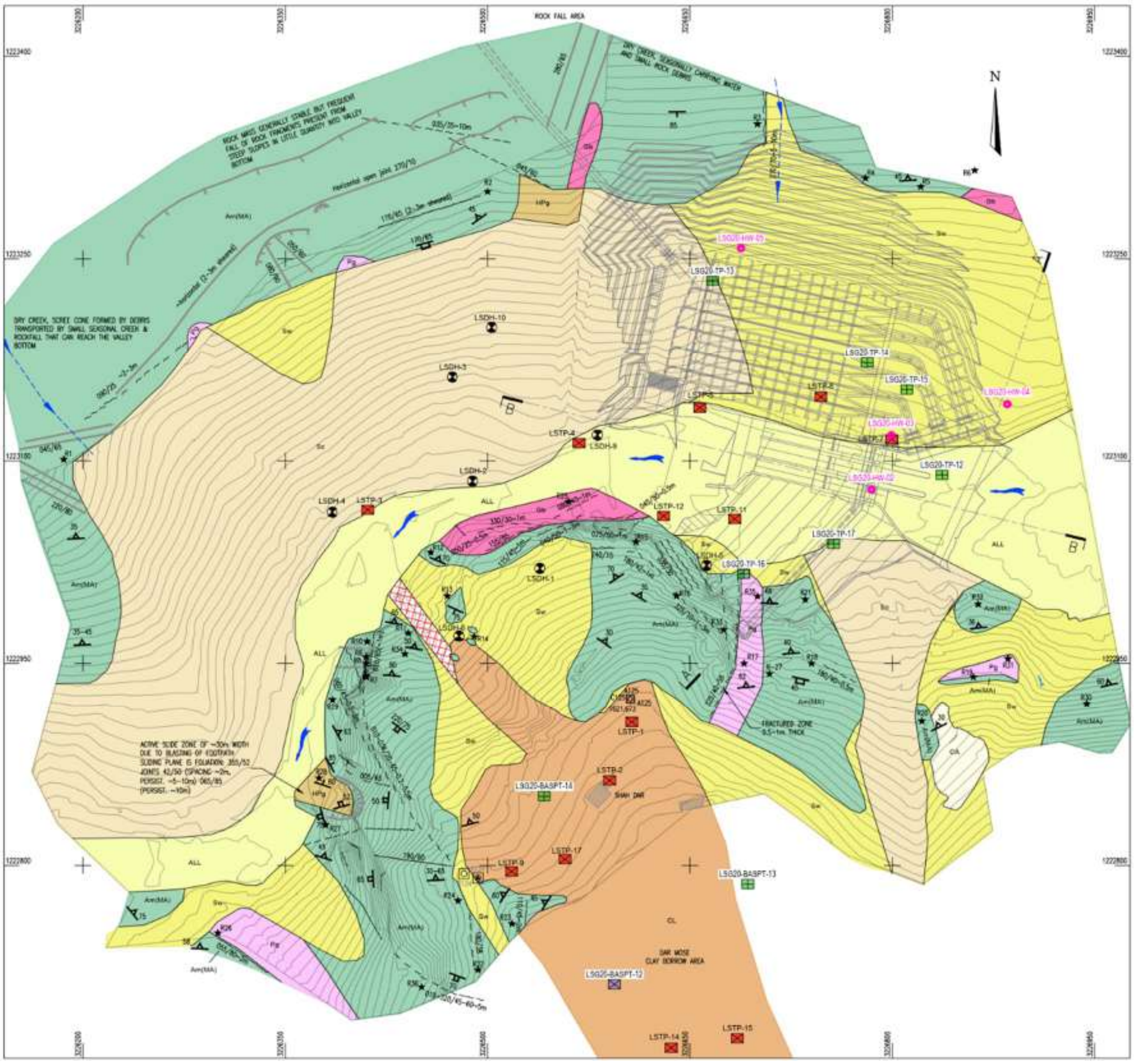
The new dam site has been selected as an outcome of a desktop study based on topographical and geological considerations. Its suitability was ultimately confirmed during a site visit and by means of field investigations carried out during the period 2020-2021 as part of the Feasibility Study Update.

The new dam axis is characterised by less scree deposits along the right bank and a lower rockfall hazard than at the older location as evidenced by the well-developed vegetation and trees growing on the scree deposits (Figure 6-3). Zones of high rock all activity usually are indeed often characterised by a lack of vegetation as observed at the old dam axis.

It was observed that the left and right abutments appeared to be roughly in the same condition as one decade ago.

Figure 6-3: Dam site (blue: axis 2010; brown: weir axis 2020-2021) (view towards downstream)

The finding from the new investigations generally confirm those from the 2008-2009 campaign at the downstream dam axis. As shown on the geological map axis (Figure 6-4), rocks form the Mandraza Amphibolite unit outcrop at both sites on both river banks, while the lower part of the slopes are covered with scree and slope wash deposits and the riverbed is filled up with very coarse grained alluvium. The encountered loose sediments can be classified as very coarse-grained alluvial sediments and scree (blocks from rockfall).



OVERBURDEN		
	SILTY CLAY: LOW TO MEDIUM PLASTIC	CL
	ALLUVIAL DEPOSITS, SUB ROUNDED, TO ROUNDED, COARSE TO FINE GRAINED WITH BOULDERS	ALL
	SLOPE WASH, ANGULAR TO SUB ANGULAR, MIXED GRAINED WITH FINES	Sw
	SCREE, ANGULAR, MEDIUM TO COARSE GRAINED MATERIAL WITH BOULDERS	Sc
	SLOPE WASH+SCREE DEPOSIT	Sw+Sc
	CULTIVATED AREA	CA

ROCK UNITS		
	KEYAL GABBRO & DIORITE (KGD)	
	GABBRO: MEDIUM TO COARSE GRAINED, MASSIVE, STRONG TO VERY STRONG.	Gb
	DIORITE: LIGHT GRAY, MEDIUM GRAINED, THICKLY BEDDED, STRONG.	Dt
	MANDRAZA AMPHIBOLITE (MA)	
	AMPHIBOLITE: FINE TO MEDIUM GRAINED, LAYERED/BANDED, SLIGHTLY TO MODERATELY FOLIATED.	Am(MA)
	NORTHERN AMPHIBOLITE (NA)	
	AMPHIBOLITE: FINE TO MEDIUM GRAINED, STRONGLY LAYERED, SLIGHTLY TO MODERATELY FOLIATED, OCCASIONAL SHEAR PLANES PARALLEL TO FOLIATION.	Am(NA)
	PLAGIOCLASE GRANITE (PG)	
	GRANITE: WHITISH GREY, MEDIUM TO COARSE GRAINED, SLIGHTLY FOLIATED. AND MICACEOUS, STRONG TO VERY STRONG.	Gr
	PEGMATITE: WHITE, CRYSTALLINE, COARSE GRAINED, MASSIVE, CONTAIN MICA CLUSTERS, STRONG.	Pg

Figure 6-4: Geological map of Lower Spat Gah Headworks site area

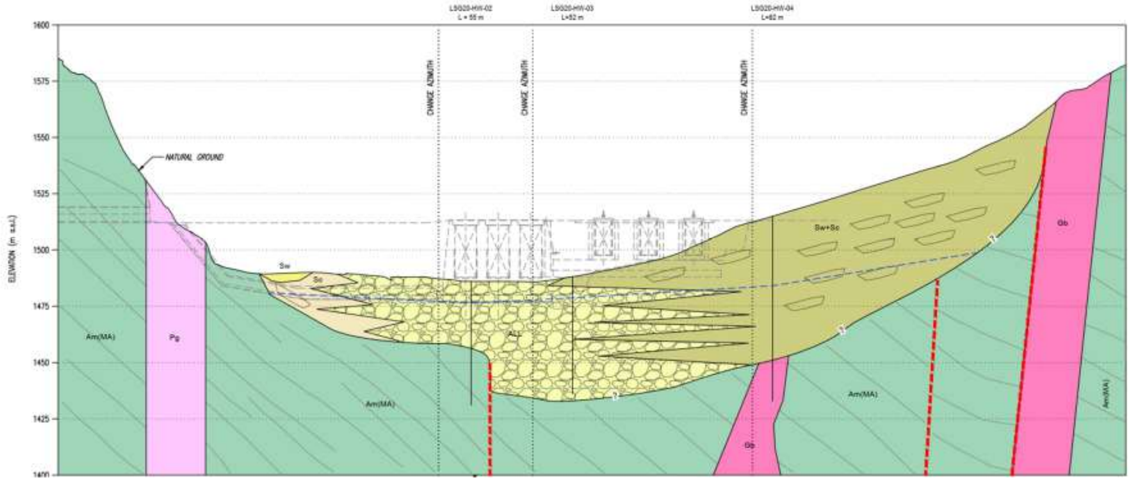


Figure 6-5: Geological section of Lower Spat Gah Headworks axis

Drillholes and Tests Results

The most frequently encountered rock type was called "amphibolite" which shows a pronounced foliation and preferred orientation of flaky minerals.

According to the petrographic investigations performed on boreholes cores, the rock was identified as "amphibolite" or "Chlorite-Epidote-Plagioclase Amphibolite or Gneiss "or as "Mylonite granite". The quartz content ranges between 8-31% and the amphibole content between 0-34%. The phyllosilicates content (biotite, muscovite and chlorite) ranges between 4-27%. A pegmatitic dyke and a small gabbro dyke, intruding the amphibolite were found along the left abutment and above the right abutment.

All lithologies found in the Mandraza unit can be classified as hard to very hard rocks. The observed conditions of the outcropping rock mass are generally good. At the new dam axis the jointed rock has a blocky appearance and in boreholes LSG20-HW-02 and LSG20-HW-04 more than 80% of the cores have a RQD value in the range of 50 to 100.

The foliation of the rocks dip towards north, which is in accordance with the regional orientation and with the results found during geological mapping for the Headrace Tunnel alignment. The orientation of the foliation planes is comparable at both banks.

The discontinuity sets show that joint set 1 and also the main shear zone orientation ("shear zones 1") are parallel to the foliation. Therefore these North dipping discontinuity planes are of greatest importance.

Water pressure tests showed that the top rock zone of approximately 35 m thickness has a high permeability with open joints, but below that depth rather low values indicate a rock mass with mostly closed joints. At the left bank a fault zone with a thickness in the range of 40 m has been encountered in hole LSDH-6 approximately 40 m downstream of the 2010 dam axis, but that zone will not affect the weir axis.

The sedimentary fill of the valley generally can be grouped in alluvial sediments, slope wash and scree deposits. The alluvium consists of poorly stratified rounded coarse-grained material with a high content of boulders and cobbles (up to a diameter of several meters). The content of cobbles and boulders observed in test pits is generally high and while gravel dominates among the finer components in Table 6-3. The right bank scree is an angular material and has no or very little fine material, the coarse blocks accumulate at the foot of slopes at the valley bottom.

Both alluvial and scree material consists of hard and durable material (amphibolites, pegmatite and gabbro) as the relevant tests reveal.

Table 6-3: Grain size distribution and classification of test pits material from the from Headworks area during the 2020-2021 investigation campaign

Test Pit	Material	Boulders and Cobbles (%) – Visual observation	Gravel (%)	Sand (%)	Fines (%)	USCS Classification
LSG20-TP-12	Alluvium	50	64	34	2	GP
LSG20-TP-13	Slope Wash / Scree	Up to about 50	71	23	6	
LSG20-TP-14	Slope Wash	About 50	71	22	7	
LSG20-TP-15	Slope Wash	< 50	47	34	19	GM
LSG20-TP-16	Slope Wash	< 50% > 50 (16a)	61	37	2	
LSG20-TP-17	Scree	About 50	46	52	2	SP

At the new dam axis, the tests show k-values in the range of $1*10^{-2}$ cm/s to $8*10^{-3}$ cm/s. Higher permeability values that could not be quantified because those exceeded the pump capacity, have been locally recorded at depth mainly in the river bed (LSG20-HW-02 and 03) indicating the possible presence of lenses of coarser and pervious material within the alluvial and scree deposits.

Standard and Cone Penetration Tests Results

Penetration tests have been carried out to define the in-situ packing of river alluvium and scree deposits.

During the 2020 - 2021 investigation campaign a total of 54 tests have been carried out at the new Dam axis and in the Desander area. Only eleven of the tests could be completed (45 cm penetration) with another two that could penetrate at least 30 cm of soil. These results indicate a dense to very dense packing (relative density) for the scree and for the alluvial deposits. It has however to be noted that the very large number of refusals is also presumably due to the presence numerous boulders. The few tests that could penetrate the full test length showed generally moderate N values and occasionally low values.

In general, these few values indicate the local presence of compact (4<N<10) and only occasionally loose (4<N<10) filling between the boulders with the exception of the values measured at LSG20-HW-05 (Desander) the CPT tests exhibiting rather low relative densities in the first 8 m of the loose scree deposits.

Rock Fall Hazard

At the right bank large cones of scree which originate from rock fall can be found. The most active scree cone is located about 400 m downstream of the newly selected weir alternative. The new weir axis location was selected under consideration of avoiding such hazard as much as possible.

Although no detail observations have been made regarding the frequency of events, it can be reasonably assumed from the size of the scree cone that a protection of the site with nets will not be sufficient, also from the cleaning point of view.

Safety nets to be installed on the berms above the desander structures are considered to mitigate the rock fall hazard.

6.5.2 Lower Gabarband Intake Area

Weir / Intake Location

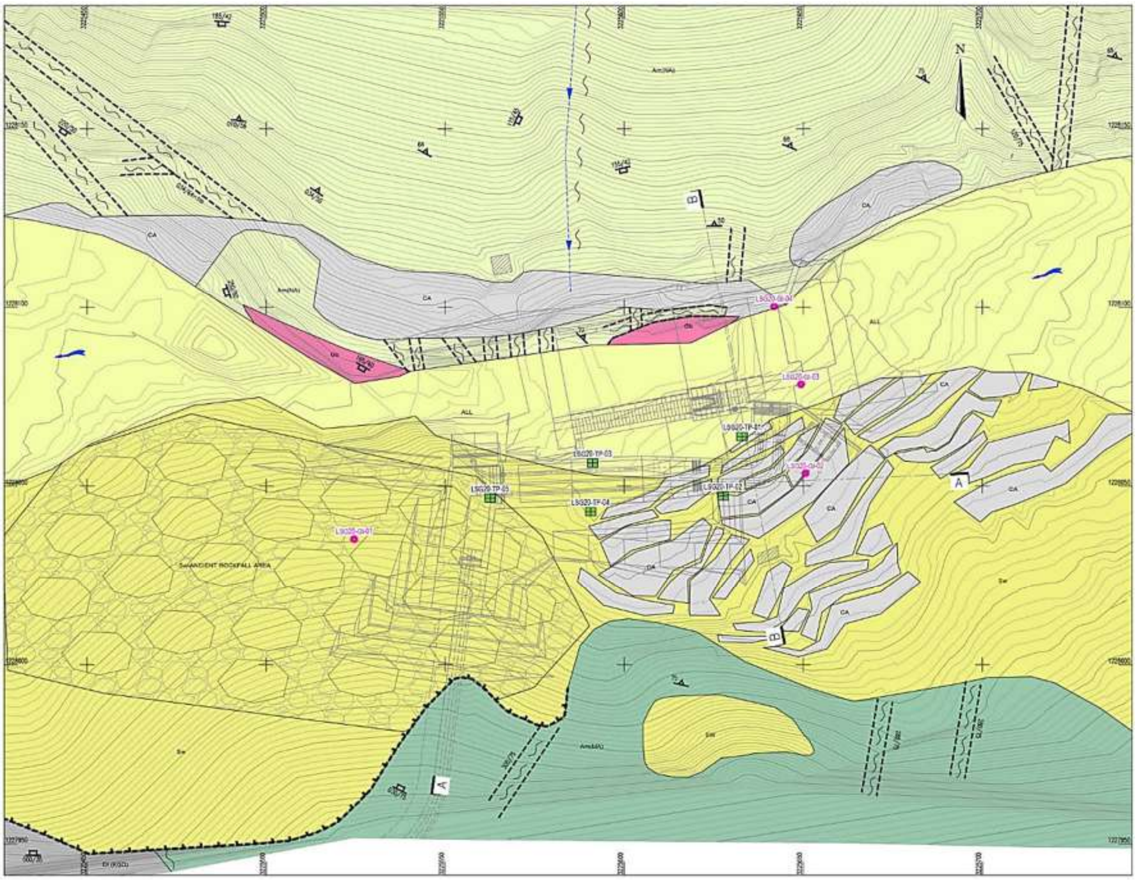
According to the original layout defined in 2010 Feasibility Study, the Headrace Tunnel should have crossed the valley in this area but after a detailed alternative study and a site inspection, a larger secondary intake has been proposed within the Gabarband valley and the location of the crossing was moved about 2.4 km m to the downstream.

As visible in Figure 6-6 the same lithologies belonging to the Mandraza Amphibolite sequence outcrop along the upper part of the left river bank. Northern Amphibolite outcrops along the right river bank.

The bottom of the slopes at the left bank are covered with scree and slope wash deposits where agricultural fields are found. Along the right bank the quaternary cover is much more limited.

Very coarse grained alluvium (Figure 6-8) with a high content of boulders and cobbles (up to a diameter of several meters) is found in the riverbed. The scree and alluvial materials consist of hard and durable material (mainly amphibolite and gabbro).

An old rockfall area has been recognised at the left bank of the Lower Gabarband Intake area as shown in Figure 6-8 but the site inspection and investigation did not evidence any recent movements or rockfalls. The fallen blocks are large to very large (several cubic meter).



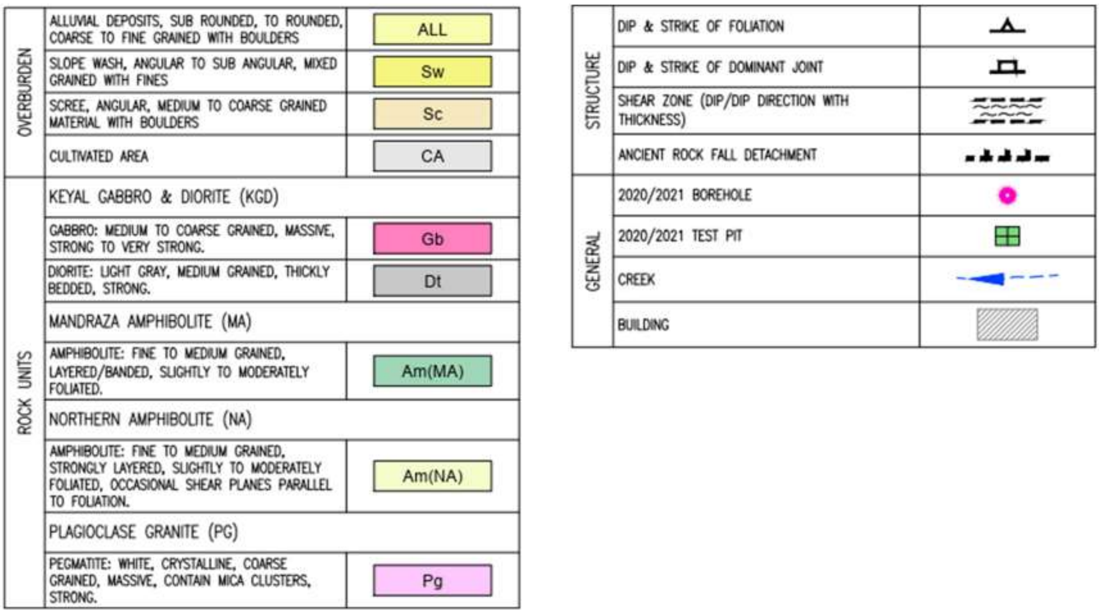


Figure 6-6: *Geological map of Lower Gabarband Intake area*

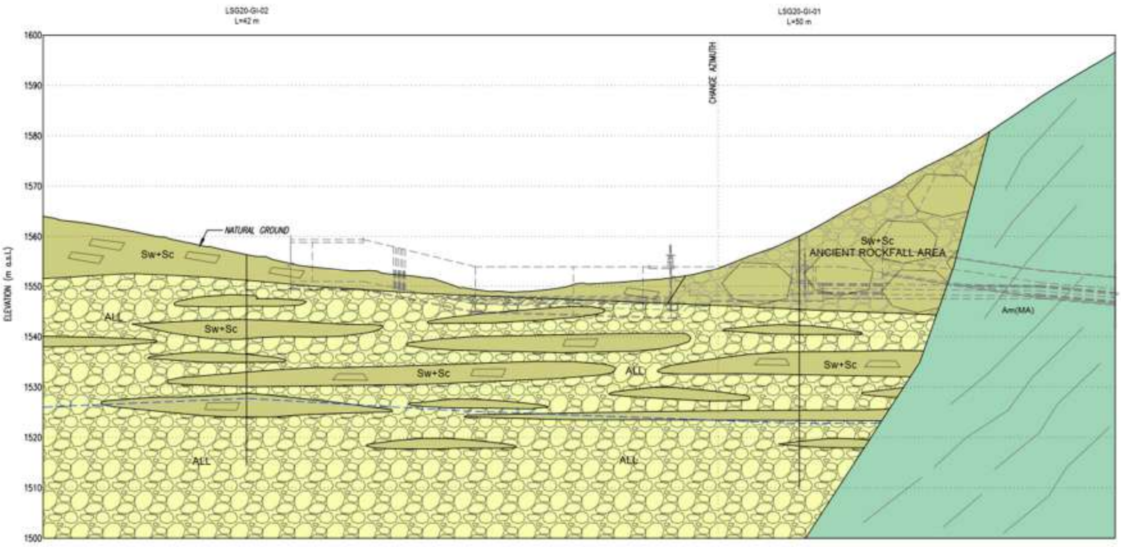


Figure 6-7: *Geological section along section A-A*

Boreholes and Tests Results

Three boreholes have been drilled along the weir / desander axis and one close to the Gabarband Intake Tunnel portal (Figure 6-8). Only one of the boreholes (LSG20-GI-04) drilled at the weir axis along the right abutment reached the bedrock. The boreholes indicate a thickness of the overburden deposits up to 50 m.

While the conditions of the outcropping rock mass are generally good in the borehole LSG-GI-04 the rock is jointed with RQD values generally lower than 50. These values can be explained by the very shallow depth reached by these boreholes and by the numerous sub-vertical fractures observed on the cores and the possible presence of a fault zone along the river.

Figure 6-8: Lower Gabarband Intake (weir) area with rock outcrop at left bank (view in downstream direction)

The sedimentary fill of the valley generally can be grouped in alluvial sediments, slope wash and scree deposits. The alluvium consists of poorly stratified rounded coarse-grained material with a high content of boulders and cobbles (up to a diameter of several meters). Both alluvial and scree material consists of hard and durable material (amphibolites, pegmatite and gabbro) as the relevant tests reveal. Gravel and sand dominates among the finer components (Table 6-4).

Table 6-4: Grain size distribution and classification of test pits material at the Lower Gabarband Intake (2020-2021 investigation campaign)

Test Pit	Material	Boulders and Cobbles (%) – Visual observation	Gravel (%)	Sand (%)	Fines (%)	USCS Classification
LSG20-TP-01	Alluvium / Scree	> 50	58	28	14	
LSG20-TP-02	Slope Wash / Agricultural fields	< 50	27	37	26	SM – NP
LSG20-TP-03	Alluvium	About 50 in the upper part; < 50 at the bottom	41	40	19	
LSG20-TP-04	Slope Wash	> 50	77	20	3	GP
LSG20-TP-05	Slope Wash	> 50	78	17	5	GP

Constant head tests have been carried out in the overburden section of boreholes. The tests show k-values in the range of $1*10^{-1}$ cm/s to $8*10^{-3}$ cm/s at the dam axis with the highest permeability values being observed at very shallow depth. In borehole LSG20-GI-01 instead the head could not be maintained in any of the test which indicates that a very high permeability characterises the ancient rock fall area.

Standard and Cone Penetration Tests Results

A total of 54 tests have been carried out 6 of which could be completed (45 cm penetration). These results are interpreted to indicate a dense to very dense packing (relative density) for the scree and for the alluvial deposits while it has to be acknowledged that the very high number of refusals is also presumably due to the presence numerous large boulders.

The few tests which could penetrate the full test length showed generally moderate N values and in one case low N value. These few values indicate the local presence of compact (4<N<10) and occasionally loose (4<N<10) filling between the boulders.

Geophysical Investigations

The investigations have been carried out in 2013 along the toe of the valley slopes but could not cross the river due to a lack of access and the absence of bridge. The investigations indicate a thickness of alluvium in the range of 10-20 m, information that was not confirmed by the boreholes indicating a greater thickness for quaternary covers.

6.5.3 Gabarband Crossing Area

Crossing location and portals areas

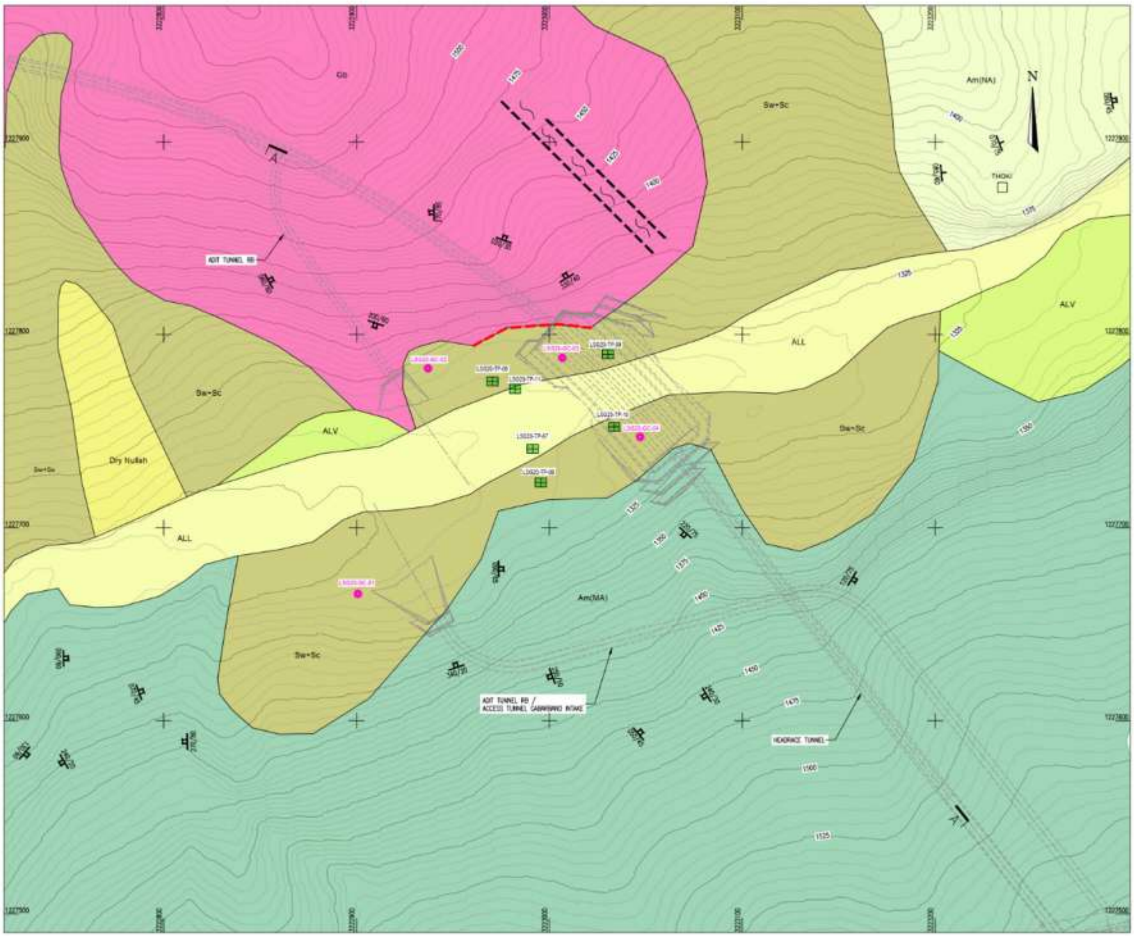
The Gabarband Crossing area has been investigated for the first time during the 2020-2021 investigation campaign after the alignment of the Headrace Tunnel alignment had been modified at the beginning of the 2021 Feasibility Study Update. The whole area has been mapped at scale 1:1,000 and four boreholes and six test pits have been excavated to check underground conditions.

The final Headrace Tunnel alignment (yellow line in Figure 6-9) was decided based on the results of the mapping and boreholes and test pits were places to investigate the selected area including the adit portals.

Here the river flows in a 300 m long narrow valley section characterised by very steep slopes and outcropping rocks mainly. Only at the base of the slopes small scree and slope wash deposits are found, while very coarse grained alluvium with a high content of boulders and cobbles (up to a diameter of several meters) is found in the riverbed.

Large and active scree deposits are found upstream and downstream of this narrow valley section along the right bank, while only local small scree or slope wash deposits cover the amphibolite along the left bank.

Figure 6-9: View from the left bank of the crossing (yellow line: actual crossing alignment)



OVERBURDEN	ALLUVIAL DEPOSITS, SUB ROUNDED, TO ROUNDED, COARSE TO FINE GRAINED WITH BOULDERS	ALL
	ALLUVIAL TERRACES, SUB ROUNDED, TO ROUNDED, COARSE TO FINE GRAINED WITH BOULDERS	ALV
	SLOPE WASH, ANGULAR TO SUB ANGULAR, MIXED GRAINED WITH FINES	Sw
	SCREE, ANGULAR, MEDIUM TO COARSE GRAINED MATERIAL WITH BOULDERS	Sc
	SLOPE WASH+SCREE DEPOSIT	Sw+Sc
ROCK UNITS	KEYAL GABBRO & DIORITE (KGD)	
	GABBRO: MEDIUM TO COARSE GRAINED, MASSIVE, STRONG TO VERY STRONG.	Gb
	MANDRAZA AMPHIBOLITE (MA)	
	AMPHIBOLITE: FINE TO MEDIUM GRAINED, LAYERED/BANDED, SLIGHTLY TO MODERATELY FOLIATED.	Am(MA)
	NORTHERN AMPHIBOLITE (NA)	
	AMPHIBOLITE: FINE TO MEDIUM GRAINED, STRONGLY LAYERED, SLIGHTLY TO MODERATELY FOLIATED, OCCASIONAL SHEAR PLANES PARALLEL TO FOLIATION.	Am(NA)

STRUCTURE	DIP & STRIKE OF FOLIATION	
	DIP & STRIKE OF JOINT	
	DIP & STRIKE OF SHEAR JOINT SET	
	SHEAR ZONE (DIP/DIP DIRECTION WITH THICKNESS)	
	INFERRED FAULT	
	OBSERVED FAULT	
	VILLAGE	
GENERAL	2020/2021 BOREHOLE	
	2020/2021 TEST PIT	

Figure 6-10: Geological map of the Gabarband Crossing area

Boreholes and Tests Results

The geological map of the Crossing area shows that the Mandraza Amphibolite sequence outcrops at the left bank with a large gabbro intrusion found along the right bank. The Amphibolite is very massive and not foliated and intruded with gabbro bodies as evidences by the LSG-GC-02 and LSG-GC-04.

According to the petrographic investigations on boreholes cores the drilled rock was identified as "Gabbro" (see petrographic evaluation in Volume 4 - Annex 9). The quartz content is very low (3-4%), the amphibole / pyroxene content range within 56% and 69%, the plagioclase and feldspar between 17% and 26% while the phyllosilicates (biotite, muscovite and chlorite) are less than 5%.

The outcropping rocks, the boreholes cores and the laboratory test results show generally hard to very hard rock and the conditions of the outcropping rock mass are generally very good.

Samples have been collected in test pit and the grain size distribution measured on the fine part of the excavated material. Cobbles and boulder make up 50% or more of the material are not considered for the definition of the overall properties of the material shown in Table 6-5.

Table 6-5: Grain size distribution and classification of test pits material from the from the Gabarband Crossing area (2020-2021 investigation campaign)

Test Pit	Material	Boulders and Cobbles (%) – Visual observation	Gravel (%)	Sand (%)	Fines (%)	USCS Classification
LSG20-TP-06	Slope Wash / Scree	> 50	61	35	4	GW
LSG20-TP-07	Alluvium	> 50	60	38	2	-
LSG20-TP-08	Slope Wash / Scree	About 50	61	37	2	-
LSG20-TP-09	Slope Wash / Scree	> 50	67	16	17	GM
LSG20-TP-10	Alluvium / Scree	> 50	60	36	40	GP
LSG20-TP-11	Alluvium	> 50	61	33	6	GP-GM

Standard and Cone Penetration Tests Results

A total of 15 tests have been carried out, one of which could be completed (45 cm penetration).

These results are interpreted to indicate a dense to very dense packing (relative density) for the scree and the alluvial deposits while it must also be acknowledged that the very high number of refusal is also presumably due to the presence of numerous boulders at depth. The only tests which could penetrate the full test length showed low N values given to the presence of some loose soil (4<N<10) at shallow depth in the riverbed.

6.5.4 Power Waterway

General

The Headrace Tunnel will mainly run through amphibolitic and magmatic rocks of good quality. The selection of the tunnel alignment was based upon several geological factors in order to define the shortest and most favourable route aiming at minimising the geological and construction risks.

The geological conditions of the tunnel are presented in the geological map in Figure 6-11 and the longitudinal section in Figure 6-12.

The geological map shows the results of the geological field mapping at scale 1:10,000 which was carried out in the main valleys of Spat Gah and Gabarband as well as in selected side valleys located next to the tunnel alignment. The geological map shows the faults which have been observed directly in the field as well as lineaments which are linear structures detected using satellite images.

Due to the remoteness and steepness of terrain no boreholes have been carried out along the Headworks Tunnel alignment but drilling works have been instead carried out as described in the previous chapters at the Lower Spat Gah Headworks area (2008-2009 and 2020-2021 investigation campaign) and at the Lower Gabarband Intake and Gabarband Crossing areas (2020-2021 investigation campaign) including tunnels portal areas.

The amphibolites found south of the Gabarband valley (dark green unit in Figure 6-11) belong to the Mandraza amphibolites. These quite massive rocks are encountered along the Headwork Tunnel between the Lower Spat Gah Headworks and the Gabarband Crossing and along the Gabarband Intake Tunnel until the junction with the Headrace Tunnel.

The Headrace Tunnel will cross the Gabarband valley at shallow depth (~10 m) with a cut and cover section excavated in alluvial deposits. North of the Gabarband valley the Northern amphibolites (light green unit in Figure 6-11) with a closer spacing of foliation planes, compared to the Mandraza amphibolites, are prevailing. Massive gabbro and diorites intrusions (reddish unit in Figure 6-11) are often found embedded in both amphibolites and have been observed as larger bodies in the Gabarband valley.

Close to the Indus River, the downstream end of the Power Waterway including the downstream end of the Headrace Tunnel, Pressure Shaft, High Pressure Tunnel and Tailrace Tunnel will be excavated in a large granitic intrusion (pink unit in Figure 6-11) with contact zones with the surrounding host rocks generally exhibiting a significant tectonic disturbance and faulting.

During the course of the geological surface mapping no disturbed or fault zone with a thickness of more than 10-20 m has been observed. However, and due to the width of valleys associated with certain lineaments and considering unfavourable intersection angles with the Headrace tunnel of some faults, the effective length of some fault zones along the tunnel could reach up to up to 50 – 100 m.

Generally it can be assumed that the tunnel will be constructed in a zone of fresh rocks with closed joints. At the drillholes of the 2010 Feasibility Study dam and powerhouse sites it was observed that the zone with weathered or open joints is usually in the range of 60-80 m below terrain. At the mountain tops it is assumed that this zone has a greater thickness but this is without significance for the tunnel.

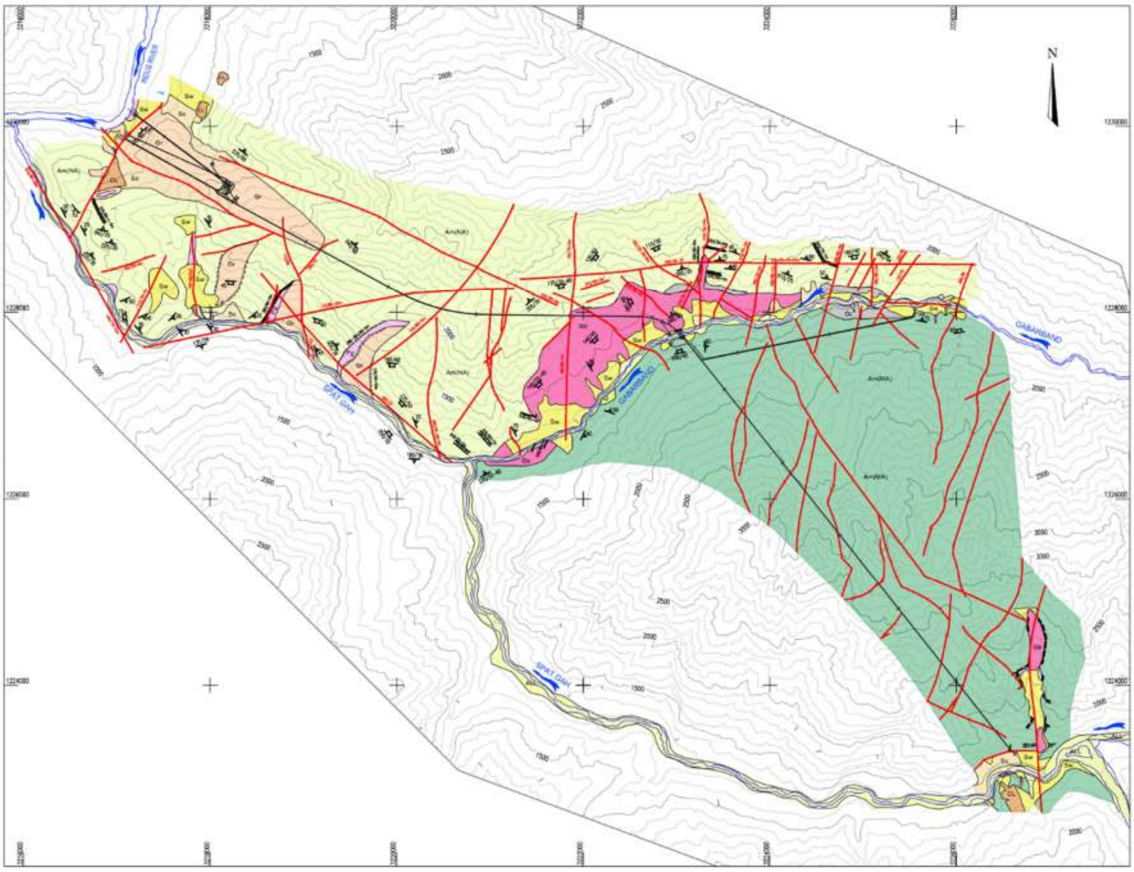


Figure 6-11: Geological map of Power Waterway

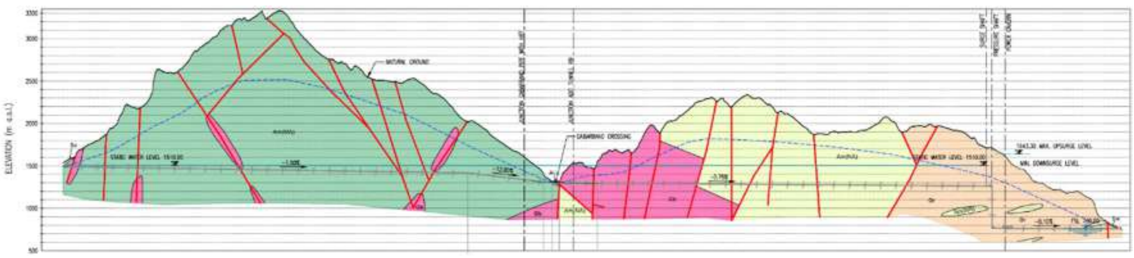


Figure 6-12: Geological section of Power Waterway

Based on the geological mapping and the investigation results, the rocks expected along the Power Waterway alignment have been divided into four rock mass types here described and with properties summarised in Table 6-6. It can be seen that the (Keyal) gabbro is classified as the "strongest" rock type in the tunnel and the Northern amphibolites as the "weakest" however it must be acknowledged that all these rock types can be classified as good or very good according to Bieniawski (1989) or the GSI ratings (according to Hoek 2005).

Table 6-6: Rock mass types encountered at Power Waterway (lithology locations shown in Figure 6-11 and Figure 6-12)

		Kiru sequence				*Kamila sequence*			
Rock mass types		RMT 1		RMT 2		RMT 3		RMT 4	
Geological unit		KGD (Keyal gabbro)		MA (Mandraza amphibolites)		NA (Northern amphibolites= Dasu amphibolites)		PG (Plagioclase granite)	
Location		encountered as intrusions at LS dam site and as large bodies in Gabarband valley (downstream of intake)		this is the rock type which is encountered at LS dam site and in between dam site and Lower Gabarband Intake		this rock unit is encountered north of Gabarband		encountered at LS powerhouse site and inclined shaft	
rock types		Interlayered gabbro and diorites with pegmatitic and granitic sills		Amphibolites (metagabbro) with pegmatitic and granitic sills		Strongly layered amphibolites		generally coarse-grained granite	
		Parameter	Rating	Parameter	Rating	Parameter	Rating	Parameter	Rating
Strength intact rock	Uniaxial compression (MPa)	120	12	120	12	70	7	120	12
Spacing	RQD	95	20	65	13	60	13	90	17
	Spacing discontinuities (m)	0.5	10	0.4	10	0.2	8	0.5	10
Condition of discontinuities	Persistence	1-3 m	4	1-3 m	4	3-10 m	2	1-3 m	4
	Separation	None	6	None	6	None	6	None	6
	Roughness	rough	5	rough	5	slightly rough	3	rough	5
	Infilling	None	6	None	6	None	6	None	6
	Weathering	Unweathered	6	Unweathered	6	Unweathered	6	Unweathered	6
Groundwater conditions	Joint Water Pressure /major principal stress	0	15	0	15	0	15	0	15
Bieniawski 1989	RMR dry	Total Rating	84 ±5	Total Rating	77 ±5	Total Rating	66 ±10	Total Rating	81 ±5
Hoek 2005	GSI		79 ±5		72 ±5		61 ±10		76 ±5
		Very good / Class I		Good / Class II		Good / Class II		Very good -good / Class I	

Faults and Lineaments

In addition to the rock mass types shown in Table 6-6 faults have to be expected. The lineaments identified using satellite images and in nature reflect zones of greater erodibility and it is generally accepted that these lineaments define potential zones of lower rock mass quality, which can be correlated with faults.

During the field work no disturbed zone with a thickness of more than 10-20 m was observed, most of these zones were in the range of 0.2-5 m and it can be reasonably assumed that such zones will be encountered regularly during excavation. The distance between such minor fault zones will be such that the surrounding rock mass is not significantly affected by it, which can be seen on high and steep rock slopes all along the valleys. As a matter of cautious and realistic approach it has to be assumed that faulted zones with greater thickness could possibly be encountered, but could not be observed directly. Such zones will presumably be encountered in valleys and the width of the valley defines more or less the maximum width of a possible fault zone (the greatest thickness was assumed with 100 m along the tunnel).

The fault zone material which was observed at natural outcrops or drillholes consisted of broken or fractured material, but no fault gauge. Therefore it can be reasonably assumed that faulted material will mainly consist of fragmented particles in sand or larger grain size with no plastic behaviour. This does not mean that no fault gauge will be encountered, but no indication has been encountered to assume that typical fault zones with a considerable thickness (>10 m) would consist of fault gauge. The total tunnel length to be done in faulted rock is assumed as 640 m.

Permeability

As there are no karstic or highly porous rock types in the Project area, it is expected in general that the rock mass will have a rather low permeability as can be seen also from the water pressure tests carried out in the drillholes. Below a rock top zone with open joints in a thickness of ~60 - 80 m the water pressure tests indicate Lugeon values in the range from 1 to 10, which corresponds roughly to a k_f value in the range of $1*10^{-7}$ m/s to $1*10^{-6}$ m/s. Therefore it can be reasonably assumed that the groundwater level will rise quite steeply from the valley bottom and the depth of tributaries in relation to the main valley supports this estimation.

Stress Condition due to Overburden

Based upon experience of deep-seated tunnels, increased overbreak with rock bursting in hard rock mass or squeezing tunnel conditions in the rock mass with moderate and fair characteristics shall be expected in areas where the overburden will exceed 1,000 m.

Thus, and considering a FSL level at 1,510 m asl, tunnel sections with natural terrain elevation of more than 2,500 m will likely require increased support measures. Based on the final proposed alignment and the topography of the Project area, it is assumed that a tunnel length of roughly 3,200 m will be affected by high stress regime. Further consideration of the influence of stress conditions and the rock mass parameter is described in Chapter 6.6.3.

6.5.5 Powerhouse Area

Drillholes and Geological Mapping

The geological information at the Powerhouse area is based upon geological surface mapping in the scale 1:2,500 and 5 short boreholes (2009, 2013 and 2020-2021) which have been drilled at the foot of a steep slope as shown in the geological drawing in Figure 6-13, west of the actual Powerhouse location. The geological map shows that amphibolitic lenses are thrusted within the granite body and that the contact between the granite and amphibolite is generally faulted and of low rock quality.

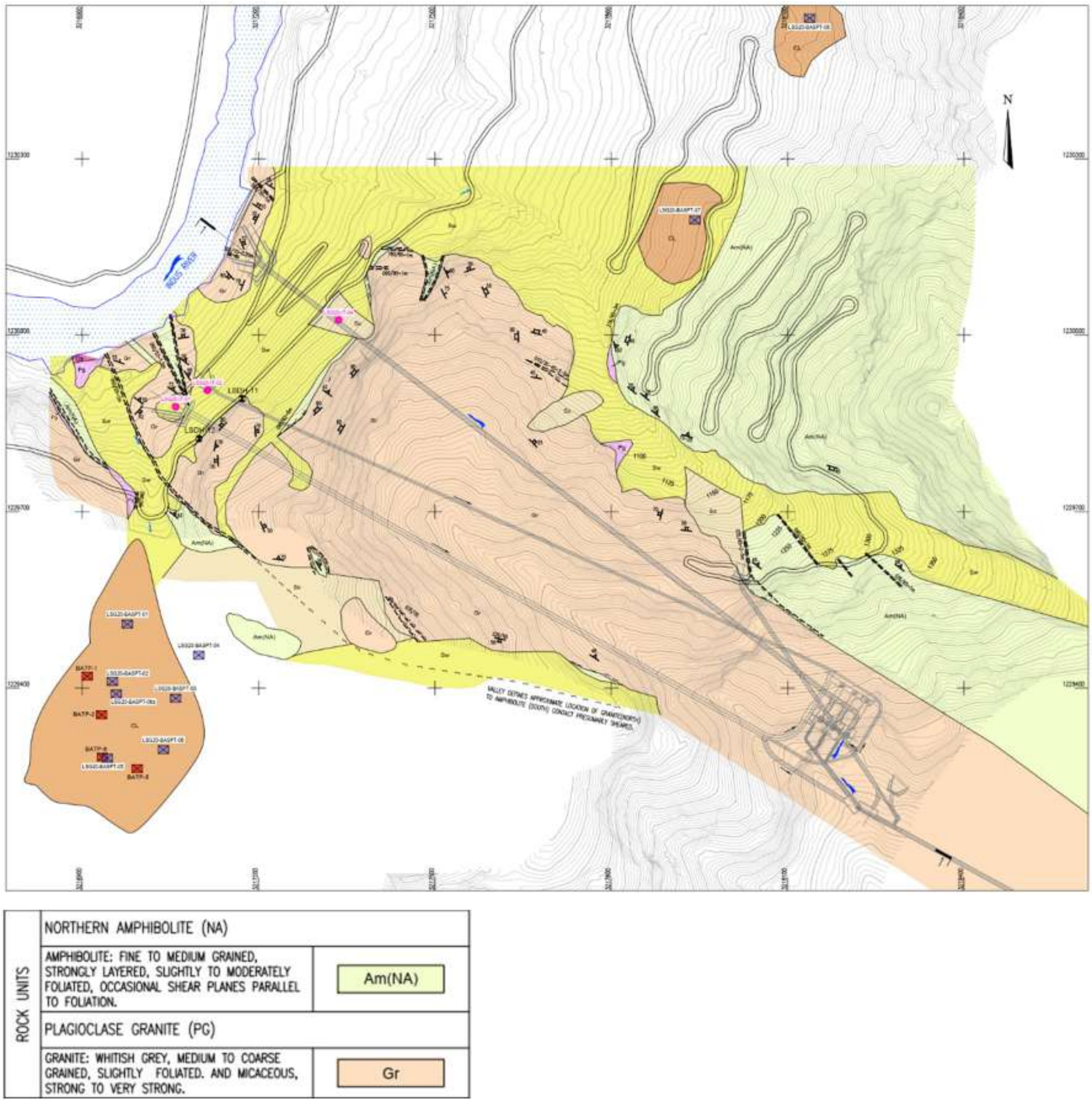


Figure 6-13: Geological map of Powerhouse area

Four out of five boreholes are located southwest of the Tailrace Tunnel at the foot of a steep slope formed by a granitic body called plagioclase granite where the access tunnels portals are located. One borehole (LSG20-IT-04) has been instead drilled along the Tailrace Tunnel alignment. Based on the good rock quality observed on the granite outcrops, favourable rock mass conditions can be reasonably expected at depth, east of the drilled boreholes (Figure 6-14), where the tunnels and the Powerhouse are located.

The position of the Powerhouse in the framework of the 2021 Feasibility Study Update was shifted further inside the mountain ridge to optimise costs and especially to reduce the length of the steel lined High Pressure Tunnel after the Pressure Shaft was changed from inclined at 36° to vertical.

The geological conditions at the new Powerhouse location are assumed to be comparable with the previous ones as both powerhouses are located in the same granitic body. However, and because the granitic body gets thinner towards the east and no boreholes could be drilled at the new Powerhouse location, the distance of the Powerhouse to the disturbed granite/amphibolite contact zone cannot be precisely defined and the presence at depth of amphibolite embedded in the granite cannot be completely be ruled out at this stage. Considering that these contacts can be also sheared it is highly recommended that the proposed Powerhouse location be confirmed at an early stage of the Project implementation with boreholes or even better using the two access tunnels and/or the Tailrace Tunnel as investigation galleries.

Figure 6-14: Photo of Powerhouse slope with granite body above the road

The underground Powerhouse is located in a light coloured granite bordered by amphibolites and the contact to these neighbouring rocks is generally sheared which is why a sound distance of the Powerhouse Cavern to these contact zones was aimed at.

The change in slope inclination from rather flat slopes next to the Indus River (~25°) to the steep slope of the granite body (~60°) is considered as the boundary of the faulted Indus zone affected by NE-SW striking faults. Other faults striking NW-SW border the granite boy toward the north and toward the south.

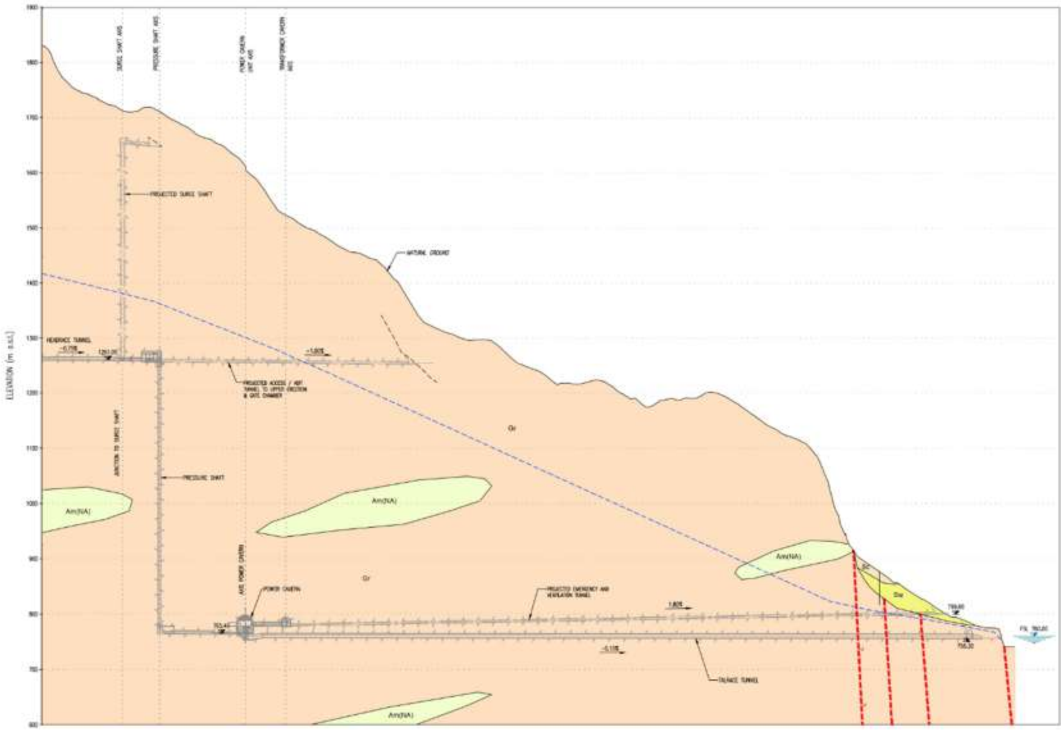


Figure 6-15: Geological section of Powerhouse and Pressure Shaft

The alignment of the Power Waterway and the Pressure Shaft (Figure 6-13) have been selected with the aim to keep the Power Waterway away from the main contact zones between the granite and amphibolite. The vertical Pressure Shaft is assumed to be located mainly in favourable granitic rock mass although the presence at depth of amphibolitic lenses cannot be completely ruled out at this stage of the Project.

The surface mapping has evidenced several inclined shear zones dipping north which are related to rock contacts. On the other side, looking at a larger scale the intersection with the topography of the main NW-SE oriented contact zones between the granite and the amphibolite indicate that these zones are mainly sub-vertical or steeply inclined. The orientation of these two zones is of major importance to define the exact rock conditions expected at the Powerhouse area.

Amphibolites and gabbro have been observed in boreholes LSDH 11, LSG20-IT-02 and 04 (Figure 6-15) which is a clear indication that amphibolitic lenses are relatively common within the granite and that those will be encountered as layers and lenses along the Tailrace Tunnel and the main access tunnels and possibly also at the Powerhouse area.

Discontinuities Orientation

The orientation of the discontinuities has been determined by surface geological mapping and however it is acknowledged that the Powerhouse location is placed deeper inside the granitic rock unit, it can be reasonably assumed that the following observations made at the surface are also valid at depth.

The orientation of foliation is not relevant in this context as the granite is generally massive and a preferred mineral orientation is observed only at the contacts to the amphibolites.

Geophysical Investigations

Geoelectrical investigations have been carried out during the 2020-2021 investigation campaign to investigate the Lineament 0 that was identified during the 2010 Feasibility Study. The investigations indicate the presence of some minor fault zones probably part of the Lineament 0 affecting the granite. The survey also shows that the thickness of quaternary deposits above the rock surface is in the range of 30 - 40 m, or even more, as confirmed by borehole LSG20-IT-04.

Rock Mass Characteristics and Laboratory Tests Results

The Powerhouse will be located in a central zone within the mountain ridge, at a considerable distance to the mixed lithologies and Lineament 0, as shown in the Powerhouse geological map (Figure 6-13). Therefore and because the boreholes executed in 2008-2009, 2013 and 2020-2021 are at rather great distance (1.1 km) from the proposed cavern location and investigated the granite only at shallow depth, it can reasonably be stated that the borehole results are not considered representative for the Powerhouse area.

The RQD evaluation of LSDH-11 (2010 Feasibility Study) shows that the top part (~60 m) of the borehole has encountered a rock mass with an RQD below 50. Below that depth the core quality increases and values greater than 50 were found. Under consideration of the rather small drill core diameter of 46 mm the core quality can be classified as good.

The borehole LSDH-12 (2013) was drilled at the same road and roughly same elevation as the hole LSDH-11 (in 2010). The rock quality (expressed in RQD) was lower than in the previous hole.

The average of the strength of the tested rock core samples is ~85 MPa. As already discussed above this value is lower than for typical granites, therefore a local influence is assumed and higher values for rock strength are assumed in the cavern area.

At the depth of the Powerhouse Cavern the joints are expected to be unweathered and generally rough. Some smooth but no slickensided surfaces have also been observed at the drill cores but such disturbances are not expected in the cavern area. Especially when the recommended drillhole investigations will be executed, more details about the quality of the rock mass will be available and adaptations of the position will be made so that the cavern will be located in the most favourable rock zones.

Therefore it can be stated that the Power Cavern will be placed in granitic rock which is of good-very good quality.

Groundwater Table and Permeability

Based on the groundwater levels measured in boreholes LSDH-11, LSG20-IT-01, LSG20-IT-02 and LSG20-IT-04, it is confirmed that the Powerhouse will be located below the groundwater level.

The permeability of the rock mass has been tested with water pressure tests (Lugeon tests). The results of the two holes (2010 and 2013) are comparable. No additional Lugeon tests have been performed during the 2020-2021 investigation campaign. The majority of results scatter between 1 and 10, with an average of ~5 Lu which corresponds to a kf-value in the range of $1*10^{-6}$ m/s. A lower value is proposed at the Powerhouse location due to the higher stress and a design value for the cavern area of $k_f = 5*10^{-8}$ m/s can be reasonably assumed based upon comparison of other projects at high overburden.

6.5.6 Tailrace Tunnel, Emergency and Ventilation Tunnel and Main Access and Power Evacuation Tunnel

In general, the different tunnels connecting the Indus area/River to the Powerhouse will be excavated in favourable conditions, but it is anticipated that those will cross a more heterogeneous and less favourable zone of about 200-300 m towards the Indus River characterised with intercalations of amphibolites and granite with tectonic contacts (shear zones, crossing Lineament 0).

The geological conditions in this area have been investigated by geoelectrical investigations (2013) and by additional boreholes and an electrical tomography survey (2020-2021). The results indicate that the thickness of the slope wash is in the range of 10-40 m. Such a thickness does however not reach the tunnels in general but will have to be locally considered for the definition of the most optimal portal location during Project implementation.

The Lineament 0 could be detected by the electrical tomography survey and the first fault zone belonging to this lineament has been detected immediately below the access road crossing this area. A second possible small fault zone has been detected about 50 m west of this first lineament and a third more pronounced lineament has been detected further West close to the Indus river.

The intersection of these faults with the Tailrace Tunnel are shown in Figure 6-15. The length of the Tailrace Tunnel will be 1.3 km and the other access tunnels to the Powerhouse will have similar length and will all cross the same geological units and faults as the Tailrace Tunnel.

6.6 Geological Interpretation

6.6.1 Lower Spat Gah Headworks Area

Rock

The orientation of the foliation has consequences for the stability of the valley flanks. Generally the left bank conditions have a higher tendency of block sliding. The sensitivity of the left bank towards sliding can be observed in the area downstream of the dam axis. Due to blasting works for a new foot path a large scale sliding was triggered and sliding followed the foliation planes. This can be taken as an indication that any large scale excavations on the left bank will need a considerable amount of rock support.

At the right bank the dip of foliation is more favourable, as the layers dip inwards of the flank.

Dam Foundation and Sediments

In order to avoid unreasonably high water losses, prevent internal erosion of the sediments and to reduce the pore pressures having a negative impact on the stability of the dam and the concrete weir, a cut-off wall has to be constructed in the alluvial foundation. The performed numerical calculations (see Volume 7 - Project Design of this Feasibility Study) show that the cut-off wall shall reach the bedrock found between 25 to 60 m below the foundation level of the rock fill dam and the flushing channel. The cut-off shall penetrate 1.5 m into the underlying rock to ensure a good seal.

Along the left abutment where the rock surface can be reached with a reduced effort, the cut-off wall sealing system shall be replaced with a grout curtain. Along the right abutment, the calculations show that the cut-off does not need to reach the bedrock and that a hanging cut-off which depth gradually reducing from the 60 m estimated in the valley centre down to a depth of about 25 – 30 m along the right abutment shall do.

As the quaternary deposits composition along the foundation show some heterogeneities with respect to grain size distribution and linked characteristics, a consolidation grouting is conservatively foreseen below the embankment dam to ensure a uniform minimum shear resistance, which is of utmost importance for the dam stability. A consolidation grouting below the concrete weir section and the desander is also conservatively foreseen to provide a homogeneous bearing capacity.

Desander Excavation and Foundation

The results of this analysis indicate that most of the excavation will be executed in quaternary loose material (mainly scree deposits) forming the foundation of the desander. The CPT tests carried out in the area indicate that the first 8-9 m of the scree deposits are quite loose (LSG20-HW-05) while the rest of these sediments can be classified as dense. The excavation of the slopes into these deposits may prove to be challenging due to the presence of large boulders. That may require the use of explosives for their total or partial removal. The frequency of large boulders is expected to increase toward the bottom of the slopes.

The top part of the slopes located above the Headrace Tunnel intake are expected to be located in bedrock as indicted by boreholes LSG20-HW-05 and by the geological map.

Permeability

The levels measured in the piezometers at the end of the investigation campaign are considered to represent the “normal” groundwater level at the end of the winter before major melting of snow on the surrounding peaks starts.

Permeability investigations of the loose sediment filled valley are described in Chapter 5.1.4. The test results show that the sediments are mainly made of alluvial sediments and scree. Based on the constant head tests results that generally range between 1*10-2 cm/s and 8*10-3 cm/s, a permeability value of : kf= 5*10-2 cm/s is recommended for the seepage calculations at the dam axis.

Liquefaction

The coarse-grained alluvial sediments or scree deposits generally do not exhibit a tendency towards liquefaction. The available data indicate that the risk of liquefaction is very low to nil.

6.6.2 Lower Gabarband Intake Area

Rock

The orientation of the foliation has consequences for the stability of the valley flanks. Generally the left bank conditions have a higher tendency of block sliding. Rock outcrops are located far away from the excavation zone and the orientation of the foliation will not impact the stability of the excavation that will be located in the overburden.

At the right bank the rock is found at shallow depth also in the weir area but the dip of foliation is more favourable, as the layers dip inwards of the flank.

Weir Foundation and Sediments

The boreholes indicate that from the river bed moving toward the left abutment the weir and the desander will entirely be founded on loose quaternary alluvial and scree deposits. The CPT penetration tests indicate a dense to very dense packing (relative density) for the scree and a very dense packing for the alluvium. Therefore the construction of a small concrete weir is considered appropriate for such foundation conditions.

Desander Excavation and Foundation

The entire structures are expected to sit on scree and alluvial deposits. Here the overburden is characterised by the presence of large and numerous boulders remains of an ancient rockfall. Given the size of the blocks observed on the surface and in the borehole on the one hand and the strength of the rock on the other hand, it is assumed that blasting will be required also in the part of the excavation and along the tunnel to remove the boulders.

Permeability

Based on the constant head tests results that generally range between 1*10-2 cm/s and 8*10-3 cm/s, a permeability value of kf= 5*10-2 cm/s is recommended for the seepage calculations at the dam axis. Here the cut-off wall has been replaced by a shallow concrete key to reduce the seepage and the risk of internal erosion.

Liquefaction

The coarse-grained alluvial sediments or scree deposits generally do not exhibit a tendency towards liquefaction. The available data indicate that the risk of liquefaction is very low to nil.

6.6.3 Power Waterway

Influence of Discontinuities on Tunnel

In the first tunnel zone in between the Lower Spat Gah intake and the Gabarband valley, the foliation will be intersected perpendicular to the tunnel axis, which generally is a favourable orientation. The dip angle is changing, in few occasions and the foliation will be quite flat. In this case the risk of block fall will be higher than usual. After the crossing of the Gabarband valley the general orientation of foliation will be approximately parallel to the tunnel axis. But as zone 3 runs in gabbro of more massive character this will be of little influence in this zone. In zone 4 the influence of the foliation orientation will be highest, due to the closer spacing of the prevailing Northern amphibolites. In zone 5 no foliation is existing because of massive granite.

The dominating joint sets have an orientation more or less perpendicular to the foliation so that the arguments discussed for the foliation could be repeated vice versa. A more detailed discussion of the influence of discontinuities on the tunnelling conditions appears too premature at this stage based on the current knowledge. But it can reasonably be assumed that except from zone 3 (~massive rock) a systematic roof support will be necessary to prevent loosening of blocks in the crown (no shotcrete lining foreseen at this stage).

Permeability

The permeability of a rock mass generally decreases with depth. Therefore values observed in surface drillholes (up to 50 m depth) are not representative for deep seated tunnels. Based on comparable tunnel projects at great overburden the permeability is expected to be 1-2 magnitudes lower.

Percentage of Fault Zones

The percentage of fault zones for different tunnel zones is assumed to be as shown in Table 6-7.

Table 6-7: Percentage of fault zones in different tunnel sections

Zone	Chainage (m)		Length	Length of Different Quality: Length of Fault Zones within this Zone		Length of Different Quality: Length of Undisturbed Rock Mass	
	From	To	(m)	(m)	(%)	(m)	(%)
1	0+000	5+724	5,732	150	2.6	5,582	97.4
2	5+724	5+811	87	Open cut			
3	5+811	7+435	1,624	120	7.4	1,504	92.6
4	7+435	9+907	2,472	150	6.1	2,322	93.9
5	9+907	10+886	979	80	8.2	899	91.8
Tailrace	0+000	1+285	1,285	140	10.9	1,145	89.1
		Total	12,179	640		11,452	

Tunnel Zones and Support Classes

Based upon the length of different geological units the tunnel support classes have been developed for the entire Power Waterway including Headrace Tunnel, Pressure Shaft and Tailrace Tunnel. The rock support distribution has been estimated based on the available geological information such as overburden and presence of pre-identified faults based on satellites information.

Concerning the rock burst the application of a lower rock support class compared to the calculated RMR class has been foreseen in order to prevent damages or safety risks in areas with high topographic cover. The effective areas where the risk of rock burst will be real shall be further investigated in the next project phases on the base of the actual rock mass conditions and behaviour in the areas characterized by high topographic cover.

Table 6-8: Headrace and Tailrace Tunnel zones and support classes

Zone	Chainage (m)			RMR	Rock Mass Quality RMR (Bieniawsky 1989) Class (%)					Support Classes (%)					
	From	To	Length (m)	RMR dry	Very Good 80-100	Good 60-80	Fair 40-60	Poor 20-40	Very Poor 0-20	I (Crown Support)	II (Crown Support)	III	IVa (Full Profile)	IVb (Full Profile)	V (Full Profile)
1	0+000	5+724	5,732	77 and 84	20	74	3	3		20	42	30	4	2	2
2	5+724	5+811	87	No rock											
3	5+811	7+435	1,624	84	80	16	2	2		18	18	27	17	10	10
4	7+435	9+907	2,472	66		95	3	3		10	40	35	9	3	3
5	9+907	10+886	979	81	44	44	6	6		20	40	18	10	6	6
Tail-race	0+000	1+285	1,285	81	47	47	3	3		20	40	18	10	6	6
		Total	12,179												

6.6.4 Gabarband Intake Tunnel

Most of the Gabarband Intake Tunnel will be excavated in the Mandraza amphibolites of generally good quality, defined as rock mass type RMT 2 with the same rock mass parameter as defined for the Headrace Tunnel. Possible magmatic intrusions (mainly gabbro) can be also found along the alignment. Only close to the portal area, at the contact between loose material and bedrock, slightly weathered rock may be encountered.

Borehole LSG20-GI-01 indicates that the tunnel portal will be located in scree deposits characterised by the presence of very large boulders, remains of an ancient rockfall. Given the unexpected presence of a very thick (> 50 m) and unfavourable quaternary cover, the tunnel alignment has been modified in order to minimise the length of the tunnel that needs to be excavated in the scree deposits and boulders.

In the amphibolite the main foliation dips in the area steeply toward the north and strikes sub-parallel to the tunnel axis. Foliation and main joints sets observed in the area dips toward the north and toward the south respectively. The orientation of the main foliation is considered to be fair to favourable in the initial part of the tunnel that strikes NNE-SSW and fair to unfavourable along the rest of the tunnel where the foliation strikes sub-parallel to the tunnel.

Intersecting faults have to be expected and the position of faults has been assumed based upon morphological indications from satellite images, named “lineaments”. The expected number and position of the faults is shown in Figure 6-16. The thickness of these lineaments has been estimated in the range from 5 m to a few decametres (“block scale fracture zones”) by Geotech 2013 and a range of 10-50 m was used in the 2010 Feasibility Study. All these lineaments strike NNW-SSE to NNE-SSW at high angle to the tunnel axis.

The most prominent faults found along the alignment are located at Chainage 1+600 m to 1+700 m where two of the most prominent lineaments observed in the area cross each other. One of these faults is the fault 26 from the 2010 Feasibility Study that strikes NNW-SSE. The importance given to this fault zone is in accordance with the observation made by Geotech Consultant study (2013). In this area the total length of the tunnel affected by the fault can reach up to 50 m, or more. The thickness of the other expected faults is estimated in the range of 10-20 m. The total fault length in this tunnel is estimated in the range of 140 m.

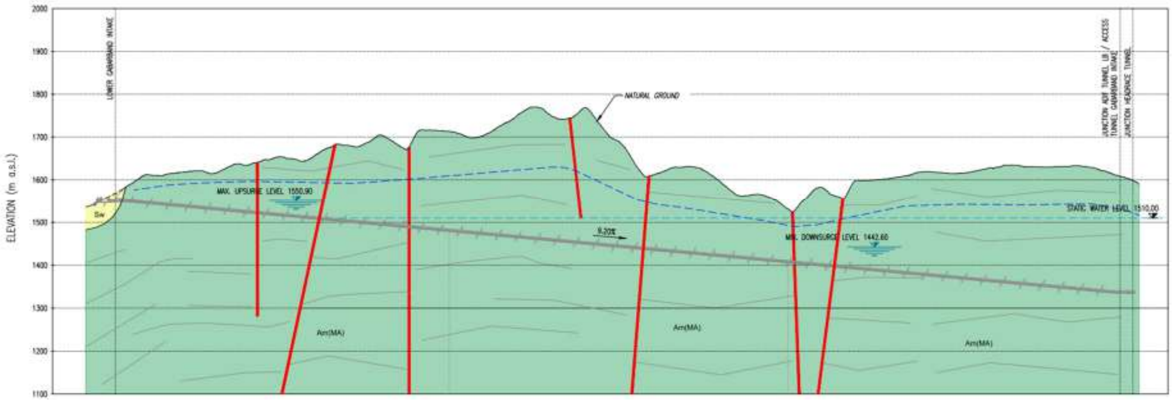


Figure 6-16: Longitudinal section along Gabarband Intake Tunnel

6.6.5 Adit Tunnels Gabarband

Two adit tunnels with a length of 136 m and 442 m will be constructed at both banks of the Gabarband River. The tunnel portals have been located at an elevation higher than the 50 year. flood water level (right bank = 1,306.69 m asl; Left bank = 1,304.50 m asl) and in locations with limited rockfall risks and reduced overburden so that the entire tunnels length will be excavated in rock.

Generally the rock quality will be favourable in both tunnels. The left bank (LB) tunnel will be excavated in Mandraza amphibolites like the Gabarband Intake Tunnel with the same rock mass parameter.

At the right bank (RB) tunnel, the whole adit tunnel will be excavated in gabbro (RMT 1).

6.6.6 Powerhouse Area

All geological information about the Powerhouse is summarised in Chapter 6.5.5.

Based upon the geological input data, very good rock mass values result using RocLab software. Considering the lack of investigation results in this area slightly more cautious rock mass parameter are proposed, which result in the reduction of the Deformation modulus from 40,000 MPa to 30,000 MPa which is still favourable.

6.7 Lower Spat Gah Reservoir

6.7.1 Water Tightness

The rock mass in the reservoir area can be assumed as practically water tight from the permeability point of view and there is no nearby valley where a leakage could occur.

6.7.2 Slopes Stability

The fluctuations of the reservoir will be low for the selected weir alternative. Therefore the slope stability is not a relevant topic.

6.8 Construction Material

Based on the available information, the concrete aggregates and the rock fill for the construction of the Lower Spat Gah Headworks, Lower Gabarband Intake, Powerhouse and Power Waterway are intended to be won from the rock excavation material of the weirs/desanders as well as tunnel excavation material.

6.8.1 Lower Spat Gah Headworks River Deposits and Slope Wash

CVC

Based on the available information, the concrete aggregates and the rock fill for the construction of the Lower Spat Gah Headworks, Lower Gabarband Intake, Powerhouse and Power Waterway are intended to be won from the rock excavation material of the weirs/desanders as well as tunnel excavation material.

The tests performed on the rock and loose sediments samples taken at the dam site reveal that the sand from the river alluvium and slope wash material of the Lower Spat Gah Headworks site (weir site 2021) can be used as construction material for CVC. As some minor doubt remains regarding the risk of Alkali-Silica Reaction (ASR) for some of the materials collected in one of the old test pits, additional tests shall be carried out at an early stage of the Construction Phase to draw firm conclusions.

Alternative sources (if required) will be located outside of the site boundaries. The EPC Contractor may have to import aggregates for CVC and shotcrete at the beginning of the works as long as the crushing system is not ready. This needs to be investigated by the Contractor.

Rock Fill Material

The test results for the production of CVC aggregates indicate that both quaternary deposits and tunnel muck from the Mandraza Amphibolite unite exhibit a high strength and can be used as source for coarse grained material. Here also, it is suggested to carry out some additional tests at an early stage of the Project implementation to proof the ASR potential of the materials that will be used for the dam construction.

Clay Core - Dar Mose Area

The investigated area covers a surface of about 37,000 m^2. Assuming a minimum average thickness of 3 m the volume of impervious core material (silt/clay) found in the Dar Mose borrow area can be estimated at about 110,000 m^3.

The granulometric curve and the tests results indicate that most of the material found in the Dar Mose area has a high silt/clay content, while a smaller group of samples shows a lower silt/clay content. Both materials are considered suitable sources for the construction of the dam clay core. Based on the test pit photographs, it can reasonably be assumed that about 30% of this volume is made of boulders. After deduction of the volumes occupied by the boulders and unsuitable coarse-grained soils, the total volume of suitable silty clay material that can be won from this borrow area is estimated at about 50,000 m^3. It has however to be noted that the presence of unsuitable material and boulders will require an extensive processing to separate the usable material from the material shall be sent to waste.

6.8.2 Gabarband Valley

CVC

The test results indicate that the gabbro and the Mandraza amphibolite units have a high strength and are of a good quality as confirmed by the specific gravity and uniaxial compression tests.

The tests performed on samples also indicate that the risk of Alkali-Silica Reaction (ASR) is very low to nil with all test results well below 0.1 (14 day threshold value for potential reactive samples).

6.8.3 Tunnels and Powerhouse

CVC

The test results from the 2020-2021 investigation campaign performed on rock samples show that the risk of Alkali-Silica Reaction (ASR) is very low to nil with all test results well below 0.1 (14 day threshold value for potential reactive samples). On the other side the petrographic analysis of the granitic samples indicate the presence of potentially deleterious “strained quartz” in this rock.

Considering the minor doubts that remain about the risk of Alkali-Silica Reaction (ASR) potential, it is recommended that further tests be carried out at an early stage of the Project implementation to confirm the suitability of the granite as source for aggregates production.

Clay Core - Jhul and Jalkot Area

The Jhul and Jalkot borrow areas cover a surface of about 80,000 m^2 and 30,000 to 40,000 m^2 respectively.

After deduction of the volumes occupied by the boulders and unsuitable soils, the total volume of suitable silty clay material that can be won from these two areas is estimated at about 200,000 m^3 and 100,000 m^3 for the Jhul and Jalkot areas respectively. It has however to be noted that the presence of unsuitable material and boulders will require an extensive processing to separate the usable material from the material shall be sent to waste.

6.9 Recommendations for Further Investigations

Based on the interpretation of the results from the 2008-2009 and 2020-2021 investigation campaign, it is recommended to undertake a series of additional investigations at an early stage of the Project implementation as shown in Table 6-9 and Table 6-10.

Table 6-9: Recommended investigations (first priority)

Structure	Location	Investigation	Amount
Investigations Lower Spat Gah Headworks			
Dam & Desander	River bed close to left abutment	1 borehole to define need of grout curtain below cut – off wall in the area south of LSG20-HW-02	60 m
Desander	Slope	2 boreholes to define the rock line in the excavation area	90 m
Dam	River bed close to left abutment	3 m interval Lugeon tests	10 pcs
Dam & Desander	Along dam axis and desander and flushing channel axes	Seismic lines Refraction and MASW to measure P and S waves in the alluvial and scree deposits. One line parallel and two perpendicular to dam axis and at desander (3 lines)	650 m
Dam & Desander	Boreholes in the dam foundation and desander slope	Down hole tests to measure s-waves and sonic log	150 m
Borrow area	Dar Mose	Test pits dug by excavator for better characterisation of volumes and quality of the suitable material and size of boulders	4
Investigations Lower Gabarband intake			
Dam and Desander	Along dam axis and desander axes	Seismic lines Refraction and MASW to measure P and S waves in the alluvial and scree deposits. One line parallel and one perpendicular to dam axis and at desander (2 lines)	350 m
Investigations Gabarband Crossing			
Crossing area	Perpendicular and parallel to river bed	Seismic lines Refraction and MASW to measure P and S waves in the alluvial and scree deposits. One line Parallel and one perpendicular to dam axis and at desander (2 lines)	250 m
Adits	Inside the tunnels	Hydrofracturing and dilatometer tests in the adits for rock properties (length steel	20 + 10

Structure	Location	Investigation	Amount
		lining and e-modulus) in the gabbro and in the amphibolite	
Slopes	Crossing and portals	Slope stability analysis above portals and crossing area (field and modelling)	1 pc
Laboratory tests			
Aggregates	Different holes and pits	Long-time tests for ASR potential of the granite and alluvial /scree at the Headworks and in the Powerhouse area	4
Investigations of Surge Shaft, Pressure Shaft and Powerhouse Area			
The investigation of these structures is very difficult because of the steep to very steep terrain and the lack of access. The powerhouse is better investigated by means of an adit tunnel (access tunnel) and short boreholes (including hydraulic and dilatometer tests) drilled by the tunnel walls. Alternatively (not recommended) a cheaper alternative would consist of one borehole from portal area of access adit to upper cavern. With inclined borehole to Powerhouse Cavern with length of ~620 m.			
Powerhouse	Access Tunnel	Use of the Access tunnel as exploratory adit to define geological condition (lithology and presence of faults)	1200 m
Powerhouse	Near portal area of adit tunnel to upper cavern	Drilling: rock quality	620 m
	Near portal area of adit tunnel to upper cavern	Borehole tests (Lugeon tests for permeability)	80 pcs
	Near portal area of adit tunnel to upper cavern	Borehole tests: Optical or acoustic scanner (optional)	620 m
	Near portal area of adit tunnel to upper cavern	Hydraulic fracturing tests in borehole	10 tests
Access road to shaft	Access area to shaft	Geological mapping of access road (area not covered by existing map.	1 pc
Laboratory tests			
Aggregates	Different holes and pits	Long-time tests for ASR potential of the granite in the Powerhouse area	4

Table 6-10: Recommended investigations (Secondary priority)

Structure	Location	Investigation	Amount
Access road in Spat Gah Valley, Access to Weir			
Spat Gah access road	Boreholes for bridges or galleries, road cuts	Assumed at 25 locations (2 holes each)= totally 50 holes	1,000 m
Access Road in Gabarband Valley			
Drilling investigation shall be carried out after preliminary road design (finding alignment, on which bank, how many bridges, etc.)			
Gabarband Valley	Access roads	Boreholes for bridges, slope support, galleries, etc.	800 m
Access Road to Surge Shaft			
Partly very steep terrain. Review of alignment and constructability necessary			
Surge Shaft access road	Lower elevation (slope wash section)	Trenches ~3 m deep	10 pcs
	Higher elevation (rock section)	3 short boreholes	60 m
Investigation Gallery to Powerhouse Cavern			
Construction of such a long investigation gallery takes time and is costly, but it is the optimum way of checking best cavern location and orientation. Other alternatives with long boreholes can be considered.			

Powerhouse	Gallery in axis Tailrace Tunnel	Rock mass quality, existence of faults in cavern area, check of quality of faults close to Indus	1,357 m
Investigation Gallery to Powerhouse Cavern			
Headworks	Dam Grout curtain	Additional boreholes and Lugeon tests in the bedrock to define the need of a grout curtain below the section of the cut of wall anchored to the bedrock	80 m / 20 Tests

7 Seismicity

7.1 General

This study assesses the earthquake hazard for the Lower Spat Gah Project in Pakistan. In 2008, an initial Probabilistic Seismic Hazard Assessment (PSHA) with the provision of initial design parameters had been performed. The present new study gives a revision of the seismic hazard based on updated information and enhanced methodology. The recent 10 years brought advances in the methodology of seismic hazard assessment. The reliable earthquake catalogue also increased in this time span by about 25% and updated modelling techniques reduced primarily the uncertainties of acceleration values in comparison to the initial study.

In the seismic hazard analysis a number of parameters play an important role, so that reasonable assumptions on uncertainties have to be made. Therefore, all assumptions are presented in the report, and their consequences are qualitatively discussed. In the present hazard study the recommendations of the ICOLD guidelines (ICOLD 2010) are followed. This chapter presents a summary of the Probabilistic Seismic Hazard Assessment Report which is covered in Volume 5 of this Feasibility Study Report.

7.2 Seismotectonic Setting

The Project site Lower Spat Gah valley is located on the Kohistan sequence, and there in the unit of Southern Amphibolites / Metaplutonic complex. The Project site is located in a seismically very active region.

The nearest major faults are the Indus Suture with extension to the Panjal Thrust and Main Mantle Thrust towards the south. Towards the west there is Duber Kale strike slip fault with branches towards the Project site. Branch no. 2 of the Duber Kale fault is passing with a distance of about 5 km towards the north of the dam site (Figure 7-1).

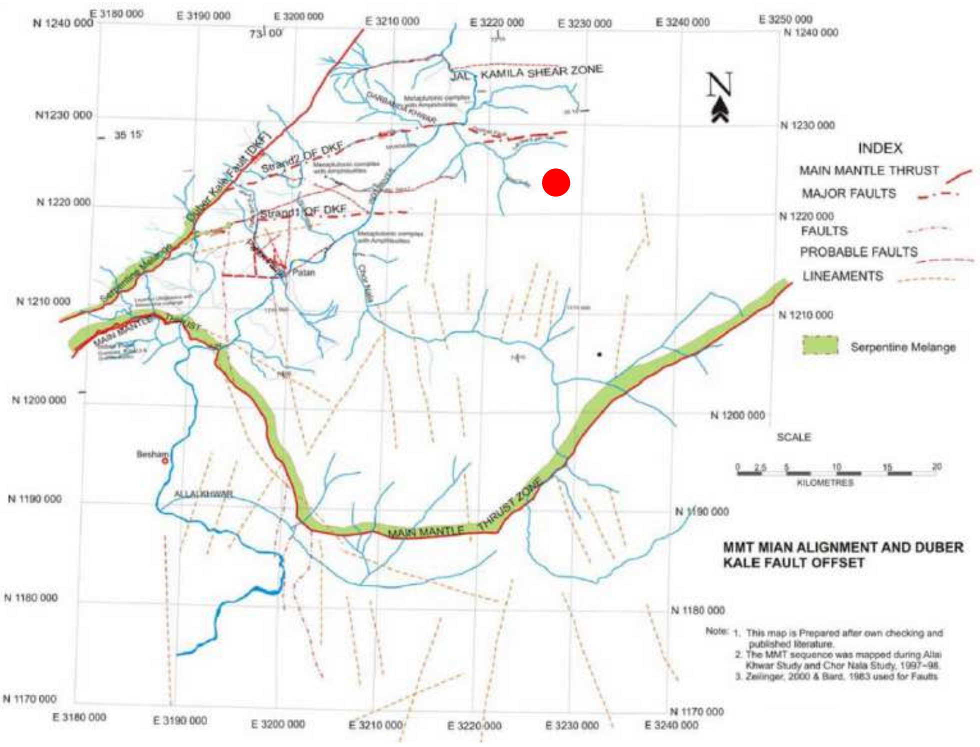


Figure 7-1: Map of local faults around Project site (from Zeilinger et al. 2000)

To the present knowledge based on site inspections, regional seismicity data and geological tectonic documentation, there is no active tectonic fault in the dam foundation and close vicinity of the selected dam axis.

7.3 Probabilistic Seismic Hazard Assessment

In the early days of earthquake engineering, the use of Deterministic Seismic Hazard Analyses (DSHA) was prevalent. These are procedures considering different potential earthquake scenarios and selecting the worst case for the design on the safety level. This procedure is still recommended to evaluate the Maximum Credible Earthquake (MCE) for seismically active regions, which are well investigated with well-defined seismogenic sources (ICOLD 2010).

In the recent years, Probabilistic Seismic Hazard Analyses (PSHA) have become the standard procedure for engineering decisions. These procedures allow to explicitly consider the probability of exceedance of a given ground motion level and thus are useful for the selection of earthquake hazard levels other than the worst-case scenario obtained from a DSHA.

Acceleration response spectra and acceleration time histories are provided for the Safety Evaluation Earthquake (SEE) at safety level and the Operating Basis Design Earthquake (OBE) at serviceability level for the dam structure as well as the Design Basis Earthquake (DBE) for the seismic design of the appurtenant structures. The calculated acceleration values are valid for rock site.

The SEE, OBE and DBE together with the corresponding engineering parameters, (i.e. peak ground acceleration, design response spectra and time histories) needed for the design of the dam and appurtenant structures, are derived based on the results of a Probabilistic Seismic Hazard Analysis (PSHA).

Acceleration response spectra are provided for the SEE, DBE and OBE for rock sites, considering 5% damping. SEE, DBE and OBE acceleration time histories are provided and have been derived for the relevant design scenarios compatible to the uniform hazard spectra.

A comparison has been made with different seismic hazard maps of Pakistan. It can be concluded that the acceleration values of the current probabilistic seismic hazard assessment are comparable to and consistent with recent hazard studies performed by third parties in the Project region.

In addition to the Probabilistic Hazard Analysis, also a Deterministic Seismic Hazard Analysis was performed. Three deterministic scenarios were investigated. The deterministic response spectrum for Scenario 1 with 84% fractile can be evaluated as Maximum Credible Earthquake (MCE). The comparison showed that the deterministic scenario of 84% fractiles gives slightly higher spectral values than the uniform hazard spectrum for the 10,000-year return period while the 50% fractile deterministic spectrum for Scenario 1 is smaller than the uniform hazard spectrum for the 10,000-year return period.

7.4 Seismic Design Criteria

According to the Bulletin 148 of ICOLD, the following earthquake levels should be used for the dam design and analysis:

- Safety Evaluation Earthquake (SEE): The SEE is the earthquake ground motion a dam must be able to resist without uncontrolled release of the reservoir. Depending on the circumstances such as the importance of the dam or the consequences of a dam failure, it is recommended that all components of the dam that are necessary for retaining and controlling the reservoir after a strong earthquake, including the bottom outlet and/or spillway gates must be designed for the SEE.

  For major dams the SEE can be either determined with a deterministically-evaluated maximum credible earthquake or a probabilistically-evaluated earthquake ground motion with a very long return period, for example 10,000 years for high risk category dams with severe consequences on the downstream area in case of a dam failure or lower depending on the risk category.

  For large dams (> 15 m) and high risk category dams, the return period of the ground motion parameters estimated with a Probabilistic Seismic Hazard Analysis is often taken as 10,000 years. For small dams (< 15 m) or large dams with small or limited damage potential shorter return periods can be specified, for example not less than 3,000 years for moderate consequence and not less than 1,000 years for low consequence of a dam failure.

- Design Basis Earthquake (DBE): The DBE with a return period of 475 years is the reference design earthquake for the appurtenant structures. The DBE ground motion parameters are estimated based on a PSHA.
- Operating Basis Earthquake (OBE): The OBE may be expected to occur during the lifetime of the dam. No structural damage is allowed, and all equipment has to remain functional. It has a probability of occurrence of about 50% during the service life of 100 years. The return period is taken as 145 years. The OBE ground motion parameters are estimated based on a PSHA.
- Reservoir-Triggered Earthquake: The Reservoir-Triggered Earthquake represents the maximum level of ground motion capable of being triggered at the dam site by the filling, drawdown, or the presence of the reservoir.

  Due to the size of the Lower Spat Gah reservoir, there is no relevant reservoir triggered earthquake to be expected.
- Construction Earthquake (CE): The CE is to be used for the design of temporary structures and takes into account the service life of the temporary structure. There are different methods to calculate this design earthquake.

In view of the size, importance and risk classification of the main structures and components of the Lower Spat Gah HPP based on the results of the dam break analysis, the following design earthquakes have been selected:

- Safety Evaluation Earthquake (SEE) for the Lower Spat Gah Headworks with a return period of 3,000 years:

  Lower Spat Gah dam (no failure) and flushing channels (structural reinforcement) including safety relevant hydro-mechanical works such as flushing channel gates under the assumption of no uncontrolled water releases in accordance with international standards.
- Safety Evaluation Earthquake (SEE) for the Lower Gabarband Intake with a return period of 1,000 years:

  Lower Gabarband Intake spillway (no failure) and flushing channels (structural reinforcement) including safety relevant hydro-mechanical works such as flushing channel gates under the assumption of no uncontrolled water releases in accordance with international standards.
- Design Basis Earthquake (DBE) with return period of 475 years:

  Powerhouse, desanders, Waterway, hydro-mechanical and electro-mechanical equipment.
- Operating Basis Earthquake (OBE) with return period of 145 years:

  Selected structures such as the Lower Spat Gah dam (slopes stability analysis) and Lower Spat Gah and Lower Gabarband Intake flushing channels (structural stability against sliding, overturning, bearing capacity).

7.5 Main Results

The different design earthquake ground motions are characterised by the following seismic parameters:

- Peak ground acceleration of horizontal and vertical earthquake components, as shown in Table 7-1.
- Acceleration response spectra of horizontal and vertical earthquake components for 5% damping, i.e. uniform hazard spectra for OBE, DBE and SEE obtained from the Probabilistic

Seismic Hazard Analysis. Figure 7-2 shows the SEE response spectra for the Lower Spat Gah Headworks site considering 5% damping and a rock surface.

- Spectrum-compatible acceleration time histories for the horizontal and vertical components of the OBE, DBE and SEE ground motion. The generated time histories do not represent characteristics of real earthquakes. The time histories are conservatively generated with a high energy content and a long strong motion duration, which also included some possible aftershocks after large earthquake events.

The installation of earthquake measuring instruments at the Project site can be evaluated in the next design phase.

Table 7-1: Site-specific peak ground acceleration (PGA) for rock sites for the different design earthquakes for the Lower Spat Gah and Lower Gabarband Intake dams

Design Earthquake	Analysis Method	Return Period (years)	Peak Ground Acceleration (g)	
			Horizontal	Vertical
OBE	Probabilistic	145	0.23	0.16
DBE	Probabilistic	475	0.35	0.23
SEE (LGI)	Probabilistic	1,000	0.44	0.29
SEE (LSG)	Probabilistic	3,000	0.61	0.41

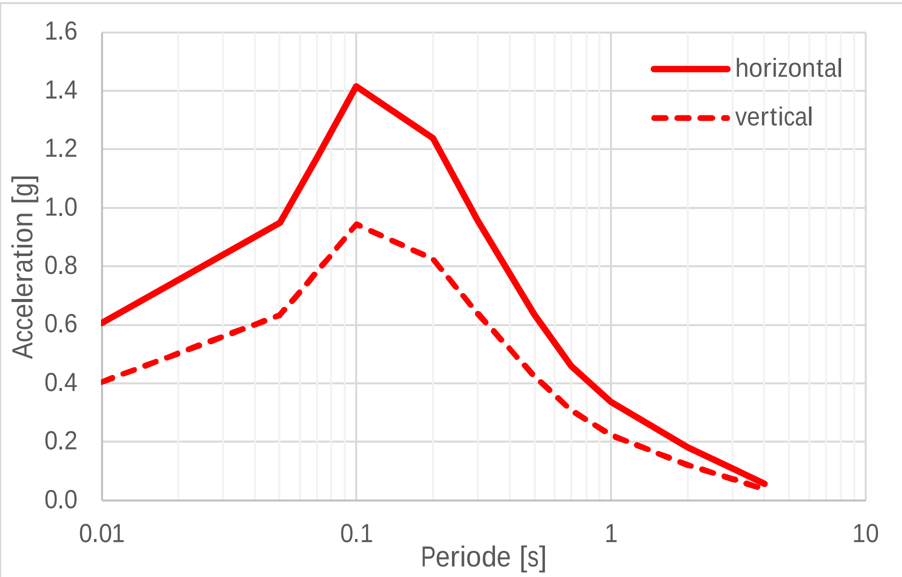


Figure 7-2: Uniform hazard acceleration response spectra for Lower Spat Gah Headworks for horizontal and vertical components of SEE, probability of exceedance 1/3,000 years (5% damping, rock surface)

7.6 References

The following data sources and literature are referenced in this seismicity chapter:

- ICOLD Bulletin 148: Selecting seismic parameters for large dams. Bulletin Print (2010).
- Zeilinger G., Burg, J.-P., Chaudhry N. M., Dawood H., Hussain S. S., 2000. Fault systems and Paleo-stress tensors in the Indus Suture Zone (NW Pakistan), Journal of Asian Earth Sciences 18, 547-559.

8 Alternatives and Project Optimisation Studies

8.1 Introduction

This chapter outlines the different alternatives studies conducted in the Inception Phase of this Feasibility Study to determine the Project layout or features. The basis for the alternatives was the Alternatives and Optimisation Studies of Volume 6 which were conducted in the early phase of the Feasibility Study.

During the Alternatives Studies, different arrangements for the Lower Spat Gah Headworks, Power Waterway, Lower Gabarband Intake and Powerhouse were studied and evaluated. The evaluation was based on preliminary cost estimates and energy calculations, and taking into account economic figures and other criteria like technical feasibility, environmental impact and risk aspects, etc. The Alternatives Studies concluded with the selection of the recommended Lower Spat Gah Project layout as the basis for the Feasibility Study design:

- Lower Spat Gah Headworks: Small weir option,
- Lower Gabarband Intake: Regular scheme with diversion discharge of 10 m^3/s,
- Power Waterway arrangement: Alternative 3,
- Pressure Shaft layout: Vertical arrangement,
- Power Waterway excavation method: D&B,
- Powerhouse location: Underground, at bottom of vertical Pressure Shaft.

The goal of the subsequent Optimisation Study was to determine the optimal set of main design parameters such as the design discharge and the Full Supply Level (FSL). The different options were evaluated based on preliminary cost estimates and energy calculations. The cost estimates were established for the recommended Lower Spat Gah Headworks, Power Waterway, Lower Gabarband Intake and Powerhouse arrangements from the Alternatives Study. Budgetary offers for the E&M equipment from suppliers were used to adequately represent the E&M costs for such a wide range of discharges.

The maximum Full Supply Level has been set during the cascade development in the 2008 Pre-Feasibility Study [2] and cannot be increased without impacting the Middle Gabarband powerhouse. It was decided to not re-optimise the cascade and accept an FSL of 1,510 m asl as the maximum possible level. It was also decided to not consider lower FSLs which would ultimately negatively affect the revenue, and the FSL has therefore been set at 1,510 m asl and could not be further optimised.

The Optimisation Studies concluded with the selection of the design discharge of 75 m^3/s with no overload for the Feasibility Study design. Should a plant factor higher than 50% be required by the Pakistani authorities, then the design discharge will be adjusted to 62.5 m^3/s with an overload factor of 1.2.

The following alternatives studies have been conducted in the Inception Phase and are outlined in this chapter:

- Peaking vs run-of-river,
- Desander design grain size,
- Headrace Tunnel sizing,
- Lower Gabarband Intake access concept and intake tunnel size,
- Powerhouse location and orientation,
- Powerhouse characteristics including turbine type and number of units, turbine speed, number of nozzles, MIV type, turbine level and flood protection level, and transformer type,
- Switchyard type (GIS).

8.2 Peaking vs Run-of-River

8.2.1 Introduction

For the Alternatives and Optimisation Study as well as during some additional preliminary design works, the Lower Spat Gah Headworks have been designed with a Full Supply Level and a Minimum Operating Level in the Spat Gah reservoir to enable as much peaking as possible as implied by PEDO. This resulted in very high costs for the desander at the Spat Gah Headworks in general that had to be designed for both the FSL and the MOL.

It has been communicated by PEDO in a meeting in April 2019 that even though peaking energy is beneficial for the Project regarding energy evacuation and energy tariff, there are no official peaking requirements. Thus, a specific optimisation of the Lower Spat Gah Headworks and the desander in particular has been conducted to evaluate the costs vs. peaking design discharge and resulting peaking energy in case the plant is operated as a conventional run-of-river (RoR) project.

The objective of this comparison is to optimise the general arrangement and the operation pattern of the Lower Spat Gah Headworks.

8.2.2 Desander Layout

Within this comparison, the design implications on the desander design of operating the Lower Spat Gah HPP as a peaking or as run-of-river plant have been separately assessed.

Preliminary desander hydraulic layouts were defined for the two operation patterns to get a better felling of the sensitivity of the Project's hydraulic layout. Six desander basins and 0.3 mm design grain size was considered in the development of the surface desander layout.

A summary of the preliminary hydraulic layouts defined as basis for the preliminary cost estimates is given in Table 8-1. As can be seen from the table, the operation pattern of the Lower Spat Gah HPP is a key design criterion that has a significant impact on the design and thus the cost of the Project.

Table 8-1: Desanders – Preliminary hydraulic layouts

Alternative		Peaking	RoR
FSL	m asl	1,510	1,510
MOL	m asl	1,500	1,508
Water depth	m	17.2	11.0
Width basin	m	13.7	8.8
Length basin	m	110	70

8.2.3 Comparison

Construction Costs

Preliminary cost estimates have been prepared for the desander and Headrace Tunnel for each of the different operating patterns based on preliminary quantities and unit rates for the main civil works cost items. The relative length of the Headrace Tunnel compared to the Alternative Study has also been taken into account.

The civil works prices have been further refined during the preliminary design works compared to the unit rates of the Alternatives and Optimisation Studies shown in Volume 6 on the basis of the two similar projects such as Tarbela 4th Extension HPP and Athmuqam HPP in Pakistan.

Note that all cost estimates for the purpose of this comparison are preliminary by nature and shall consequently be viewed cautiously.

Costs Comparison

The preliminary cost estimates have been prepared based on the preliminary layout designs and BoQ prepared for the two operating patterns. The results are shown in Table 8-2.

Table 8-2: Surface desanders – Preliminary cost estimates

Alternative		Peaking	RoR
MOL	(m asl)	1,500	1,508
Civil costs	(million USD)	87.0	56.9

Revenue

The energy model which was set-up for the Alternatives and Optimisation Study for a 54-year period has been used. The same input data and methodology has been used for the energy simulations as shown in Chapter 2 of Volume 6 - Alternatives and Optimisation Studies and are thus not repeated in this chapter.

The peaking operation of the energy simulation is as described in Chapter 10.4. The concept of guide curves was also adopted in case the Project is designed as a run-of-river plant. For a run-of-river plant, meaning that no seasonal operation (i.e., draw down and re-fill of the reservoir) is considered and the water levels are considered to be at Full Supply Level at this stage. Intra-daily peaking operation was not considered for this comparison but may be considered in a next Project stage to enable hourly peak operation during the dry season and, in case water is copiously to enhance the generation of power output during the Feasibility Study Phase.

Assuming a standalone operation for comparison purposes, the energy output is presented in Table 8-3. The energy generation for the RoR operation is slightly higher because the reservoir level is higher on average (as a result of the higher MOL) and the head losses are lower because the average turbine discharge is lower (as a result of continuous instead of focused peaking operation).

Table 8-3: Mean annual energy output

		Peaking	RoR
Mean annual energy	(GWh/yr)	1,903	1,919

8.2.4 Recommendation

Based on the results presented this chapter, it can be concluded that:

- Operating the Lower Spat Gah as a run-of-river project generates about 0.8% additional power compared to peaking,
- Designing the Lower Spat Gah HPP as a peaking plant results in additional costs of about 30 million USD compared to the run-of-river option.

Due to conflicting interests regarding peaking capabilities between the provincial and federal governments, the Panel of Experts was asked to decide on the operating pattern of the Lower Spat Gah Headworks.

8.3 Desander

8.3.1 Desander Design Grain Size

Sediment particles are removed in the desander to exclude the particles from being transported into the Headrace Tunnel and to lower the abrasion of the turbines. The decision of the desander design grain size can be based on the total costs from the desander construction and operation costs, and the turbine repair and replacement costs. The optimal particle size is at the minimum total costs and would be chosen as the design grain size. Due to the high head of the scheme, various literature recommends a design grain of 0.2 mm to be applied. The available grain size distribution of suspended sediment (see Volume 3 - Hydrology, Figure 6-2) shows that the sediment fraction between 0.2 and 0.3 mm is small compared to the fraction below 0.2 mm. A desander construction cost vs turbine maintenance cost has therefore been prepared for the two grain sizes.

The desander construction costs can be estimated with standard design procedures and increase potentially with a decreasing grain size. Preliminary cost estimates for the two studies grain sizes showed that the desander construction for the 0.2 mm grain size would be about 11 million USD more expensive than for the 0.3 mm grain size.

The abrasion depends on the particle size, particle shape, particle hardness, flow velocity and turbine material. At the desander design stage, the grain size distributions from the ongoing sediment analysis study have not been available. Thus the grain size distributions available from the Spat Gah valley from 2007 has been used. It is noted that the particular shapes and hardnesses remain largely unknown to date and shall be investigated in the next design stage.

Ortmanns (2006) has established repair cycles of Pelton turbine buckets as well as nozzles and needles, which were used to estimate the required repairs for the Lower Spat Gah HPP. Based on the (scarce) sediment measurement data available, an average concentration of 25 ppm, or 0.025 g/l, during the high-flow season and 5 ppm, or 0.005 g/l, during the low-flow season was assumed. Based on the available grain size distribution from 2007 the removal rate during the high-flow season is 5% for the 0.3 mm design grain and 10% for the 0.2 mm design grain. The removal rate is estimated to zero during the low-flow period as the particles tend to all be smaller than the design grain. The rest of the sediments was assumed to be carried to the turbines for this simple approach. The operational times of the turbine parts have then been estimated with the figures from Ortmanns (2006) and the number of replacements over the 30 year Concession Period estimated. The preliminary turbine repair and replacement costs have been estimated based on the Consultant's experience, summed up over the 30 years of operation and discounted with a 10% discount rate. The discounted O&M costs for the 0.3 mm grain size were estimated to be about 1.5 million USD higher than for the 0.2 mm grain size.

Table 8-4: Desander design grain size cost comparison

Grain Size	Construction Cost (million USD)	Discounted Operation Period O&M Costs (million USD)
0.2 mm	101	3.2
0.3 mm	90	4.7

The preliminary comparison showed that the lower desander construction costs of the 0.3 mm grain size outweigh the slightly higher O&M costs during the Concession Period. Therefore the design grain size was preliminarily set as 0.3 mm.

The important turbine parts such as runner, nozzle, nozzle-needle and deflector may be protected by a wolfram carbide coating to reduce the intensity of abrasion. During operation, regular maintenance and repair works of the most sensitive parts of the turbine parts shall be foreseen during the low inflow season to avoid unnecessary loss of power generation.

As mentioned in Volume 3 – Hydrology of this Feasibility Study, it is recommended to pursue additional sediments sampling and testing campaign with emphasis on the high inflow season during the year 2022 to improve the current knowledge and better assess the anticipated turbine life/amount of repair and maintenance works during operation, and eventually confirm the adequacy of the selected design grain size for desander design.

8.3.2 Desander Location

It has been assessed if an underground alternative for the desander location is more favourable than a surface desander for a peaking plant. A rough estimate of the concrete and excavation volumes of the underground alternative showed that the costs are about 20% higher and do not outweigh any potential advantage. In addition the surface alternative has an easier constructability and lower geological risk.

Should the operating pattern be adjusted from peaking to pure run-of-river, then the costs would be about the same for a 6-basin configuration.

8.4 Headrace Tunnel

8.4.1 Economic Optimisation of Tunnel Cross Section

The diameters for the concrete and steel lined sections of the Power Waterway have been determined based on an optimisation process with minimisation of the sum of concrete/steel costs and the net present value of energy due to the head losses along the Power Waterway relevant segments. The discount rates, steel costs, energy tariff have been assumed as in the Alternatives and Optimisation Study phase during the Inception Phase. The ranges of studied diameters for this specific optimisation are as follows:

- Range of concrete tunnel diameters: 4.00-6.00 m,
- Range of velocity on concrete tunnel sections: 2.7-6.0 m/s,
- Range of steel sections diameters: 3.70-4.40 m,
- Range of velocity on steel lined tunnel sections: 4.9-7.0 m/s.

The minimum excavation size for a tunnel excavated by drill and blast is in the range of 4 m depending on the contractor’s equipment. Such a small tunnel diameter would however lead to very (too) high velocities for the lining and has thus not been further considered. The results of the optimisation studies are shown in Figure 8-1 and Figure 8-2. As can be seen, the optimal internal diameter of the concrete and steel lined sections of the Power Waterway shall be 5.30 m and 4.00 m, respectively. The velocity at design discharge in the optimal diameters reaches 3.4 m/s and 6.0 m/s, respectively for concrete and steel lined sections which are within the industry reasonable ranges.

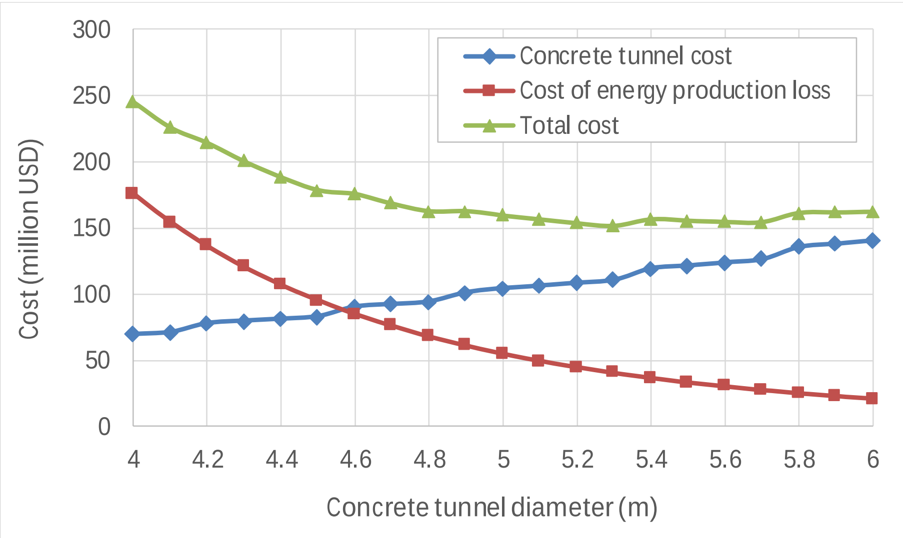


Figure 8-1: Headrace Tunnel concrete lined section optimisation results

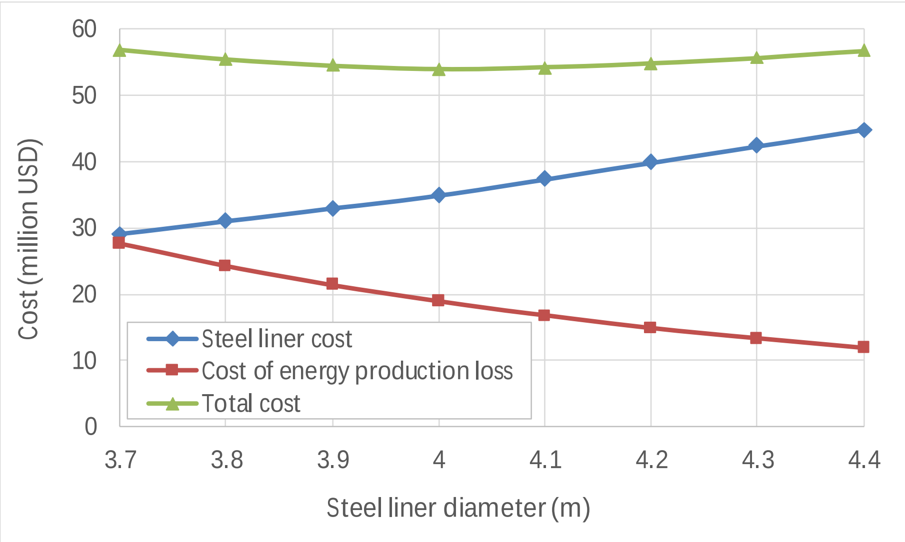


Figure 8-2: Headrace Tunnel steel lined section optimisation results

8.5 Access Concept Lower Gabarband Intake and Cross Section Lower Gabarband Intake Tunnel

8.5.1 Access Concept Lower Gabarband Intake

The access conditions to the Lower Gabarband Intake are particularly challenging if not unfavourable. This has been confirmed by the repeated landslides faced during the geological investigations. This factual observation led to an underground access design of the Lower Gabarband Intake being privileged as documented in Volume 6.

In addition, the costs of a surface access road would be in a similar range as the cost for the access road to the Gabarband Crossing with about 13 million USD. The additional costs to enlarge the tunnel for the design vehicle as outlined before was estimate to be less than 10 million USD, thus cheaper than a surface access road.

8.5.2 Gabarband Intake Tunnel

This chapter presents a high-level alternatives concept study of different layouts of the Gabarband Intake Tunnel with the goal to select the best suited option. This concept study has been conducted at the beginning of the Feasibility Study phase and slightly deviates from the final dimensions shown on the drawings and in other chapters of this report.

The design vehicle for the option study is 3.5 m wide and 4.0 m high , which is suitable for the equipment transport to the Gabarband Intake Tunnel considering that i) no large bored pipe, cut-off wall construction and hydro-mechanical equipment is needed and ii) the main site installations will be located at the Gabarband Crossing. The four developed tunnel layout options are schematically shown in Figure 8-3.

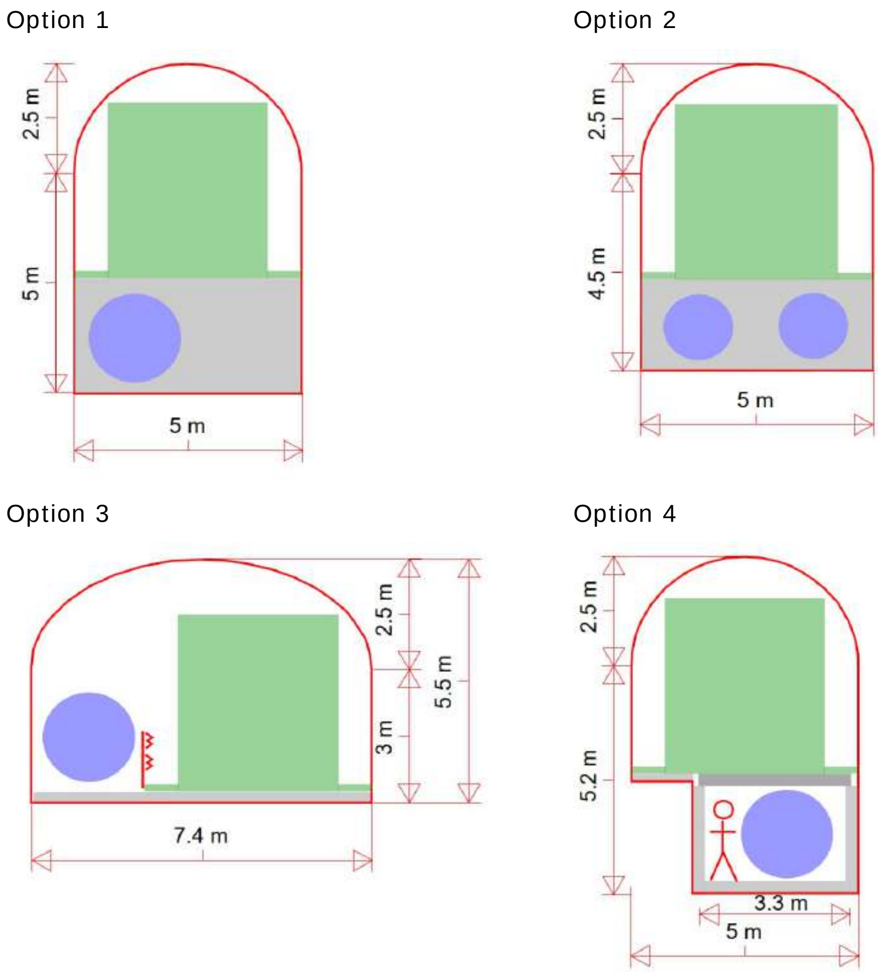


Figure 8-3: Gabarband Intake Tunnel cross section options

Preliminary costs were estimated for the excavation, rock support, concrete as well as the GRP pipe. The costs for all options was very similar and thus other criteria were applied to select the preferred option.

Options 1 and 2 were not considered further given the slower construction progress and obstruction of construction traffic when the pipe is installed compared to Option 3. Options 3 and 4 have a high flexibility regarding maintenance considering that the pipe can be easily inspected. The in situ concrete box of Option 4 would have to be constructed directly after the excavation of the main tunnel part and then covered with a pre-cast cover to allow for traffic. The pipe could then be installed at a later time. The construction of the concrete box at the bottom would however lead to lower progress rates and a delayed access to the Lower Gabarband Intake which may ultimately affect the critical path of the Project.

In conclusion, Option 3 was selected as the preferred option due to the shorter construction time and high maintenance flexibility during Project operation.

8.6 Powerhouse Location and Orientation

The position of the Powerhouse at the bottom of the Pressure Shaft has been proposed in the Alternatives Study of the Inception Phase as a result of an economic comparison.

The geological information available in the Powerhouse area is at the surface only. The theoretical interpolation of the geological boundaries of the granitic body shows mainly vertical boundaries but the boundary inclination remains uncertain at this stage. It can be assumed that the

Powerhouse is located in favourable granitic rocks and less likely to encounter amphibolite. It is acknowledged that the interpretation of the data at the Powerhouse depth, independent of its location, is of rather limited validity in the absence of direct data at depth. This is why it is recommended to investigate and confirm the proposed location and orientation of the Powerhouse Cavern using the two Powerhouse access tunnels as exploratory adits at the beginning of the construction phase to locate the Powerhouse in the most suitable geological unit to minimise the rock support, construction time and the geological risk. Thus, it cannot be excluded that the Powerhouse position may have to be slightly adjusted when direct reliable geological information is available.

The orientation of the Powerhouse has not been adjusted as it is arranged to have the most suitable orientation with regards to the assumed discontinuities to optimise rock support as documented in the Volume 4 – Geology.

8.7 Powerhouse Characteristics

8.7.1 Turbine Type

The selection of the turbine type is usually driven by aspects such as operating conditions, turbine and civil works costs, ease of maintenance of the worn components, or transport. These aspects are however not taken into consideration for the Lower Spat Gah Project because it has a rated net head for which only Pelton type turbines would be suitable as shown in Figure 8-4. The Pelton turbines have the advantage of excellent part load capability because the Project can be operated as a run-of-river project during the non-peaking hours.

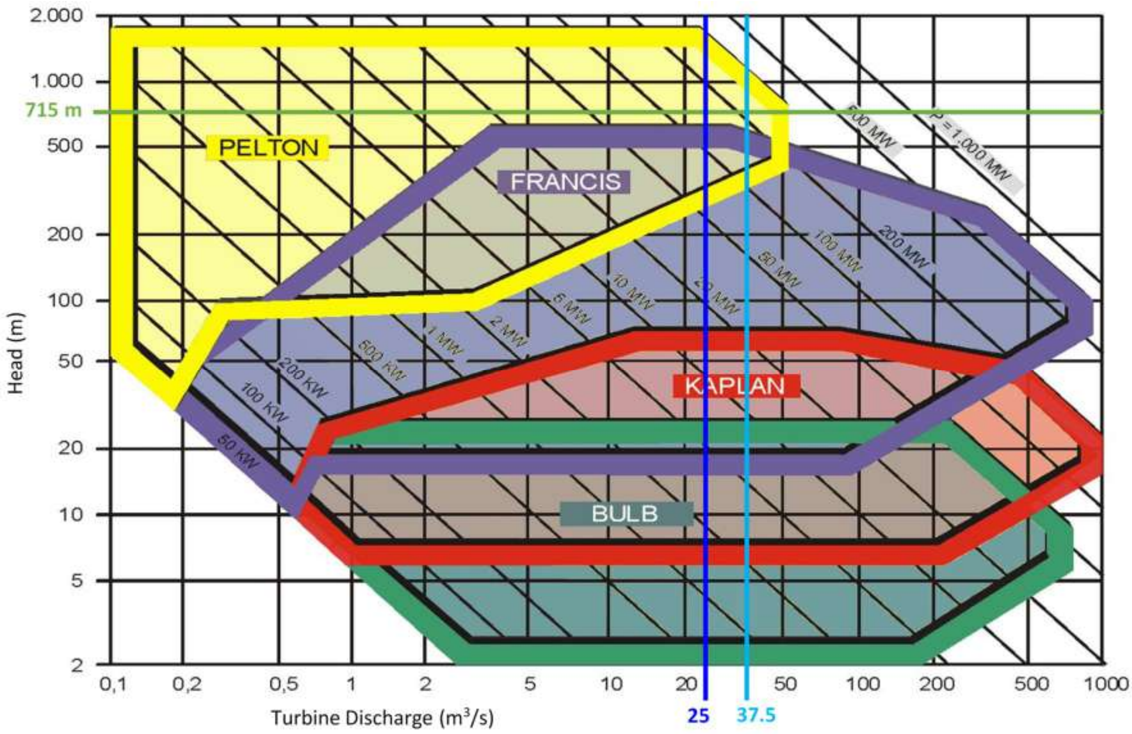


Figure 8-4: Operating range of different number of turbine - application for Lower Spat Gah

8.7.2 Number of Turbines

A comparison of the number of turbines was conducted in order to select the most economic/suitable number for the Project. The study was based on the hydraulic parameters from the Optimisation Study in Volume 6 regarding reservoir levels, turbine level and head losses.

The natural stream flow conditions, storage capacity of the planned reservoir and transport are relevant for the choice of number of units. The Lower Spat Gah Project will be operated as a peaking plant for several hours a day and a run-of-river plant in the remaining hours of the day if the water inflow allows for it.

The determination of the best suitable number of generating units is a compromise between plant flexibility/energy production (favouring a high number of units) and feasibility on one hand and construction costs on the other hand. A minimum of two generating units is recommended such that in case of maintenance and repair of one generating unit, the second generating unit is still available for energy production. Two Pelton type turbines also allow for excellent part load capabilities during the low flow periods.

The turbine size of a 2-unit setup is at the upper feasible limit of Pelton turbines. Due to the large flow and the resulting large size of the units with a 2-unit setup, a setup of three turbines is also considered. The main criteria for the design calculation of the units is a rated net head of 714.6 m and a total plant discharge of 75 m^3/s. The unit discharge is 37.5 m^3/s for 2 units and 25 m^3/s for 3 units. The resulting preliminary main data and dimensions are shown in Table 8-5.

Table 8-5: Main data and dimensions of 2 and 3 Pelton units

Parameter		2 Units	3 Units
Type of turbine	(-)	Vertical Pelton	Vertical Pelton
Number of jets	(-)	6	6
Rated turbine output	(MW)	236.5	157.7
Rated net head	(m)	714.6	714.6
Rated discharge	(m^3/s)	37.5	25.0
Synchronous speed	(rpm)	333.33	428.57
Diameter ring pipe	(m)	16.5	12.7
Bucket width	(m)	0.88	0.72

Due to its location in a remote and difficult to access area, the size of the unit is a decisive factor that needs to be considered. This applies especially for the transformer which is the biggest and heaviest part to transport to site. Also the access roads and tunnels need to be bigger with the 2-unit solution which will additionally increase the costs. In relation to transport the 3-unit solution is to be preferred.

The installation time of the 2-unit solution is expected to be slightly shorter but at least this advantage is outweighed by the fact that the handling of the bigger parts of the 2-unit parts is more sophisticating.

The costs for the E&M equipment were estimated based on budgetary proposals from international suppliers as well as the Consultant's records. The overall costs including all technical main systems amounted to similar costs of 75.1 million USD for 2 units and 73.4 million USD for 3 units. The difference in costs for the 3-unit setup compared to the previous Project phase is due to a calculation discrepancy in the previous Project phase. The costs for 3 units are lower mainly because the synchronous speed is higher (428.57 rpm vs 333.33 rpm) and therefore the generator has lower costs.

The unit size also has an impact on the dimensions of the Powerhouse Cavern which were roughly estimated based on the unit dimensions. The excavation and concrete volumes for 3 units are slightly higher than for 2 units. The estimated preliminary excavation and civil costs for a 2-unit setting and a 3-unit setting are expected to be similar with 31.0 million USD and 32.1 million USD, respectively.

The impact of the number of turbines on the generated energy was analysed with the efficiencies used in the Optimisation Study. The energy was calculated using the same in-house software tool as described in Chapter 9 and is based on the 45 years of inflow data as described in Volume 6. Table 8-6 shows the output of the simulation. The depreciated energy was calculated for 30 years of operation and discounted to Year 0 with a discount rate of 10%. The revenue has been calculated from the average annual energy generations using a tariff of 6.6 USc/kWh for the years 1-12 and 3.3 USc/kWh for the years 13-30 as assumed in the previous Project phases, and discounted over 30 years of operation that are on the lower side. It can be noted that the annual energy generation is insignificantly higher for 3 units than for 2 units due to slightly higher efficiencies at lower flows.

Table 8-6: Energy calculation results for stand-alone operation

Results		2 Units	3 Units
Average annual energy generation	GWh/yr	1,902	1,903
Depreciated energy generation	GWh	17,930	17,944
Depreciated power revenue	million USD	1,019.3	1,020.1
Difference in power revenues	million USD	-	0.8

The E&M and civil works costs as well as the power revenue difference are summarised in Table 8-7 to compare the number of units. The overall costs for 3 units are slightly smaller than for 2 units.

Table 8-7: Overall cost comparison of 2 and 3 Pelton units

Costs		2 Units	3 Units
E&M equipment	million USD	75.1	73.4
Powerhouse	million USD	31.0	32.1
Difference in power revenues	million USD	-	-0.8
Total	million USD	106.0	104.7

Furthermore, and however not directly accounted for cost wise in the above calculations, the 3-unit layout has the following advantages:

- Operation and maintenance:
  - Better efficiency in partial flow of plant,
  - More operation flexibility,
  - Reduced energy loss during planned and unplanned outages,
  - More operation safety,
  - More availability in case of maintenance.
- Because of smaller equipment size:
  - Lower weight of transport vehicle,
  - Smaller and cheaper EOT crane,
  - Smaller equipment to handle for installation and maintenance.
- Civil design
  - Smaller parts to transport (road, bridges, tunnel),
  - Smaller, cheaper and faster to construct Main Access and Power Evacuation Tunnel required due to more compact transformers.

The only disadvantage of the 3-unit solution is the slightly longer installation time. The size of the turbines and generators of the 2-unit layout become too big and the advantage of having one unit less becomes void. The larger size also makes the transport and installation more complicated and therefore potentially more expensive and hazardous. The Powerhouse Main Access and Power

Evacuation Tunnel also needs to be larger and the costs will thus additionally increase for the 2-unit layout which was not accounted for in the above comparison.

Because there is no significant cost advantage for a 2-unit layout and because a 3-unit layout is more beneficial regarding installation, operation and maintenance, it was recommended to select the 3-unit layout. As a 3-unit layout greatly solves the transportation issues, the 4-unit layout was not investigated. In addition, the 3-unit layout already reached equilibrium between increased costs and additional energy production, thus a further increase of number of units would not bring additional economic benefits, and the OPEX cost are higher with more units.

8.7.3 Number of Nozzles

For the given head and resulting size of the runner, four, five and six-nozzle vertical Pelton turbines are technically possible. Even though minimally more expensive than a four and five-nozzle turbine, a six-nozzle turbine has higher efficiencies and better part-load capabilities and was thus selected.

8.7.4 Speed

The speed selection of the unit is primarily determined by the given head, flow, number of nozzles and desired operating regime.

Generally a higher speed leads to smaller turbine and generator dimensions, which is directly reducing the cost of the equipment and civil structures. Therefore, it is desirable to select a synchronous speed as high as technically possible. This applies in particular to cavern powerhouses as the space is limited there.

A speed of 428.57 rpm has been selected as the synchronous speed for a six-nozzle turbine because this is the maximum speed for this Project based on the design for the prevailing hydraulic conditions. This speed has also been conservatively proposed in the budgetary proposals received by Suppliers to remain on the safe side from a cost perspective.

It is however acknowledged that E&M Suppliers may propose a four or five-nozzle turbine and corresponding speed at the bidding stage to eventually optimise cost and provide a more operator friendly solution regarding the risk of sediment abrasion as it has been checked by the Consultant that a five-nozzle Pelton turbine would fit in the current Powerhouse design with only very minor adjustments required on the civil side.

8.7.5 Main Inlet Valve Type

The selection of the main inlet valve (MIV) type depends on the design pressure. A cost vs. head loss comparison can be conducted if more than one valve type is possible. Table 8-8 compares the characteristics of the two possible types, butterfly valve and spherical valve.

Due to the design pressure of 90 bar only the spherical valve type is applicable and has been chosen for the Lower Spat Gah Project.

Table 8-8: Comparison of main inlet valve types

Characteristic	Butterfly Valve	Spherical Valve
Typical head range	To 25 bar (2.5 MPa)	To 200 bar (20 MPa)
Diameter	To approximately 6,000 mm	To approximately 3,000 mm
Reliability	High, shutoff off free-flow possible	Shutoff of free-flow discharge possible, double seal arrangement with operation and maintenance seal usual
Head loss	Moderate and depending on design – Lentil-Type Disc for smaller diameters and standard valves and Biplane-Type disk for larger diameters	Negligible because it corresponds to the head of an equivalent length of pipe
Leakage	Low	Very low
Type of seal	Rubber to metal	Metal to metal
Control system	Automatic - closing with counterweight and opening with hydraulic servomotor	Automatic - closing with counterweight or pressure storage system and opening with hydraulic servomotor
Maintenance	Low	Moderate
Cost	Moderate, standard design for smaller diameters available	Expensive, custom-designed and cost is 2-3 times that of butterfly valves
Delivery Time	9 - 15 months - depending on the diameter	12 - 24 months

8.7.6 Turbine Centreline and Flood Protection Level

The Indus River water levels in natural flow conditions are below the Tailrace Outlet Structure and do not impact the design of the Project. The Patan hydropower plant is however planned further downstream on the Indus River. The Full Supply Level of the future reservoir has been assumed at 760.00 m asl as given in the 2010 Feasibility Study and confirmed based on a more recent status of the Project. It has therefore been assumed that the flood water level of the future Patan reservoir is 1 m above the FSL at 761.00 m asl. This water level has been set as the downstream boundary condition to calculate the water level in the Tailrace Tunnel directly below the turbines in order to determine the turbine centreline with an appropriate freeboard to avoid too frequent powerhouse shutdowns.

With the given tunnel length, slope and invert levels, the water level at the beginning of the Tailrace Tunnel results to 762.4 m asl. A preliminary clearance of 2.5 m is required between the turbine wheel and the flood water level. With the given turbine dimensions, this results in a turbine axis elevation of 765.40 m asl.

8.7.7 Transformer Type

The unit transformers can either be single-phase type or three-phase type transformers. For the unit transformers, three-phase type transformers have been chosen for the following reasons:

- No requirement for spare transformers inside the cavern on the Operator’s side,
- The final dimensions for one three-phase transformer are smaller than three single-phase units (approximately L x W x H: 9 x 5 x 7 m compared to 18 x 5 x 7 m). The remaining space in the Powerhouse can be used for other equipment. The relevant transport dimensions for tunnel access and the width/height of the units remain however quite similar (no significant benefit),

- The overall weight for one three-phase transformer is smaller than three single-phase units (approximately 120 ton compared to 240 ton). The relevant transport weight is only a bit larger than for one single-phase unit,
- The costs of the transformer are directly linked to the volume and weight of the equipment. Therefore the cost of one three-phase unit is approximately 40 - 50% lower than for three single-phase units. The cost savings for the three main transformer units alone will lead to around 3.4 million USD without taking into consideration potential savings on the civil side due to a reduced Transformer Cavern length.

Table 8-9: Comparison of transformer type

	One Three-Phase Transformer	Three Single-Phase Transformers
Total size (L x W x H)	9 x 5 x 7 m	18 x 5 x 7 m
Overall weight	120 ton	240 ton
Costs for 3 units compared to three-phase transformers	0	+3.4 million USD

The assessment is based on the preliminary equipment dimensions and on the assumption that standard transport equipment which is typically used for such tasks will be available and used by the Contractor. The transport equipment is namely a low bed trailer with a truck. Precondition is that the transport takes place in the low inflow season of the year.

Based on the route survey performed for this Feasibility Study, it is understood that only the access roads located on the left bank of the new bridge across the Indus River will need to be upgraded to facilitate the transport of the equipment to the Powerhouse site. The slightly heavier three-phase transformer are expected to, if at all, only require marginally more road upgraded measures than the single-phase transformer would, considering the short length of the access road to the Powerhouse portal from the new bridge across the Indus River and considering the fact that the Karakoram Highway to the Project site is understood to be suitable for the design vehicles required for the upstream Dasu and Diamer-Basha projects.

Because the single-phase transformers do not offer a real advantage in transport size or weight and because of the price advantage of the three-phase transformers, the three-phase transformers were selected for this Project.

8.8 Switchyard Type and Location

In line with common practise for powerhouses with long access and evacuation tunnels, a gas-insulated switchgear (GIS) type located in the Transformer Cavern has been selected for the Lower Spat Gah Project in accordance with the findings of the 2010 Feasibility Study and also because of the yet to be finalised grid connection requirements.

When the confirmation from NTDC regarding grid connection length, voltage as well as the location and voltages of the switchgear at the grid connection point is available, it can be discussed if a high-voltage switchgear is required in the transformer cavern. Directly connecting the transformer to the Connection Switchyard does however have the risk of revenue loss when one of the transmission cables breaks because the unit cannot be operated during the repair time. Having a GIS in the Transformer Cavern would allow the continuation of operation of all units in case of a high voltage cable defect because the energy can be conveyed through the remaining cables. It is therefore recommended to discuss the grid connection and requirements for the high voltage switchgear with NTDC for the final design implementation.

9 Project Concept and Operational Aspects

Corresponding Drawing

LSG-FS-000-003 Project Overview, Schematic Hydraulic Scheme, Longitudinal Profile

9.1 Project Concept

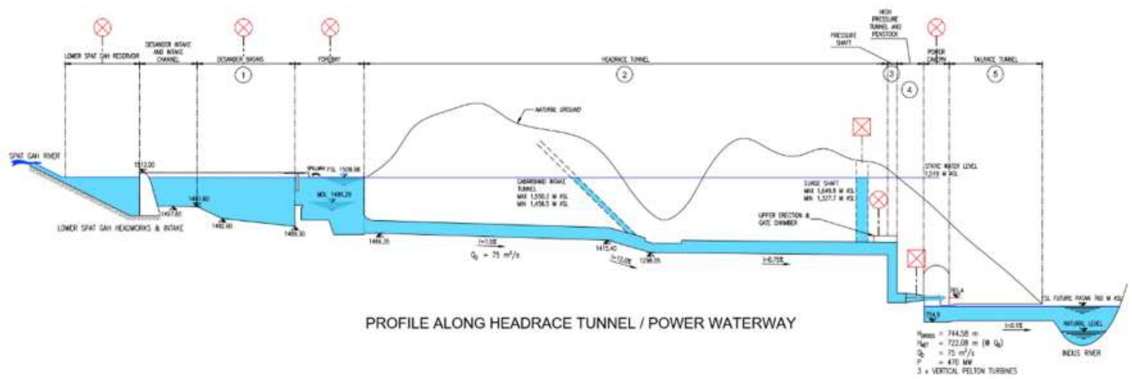
9.1.1 Overview

The Lower Spat Gah HPP is a run-of-river project with potential peaking capabilities located on the Spat Gah and Gabarband Rivers in the Khyber Pakhtunkhwa Province in Northern Pakistan. The proposed concept and the main design parameters have been selected based on the Alternatives and Optimisation Study conducted during the Inception Phase (Volume 6). The Project is planned with headworks on the Spat Gah River to convey water to the Powerhouse and a secondary intake on the Gabarband River connecting to the Headrace Tunnel. The water is released from the Powerhouse to the Indus River about 1.3 km upstream of the confluence with the Spat Gah River.

The Lower Spat Gah HPP consists of the following main structures:

- Lower Spat Gah Headworks with rockfill dam, flushing channels, intake on the right bank, surface desander and forebay,
- Lower Gabarband Intake with weir structure, intake on the left bank, surface desander and forebay,
- 2.4 km long Gabarband Intake Tunnel connecting to the Headrace Tunnel with free-flow section at the beginning and pressurised section after,
- 10.9 km long pressurised Headrace Tunnel,
- 0.5 km high Pressure Shaft,
- 0.2 km long High Pressure Tunnel including penstock,
- Power Cavern with 3 Pelton turbines,
- 1.3 km long free-flow Tailrace Tunnel.

The Project is planned as a run-of-river scheme and the limited storage capacity between the Full Supply and Minimum Operating Level of the reservoir is used as an active storage for peaking capabilities.



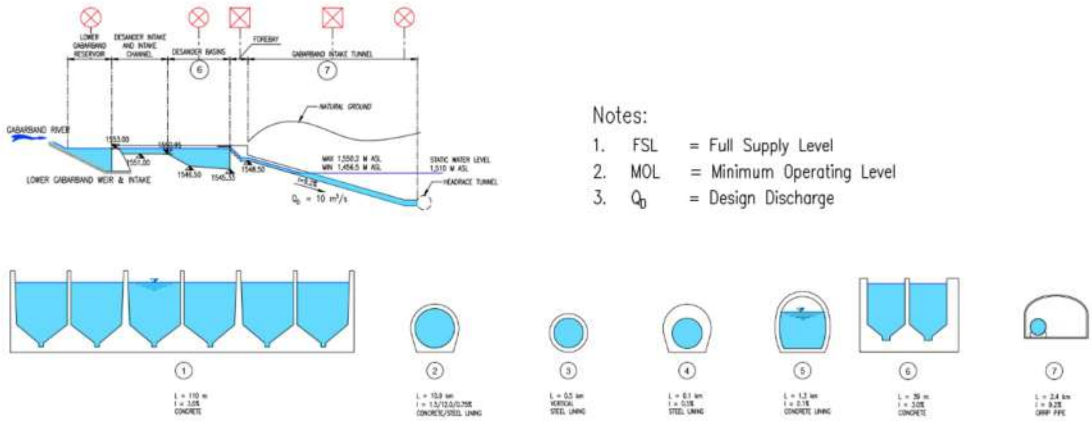


Figure 9-1: Schematic hydraulic longitudinal profile

9.1.2 Lower Spat Gah Headworks

The Lower Spat Gah Headworks is located on the Spat Gah River and consists of a dam, flushing, and intake and desander section. The clay core rockfill dam is located on the left bank and connects the left abutment with the flushing structure. The flushing structure has three channels equipped with radial gates, and the gate No. 3 next to the desander intake also has a flap gate on the top. The flap gate is foreseen to regulate the reservoir water level up to its capacity most of the year. It will also be used to flush debris downstream. The sediments in front of the desander intake will be periodically flushed, ideally during flood conditions. The residual flow will be released through a valve-controlled pipe from the desander intake through the flushing channel No. 3 right wall.

The intake to the Power Waterway system and desander is located on the right river bank. The intake has a separate opening for each two desander basins and is protected with a trash rack to prevent the inflow of large debris. A trash rack cleaning machine will be provided to remove accumulated debris which could not be flushed downstream. Each of the three intakes consists of a sluice gate, which can be closed to isolate the desander and Power Waterway system from the river flow as well as enable the desander flushing process for each basin pair without stopping the power plant operation. The diverted water is then conveyed through the intake channels into the desander basins. The purpose of the six desander basins is to deposit particles exceeding a size of 0.3 mm (Chapter 8.3.1) and thus removing them from the water being conveyed to the Powerhouse. The sediment can be flushed back to the Spat Gah River by a flushing channel. Each basin has a sluice gate at the bottom and slide gates on top of the end sill to be flushed separately.

The inflow into the forebay downstream of the desander is over the end sill crest at 1,498.25 m asl at the downstream end of the basins. The reservoir, desander and forebay are designed to operate with communicating water levels, resulting in a continuous and corresponding water level between the forebay and reservoir. The water level above the end sill and in the forebay for the design discharge at Full Supply conditions is at 1,509.98 m asl. This is the FSL for the forebay.

The Powerhouse will be operated such that the reservoir active storage is optimally used during the two peaking periods of two hours in the morning and evening. When the complete active storage is used to generate peaking energy then the reservoir level is lowered to the MOL. The MOL in the forebay is 1,499.65 m asl and corresponds to the MOL in the reservoir minus the head losses in between.

The connected water body from the Lower Spat Gah forebay to the reservoir provides ample regulating volume for both steady-state and transient operation states of the generating equipment. An overflow section has also been included in the forebay for water to flow back into the river in case the desander intake remains open but the turbine operation has stopped.

9.1.3 Lower Gabarband Intake

The Lower Gabarband Intake is located on the Gabarband River and consists of a spillway, flushing channel, lateral intake, desander and the inlet to the Gabarband Intake Tunnel. The spillway is an ungated concrete structure. The flushing channel consists of one bay with a radial gate, which is foreseen to regulate the reservoir water level. It will also be used to flush debris downstream. The sediments in front of the desander intake will be periodically flushed with the radial gate, ideally during flood conditions. The residual flow is released through a valve-controlled pipe from the desander intake through the flushing channel left wall.

The Normal Operating Level (NOL) at the Lower Gabarband Intake is at 1,553.00 m asl and the MOL at 1,552.06 m asl, which corresponds to the desander end sill level. Up to the maximum diversion discharge the reservoir regulates itself as a result of the desander end sill overflow. Up to the discharge capacity of the radial gate the flushing channel gate regulates the reservoir to be at the NOL. For larger inflows water starts flowing over the spillway and the reservoir level rises.

9.1.4 Power Waterway

The Power Waterway consists of the following structures:

- Pressurised Headrace Tunnel,
- Partly pressurised Gabarband Intake Tunnel,
- Surge Shaft,
- Pressure Shaft,
- High Pressure Tunnel,
- Free-flow Tailrace Tunnel.

Headrace Tunnel

A forebay is located at the upstream end of the Headrace Tunnel and just downstream of the Lower Spat Gah desander. The tunnel intake invert is set to avoid water levels in the forebay lower than the tunnel soffit as a result of load rejection as well as critical submergence.

The Headrace Tunnel conveys the flow from the forebay to the Pressure Shaft under pressurised flow conditions. The size of the tunnel has been determined with an economic optimisation and is larger than the space required during construction for the muck haulers and ventilation. The rock support is divided into several classes (five in total) and based on the local geological conditions met during excavation and a concrete lining is systematically applied. The section near the Gabarband Crossing will have systematic steel lining over a length of circa 760 m with the required length based on hydraulic confinement requirements.

Gabarband Intake Tunnel

The Gabarband Intake Tunnel conveys the water with a GRP pipe on the side of the tunnel from the Lower Gabarband Intake to the Headrace Tunnel. The elevation of the intake is above the Full Supply Level of the Lower Spat Gah Headworks and the water is flowing in free-flow conditions in the upper part of the pipe while it flows under pressurised conditions in the lower part. A butterfly valve is installed at the downstream end of the GRP pipe to allow for emergency closure as well as maintenance closure such that the pipe can be inspected independently of the Headrace Tunnel. The Gabarband Intake Tunnel is sized to allow for access to the Lower Gabarband Intake during construction as well as access during operation.

Surge Shaft

At the downstream end of the Headrace Tunnel, just upstream of the Upper Erection and Gate Chamber, is the 0.4 km high vertical Surge Shaft. The Surge Shaft is systematically concrete lined as water level oscillations will occur. The throttle connecting the Headrace Tunnel to the Surge Shaft itself will be steel lined.

Upper Erection and Gate Chamber

The Upper Erection and Gate Chamber is located at the downstream end of the Headrace Tunnel and houses the emergency and maintenance butterfly valve as well as the concrete-encased bend at the upper end of the Pressure Shaft. The butterfly valve will serve as one of the emergency closing systems and also allows for inspection of the Pressure Shaft and High Pressure Tunnel without having to dewater the Headrace Tunnel.

The access is through the access tunnel to the Upper Erection and Maintenance Gate Chamber. The erection crane in the chamber will be used for the erection and the maintenance of the butterfly valve and a temporary erection crane/winch (not shown on the drawings) will be used for the installation of the Pressure Shaft steel liner.

Pressure Shaft

Downstream of the gate chamber is the 0.5 km high vertical Pressure Shaft with a systematic steel lining. The size of the lining is based on a cost optimum between construction costs and generation losses due to head losses.

High Pressure Tunnel

The High Pressure Tunnel connects the Pressure Shaft with the penstocks to the three turbines of the Powerhouse and includes a Lower Erection Chamber for installation of the steel cans. The tunnel is excavated as a horseshoe profile and is systematically steel lined with the same inner diameter as all the other steel lined sections of the Power Waterway.

Tailrace Tunnel

The Tailrace Tunnel conveys the water in free-flow conditions from the Powerhouse to the Tailrace Tunnel Outlet Structure and thus to the Indus River. The tunnel is excavated as a modified horseshoe profile and is systematically concrete lined. The Tailrace Tunnel ends at the Tailrace Outlet Structure from which the water flows into the Indus River. The Tailrace Outlet Structure is located about 1.3 km upstream of the confluence of the Spat Gah River with the Indus River.

9.1.5 Powerhouse

The underground Powerhouse is located about 1.3 km from the Tailrace Outlet Structure on the left bank of the Indus River. It will be equipped with three six-nozzle vertical Pelton turbines with a total Installed Capacity of 470 MW and a plant design discharge of 75 m^3/s.

The maximum gross head between the forebay at FSL and the turbine axis is 744.58 m. The head losses in the waterway at design discharge are 22.50 m and result in a net head of 722.08 m with the forebay at FSL.

9.1.6 Power Evacuation

The switchyard of the Lower Spat Gah HPP will be located in the Transformer Cavern next to the Powerhouse Cavern and consists of a 220 kV gas-insulated switchgear (GIS). The voltage is assumed due to the yet to be determined exact grid connection. The power will be evacuated through the 0.3 km long Emergency and Power Evacuation Tunnel and the 1.2 km long Main Access and Power Evacuation Tunnel to the surface. Based on the power systems study, a Connection Switchyard will be located near the Power Cavern access tunnel portals at which the voltage is stepped up to 765 kV. From there a 765 kV transmission line will connect to the 765 kV Dasu - Manshera transmission line. The exact grid connection point is unknown at the time of writing of this Feasibility Study Report and the main characteristics of the power line will have to be defined once the power system study have been discussed and approved by NTDC.

9.2 Operation of the Scheme

9.2.1 General

The purpose of the two dams/weirs is to (i) to divert the water from the Spat Gah and Gabarband Rivers into the Power Waterway system, (ii) to continuously release the residual flow into the downstream reach of the respective river, and (iii) to safely pass the floods downstream of the dams/weirs.

The operation concept of the Lower Spat Gah reservoir is run-of-river with two 2-hour peaking periods, which means that the Powerhouse will be operated such that the reservoir active storage is optimally used during the peaking period in the morning and evening.

During the high-flow period of the year when the inflow is higher than the design discharge the reservoir will be operated at the Full Supply Level and the excess water is spilled. During the low-flow period of the year when the complete inflow is needed to fill the reservoir for the peaking period, no energy will be generated between the two periods. The water level of the reservoir will fluctuate between the FSL at the beginning of the peaking period and a lower reservoir level at or above the MOL at the end of the peaking period. For inflows in between those extreme cases the Powerhouse will be generating energy such that the reservoir is full at the beginning of the peaking period. The reservoir will also fluctuate between the FSL and MOL with the peaking cycles.

The operational concept of the Lower Gabarband Intake is such that the water level in the reservoir is regulated by the flow over the desander end sill up to the design diversion discharge. For inflows larger than the design diversion discharge and residual flow the water level is kept constant at the Full Supply Level as much as possible.

The spillway devices at the Lower Spat Gah Headworks and Lower Gabarband Intake are:

- Lower Spat Gah Headworks: the flap gate on top of the flushing channel radial gate next to the desander intake is the primary water release during normal operation. The secondary water level regulation is the radial gate of the same flushing channel. During floods one to all flushing channel radial gates are opened to allow sediment flushing from the desander intake area.
- Lower Gabarband Intake: the flushing channel radial gate is the primary release during normal operation as well as flood conditions. During floods the ungated spillway will also be overflown.

The operation pattern of the Lower Spat Gah Headworks and Lower Gabarband Intake are as follows:

- Flows in the two rivers equal to or smaller than the residual flow are released back into the river.
    - At the Lower Spat Gah Headworks, the water is released through the valve-controlled residual flow pipe. The valve is used to regulate the reservoir and release the inflows.
    - At the Lower Gabarband Intake, the water is also released through the valve-controlled residual flow pipe and the reservoir is also controlled with the valve.
- Flows higher than the residual flow, but equal to or smaller than the design discharge are stored in the Lower Spat Gah reservoir and can be diverted at the Lower Gabarband Intake by the amount exceeding the residual flows.
    - At the Lower Spat Gah Headworks, the reservoir will be regulated to allow for maximum peaking energy generation. The diverted flow and the reservoir level is controlled by the turbine discharge with the goal to fill the reservoir for the peaking periods. The reservoir water level at the end of the peaking period will be at or above MOL depending on the reservoir inflow.
    - At the Lower Gabarband Intake, the flow into the tunnel is controlled by the desander end sill. The reservoir level will then adjust itself so that the outflow matches the inflow. Water is only diverted into the Gabarband Intake Tunnel when the turbines are operating.

- Flows higher than the design discharge are controlled as follows:
  - At the Lower Spat Gah Headworks, excessive flow releases are first controlled by the flap gate on top of the flushing channel radial gate next to the desander intake. For discharges higher than the flap gate capacity the radial gate No. 3 will be opened to help regulate the reservoir water level,
  - At the Lower Gabarband Intake, the flushing channel radial gate will be used to regulate the reservoir level and release the discharge.
- Floods will be controlled as follows:
  - At the Lower Spat Gah Headworks, the floods are regulated with the flushing channel radial gates. This also accomplishes sediment flushing. The reservoir level can be kept at the FSL up to a PMF if all gates are operational. If one of the gates is not operational the reservoir level rises up to 1,510.74 m asl in case of a 10,000-year flood,
  - At the Lower Gabarband Intake, the floods are only controlled with the flushing channel radial gate. The NOL in the reservoir can be kept up to a flood of about 76 m^3/s, which corresponds to about a 1 to 2-year flood. For higher floods the water will start flowing over the fixed-crest spillway.
- However, during larger flood events, if the river water contains a high concentration of bed load, suspended load or floating debris, it can be economically favourable to stop the operation of the Powerhouse and close the desander intake gates in order to prevent excessive sediment load from entering the Power Waterways. The exact return period at which the desander intake gates shall be closed (i.e. typically annua 2 or 5-yr flood) will have to be defined during the next Project stage based on sediment transport studies.

Flows and water levels are controlled with sensors throughout the system at the following locations:

- Flushing channels of the Lower Spat Gah Headworks,
- In each desander basin of the Lower Spat Gah Headworks,
- Forebay upstream of the Headrace Tunnel,
- Flushing channel of Lower Gabarband Intake,
- Overflow crest at the end of each desander basin at Lower Gabarband Intake,
- Penstock upstream of the butterfly valve at the Gabarband Intake Tunnel,
- Surge Shaft,
- Penstock upstream of the MIV,
- Powerhouse Tailrace Tunnel.

9.2.2 Operational Conditions

The operation of the Lower Spat Gah HPP is described for:

- Normal conditions: flows from minimum discharge up to smaller floods which will carry increased sediment loads and floating debris,
- Flood Conditions.

9.2.2.1 Normal Operation

Lower Spat Gah Headworks

During river flows, exclusive of the residual flow, lower than the design discharge of the Headrace Tunnel, the Headrace Tunnel flow is depending on the inflow and the time of day. However, all the flushing channel gates are closed and the reservoir level ranges between the FSL at 1,510.00 m asl and the MOL at 1,500.00 m asl.

The reservoir will be drawn down from the FSL to the MOL during the peaking period such that a constant energy output can be generated for the 2-hour period. If the volume of the reservoir storage and the inflow into the reservoir is larger than the Headrace Tunnel design discharge then the reservoir will not reach MOL and is operated at or near the FSL.

During the non-peaking period the inflow will be used to bring the reservoir back up to the FSL. The flow in the Headrace Tunnel will depend on the inflow and required reservoir volume to fill. During the low-flow periods all the inflow can be stored for peaking energy generation and the Powerhouse will not be operated in between. With higher inflows more water will be available to be diverted and used for energy generation in between the peaking periods.

For river flows higher than the Headrace Tunnel design discharge, the reservoir and forebay operation level will be kept constant at the FSL, which corresponds to 1,510.00 m asl in the reservoir and 1,509.98 m asl in the forebay. The Powerhouse will be operated at design discharge during the whole day. Excessive water will be released with the flap gate on top of the flushing channel radial gate next to the desander intake. When the spilled water exceeds the capacity of the flap gate, the flushing channel radial gates will be used to maintain a constant FSL.

Lower Gabarband Intake

Flow will only be diverted at the Lower Gabarband Intake if the Powerhouse is generating energy. During non-operational periods the intake to the desander intake will be closed and the inflow released back into the river.

Assuming that the Powerhouse is generating energy and deducting the residual flow, the reservoir water level will be between the NOL and MOL for river flows lower than or equal to the design discharge of the Gabarband Intake Tunnel. The water level in the reservoir is determined by the flow into the tunnel over the desander end sill. The flushing channel radial gate is closed.

For river flows higher than the Gabarband Intake Tunnel design discharge, the reservoir level will be kept constant at the NOL of 1,553.00 m asl as long as the flushing channel radial gate can be used for water release.

9.2.2.2 Operation during Flood Events

Lower Spat Gah Headworks

The safety device of the Lower Spat Gah Headworks for flood conditions is the gated flushing channels. A constant water level of 1,510.00 m asl can be maintained for all flood conditions up to and including the PMF if all gates are operational.

At least one of the radial gates preferably at the channels No. 2 and No. 3 will be opened at least once a year during floods to flush sediments from the intake. This decreases the requirements for flushing during lower flow periods when the flow would have to be used for flushing instead of diversion. During larger floods opening the radial gates allows for sediments to be flushed from within the reservoir area.

The flushing channel gates are designed according to the (n-1) rule. This means a safe passing of the floods must be guaranteed even if the most capable gate, i.e. one of the radial gates, is not functioning. This design leads to increased water level in the reservoir of 1,510.74 m asl and a decreased freeboard.

However, during flood events with a high concentration of bed load and suspended load it can anyhow be economically favourable to stop the operation of the intakes and Powerhouse and close the desander intake gates in order to prevent excessive sediment load entering the Power Waterway. This would lead to increased flushing of the desander and increased sediment loads in the Power Waterway.

Lower Gabarband Intake

The main safety device of the Lower Gabarband Intake for flood conditions is the ungated spillway. A constant water level in the reservoir can be maintained by the flushing channel gate during smaller floods up to a about 76 m^3/s. If the flood exceeds the capacity of the flushing gate, the excess water will additionally be spilled over the fixed weir crest.

The flushing channel gate will be opened at least once a year during flood conditions to flush sediments from the intake. This decreases the requirements for flushing during lower flow periods when the flow would have to be used for flushing instead of diversion. Opening the radial gate during floods allows for sediments to be flushed from within the reservoir area.

The ungated spillway provides a safe passage of the floods because no gates need to be operated and no power needs to be available. The flushing gate has not been taken into consideration for the safety flood routing to adhere to the (n-1) rule.

If the reservoir level increases too much above the NOL, the desander gates will have to be closed. The flood return period at which the desander intake gates shall be closed has to be defined during the next Project stage.

However, during flood events with a high concentration of bed load and suspended load it can anyhow be economically favourable to stop the operation of the intake and power plant and close the desander intake gates in order to prevent excessive sediment load entering the waterway system. Otherwise it would lead to increased flushing of the desander and increased sediment loads in the waterway system.

Powerhouse

The operation of the power plant is stopped when the floods at the Lower Spat Gah Headworks and Lower Gabarband Intake reach a level that corresponds to a flood with a return period that will have to be defined at a later stage during the preparation of the Operation and Maintenance Manuals.

The operation of the Powerhouse has to be stopped when the water level in the Indus River at the Tailrace Tunnel Outlet Structure reaches a water level of 761 m asl. At this level the freeboard to the Pelton turbines is smaller than the required freeboard, and the turbines are stopped. This level will only be reached when the Patan dam is built and the spillway has to pass floods. Once the Patan dam is built its reservoir flood levels have to be studied and any potential measures evaluated.

9.2.3 Residual Flow Release

Lower Spat Gah Headworks

The residual flow at the dam will be released through an embedded steel pipe in the pier between the desander and right most flushing channel, and is controlled by a small valve. The valve is automatically or manually operated, and open during all operation conditions. This guarantees flow releases during power outages.

Lower Gabarband Intake

The residual flow at the dam will be released through an embedded steel pipe in the left flushing channel pier and is controlled by a small valve. The valve is automatically or manually operated, and open during all operation conditions. This guarantees flow releases during power outages.

9.2.4 Floating Debris Management

Any floating debris at the Lower Spat Gah Headworks is released over the flap gate of the most right flushing radial gate in order to avoid clogging of the desander intake trash rack. During large floods the flushing gates will be opened and the debris will also be flushed out below the gates. Any debris accumulating in front of the intake can also be removed with the trash rack cleaning machine.

The debris at the Lower Gabarband Intake is also released over the spillway during flood events. The trash rack cleaning machine can also remove any debris at the intake trash rack.

9.2.5 Sediment Flushing

Deposits in front of the intake at the Lower Spat Gah Headworks and Lower Gabarband Intake need to be removed to avoid entrainment of sediments into the Power Waterway system. The normal procedure is by flushing the intake area. This is achieved by operating the right most radial gate of the flushing structure at the Lower Spat Gah Headworks and by operating the radial gate of the flushing channel at the Lower Gabarband Intake. An effective flushing of the sediment in front of the intakes can be achieved with a relatively short opening of the respective radial gate.

An effective emptying of a larger section of the Lower Spat Gah reservoir deposits can be achieved with good results by flushing the deposits during higher floods and lowering the reservoir levels on the receding section of the flood. The radial gates of the Lower Spat Gah Headworks are operated frequently to regulate the reservoir level for river flows exceeding the design discharge. It is estimated that the flushing channels need to be operated multiple times a year during the high-flow season floods depending on the volume to be flushed out during a flushing event as shown in Volume 3 - Hydrology. The sediments will therefore be removed from the intake area frequently.

The radial gate at the Lower Gabarband Intake is expected to be operated more frequently but for shorter periods than the Lower Spat Gah Headworks flushing channel due to the smaller reservoir.

9.2.6 Unusual Conditions

The intake gates of the Lower Gabarband Intake desander will be closed when the reservoir reaches a water level above the NOL. This water level and the corresponding flood return period will have to be determined in a next Project phase.

During an emergency plant shutdown the water level of the Lower Spat Gah forebay to the reservoir will increase and the flows will be released at the forebay overflow section. The desander intake gates will then immediately be closed. In case the gates at the desander intake do not close the flow can be spilled back into the Spat Gah River at the above forebay overflow section.

The water level in the Lower Gabarband Intake tunnel will also increase during an emergency plant shutdown. The desander intake gates will then immediately be closed. The forebay has been designed to accommodate any water level increase in the Gabarband Intake Tunnel back into the forebay without having to spill back into the Gabarband River. It contains a forebay overflow section for the water to be returned back to the Gabarband River in case the desander intake remains open but the water cannot flow into the Gabarband Intake Tunnel.

9.2.7 Flushing of Desander Basin

Lower Spat Gah Headworks

While two basins are flushing, the other four basins remain in operation. The discharge in the Power Waterway system will then be lower than the available capacity.

The flushing procedure for one desander basin pair is as follows:

- Closing of the intake gate,
- Closing of the end sill crest gates of both basins,
- Opening of the flushing gate of one basin,
- When the water level in the chamber is down, open the intake gate slightly to provide for free-surface flushing,
- Closing of the intake gate,
- Closing of the open flushing gate,
- Opening of the flushing gate of the other basin,
- When the water level in the chamber is down, open the intake gate slightly to provide for free-surface flushing,
- Re-operate.

Flushing with a settler is alternate, which leads to less intake capacity during flushing, because two basins cannot be used.

Lower Gabarband Intake

While one basin is flushing, the other basin remains in operation. The discharge in the Headrace Tunnel system will then be half of the available capacity.

The flushing procedure for one desander basin is as follows:

- Closing of the intake gate,
- Opening of the flushing gate,
- When the water level in the chamber is down, open the intake gate slightly to provide for free-surface flushing,
- Re-operate.

Flushing with a settler is alternate, which leads to less intake capacity during flushing, because one chamber cannot be used.

9.3 Access Concept, Inspection and Maintenance during Operation Phase

9.3.1 Lower Spat Gah Headworks

The Lower Spat Gah Headworks are reached via the main access road from near the Powerhouse portal area along the Spat Gah valley. The last 300 m are in a tunnel which ends at the left abutment of the rockfill dam at the crest level. The weir, desander intake, desander and headrace tunnel inlet can be reached via the road on the dam crest, weir bridge and roads around the intake and desander.

9.3.2 Lower Gabarband Intake

The Lower Gabarband Intake is reached from the Spat Gah access road via a surface road and the Gabarband Intake Tunnel. The surface road leads from the Spat Gah and Gabarband Rivers confluence to the Gabarband Crossing of the Headrace Tunnel.

An access tunnel connects the crossing area with the Gabarband Intake Tunnel. The Gabarband Intake Tunnel has been designed to contain the water conveying pipe on one side of the tunnel and access with a small truck driving on the other side of the tunnel. At the Lower Gabarband Intake a road leads from the portal along the desander to the intake and weir.

9.3.3 Power Waterway

If the Power Waterway needs to be inspected or maintained, it has to be fully or partly dewatered. If the whole waterway upstream of the Powerhouse has to be accessed then the gates at the Headrace Tunnel intake and the Lower Gabarband Intake tunnel inlet need to be closed and the waterway dewatered. The access would be either from the Headrace Tunnel intake, the manhole next to the Gabarband Intake butterfly valve or from the Upper Erection and Gate Chamber.

If only the Pressure Shaft and/or the High Pressure Tunnel need to be inspected then the butterfly valve at the downstream end of the Headrace Tunnel can be closed and the Headrace Tunnel does not have to be fully dewatered. The access would either be from the Upper Erection and Gate Chamber manhole or the MIV manhole.

If only the GRP pipe needs to be inspected then the butterfly valve at the downstream end of the Gabarband Intake Tunnel can be closed and the rest of the Power Waterway does not have to be dewatered. The access would either be from the manhole at the downstream end of the pipe, the manhole in the middle of the pipe or from the Gabarband Intake forebay.

9.3.4 Power Cavern

The Power Cavern is mainly accessed through the Main Access and Power Evacuation Tunnel from the Powerhouse portal area.

9.3.5 Hydro-Mechanical Equipment Handling for Maintenance

A mobile crane is foreseen for the maintenance of the Headrace Tunnel intake gate and stoplogs as well as the Lower Gabarband flushing gate and stoplogs. It has been foreseen that such a mobile crane will be borrowed from outside the Project if needed for any planned maintenance works.

Alternatively a gantry crane could be installed at the Headrace Tunnel inlet and the Lower Gabarband flushing channel at the Client’s convenience.

10 Energy Simulations

10.1 Introduction

A hydrologic reservoir simulation model was applied to estimate the potential energy generation of the projected hydropower plant. The energy model is based on available topographic data and daily inflow series at the diversion weir sites obtained from the hydrology study (see Volume 3 – Hydrology).

The software used for the energy simulations is an in-house software tool capable of modelling reservoir operations, taking the natural and artificial inflow, live storage of the reservoir and turbine characteristics as well as energy prices for optimisation into account. Simulations considering energy prices to maximise revenues were not established within this study. The energy model is also taking into account hydraulic head losses and residual flows as well as efficiencies of the generating equipment. The main inputs and results are summarised in the following sub-chapters.

10.2 Energy Model

The energy models have been set up for a 54-year period to reflect the hydrology inflow series duration. The following input data have been used for the energy calculations:

- Hourly inflow at dam/weir locations for a period of 54 years,
- Reservoir parameters (live storage curve, FSL, MOL),
- Reservoir operation guide curve,
- Turbine capacities,
- Turbine levels, head losses and efficiencies of generating equipment,
- Monthly evaporation data,
- Residual flow requirements.

The intraday energy simulation is based on hourly time steps allowing demand driven operation (peaking). The simulation of the operation of the hydropower scheme takes ecological flow requirements into account.

The results of the simulations are:

- Energy generation data for a period of 54 years,
- Flow releases.

10.3 Model Input

10.3.1 Hydraulic System

Two separate energy models have been set up, one with the complete cascade in place and one with Lower Spat Gah Project as a stand-alone scheme. In the model with the whole cascade, all three stages including the Upper Spat Gah Project and the Middle Gabarband projects are incorporated into the simulation. The two upper stages change the distribution of the available (natural) inflows at the Lower Spat Gah dam and Lower Gabarband Intake. The model with only the Lower Spat Gah simulates the energy generation with no upstream schemes and therefore the natural inflow at the dam and intake.

The hydraulic system of the Upper Spat Gah Project includes the following main structures:

- Upper Spat Gah dam with reservoir,
- Upper Gabarband weir and diversion tunnel,
- Headrace tunnel,
- Powerhouse with Pelton turbine level.

The hydraulic system of the Middle Gabarband Project consists of the following main structures:

- Middle Gabarband dam with reservoir,
- Middle Spat Gah weir and diversion tunnel,
- Headrace tunnel,
- Powerhouse with Pelton turbine level.

The hydraulic system of the Lower Spat Gah Project includes the following main structures:

- Lower Spat Gah Headworks with reservoir,
- Lower Gabarband weir and intake tunnel,
- Headrace tunnel,
- Powerhouse with Pelton turbine level.

The two upper stages of the cascade are simulated with the data given in the 2010 Feasibility Study [3], but have not been adjusted or studied during this Feasibility Study.

10.3.2 Topographic Data

The energy model is based on the topographic data as presented in Chapter 4. The reservoir volume-area-curves of the Upper Spat Gah, Middle Gabarband, and Lower Spat Gah as shown in Figure 10-1 to Figure 10-3 were applied in the models.

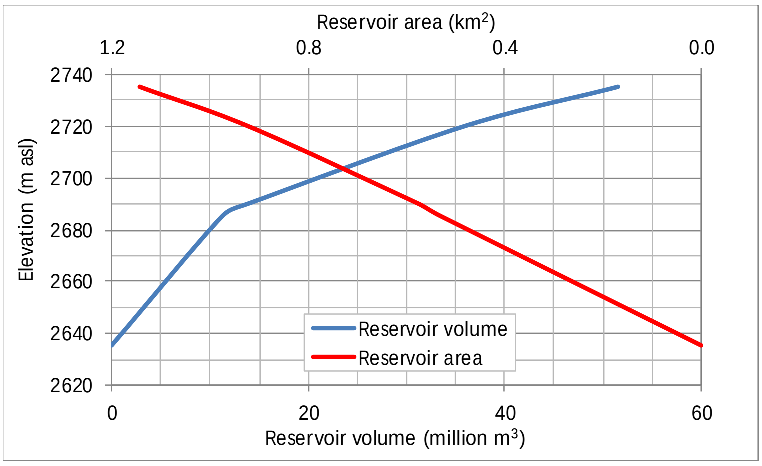


Figure 10-1: Volume-area-curve for Upper Spat Gah reservoir

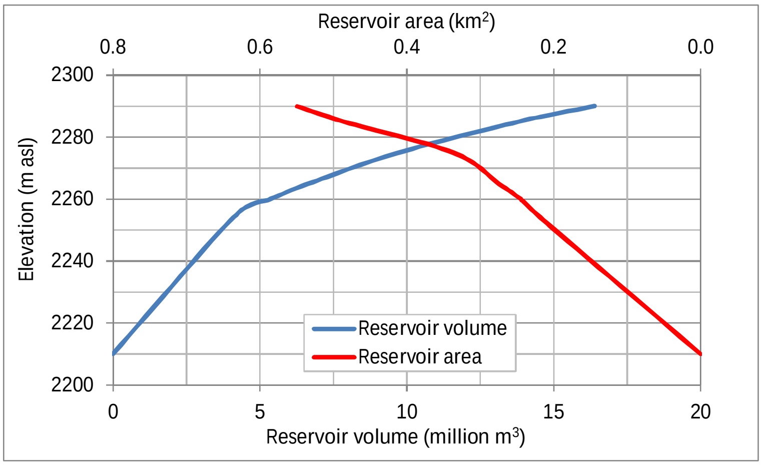


Figure 10-2: Volume-area-curve for Middle Gabarband reservoir

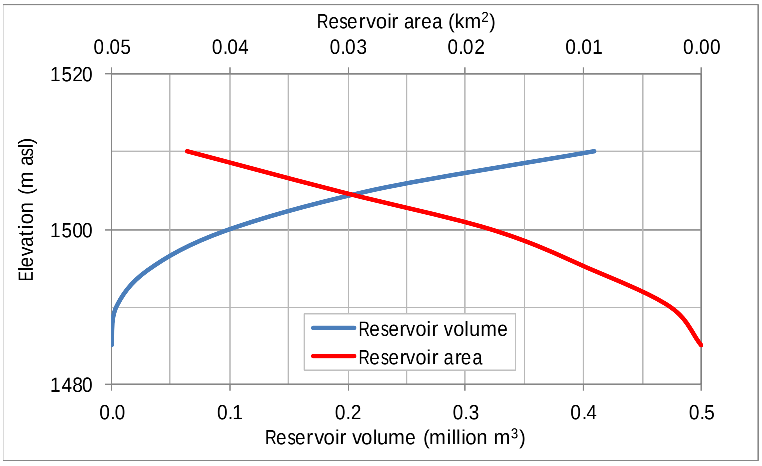


Figure 10-3: Volume-area-curve for Lower Spat Gah reservoir

The Full Supply Levels (FSLs) and Minimum Operating Level (MOLs) of each reservoir are given in Table 10-1. The levels of the Upper Spat Gah and Middle Gabarband reservoirs are according to the 2010 Feasibility Study. The full Lower Spat Gah reservoir volume has been taken into account for the energy simulation, disregarding any potential impacts of sediment accumulating inside the reservoir and thus reducing the available volume for peaking as regular flushing has been assumed. A sensitivity analysis regarding potential impacts and partial filling is recommended for the next Project stage before entering power purchase agreement negotiations.

The relevant levels for the energy generation of the Lower Spat Gah scheme are the water levels in the Lower Spat Gah forebay. The head losses from the desander intake to the forebay resulted in the MOL and FSL shown at the forebay.

Table 10-1: Full Supply Level (FSL) and Minimum Operating Level (MOL) of Lower Spat Gah cascade reservoirs

Dam Type	MOL (m asl)	FSL (m asl)
Upper Spat Gah reservoir	2,685.00	2,735.00
Middle Gabarband reservoir	2,255.00	2,290.00
Lower Spat Gah reservoir	1,500.00	1,510.00
Lower Spat Gah forebay	1,499.29	1,509.98

10.3.3 Hydrological Data

The inflow series is based on the calculations detailed in Volume 3 – Hydrology of this Feasibility Study. The inflow time series of the Lower Spat Gah dam is scaled from the daily observations at Talhata and calibrated to the 2007-2009 data at Goshali. Inflows to the other dam and weir site locations are derived based on the respective runoff. The established 54-year long inflow time series shown in Figure 5-5 includes flow data from 1 January 1960 – 31 December 1992 and 1 January 1996 – 31 December 2016.

The mean monthly reservoir evaporation values as used in the 2010 Feasibility Study are shown in Table 10-2 and were used in the energy simulations.

Table 10-2: Mean monthly reservoir evaporation (from [3])

Month		1	2	3	4	5	6	7	8	9	10	11	12
Upper Spat Gah dam	mm/month	0	0	0	17.3	61	112	112	94	70	31	2.5	0
Middle Gabarband dam	mm/month	0	0	2.6	37	87	140	142	122	94	51	19	0
Lower Spat Gah dam	mm/month	8	7	31	69	126	181	188	165	130	83	43.3	19

10.3.4 Residual Flow Release

The residual flow release in Table 10-3 at each dam/weir site consists of the environmental flow and the irrigation release. The environmental release was calculated according to CEMAGREF with the following formula:

$$Q_e = \left[\frac{0.0651 * Q_m + 2}{100}\right] * Q_a$$

where:

- Q_e mean monthly environmental flow (m^3/s)
- Q_m mean monthly flow at dam/weir site (m^3/s)
- Q_a mean annual flow at dam/weir site (m^3/s)

The environmental flow is calculated with the mean monthly and annual flow values at the Lower Spat Gah Headworks and Lower Gabarband Intake as given in Chapter 5.4.3.

Irrigation flows of 0.17 m^3/s and 0.056 m^3/s as estimated in the ESIA (see Volume 11) have been taken into account for the Lower Spat Gah Headworks and Lower Gabarband Intake, respectively.

Table 10-3: Residual flow release at dam/weir sites

Month		1	2	3	4	5	6	7	8	9	10	11	12
Upper Spat Gah dam	m^3/s	0.74	0.75	0.86	1.16	1.69	2.28	2.05	1.47	1.08	0.87	0.79	0.76
Middle Spat Gah weir	m^3/s	0.80	0.81	0.93	1.27	1.88	2.54	2.29	1.63	1.19	0.94	0.86	0.82
Lower Spat Gah dam	m^3/s	1.22	1.25	1.43	2.00	3.00	3.97	3.52	2.50	1.83	1.45	1.32	1.25
Upper Gabarband weir	m^3/s	0.13	0.13	0.14	0.15	0.17	0.20	0.19	0.16	0.15	0.14	0.13	0.13
Middle Gabarband dam	m^3/s	0.16	0.16	0.17	0.19	0.22	0.26	0.24	0.20	0.18	0.17	0.16	0.16
Lower Gabarband weir	m^3/s	0.23	0.23	0.24	0.26	0.30	0.33	0.32	0.28	0.25	0.24	0.23	0.23

10.3.5 Design Discharge

The design discharges of the upper two schemes of the cascade are fixed:

- Upper Spat Gah 60 m^3/s
- Middle Gabarband 66 m^3/s

The discharge of the Lower Spat Gah Powerhouse was determined at 75 m^3/s during the Optimisation Study.

10.3.6 Head Losses

The head losses are a result of the friction and local losses in the waterway and were calculated as part of the Headrace Tunnel, Pressure Shaft and High Pressure Tunnel design and resulting characteristics (Chapter 13). The head losses ΔH are given as a function of the total turbine discharge Q and the hydraulic coefficient c = 0.003999 as follows:

$$\Delta H = c \cdot Q^2$$

The equation results in head losses of 22.50 m for the Power Waterway for the design discharge. The coefficient is an average of the different losses of the three penstock sections due to its asymmetrical shape.

10.3.7 Turbine Level

The level of the turbine axis is at 765.40 m asl. The turbine can be operated up to a tailwater level which corresponds to a flood level at the Indus River of 761.00 m asl. This level will not be reached in its natural state and is a provision for the construction of the Patan reservoir and potential flood levels. The clearance of the wheel bottom to the design tailwater level is roughly 2.5 m.

The Pelton turbine levels of the upper cascade projects are 2,295.00 m asl for the Upper Spat Gah Powerhouse and 1,515.00 m asl for the Middle Gabarband Powerhouse.

10.3.8 Mechanical Efficiency

The efficiency of the turbines has been considered variable as a function of the discharge as shown in Figure 10-4. The efficiency curve is based on preliminary input from suppliers. An operating range of 10-100% of the design discharge of one turbine was considered, with a maximum turbine efficiency of 91.7%. The 10% minimum turbine discharge equals a flow of 2.5 m^3/s. The overall range for all three turbines is therefore between 3.3% and 100% of the Project design discharge of 75 m^3/s, that means between 2.5 m^3/s and 75 m3/s (Figure 10-6).

The combined efficiency curve of the three equivalent Pelton turbines is based on the goal to always achieve the maximum possible overall mechanical and electrical efficiency. The number of turbines and flow through each turbine is regulated based on that goal. The mechanical and electrical plant efficiency curve shown in Figure 10-5 is used for the energy calculations.

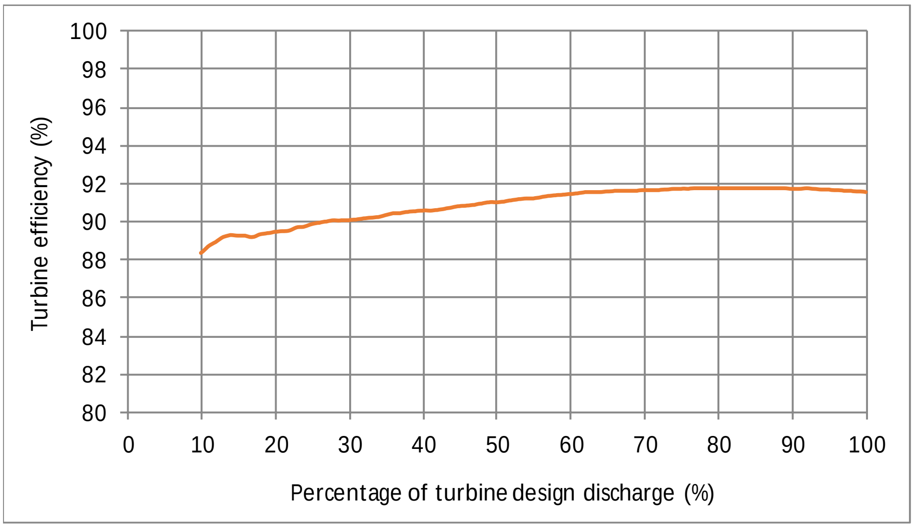


Figure 10-4: Turbine efficiencies for one unit

10.3.9 Electrical Efficiencies

The combined efficiency of the generator and transformer was assumed to be constant at 97.5%. The efficiencies for all turbine discharges are shown in Figure 10-4 in relation to the discharge of one turbine. Figure 10-5 shows the combined mechanical and electrical efficiencies in relation to the plant discharge.

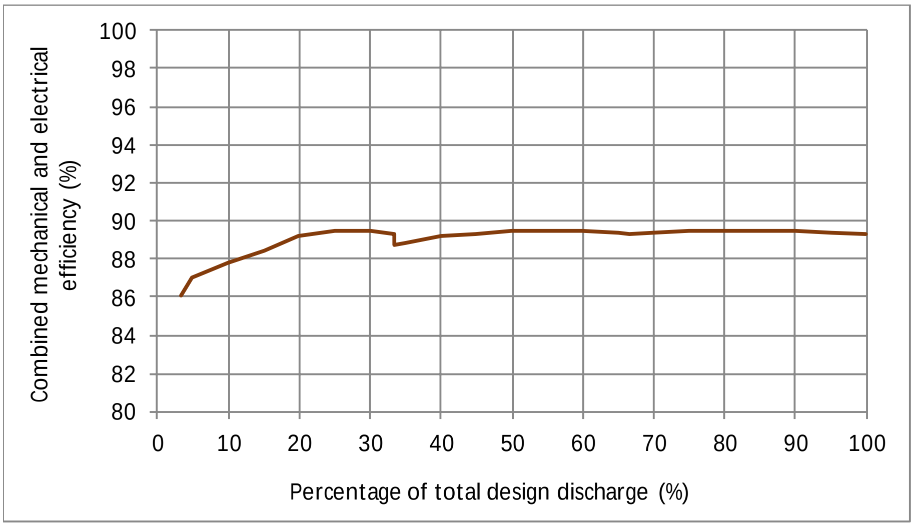


Figure 10-5: Combined mechanical and electrical efficiency in relation to plant discharge (three Pelton turbines)

10.3.10 Production Losses and Own Consumption

The production losses due to general availability of the plant (forced outages), maintenance works (planned outages), reservoir and desander flushing and own consumption (to cover the energy demand of the scheme and the auxiliaries) have been assumed as a percentage of the generated power. The average figures for the losses are:

- Losses due to reservoir and desander flushing, including flood events: 2%,
- Losses due to own consumption: 1%.

As a result, these losses sum up to a net energy output of about 97.0% of net plant output.

The expected 98.5% availability due to O&M losses have not been accounted for in the energy generation calculations as NEPRA has approved Feasibility Study projects with no O&M losses reflected in their energy generation estimates as per the Client's instruction.

The spillway losses are variable based on the inflow series and are calculated as part of the hydrological conditions within the energy simulation.

Losses due to flushing have been considered for the reservoirs and desanders based on the sediment sampling conclusions. For the desanders it was assumed that flushing is required 1 to 2 times a week, while four flushing events were considered for the Lower Spat Gah Headworks and 8 flushing events at the Lower Gabarband Intake. Flood events can be used for reservoir flushing and are thus included in the flushing losses.

10.3.11 Transmission Losses

The grid connection point was assumed to be at the Connection Switchyard near the Powerhouse portals. It was therefore assumed that NTDC will procure, construct and operate the 765 kV transmission line between the Connection Switchyard and the 765 kV Dasu - Manshera transmission line. For the energy simulation, the losses for the 220 kV HV cable inside the Main Access and Power Evacuation Tunnel and to the Connection Switchyard as well as the step-up transformer at the Connection Switchyard were assumed to be part of the Project's energy losses. The losses in the cable and step-up transformer are estimated to 0.02% and 0.3%, respectively.

10.3.12 Overall Efficiency

The overall plant efficiency shown in Figure 10-6 includes the head losses (Chapter 10.3.6), turbine efficiency (Chapter 10.3.8), the generator and transformer efficiency (Chapter 10.3.9), the production losses and own consumption (Chapter 10.3.10) and the transmission losses (Chapter 10.3.11).

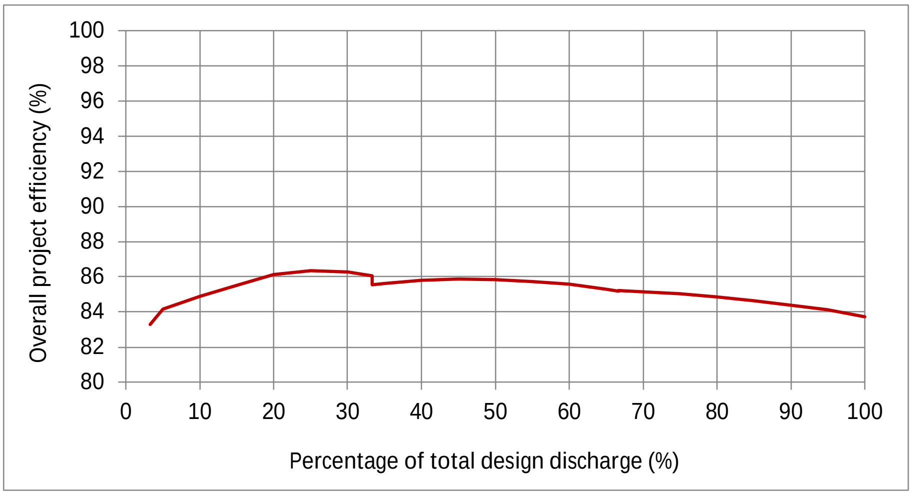


Figure 10-6: Overall plant efficiency

10.4 Reservoir Operation

The reservoir is considered to be operated with a guide curve defining target water levels. As a first priority the model will try to meet the demand for the residual flow and compute the reservoir releases accordingly. As a second priority the model will try to reach the target water level and release water for power generation. If the actual reservoir water level falls below the target water level, no additional water will be released.

The Lower Gabarband Intake has a reservoir with no real storage capacity and the water is therefore just diverted up to the maximum tunnel capacity after trying to release the residual flow first.

The intraday energy simulation is based on hourly time steps allowing demand-driven operation (peaking). The simulation of the operation of the hydropower scheme applies an optimisation algorithm where the available water will be preferable turbinated during peak hours, and only the residual flow will be released during the remaining off-peak hours. During high-flow periods the water will be turbinated for the whole day as the target water level can be met at any given time. The guide curve, which defines the target water level for each end of a day and is considered the operation rule, has been roughly optimised and is preliminary at this stage.

Peaking has been set up to allow for 2 hours of peaking in the morning and 2 hours of peaking in the evening based on information from PEDO in the meeting of 15 April 2019, targeting 4 hours of peaking a day as originally wished by WAPDA in the 2010 Feasibility Study.

10.5 Results

10.5.1 Overview

The results from the energy simulation are listed in Table 10-4, with the mean annual generated energy amounting to 1,925 GWh for the stand-alone operation.

The shown mean inflow is the average annual inflow into the Lower Spat Gah reservoir and the diverted discharge at the Lower Gabarband weir. The residual flow and spill at the Lower Gabarband Intake have already been deducted and are not included.

The values for mean and maximum annual power include the plant losses, but do not consider the production, flushing, own consumption or transmission losses. The values for mean total energy do however take all the losses in the system into account and represent the values which could be measured at the Connection Switchyard near the Powerhouse portal area. The load factor is the ratio between the actual energy generated by the plant to the maximum possible energy that could be generated if the plant operated at its design discharge for the duration of an entire year.

With the given inflow and residual flow curves the Lower Spat Gah Project will be able to generate at least 71 MW during the 4 hour peaking period in the day with the lowest flow of the 54-year inflow series.

Table 10-4: Summary of main results with 54-year average annual energy generation

Flows (m^3/s)	Stand-alone Operation	Cascade Operation
Mean inflow Lower Spat Gah Headworks and Lower Gabarband diversion	46.1	43.0
Mean turbine discharge	35.8	36.1
Mean residual flow at Lower Spat Gah Headworks	2.1	2.1
Mean spillway losses at Lower Spat Gah Headworks	8.2	4.9
Power (MW)		
Mean power (after transformer)	227	228
Max power (after transformer)	466	466
Load factor	49%	49%
Energy (GWh/yr)		
Mean total annual energy (at grid connection substation)	1,925	1,931

The total estimated average monthly inflows into the reservoir (from Figure 5-6) will be released as residual flow, used for power generation and the rest discharged over the spillway as listed in Table 10-5 and shown in Figure 10-7.

It can be noted that spillway losses mainly occur during the high-flow season when the inflow exceeds the plant design discharge, while all the inflow during the low-flow season minus the residual flow is used for power generation.

The mean monthly values given are for the stand-alone operation because it is assumed that the Lower Spat Gah Project will be operated without the upper schemes in at least the first phase of the concession period.

Table 10-5: Mean monthly inflows (at Lower Spat Gah Headworks and Lower Gabarband diversion) and turbine discharges for stand-alone operation

Month	Mean Inflow into Lower Spat Gah Headworks and from Lower Gabarband Diversion (m^3/s)	Mean Residual Flow at Lower Spat Gah Headworks (m^3/s)	Mean Turbine Discharge (m^3/s)	Mean Spillway Losses at Lower Spat Gah Headworks (m^3/s)
January	10.4	1.2	9.2	0.0
February	11.4	1.2	10.2	0.0
March	19.5	1.4	18.1	0.0
April	44.2	2.0	41.8	0.4
May	83.8	3.0	67.4	13.4
June	122.2	4.0	73.9	44.3
July	106.1	3.5	70.9	31.7
August	66.3	2.5	59.0	4.8
September	37.8	1.8	34.4	1.6
October	20.9	1.5	19.2	0.2
November	14.8	1.3	13.5	0.0
December	11.8	1.3	10.6	0.0

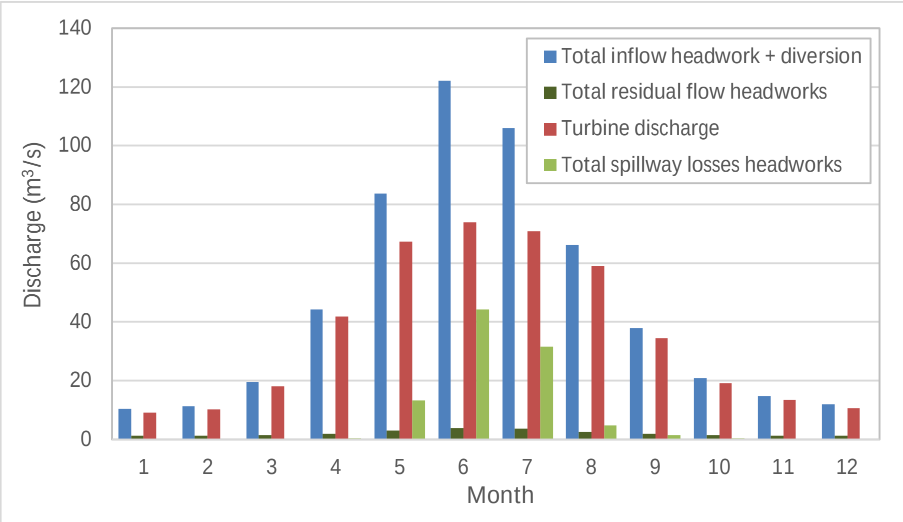


Figure 10-7: Mean monthly inflow at Lower Spat Gah Headworks plus Lower Gabarband diversion, turbine discharge and spillway discharge at Lower Spat Gah headworks for 54-year simulation period

The difference of the cascade operation is a slightly more even distribution of the turbine discharge over the year as well as smaller spillway losses at the Lower Spat Gah Headworks as shown in Figure 10-8. The average inflow into the Lower Spat Gah Headworks and the diversion from the Lower Gabarband Intake is higher for the stand-alone operation compared to the cascade operation (see Table 10-5). The mean spillway losses at the Lower Spat Gah Headworks are also higher for the stand-alone operation compared to the cascade operation (Table 10-5 and Figure 10-8). The resulting average turbine discharge is only slightly lower for the stand-alone operation compared to the cascade operation.

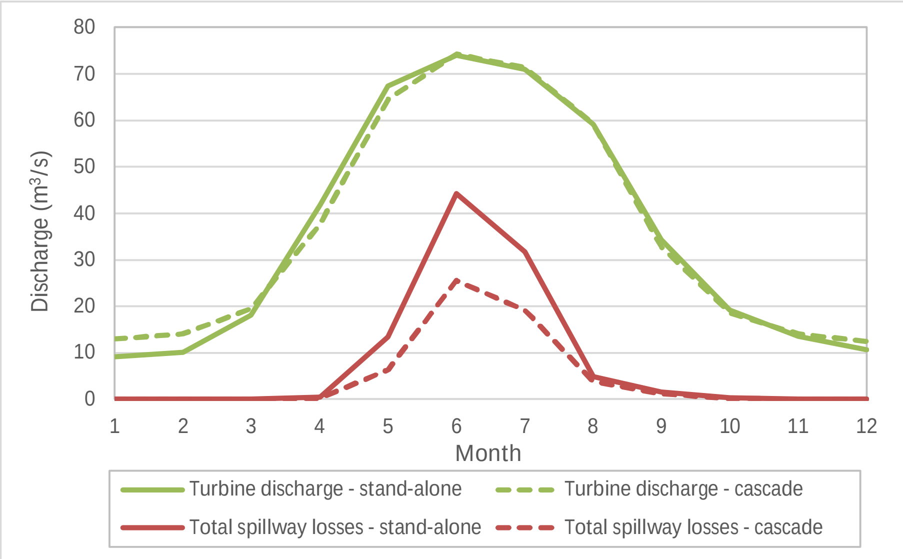


Figure 10-8: Mean monthly turbine discharge and residual flow for stand-alone vs cascade operation

The distribution of the annual energy over the year follows the average inflow and is listed per month in Table 10-6 and shown in Figure 10-9. The mean monthly revenues in Table 10-6 are calculated with the energy tariff of 9.88 USc/kWh and 5.31 USc/kWh for years 1-12 and 13-30, respectively as resulting from the financial analysis.

Table 10-6: Mean monthly power, energy generation and revenues for stand-alone scheme

Month	Mean Monthly Power (after transformer) (MW)	Mean Monthly Energy Generation (at Connection Switchyard) (GWh)	Mean Monthly Revenues (million USD)	
			Year 1-12	Year 13-30
January	57.9	42	4.1	2.2
February	64.5	42	4.2	2.2
March	115.0	83	8.2	4.4
April	265.0	185	18.2	9.8
May	427.0	307	30.3	16.3
June	468.5	326	32.2	17.3
July	449.2	323	31.9	17.2
August	374.2	269	26.6	14.3
September	218.7	152	15.0	8.1
October	122.3	88	8.7	4.7
November	86.0	60	5.9	3.2
December	67.0	48	4.8	2.6
Total	-	1,925	190.1	102.3

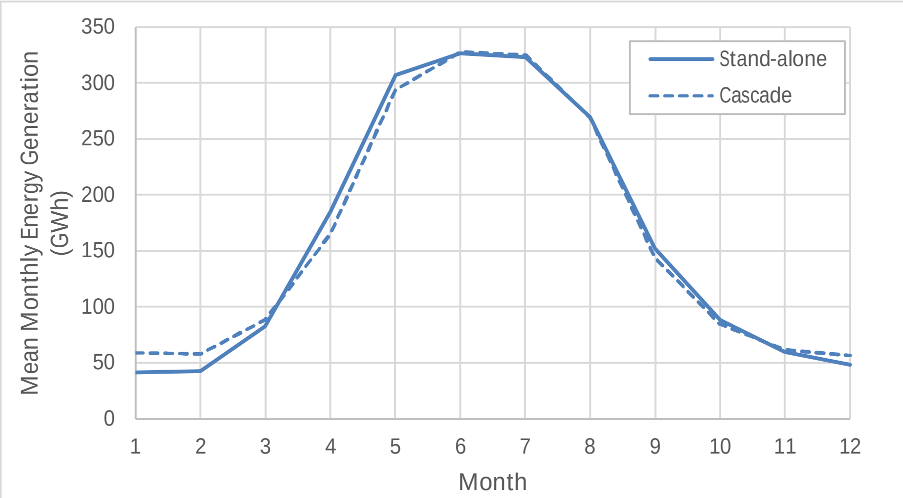


Figure 10-9: Mean monthly energy generation

10.5.2 Peaking

Two hours of peaking in the morning and evening have been assumed for the energy generation in the energy model without any restrictions regarding annual peaking availability. This results in the highest possible peaking energy which can be generated. As can be seen in Table 10-7 the potential total peaking energy to be generated is 537 GWh/yr for the stand-alone operation and 652 GWh/yr for the cascade operation.

A 90% annual peaking availability criterion was applied to back-calculate the peaking design discharge. The criterion means that 90% of the maximum possible annual peaking energy at a specified peaking discharge needs to be generated. Lowering the peaking discharge means that this discharge can be reached more often and that the availability increases. The results of the energy simulations were processed to determine the peaking output and the corresponding peaking design discharge with a 90% peaking availability and are shown in Table 10-7. The annual distribution of the peaking energy is shown in Figure 10-10.

If the Lower Spat Gah Project is operated within the Spat Gah cascade then the Project design discharge of 75 m^3/s is also the peaking design discharge due to the storage of inflows in the upper reservoirs during the high-flow season and release during the low-flow season. The generated peaking energy results to 652 GWh/yr and the peaking availability is 98.9%.

If the Lower Spat Gah Project is operated as a stand-alone scheme then the peaking design discharge is 65.5 m^3/s to guarantee a 90% availability. The generated peaking energy amounts to 518 GWh/yr.

The results of the peaking may be on the optimistic side as the full reservoir volume has been taken into account for the energy simulations, not considering any potential storage losses due to sediment accumulation if flushing is not carried out regularly. Further studies including a sensitivity analysis are therefore recommended for the next Project stage before discussing any peaking values as part of power purchase agreement negotiations. It is also an opportunity to adjust the operating pattern to pure run-of-river as outlined in Chapter 8.2.

Table 10-7: Peaking energy total vs 90% availability criterion

	Average Annual Peaking Energy Generation (GWh/yr)	
	Stand-alone	Cascade
Potential total	537	652
With 90% availability criterion (corresponding peaking design discharge)	518 (65.5 m^3/s)	652 (75 m^3/s)

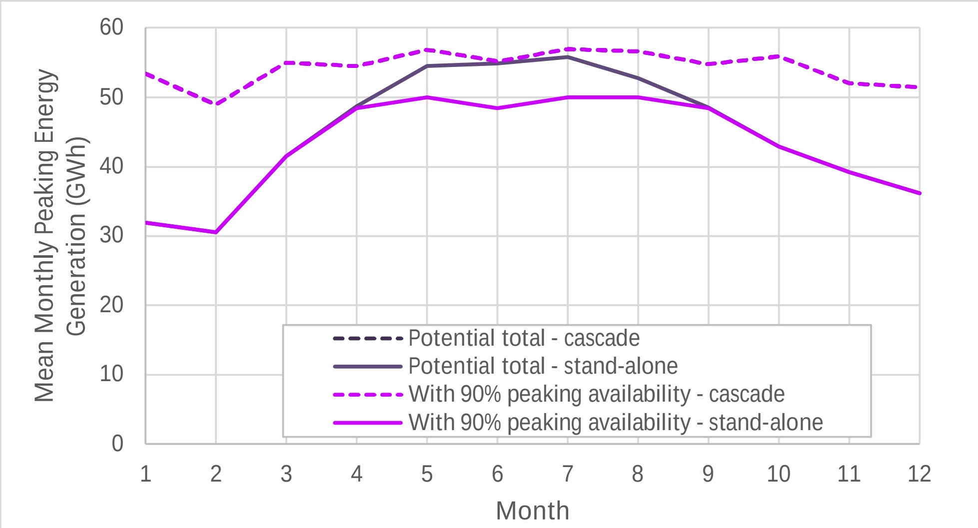


Figure 10-10: Mean monthly peaking energy generation

11 Civil Design - Lower Spat Gah Headworks

Corresponding Drawings

LSG-FS-060-001	Lower Spat Gah Headworks, General Arrangement, Overview Plan
LSG-FS-060-002	Lower Spat Gah Headworks, General Arrangement, Plan View
LSG-FS-060-003	Lower Spat Gah Headworks, Rockfill Dam, Typical Sections & Detail 1
LSG-FS-060-004	Lower Spat Gah Headworks, Spillway & Flushing Channels, Section A-A
LSG-FS-060-005	Lower Spat Gah Headworks, Spillway & Flushing Channels, Section B-B
LSG-FS-060-006	Lower Spat Gah Headworks, Desander, Section C-C
LSG-FS-060-007	Lower Spat Gah Headworks, General Arrangement, Section 1-1
LSG-FS-060-008	Lower Spat Gah Headworks, Weir & Desander, Sections 2-2 & 3-3
LSG-FS-060-009	Lower Spat Gah Headworks, Forebay & Headrace Tunnel Intake, Sections 3a-3a to 6-6
LSG-FS-060-010	Lower Spat Gah Headworks, Excavation, Plan View
LSG-FS-060-011	Lower Spat Gah Headworks, Excavation, Sections E1-E1 & E2-E2
LSG-FS-060-012	Lower Spat Gah Headworks, Excavation, Section E3-E3
LSG-FS-060-013	Lower Spat Gah Headworks, General Arrangement, Construction Phasing - Sheet 1/3
LSG-FS-060-014	Lower Spat Gah Headworks, General Arrangement, Construction Phasing - Sheet 2/3
LSG-FS-060-015	Lower Spat Gah Headworks, General Arrangement, Construction Phasing - Sheet 3/3

11.1 Introduction

This chapter gives a description of the civil structures of the Lower Spat Gah Headworks and their design, including the dam, flushing channels, desander intake and desander. More detailed design criteria and comprehensive calculations performed as basis for the Feasibility Study design are compiled in Volume 7 – Project Design.

11.2 Reservoir Characteristics

The Lower Spat Gah Headworks generates a small reservoir on the Spat Gah River. The reservoir volume-area-curves in Figure 10-3 have been developed from the available topographic data. Table 11-1 lists the general characteristics of the reservoir.

Table 11-1: Main characteristics of Lower Spat Gah reservoir

Reservoir	
Full Supply Level (FSL)	1,510.00 m asl
Minimum Operating Level (MOL)	1,500.00 m asl
Reservoir volume at FSL at MOL	 0.41 million m^3 0.10 million m^3
Active storage volume	0.31 million m^3
Surface area at FSL at MOL	 0.044 km^2 0.018 km^2
Backwater length at FSL	0.2 km

11.3 Hydraulic Design Dam

11.3.1 Introduction

This chapter describes the layout planning and design of the Lower Spat Gah Headworks. The concept for river diversion during construction is also discussed. This hydraulic design chapter contains the design description and the hydraulic design.

11.3.2 General Layout

The storage and flow diverting Lower Spat Gah Headworks comprises a rockfill dam, three gated flushing channels also acting as spillway, and an intake diverting flow to the Power Waterway. The flushing channels shall also be capable of sediment flushing.

During the construction period, the river shall be diverted through the main river channel (construction Stage 1) and the flushing channels (construction Stage 2). The whole dam structure will be partly founded on rock and partly on a thick alluvium layer.

Table 11-2 lists the general characteristics of the Lower Spat Gah Headworks.

Table 11-2: Main characteristics of Lower Spat Gah Headworks

Reservoir	
Full Supply Level (FSL)	1,510.00 m asl
Minimum Operating Level (MOL)	1,500.00 m asl
Water level – design flood (1,000-year)	1,498.98 m asl
Water level – check flood (10,000-year)	1,503.46 m asl
Water level – safety floods (10,000-year, n-1 / PMF)	1,510.74 / 1,507.90 m asl
Clay Core Rockfill Dam	
Location	Left bank
Top of parapet wall	1,513.20 m asl
Crest elevation	1,512.00 m asl
Foundation elevation	1,478.20 m asl
Crest length	124.4 m
Flushing Channels	
Location	Main river channel
Sill crest elevation	1,488.00 m asl
Type of gate	Radial gates with flap gate on gate No. 3
Gate dimensions (WxH)	9.50 m x 23.71 m
Top of parapet wall	1,514.20 m asl
Crest elevation	1,513.00 m asl
Foundation elevation	1,474.00 m asl
Crest length	43.0 m

11.3.3 Main Design Criteria

11.3.3.1 Basic Data

Floods

The flood peak discharges at the Lower Spat Gah Headworks site on the Spat Gah River are given in Table 5-6. The low-flow season in the Project area has been assumed from October to March.

Topography

The survey information given as summarised in Chapter 3 and presented in more detail in Volume 2 – Topography was used.

Geology

The Lower Spat Gah Headworks site is mainly located on top of deep coarse-grained river sediments and slope wash while the bedrock is mainly amphibolite as described in Chapter 6 and further documented in Volume 4 – Geology.

11.3.3.2 Hydraulic Design Criteria

The main requirements of the Lower Spat Gah Headworks are to provide the means to store water and to divert water to the Power Waterway.

The Lower Spat Gah Headworks will consist of a dam, flushing channels and desander. The whole Lower Spat Gah Headworks structure shall mainly be founded on sediments.

The following load cases for the hydraulic design of the flushing channel are defined:

- Design flood: 1,000-year flood,
- Check flood: 10,000-year flood,
- Safety flood: Check flood with one flushing channel gate not operational (n-1 rule) or PMF (flushing channel gate open); whichever represents the more critical condition.

The flushing channels will also be used to periodically clear the bed load and debris from the front of the desander intake and to act as a river bypass during construction.

The Lower Spat Gah Headworks height is determined based on topographic, hydraulics (flushing channel capacity and FSL) and freeboard requirements. The Full Supply Level (FSL) of 1,510.00 m asl has been set by the upstream scheme boundary condition.

The flushing channel capacity is determined using standard broad crest discharge relationships and appropriate discharge coefficients.

Minimum freeboards of 0.26 m and 1.26 m to the dam core crest and dam crest respectively have been checked to be available for the critical safety flood event. A minimum freeboard of 1 m from the water level below the bridge to the underside of the concrete bridge has been also checked to be available in case large floating trees are transported for the critical safety flood event.

The criterion for the flushing channels’ length is set such to protect the dam body downstream slope and toe from regressive erosion during flushing channels operation

A variable flow ranging from 1.2 to 4.0 m^3/s is released as residual flow through a valve-controlled by-pass, which is installed in the right most flushing channel pier next to the desander, and discharges into the concrete flushing channel downstream of the gate.

11.3.3.3 Diversion during Construction Criteria

The Lower Spat Gah Headworks structure will be constructed in two main phases. The initial construction works in the river bed as well as the placing of the cofferdams will be carried out during the low-flow seasons.

According to the USBR (1990) criterion, the flood should generally be approximately five times the duration of the construction period. With a construction duration of about two years for each stage, this criterion gives a 10-year flood. The construction pits shall therefore be designed to be safe against floods up to a 10-year return period.

During construction stage 1, structures at the right bank, i.e. the flushing channels No. 2 and 3, desander intake and desander shall be constructed while the river is being diverted within the natural main river bed. The construction site will be protected by the intermediate pier between the flushing channels No. 1 and 2 as well as upstream and downstream cofferdams.

During construction stage 2, which comprises completion of the flushing channel No. 1 and the dam, the river will be diverted through the two completed flushing channels at the right river bank.

11.3.4 Hydraulic Design

11.3.4.1 General

The main requirements of the Lower Spat Gah Headworks are to provide means to store water in the reservoir and to divert water to the Power Waterway. In particular, the following requirements have to be met by the Lower Spat Gah Headworks:

- Enable a certain water level at the desander intake to catch the river flows up to the design discharge,
- Allow flushing of sediments in front of the desander intake,
- Passing of floods, and avoid blockage due to floating tree branches and logs during floods,
- Ensure a residual flow in the Spat Gah River downstream of the Lower Spat Gah Headworks site during all hydrological conditions.

11.3.4.2 Outline Design

The flushing channels are a gated concrete structure consisting of three bays with an overall length of about 92 m and a crest length of 43.0 m (including the flushing channel bays, piers and side walls) and a maximum height of 39 m (measured from the deepest foundation level to the dam crest top level excluding the parapet wall).

Each flushing channel includes a 9.50 m wide and 23.71 m high radial gate with the gate sill level at 1,487.09 m asl. The radial gate in the right most bay No. 3 includes a flap gate mounted on top of the radial gate.

The flushing channels are designed with a steep slope invert to allow for easy and effective release of the sediment. The invert inclination of the flushing channels is 10%, which is very similar to the inclination of Spat Gah River in its current (natural) conditions. The flushing channel bay width has been selected to provide enough room for safe passage of large floating tree logs.

The gates are capable of maintaining a constant headwater level at or below the FSL for any flood condition if all gates are operational. During the 10,000-yr flood the water level increases 0.74 m above the FSL if one gate is not operational.

The flushing channel radial gate hydraulic cylinder mounting positions have been designed and placed to keep the respective positions out of the discharging flows for any flood condition.

Stoplog grooves and stoplogs are provided upstream of the flushing channel radial gates. Stoplogs are technically not needed on the downstream side of the flushing channel radial gates due to the low water levels. However, stoplog slots and one optional stoplog element are foreseen downstream to increase the safety during maintenance works in case the downstream tailwater level is affected during operation and higher water levels may be expected. The stoplogs will be placed with the gantry crane.

The flushing channels provide a number of important functions: (a) stage 2 construction diversion water passage, (b) flood control incorporation, (c) maintain the intake free of bed load and debris, (d) allow sediment and debris flushing from the reservoir to maintain its storage and (e) release excess flows during normal operation between the MOL and FSL as well as during floods.

The flushing channel radial gate No. 3 nearest to the desander intake is of the hybrid type, having a small flap gate mounted on the top of the gate leaf. The flap gate will be used to release the excess flows during normal operation at FSL. The flap gate will also assist in passing floating debris.

The intermediate pier between the flushing channels No. 1 and 2 and the overflow sections is continued towards upstream and downstream as this pier will be used as a retaining structure for the upstream and downstream cofferdams during the construction phases. The intermediate pier between flushing channels No. 2 and 3 has also been extended towards upstream to improve the sediment flushing efficiency of the flushing channel and better guide the flow towards the flushing channel No. 3.

11.3.4.3 Hydraulic Design

The flushing channel has been designed to safely pass a design flood of 1,622 m^3/s, equivalent to a 1,000-year flood event, and was checked for a 10,000-year flood of 2,595 m^3/s as well as for the safety floods for a PMF of 3,625 m^3/s and 10,000-year flood of 2,595 m^3/s with the n-1 criterion without any dam overtopping.

The flushing channel capacity is not affected by the downstream tailwaters due to the steep slope of the river and accordingly low tailwater levels.

With the flushing channel gates fully open, discharge through the flushing channel gates will be free-surface flow with critical depth formed at the sloped channel inlet. For the operation of the flushing channels with the gates fully open, the estimated headwater levels for the 1,000-year (design) flood (1,622 m^3/s) and the 10,000-year check flood (2,595 m^3/s) will be at elevations 1,498.98 m asl and 1,503.46 m asl, respectively. The headwater levels for the PMF (3,625 m^3/s) will be at elevation 1,507.90 m asl. With one flushing channel gate closed (n-1 criterion), the headwater level for the 10,000-year flood will reach the elevation of 1,510.74 m asl.

In order for the water level in the reservoir to reach the dam core crest or the dam crest in a PMF event with no wind, the inflow would have to be around 4,360 m^3/s or 4,600 m^3/s, respectively. This corresponds to factors of 1.68 and 1.77 to the 10,000-year flood which is considered highly unlikely.

The rating curve for the operation of the flushing channels with all gates fully open is shown in Figure 11-1.

To clean up the desander intake area from sediment and flush accumulated sediment from the river in general, the flushing channels need to be operated multiple times a year during the high-flow season floods depending on the volume to be flushed out during a flushing event. The flushing channels are however planned to be operated more often than that in order to regulate the reservoir water level for small floods.

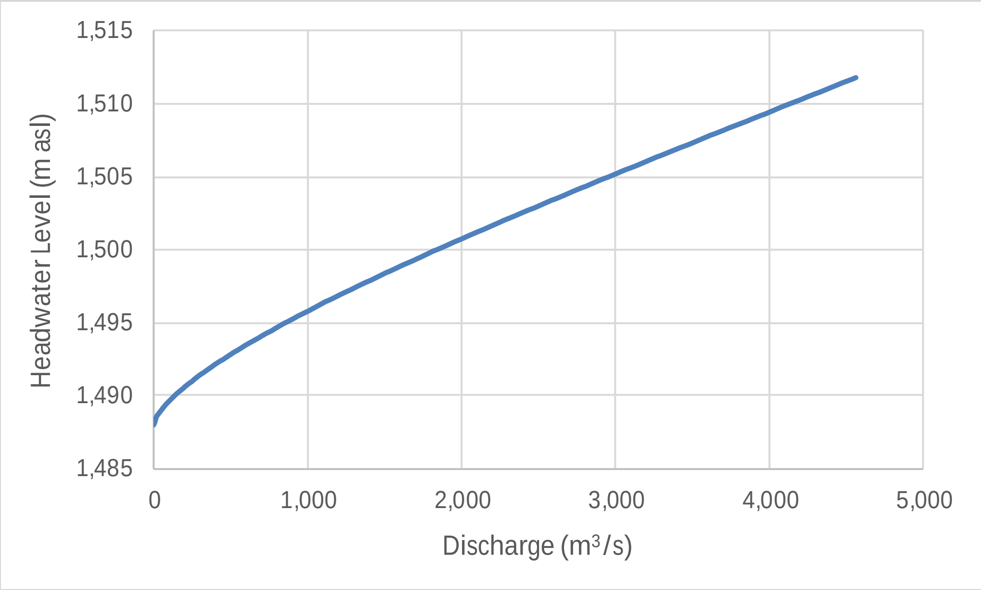


Figure 11-1: Headwater rating curves for operations of flushing channels (radial gates fully open)

The criterion for the flushing channels' length is set such to protect the dam body downstream slope and toe. As there is naturally a super-critical flow regime in the river, no hydraulic jump shall take place inside the flushing channel. Downstream protection including rip-rap and concrete slab is provided to prevent scouring of the riverbed materials downstream of the dam and flushing channels.

With the proposed flushing channel design, the sediment shall be transported to the downstream river reach during annual floods.

11.3.4.4 Design Floods and Freeboard

As mentioned in Chapter 11.3.3.2, the design of the flushing channels is carried out for the following load cases:

1) Design flood, which corresponds to the 1,000-year flood with all flushing gates fully open (3 gates),
2) Check flood, which corresponds to the 10,000-year flood with all flushing gates fully open (3 gates),
3) Safety flood, which corresponds to the 10,000-year flood with one flushing gate closed (n-1 criterion) or PMF (all flushing channel gates open); whichever represents the more critical condition.

The defined load cases lead to the following headwater levels in the reservoir if the gates are fully open:

- Design flood (HQ1,000, n): 1,498.98 m asl
- Check flood (HQ10,000, n) 1,503.46 m asl
- Safety flood I (HQ10,000, n-1) 1,510.74 m asl
- Safety flood II (PMF, n) 1,507.90 m asl

As shown above, the 10,000-year flood with one flushing channel gate closed results in the more critical headwater level than the PMF and therefore it will be selected as the safety flood.

Generally, an adequate freeboard represents an adequate safety margin during severe floods. The freeboard is provided to meet the following criteria from Minor's Design of spillways for large dams:

a. Design flood 1/1,000 years:

   For (n-1) gates open if gated spillway; Wind velocity 1/100 year; Dry margin between the water level plus waves and run-up and the top of the dam must be fd ≥ 2.00 m.

b. 1/10,000 years flood:

   For all gates open and a wind velocity 1/10 year the water level plus waves and run-up may reach the top of the dam, but waves are not allowed to splash across the top of the dam. The water level without waves and run-up must not be higher than the top of the core.

c. PMF:

   With all gates open and no wind the water level may reach the top of the dam, but it must be not higher than 1 m above the core.

d. Safety flood I:

   As an additional load case, the safety flood I (with one gate closed) and no wind is checked so that the water level may reach the top of the dam, but it must be not higher than 1 m above the core.

As there is no wind data available, conservatively wind velocities of 50 miles/h (22.4 m/s) and 160 miles/h (71.5 m/s) respectively are assumed as 1/10 and 1/100-year wind velocities as recommended by USBR. The reservoir effective fetch is calculated based on standard procedure and estimated around 200 m.

A freeboard of 0.26 m to the dam core crest and 1.26 m to the dam crest has been provided for the safety flood I (10,000-year with n-1) condition. With the dam core crest level at 1,511 m asl, freeboards of 6.48 m, 5.76 m, 0.26 m and 3.10 m will be available to the clay core crest during the design, check, safety flood I and PMF events, respectively (Table 11-3).

The freeboard to the flushing channel crest (1,513.00 m asl) is higher by 1.0 m and thus also fulfils the freeboard requirements.

Table 11-3: Available freeboard during flood events

Freeboard Reference	Flood Freeboard Event			
	Design Flood (1,000-year, n-1)	Check Flood (10,000-year)	Safety Flood I (10,000-year, n-1)	Safety Flood II (PMF)
Available freeboard to dam crest (m)	7.48	6.76	1.26	4.10
Available freeboard to dam core crest (m)	6.48	5.76	0.26	3.10

11.3.4.5 Residual Flow Outlet

The residual flow requirements at the Lower Spat Gah Headworks resulted to 1.2 to 4.0 m^3/s and consists of the environmental flow and irrigation flow. For the design it has been assumed that the irrigation flow will also be released downstream through the residual flow outlet.

The residual flow is released through a pipe of 0.80 m diameter embedded in the right most flushing channel pier. A gate valve (0.80 m diameter) is provided to control the discharge at various operating levels. The arrangement is designed to release 4.0 m^3/s at 100% valve opening when the headwater level is at the MOL. For operation at headwater levels between the FSL and the MOL, the residual flow valve opening will be adjusted through automatic control from SCADA.

The residual flow pipe discharges will be arranged into the flushing channel bay No. 3 comprising of high-strength concrete.

11.3.5 Tailwater Rating Curve

The Spat Gah River water surface profile analysis has been carried out using the 1D HEC-RAS model developed by USACE. The river Manning's roughness coefficients were estimated utilising well-known hydraulic references such as Chow's Open Channel Hydraulics (1959).

The model geometry is based on the detailed topography from the 2010 Feasibility Study. The Lower Spat Gah Headworks tailwater levels for different discharges are shown in Figure 11-2.

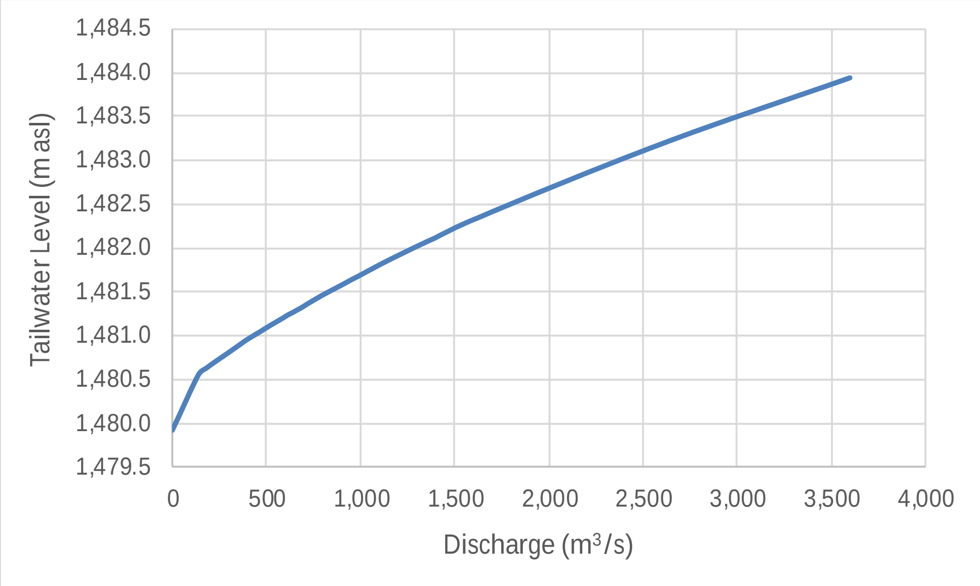


Figure 11-2: Lower Spat Gah Headworks tailwater levels

11.4 Hydraulic Design Desander

11.4.1 Introduction

This chapter present the hydraulic design of the Lower Spat Gah desander including the desander intake and the desander flushing channel. The design of the forebay and power intake downstream of the desander end sill is presented in the chapter of the Power Waterway (Chapter 13).

This chapter only presents the design particular to the desander and is to be read in conjunction with other civil design chapters such as for the dam and Power Waterway and the Volume 7 – Project Design providing more detailed information about the way the structure has been hydraulically designed.

11.4.2 General Layout

The layout of the desander consists of an intake section and desander itself. The intake conveys the water from the reservoir to the desander. At the downstream end of the desander, the water flows through an end opening section into the forebay of the power intake while sediments will remain at the bottom of the desander basins, to be flushed back into the river through the flushing channels. The desander is designed with six basins and intake channels, and an intake for each pair of basins.

Table 11-4 lists the general characteristics of the intake and desander.

Table 11-4: Main characteristics of Lower Spat Gah desander intake and basins

Discharge	
Design discharge Q_d	75.0 m^3/s
Intake	
Type	Lateral
Inlet sill level	1,497.80 m asl
Inlet size (W x H)	Three 14.10 m x 6.60 m
Intake Channel	
Width	7.00 m (u/s branches) / 3.50 m (d/s branches)
Water depth at FSL & Q_d	12.2 m
Length calming section upstream basins	Minimum 17.50 m
Invert upstream of basins	1,497.60 m asl
Transition Zone	
Length	25.00 m
Vertical and lateral slope	1:5 (V:H) or less steep
Calming racks	Three rows for each basin
Desander Basins	
Number	6
Design grain size	0.3 mm
Length	110 m
Dimensions (W x H) at beginning at FSL	13.7 m x 17.4 m
Flushing channel width	1.30 m
Flushing channel slope	3%
Flushing gate	Sluice
Desander End Sill	
Type	Broad-crested with gates on top
Crest level	1,498.25 m asl

11.4.3 Design Criteria

The design grain size for the desander basin design shall be 0.3 mm (see Chapter 8.3.1).

The functional design criteria of the desander are as follows:

1. A trash rack shall be foreseen at the intake to prevent any floating debris from entering it. A concept for the removal of material from the trash rack in case of clogging is to be foreseen.
2. The desander shall be operational at both the MOL and FSL reservoir levels at the Powerhouse total design discharge (75 m^3/s)
3. The desander shall be designed so that each twin basins can be flushed independently while allowing for continuous operation of the power plant at proportionally reduced plant discharges.
4. The desander shall be able to operate and flush sediment back into the river for any flood condition.

11.4.4 Design

11.4.4.1 General

The purpose of the desander is to remove sediment particles with a diameter of d = 0.3 mm or more from the water before it is conveyed to the forebay and the subsequent waterway in order to avoid deposition in the waterway and abrasion of the turbines.

The desander is designed with six basins, three intakes and three intake channels bifurcated to six individual ones. The design discharge of the desander system equals the total Powerhouse discharge of 75 m^3/s. The selected number of basins during the Feasibility Study is based on several factors such as the number of gates and operational complexity as well as engineering judgement (Chapter 11.4.3).

An overflow section is foreseen at the forebay to return the flow entering the desander after a load trip while the intake gates are closing. The crest level of the spillway is at 1,510.10 m asl with a crest width of 21.00 m.

11.4.4.2 Intake

The intake to the desander is located next to the sediment flushing channels of the dam on the right river bank and is designed to divert the water into the waterway with as little coarse sediment as possible. The pier between the flushing channels No. 2 and No. 3 improves the flow conditions towards the intake and helps to maintain the approach section free of sediment.

In order to not entrain sediment which settled upstream of the flushing channel radial gates, the invert of the intake is at an elevation of 1,497.80 m asl, which is about 11 m above the river. The sediment entry into the desander is therefore expected to be reduced because of the elevated intake.

The intake dimensions were determined with the recommended maximum velocity at the trash racks of less than 1 m/s at the MOL and design discharge, which is also suitable to reduce the entrainment of fine gravel by turbulence. Three intakes are foreseen, and a width of 14.10 m and a height of 6.60 m per intake fulfil this criterion.

The flow area downstream of the intake is gradually reduced to the size of the intake channel to increase the flow velocity. After the contraction, a fixed-wheel gate will be provided for each intake. The gates have the following functions:

- Revision of desander and Power Waterway: If the desander or Power Waterway need to be emptied for a revision, the gates can be closed,
- Flushing of desander basin: The gates will be operated during flushing of the basins,
- Emergency closure device to cut off the flowing water flow into the desander.

Just upstream of each gate will be a slot for stoplogs. They will be manually lowered into the slot for revisions of the gate or if the gate cannot be closed.

11.4.4.3 Intake Channels

Three intake channels are foreseen between the intake and the bifurcations. The six channels between the bifurcations and transition zones at the beginning of the desander basins have a length of at least five times of the channel width (17.50 m) in the straight reach downstream of the bend. The purpose of the channels is to guide the flow to the desander basins in a uniform flow with no turbulences.

The velocity in the intake channels is such that sediment deposition is avoided. The minimum velocity is determined with the Zanke criterion to prevent a deposition of sediments.

For hydraulic stability reasons the Froude number along the channels is kept below 0.45 while operating at MOL and design flow condition.

11.4.4.4 Transition Zone

The purpose of the transition zone at the beginning of the desander is the adjustment from the intake channel to the basin cross section.

For the proper operation of the desander the flows have to be calmed and uniformed as much as possible and the installation of three calming racks is therefore foreseen in the transition zone.

11.4.4.5 Desander Basins

The desander system is designed to remove particles with a diameter of 0.3 mm and larger for the diversion design discharge of 75 m^3/s (12.5 m^3/s per desander basin). In order to avoid re-suspension of the settled particles, the flow velocity in the desander basins should not exceed the critical velocity v_{cr} of the design particle.

The desander cross sectional area has to fulfil the requirements for the MOL and full Powerhouse operating condition, while the length of basins has to be checked against the FSL and full Powerhouse operating condition.

To avoid the re-suspension of a particle with a diameter of 0.3 mm according to Zanke, the critical velocity v_{cr} is 0.19 m/s.

The geometric ratio of the basins is designed to avoid irregular flow patterns. The flow velocity criterion is fulfilled with a selected width of each basin of 13.7 m and an water depth of 7.1 m at the start of the desander basin, while operating at MOL and full powerhouse design flow condition. The calculated flow velocity in each basin equals to 0.188 m/s and thus fulfils the critical velocity v_{cr} = 0.19 m/s for the mentioned operational condition.

The length of the desander basins results from the classic sand trap design approach: A particle with the design grain size entering the desander basin at the FSL or MOL water surface shall sink to the basin's bottom while travelling through the basin, considering a constant sinking velocity over the basin length. The resulting lengths of the desander are 27 m for the FSL and 43 m for the MOL. However, to fulfil the L ≥ 8 * width criterion, the desander length results in 110 m.

11.4.4.6 Desander End Opening Section

At the downstream end of the desander is an opening to convey the water into the forebay of the Headrace Tunnel intake. The opening is foreseen to minimise the gate section which is necessary to isolate each twin-basin during desander flushing operations while the other basins could supply flow to the Headrace Tunnel intake. These gates shall prevent the backflow and re-suspension of the sediment accumulated at the basins inverts which are considered to be flushed.

The invert elevation of the openings is at 1,498.25 m asl. The openings have dimensions of 5.10 m width and 6.15 m height.

11.4.4.7 Flushing Channel

A flushing channel is located at the bottom of each basin. A sliding gate is located at the downstream end, after which the channel conveys the sediment back to the river. The wetted surfaces will be specially treated as a protection against abrasion.

The elevation of the flushing channel invert at the gates is at 1,489.30 m asl, which allows the operation of the flushing channel during all flood conditions.

11.4.4.8 Water Level from Intake to End Sill

The water level from the forebay up to the intake was determined taking friction and local losses into account. The friction losses were calculated with the equation from Manning.

The results of the water level surface calculations for the design discharge conditions along Channel 1 are compiled in Volume 7 – Project Design, Annex 1.4. The losses along different channels differ slightly because of the different intake channel lengths and bends.

11.4.4.9 Forebay Overflow Section

An overflow section is foreseen at the forebay to return the flow entering the desander back into the river after a load trip while the intake gates are closing. The crest level of the spillway is foreseen at 1,510.10 m asl with crest length of 21.0 m.

11.4.4.10 Flushing of Desander Basins

While two basins are flushing, the other four basins remain in operation. The discharge into the power intake will then be equal to two thirds of the available capacity.

For the flushing of two adjoining desander basin the end opening gates of those basins have to be closed.

11.5 Concept of River Diversion during Construction

11.5.1 General

Water needs to be diverted during construction to allow the Lower Spat Gah Headworks to be built in dry conditions. The construction stages are typically timed to suit prevailing hydrological conditions and minimise the risk of overtopping partially completed works. The purpose of the Lower Spat Gah Headworks construction diversion concept discussed in this section is not to describe how the construction is to be carried out. However, the purpose is to demonstrate that the construction diversion is feasible and to recommend reasonable diversion floods and associated cofferdams elevations that are typically acceptable to investors and insurers

As explained in Volume 3 – Hydrology of this Feasibility Study, the high-flow season takes place during the April to September months with the highest discharges between May and July.

A two-stage construction procedure is proposed for the Lower Spat Gah Headworks. The proposed diversion concept is illustrated in Figure 11-3 and is further discussed in the following sections.

11.5.2 Diversion Stages

After some initial works, the construction of the Lower Spat Gah Headworks is done during two main construction stages as follows:

- Initial works: Excavation of the right bank and Headrace Tunnel intake,
- Stage 1: Construction of the flushing channels No. 2 and 3, desander intake and desander,
- Stage 2: Construction of the flushing channel No. 1 and the clay core rockfill dam.

Prior to the river diversion, the intermediate pier separating the flushing channels No. 1 and No. 2 is constructed. The construction of this intermediate pier should be started in the beginning of the first low-flow season (October to March).

Stage 1 works will be carried out along the right bank and the river will be allowed to follow its natural course at the dam site, i.e. along the main channel and left bank. The Stage 2 works will be carried out at the river main channel and the left bank, and the river will be diverted to flow through the flushing channels No. 2 and 3 constructed in Stage 1.

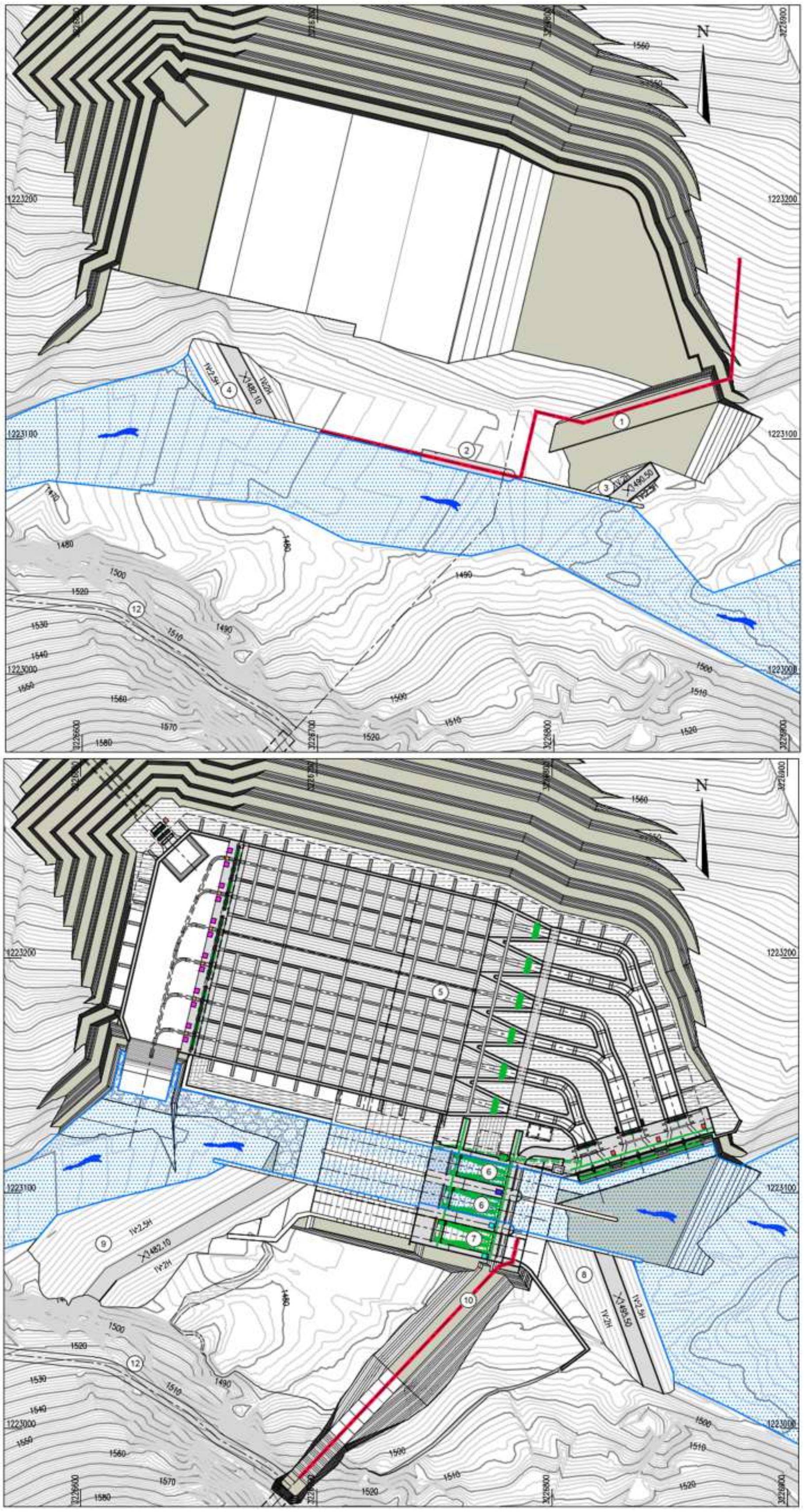


Figure 11-3: Lower Spat Gah Headworks river diversion concept

11.5.3 Initial Works

After construction of the access road, bridge and site installations, the excavation of the right bank around the Headrace Tunnel intake as well as the excavation and construction of the Headrace Tunnel portal are proposed to be carried out.

11.5.4 Construction Stage 1

During the Stage 1 diversion, construction of the structures on the right bank which includes the flushing channels No. 2 and 3, the desander intake, and the desander will be constructed. This construction pit will be protected by short and low upstream and downstream cofferdams. The cofferdams are foreseen with one end banked up against the intermediate pier and the other end closed against the right bank.

During the very beginning of the low-flow season when large floods are not expected, the intermediate pier between flushing channels No. 1 and 2 with the sealing element below the foundation level can be built.

Therefore the works can be executed with a low in situ designed river water protection. The main work safety element is proposed to be a simple flood warning system. At this phase, the construction pit can be quickly evacuated in case of a flood and potential damages would be very low.

The downstream channels of the flushing channels No. 2 and 3 need to be excavated at the final stage of the flushing channel construction procedure.

The intermediate pier will inevitably narrow the natural river and reduce to some extent its discharge capacity. To evaluate the river capacity reduction, the Stage 1 diversion was modelled by HEC-RAS. Figure 11-4 shows the river water levels for floods along the intermediate pier while the right bank construction works are in progress. The outline of the proposed Stage 1 cofferdam is shown in Figure 11-3.

With upstream and downstream cofferdams with crest levels of 1,490.50 m asl and 1,482.10 m asl respectively, as shown in Figure 11-3, the Stage 1 diversion cofferdams provide protection for up to a 494 m^3/s flood (equivalent to 10-year flood) with about 1 m freeboard. As the Stage 1 construction is estimated to take approximately 2 years, the risk of flooding during the Stage 1 is low and deemed acceptable.

The access to the construction pit shall be via the site main access road which is arranged from downstream on the left bank with a bridge.

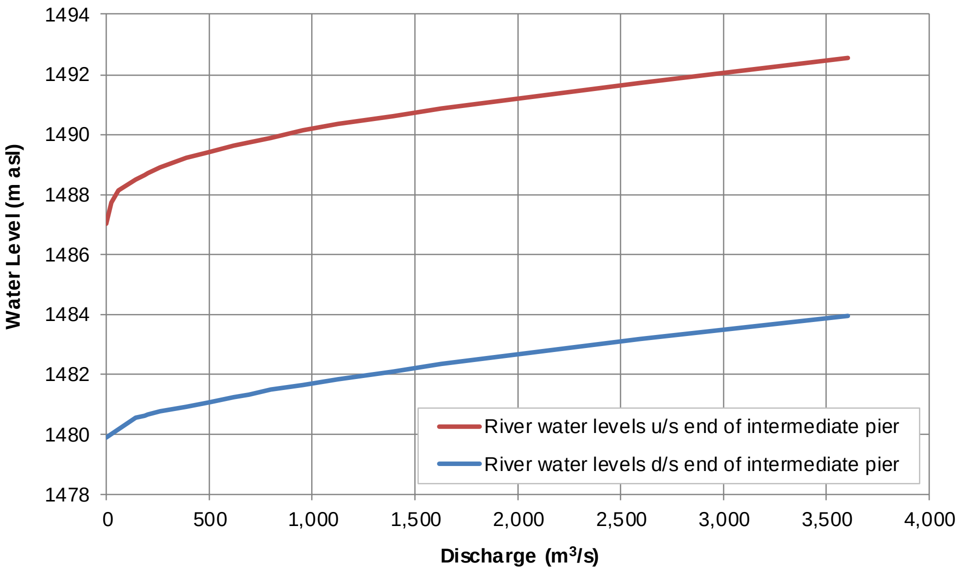


Figure 11-4: Discharge rating curve along intermediate pier for construction stage 1

11.5.5 Construction Stage 2

Once the Stage 1 construction is completed, the Stage 1 cofferdams will be removed at the beginning of the third low-flow season. The river will be diverted through the completed flushing channels No. 2 and No. 3 by constructing the Stage 2 cofferdams during the third low-flow season. During Stage 2 the flushing channel No. 1 and the clay core rockfill dam will be constructed.

The flushing channel capacity curve for floods during construction Stage 2 is presented in Figure 11-5.

A crest level of 1,495.50 m asl and 1,482.10 m asl have been proposed for the Stage 2 upstream and cofferdams respectively. The discharge capacity of the Stage 2 diversion would be 494 m^3/s (equivalent to 10-year flood) with 1 m freeboard to the proposed upstream cofferdam crest. With this configuration, the risk of the Stage 2 cofferdam overtopping during a single high-flow season would be very low and is deemed acceptable.

The construction of the flushing channel No. 1 and the dam can be scheduled and completed within about 1.5 years depending on the progress rate and work stops for the dam due to rain or freezing temperatures.

The outline of the proposed Stage 2 cofferdams is shown in Figure 11-3.

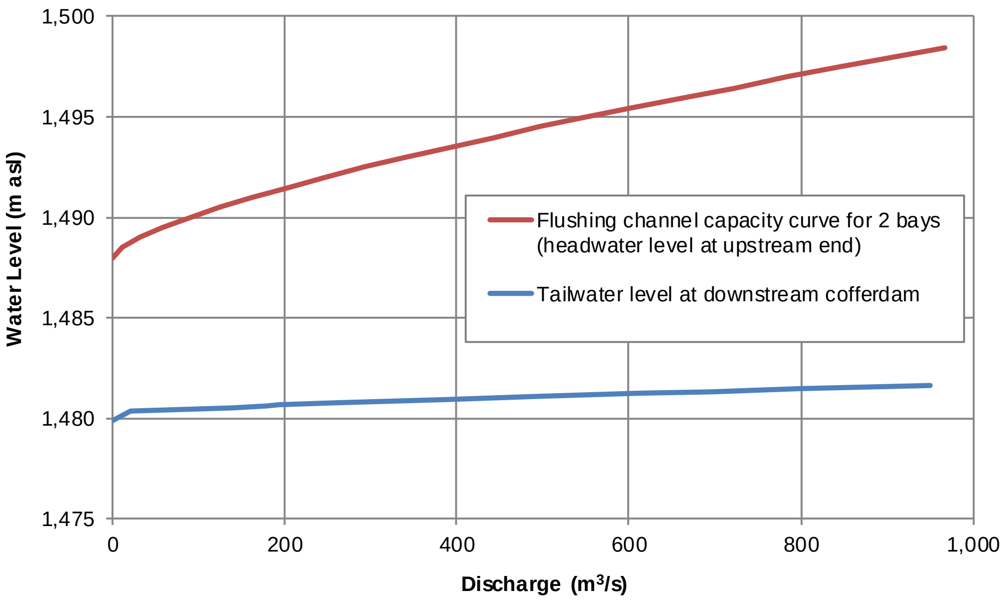


Figure 11-5: Discharge rating curve along intermediate pier for construction stage 2

11.5.6 Cofferdams Design

Figure 11-6 shows a typical cross section of the embankment cofferdams. Due to the expected high alluvial overburden on site and the heterogeneous river deposits the cofferdams need to be placed upstream and downstream of the excavation pit in a manner that only limited seepage occurs in the pit. The need of a sealing element in the alluvial deposit is conservatively foreseen at the Feasibility Study stage for all cofferdams and will have to be concluded based on numerical seepage calculations during the Detailed Design phase of the Project.

The upstream cofferdam during diversion Stage 2 may require an upstream clay blanketing to reduce the hydraulic gradients and seepages during cut-off wall works that is conservatively foreseen at the Feasibility Study stage. The same applies to the downstream cofferdam with a possible downstream clay blanketing. The thickness and the depth of such sealing system will have to be optimised during the Detailed Design phase of the Project.

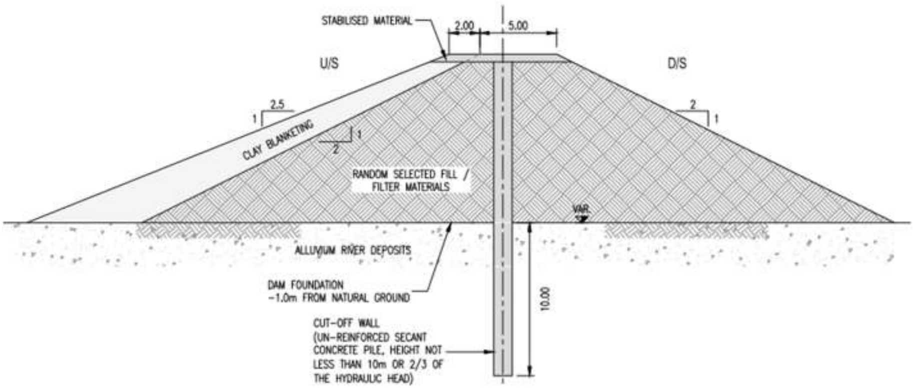


Figure 11-6: Typical cofferdam cross section

11.6 Embankment Dam Design

11.6.1 Introduction

A 2D seepage as well as slope stability analysis of the Clay Core Rockfill Dam (CCRD) has been performed for this Feasibility Study. The slope stability was analysed through a static, pseudo-static (OBE event) and Newmark analysis (OBE and SEE event). All analyses have been carried out with the software GeoStudio 2021 R2.

This chapter presents a summary of the analyses performed as part of the Feasibility Study design. More information and detailed results have been compiled in Volume 7 – Project Design.

11.6.2 Design Criteria

This chapter describes the design parameters and design methods that have been used for the performed seepage and slope stability analysis.

11.6.2.1 Geometrical Model

Figure 11-7 presents the representative dam cross section that has been used to perform the 2D seepage and slope stability analyses. The idealised cross section reflects the most unfavourable geometrical conditions (e.g. the highest cross section) related to seepage and slope stability. The top surface of the base rock and the thickness of the alluvium cover were derived from the geological drawings which are based on the 2020/2021 geological site investigations. The cut-off wall reaches from the gallery down to the rock surface. The anchoring length in the bedrock is modelled with a minimum penetration depth of 1 m. The clay core and the cut-off wall form a technical watertight sealing arrangement.

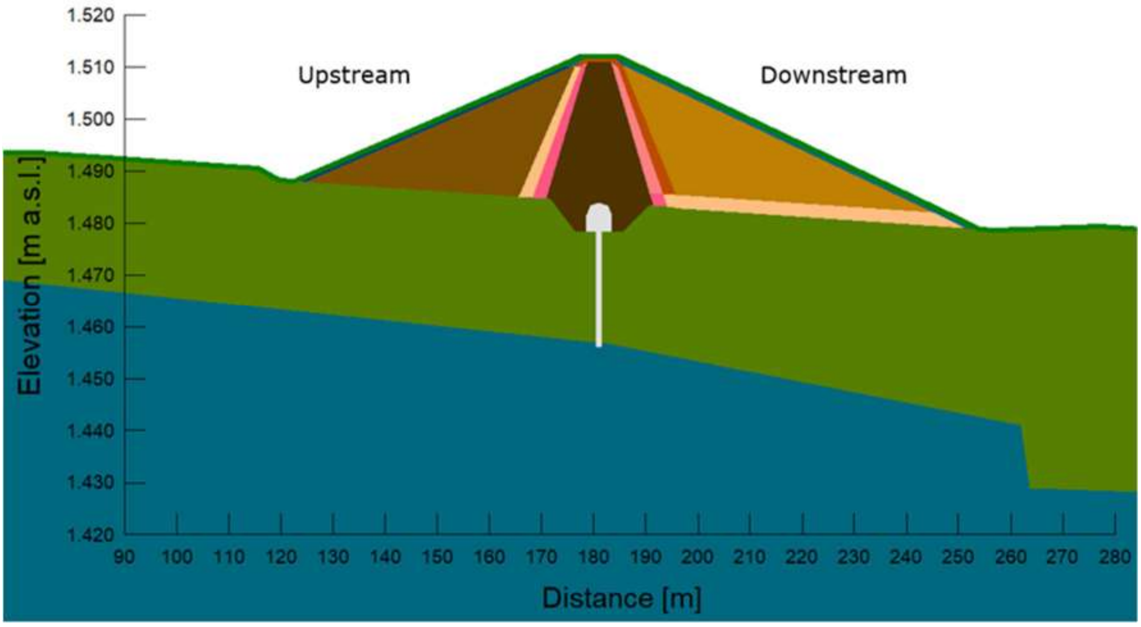


Figure 11-7: Geometrical model - CCRD

The dam crest is at elevation 1,512.00 m asl which leads to an average dam height of approximately 30 m. Table 11-5 summarises the salient dam features.

Table 11-5: CCRD geometry

Dam Crest Elevation (m asl)	Slope Inclination Downstream (V:H)	Slope Inclination Upstream (V:H)	FSL (m asl)	MOL (m asl)
1,512.00	1:2.1	1:2.3	1,510.00	1,500.00

11.6.2.2 Methodology

A steady-state and a transient seepage analysis were carried out. The steady-state seepage analysis has been performed to determine the pore pressure distribution and the phreatic line. This information served as the basis for the dam slope stability analyses. A transient analysis was performed to analyse the rapid drawdown condition. Therefore, the results of this analysis were the basis for the slope stability calculations in the case of a rapid drawdown event.

The Morgestern Price Limit Equilibrium Method has been used for the calculation of the factors of safety (common international practice). Static and pseudo-static 2D slope stability analyses have been performed and the most critical slip surfaces for the upstream and downstream slopes have been identified. The seismic loads have been applied in accordance with the approach presented in Chapter 11.6.2.4. The analysed load cases are presented in Table 11-6.

11.6.2.3 Material Parameters

Despite the comprehensive 2008-2009 and 2020-2021 investigations campaigns performed on samples, limited information concerning material parameters and foundation conditions are available to characterise the foundation as a whole taking into account the contribution of the larger material and other boulders. Therefore, the used parameter sets for analysis were estimated based on available geotechnical data presented in the Volume 4 - Geology and summarised in Chapter 5 , data from comparable projects and recognised literature. The hydraulic and strength material parameters used for the calculations are given in Volume 7 – Project Design. The material parameter sets have to be verified in an early stage of the Project implementation by material testing and the calculations will have to be revised as applicable.

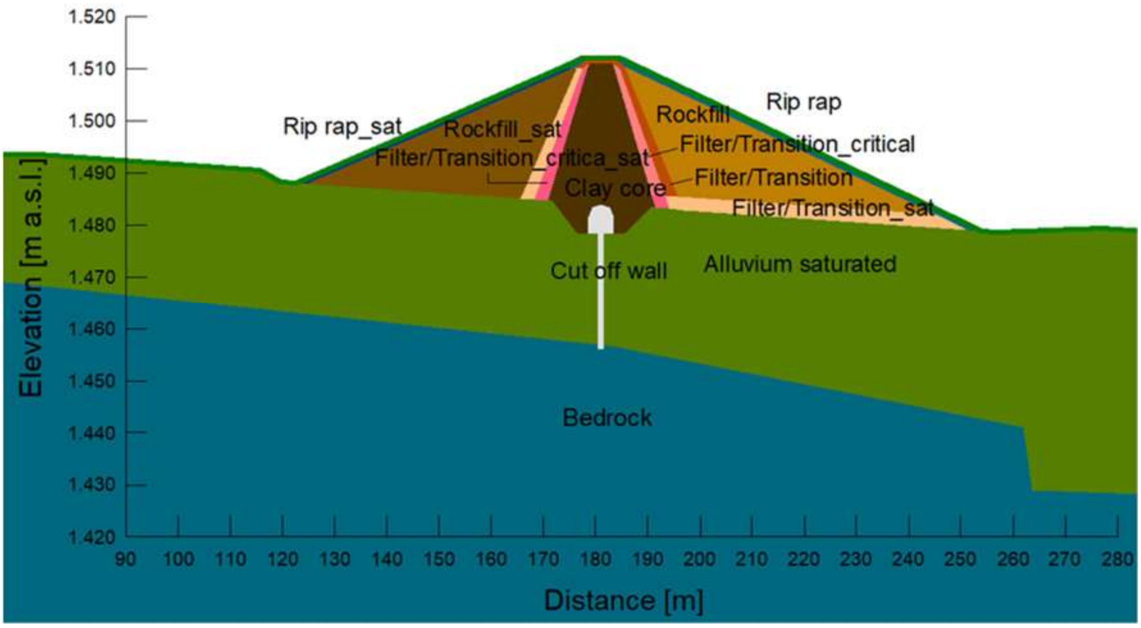


Figure 11-8: CCRD geometrical model with assigned materials

11.6.2.4 Earthquake Input

Two different earthquake inputs have been used for the analysis of the dam structure under seismic loading. Following the recommendations provided in ICOLD Bulletin 148 a return period for the OBE of 145 years and 3,000 years for the SEE event have been considered. The latter corresponds to a so called “moderate consequence structure”.

On one hand, the PGA values were employed for the pseudo-static analysis and on the other hand, acceleration time histories were used for the Newmark analysis. The output of the Probabilistic Seismic Hazard Assessment is response spectra and generic acceleration time histories for rock sites.

Because the alluvial foundation below the CCRD will affect the earthquake motions, a one-dimensional site response analysis has been carried out with the software Deepsoil and amplified values on the top of the alluvium layer have been used as input for the Newmark analysis. To further enhance the understanding of the behaviour of the CCRD under seismic loading, a recorded earthquake (Kobe) has been modified (site response analysis) in addition to the generic earthquakes provided in the Probabilistic Seismic Hazard Assessment. This input motion has been matched to the site response spectrum defined for SEE motion within the Probabilistic Seismic Hazard Assessment.

The earthquake acceleration time series have been applied in all analyses in the dam foundation area (dam footprint).

11.6.2.5 Load Cases and Factors of Safety for the Slope Stability Analysis

Load cases considered in the slope stability analysis as well as the corresponding minimum required factors of safety are presented in Table 11-6. Because the PMF level with all three gates open (1,507.90 m asl) is lower than the FSL, this load case was not analysed separately.

Table 11-6: Load case combinations and minimum required factors of safety

Load Case Combination	Reservoir Water Level			Earth-quake		Slip Circle Location		Load Case Classes	Required Factor of Safety	Decisive Loading Case
	Storage empty	FSL	MOL	No earthquake	OBE	Upstream	Downstream			
LCC1	X			X		X		LCC I, Usual Case	1.5	End of construction
LCC2	X				X	X		LCC II, Unusual	1.2	End of construction + OBE
LCC3		X		X			X	LCC I, Usual Case	1.5	FSL downstream
LCC4		X			X		X	LCC II, Unusual	1.2	FSL downstream + OBE
LCC5		X		X		X		LCC I, Usual Case	1.5	Upstream FSL
LCC6		X			X	X		LCC II, Unusual	1.2	Upstream FSL + OBE
LCC7			X	X		X		LCC I, Usual Case	1.5	Upstream MOL
LCC8			X		X	X		LCC II, Unusual	1.2	Upstream MOL + OBE
LCC9		X*		X		X		LCC II, Unusual	1.3	Rapid drawdown

*Rapid drawdown (from FSL to empty reservoir)

11.6.3 Results

11.6.3.1 Seepage Analysis

The FSL of 1,510.00 m asl has been used for the seepage calculation. The downstream ground water level of 1,465 m asl has been applied at the right geometrical model boundary. The calculated pore water pressure distribution and flow paths can be seen in Figure 11-9.

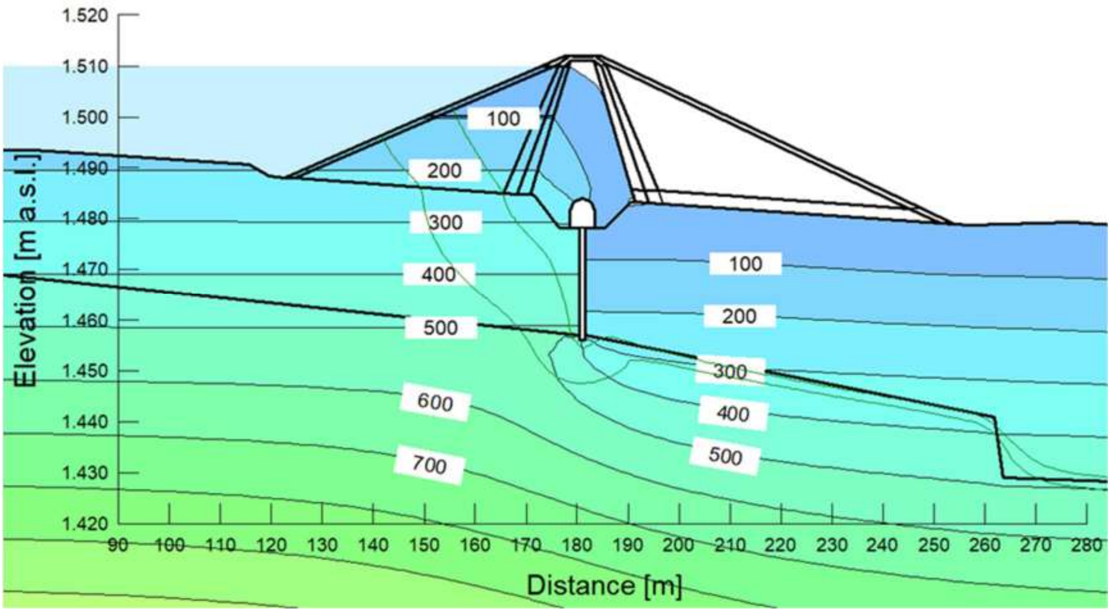


Figure 11-9: Seepage analysis FSL - pore water pressures (kPa)

The steady-state analysis shows that the sealing arrangement (cut-off wall and clay core) and the drainage blanket in the downstream dam shoulder foundation leads to a satisfying pore pressure distribution. The extension of the cut-off wall down to the rock surface (with a minimum penetration depth of 1 m) will limit the seepage quantities and the risk of internal erosion. The findings from the site investigations indicate that lenses of fines and the extension of the same in the foundation is limited. Therefore, the risk of liquefaction during earthquake shaking is expected to be very low to nil.

11.6.3.2 Static and Pseudo-Static Slope Stability Analysis

Static and pseudo-static 2D slope stability analyses have been performed and the most critical slip surfaces for the upstream and downstream dam slopes have been obtained. More information is provided in Volume 7 – Project Design, Annex 1.1. The computed factors of safety for these critical slip surfaces can be seen in Table 11-7.

Table 11-7: Load case combinations, minimum required and reached factors of safety

Load Case Combination	Reservoir Water Level			Earth-quake		Slip Circle Location		Load Case Classes	Required Factor of Safety	Reached Factor of Safety	Decisive Loading Case
	Storage empty	FSL	MOL	No earthquake	OBE	Upstream	Downstream				
LCC1	X			X		X		LCC I, Usual Case	1.5	2.85	End of construction
LCC2	X				X	X		LCC II, Unusual	1.2	1.23	End of construction + OBE
LCC3		X		X			X	LCC I, Usual Case	1.5	1.95	FSL downstream
LCC4		X			X		X	LCC II, Unusual	1.2	<1.2	FSL downstream + OBE
LCC5		X		X		X		LCC I, Usual Case	1.5	2.61	Upstream FSL
LCC6		X			X	X		LCC II, Unusual	1.2	<1.2	Upstream FSL+OBE
LCC7			X	X		X		LCC I, Usual Case	1.5	2.33	Upstream MOL
LCC8			X		X	X		LCC II, Unusual	1.2	<1.2	Upstream MOL+OBE
LCC9		X*		X		X		LCC II, Unusual	1.3	1. 36	Rapid drawdown

*Rapid drawdown (from FSL to empty reservoir)

11.6.3.3 Newmark Analysis

Newmark analyses have been performed for the OBE and the SEE event (generated and recorded/matched earthquake records). With the Newmark method, the movement of rigid sliding blocks induced by earthquake shaking along a slip surface is determined. The movements of representative sliding blocks have been investigated. The calculated displacements are summarised in Table 11-8. Critical sliding blocks are presented in Volume 7 - Annex 1.1. All analysed cases lead to acceptable displacements and do not critically affect the dam stability nor its integrity. However, repair and rehabilitation works after the CCRD experienced considerable deformations might be required.

Table 11-8: Newmark results for OBE and SEE event (generated and recorded/matched records)

Earthquake	Load Case	Displacement of the Sliding Block with Largest Deformation (m)	Displacement of Deeper Sliding Block passing through Clay Core (m)
OBE	FSL DS	0.0013	Negligible
	FSL US	0.03	Negligible
	MOL US	0.002	Negligible
SEE (3,000-year)	FSL DS	0.09	0.06
	FSL US	0.29	0.13
	MOL US	0.07	0.03
Kobe matched	FSL DS	0.45	0.22
	FSL US	0.56	0.38
	MOL US	0.29	0.10

11.6.4 Conclusion and Considerations for Further Design Stages

The performance of the CCRD under static, pseudo-static and dynamic loading indicates a safe dam design and meets international standards. All factors of safety for static load cases satisfy the design requirements. Where the stability could not be proved using a pseudo-static analysis only ($SF_{calculated} < SF_{required}$), a more sophisticated Newmark deformation analysis has been carried out. For three pseudo-static load cases (LCC4, LCC6 and LCC8) the required factors of safety could not be reached. The factors of safety against sliding required by the pseudo-static method may not be attainable for larger seismic forces representative of moderate to high intensity ground motions (refer to e.g. FEMA 2005). Therefore, a supplementary Newmark analysis has been performed for the OBE case. All analysed cases lead to acceptable displacements. The calculated movement of the rigid sliding blocks according to the Newmark method indicate deformations smaller than the clay core width. Therefore, no uncontrolled release of water is expected in the case of an OBE/SEE (3,000-year) event.

The imported earthquake acceleration time series have been applied on the dam footprint, the stability behaviour of dam body itself in a case of the OBE and SEE (3,000-year) event has been analysed by means of the Newmark analysis. According to the performed analyses, the dam stability is significantly affected by the alluvium material at the foundation. Therefore, it is important to ensure during the Project implementation that the alluvium material in the foundation will not lose strength and stiffness during a seismic event. In order to ensure a homogeneous and sufficient shear strength/ resistance in the alluvial foundation, soil improvements in the dam foundation are taken into account in the BoQ.

The performed seepage analysis show that the designed sealing arrangement consisting of a clay core and a cut-off wall down to the rock surface is suitable considering the reservoir levels and present groundwater.

It is recommended that a stress-strain behaviour of the CCRD be studied with load-deformation analysis at an early stage of the Project implementation to confirm the above conclusions.

All assumptions and conclusions are valid for the introduced geometries, loads and assigned material parameters. Further material testing and site investigations shall be carried out at an early stage of the Project implementation to verify the assumptions made at this stage of the Project.

11.7 Concrete Structures Stability

11.7.1 Introduction

This chapter presents a summary of the stability checks performed as basis for the Feasibility Study design of the Lower Spat Gah Headworks flushing channels and desander structures.

The following checks have been performed to verify the overall stability of the Lower Spat Gah Headworks concrete structures:

- Flotation (buoyancy),
- Sliding,
- Rotation (overturning),
- Bearing capacity.

The flushing channel is a water retaining control structure that controls the reservoir water level with a radial gate and a channel alike structure downstream that channels the flow and protects the headworks from erosion. The stability analysis is limited to the control structure, proofing that this structure is stable for the below defined load cases without relying on force transmission to the channel structure. The limit between control structure and channel structure is considered at the contraction joint between the structures, with the overturning point at the bottom of the downstream concrete key of the control structure. More information and details results have been compiled in Volume 7 – Project Design.

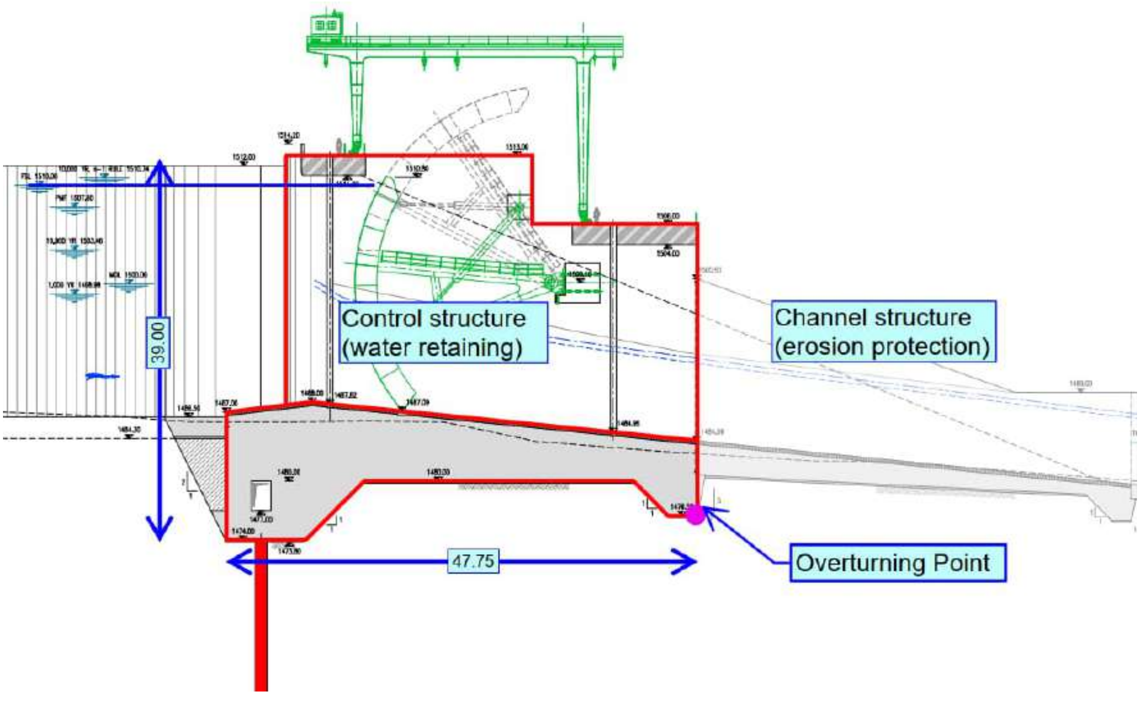


Figure 11-10: Section of flushing channel

11.7.2 Design Criteria

This chapter documents the design parameters and methodology which have been used to determine the global stability of the structure.

11.7.2.1 Design Parameters and Loads

Static Loads

The loads applied in the calculation are as follows:

- Dead loads: The dead loads are calculated according to the actual set of drawings, considering the weight of the concrete structure (24 kN/m^3) and the weight of water (10 kN/m^3)
- Hydrostatic loads: Hydrostatic loads are considered as per the respective water levels during operation and design flood levels; according to the selected load case the related tailwater level has been used.
- Uplift: Uplift pressures are considered as an external load (linearization of effective stresses). As an outcome of the numerical seepage analysis (Chapter 11.6.3.1), the uplift pressure downstream of the cut-off wall has been reduced to 70% of the upstream water pressure. A linear uplift pressure reduction towards the downstream end of the concrete weir has been taken into account.
- Earth pressure loads (when applicable): Earth pressure is taken as Ka and Kp on relevant areas; γ = 20 kN/m^3 and 11 kN/m^3 are taken respectively for saturated and submerged conditions.

Live Loads

Live loads are not considered for the stability analysis.

Water Levels

The following design water levels are considered:

- Upstream
  - FSL 1,510.00 m asl
  - 10,000-year flood (n-1) 1,510.74 m asl
  - PMF 1,507.80 m asl (not governing)
- Downstream
  - Normal operation 1,480.00 m asl (0.3 m above concrete)
  - 10,000-year flood 1,483.18 m asl
  - PMF 1,483.93 m asl (not governing)

Geotechnical Parameters

The following geotechnical parameters have been assumed for the alluvium:

- Alluvium
  - Unit weight 20 kN/m^3
  - Cohesion c' 0 kPa
  - Friction angle φ, static 38°
  - Friction angle φ, residual 30°
  - Allowable bearing capacity σ 400 kPa

Design Earthquakes

Earthquake loads have been selected in accordance with the Seismic Hazard Assessment Report (Chapter 7). An amplified response spectrum at the foundation of the concrete structure is calculated and applied.

Effects of water in case of earthquake

The hydrodynamic forces are based on the Westergaard method and act additionally to the hydrostatic water forces.

11.7.2.2 Loading Conditions and Safety Factors

To satisfy the stability analysis requirements for a concrete structure, the specific safety factor SF shall be equal to or greater than defined in the USACE EM 1110-2-2100. The safety factor is defined as the ratio of the resisting forces to the forces tending to cause a movement.

The safety factors depend on the different failure scenarios, such as flotation, sliding and rotation, as well as the load condition category as listed in Table 11-9.

Table 11-9: Load condition category and return period

Load Condition Category	Return Period
Usual	Less than or equal to 10 years. Primary function of the structures
Unusual	Greater than 10 years but less than or equal to 300 years
Extreme	Greater than 300 years, emergency conditions or the combination of unusual loading events. Major accidents

The safety factors against sliding, overturning, flotation and bearing pressure as shown in Table 11-10 shall be met. Considering the moderate to low consequences for dam failures, the Lower Spat Gah Headworks and Gabarband Intake concrete structures are classified normal and the relevant safety factors are applied.

Table 11-10: Safety factor requirements

Load Condition	Flotation	Sliding*		Overturning	Foundation Bearing Pressure
		Critical	Normal		
Usual	1.3	2.0	1.5	100% of base in compression	< allowable
Unusual	1.2	1.5	1.3	75% of base in compression	< 1.15 x allowable
Extreme	1.1	1.1	1.1	resultant within base	< 1.50 x allowable

* The factors of safety for sliding are different for critical structures and for normal structures and further depend on whether site information is well defined, ordinary or only limited. Critical structures are generally water retaining structures, whose failure will result in loss of life.

11.7.2.3 Load Cases

The load cases have been combined to i) usual, ii) unusual, iii) extreme load case combinations. An overview of the investigated load case combinations is provided in Table 11-11 and Table 11-12 for the flushing channels and desander structures respectively.

Table 11-11: Load condition category (Lower Spat Gah flushing channels)

Load Condition Category	Load Case Description	Upstream Water Level	Gate
LC1-Usual	Operating situation	FSL	closed
LC2-Unusual	Earthquake – OBE	FSL	closed
LC3-Extreme	Earthquake – SEE	FSL	closed
LC4-Extreme	Flood	10,000-yr	one gate closed
LC5-Post SEE	Normal condition, residual shear strength parameter, no uplift pressure reduction	FSL	closed (to be opened after SEE event)

Table 11-12: Load condition category (Lower Spat Gah desander)

Load Condition Category	Load Case Description	Hillside Water Level	Gate	Channel
LC1-Usual	Operating situation	High	Opened	Filled - MOL
LC2-Unusual	Maintenance	Normal	Closed	Emptied
LC3-Unusual	Earthquake – OBE	Normal	Opened	Filled - FSL
LC4-Extreme	Earthquake – DBE	Normal	Opened	Filled - FSL
LC5-Extreme	Flood	Top of structure	Closed	Filled - FSL

11.7.3 Stability Analysis Results

11.7.3.1 Flushing Channels

The computed safety factors for the flushing channel structure are presented in Table 11-13. The detailed calculations are compiled in Volume 7 – Project Design, Annex 1.2.

Table 11-13: Results overview flushing channel

Load Case		Sliding SF_S		Rotation			Flotation SF_F		Bearing Pressure (kPa)	
Condition	Combination	Actual	Req.	Max. eccentricity	Base in com-pression Actual (%)	Base in com-pression Req. (%)	Actual	Req.	Max	Allow
Usual	LC1 - Normal	2.67	1.5	Middle third = L/6	100	100	2.61	1.3	352	400
Unusual	LC2 - OBE	1.38	1.3	Middle half = L/4	100	75	2.42	1.2	485	460
Extreme	LC3 – SEE	0.93	1.1	In base = L/2	73	>0	2.24	1.1	675	600
Extreme	LC4 - Flood	2.48	1.1	In base = L/2	100	>0	2.32	1.1	335	600
Extreme	LC5 – Post SEE	1.47	1.1	In base = L/2	100	>0	1.64	1.1	282	600

For all considered cases, the minimum safety factors against flotation and rotation are met. In case of global sliding the required safety factors are met except for the extreme load case combination considering the SEE. According to international standards this can be accepted if no uncontrolled water release happens during and after a SEE event. Preliminary permanent sliding calculations have been performed for this phase but more detailed calculations need to be executed during the Detailed Design phase of the Project using conventional Finite Element Model(s). Nevertheless, the criterion of no uncontrolled release of water can be met with for example an overlapping contraction joint to the neighbouring structures.

The bearing pressures for the seismic load cases are slightly higher than the allowable bearing pressures. Given the uncertainties in the current design stage and considering that some damages of the concrete structure or the foundation at the interface to the downstream channel structure can be accepted, this can be accepted.

11.7.3.2 Desander

The computed safety factors for the desander structure are presented in Table 11-14. The detailed calculations are compiled in Volume 7 – Project Design, Annex 1.3.

The desander structure is safe for all considered load case combinations. Because the desander is not a water retaining structure (gates at intake) that is critical for the safety of the Project, the stability was checked against the DBE. Nevertheless a stability check has been carried out for the SEE considering a support against sliding at the intermediate block between desander and flushing channel. This force has subsequently been considered for the stability calculations of the intermediate block itself.

For structural reasons, beams are provided on the top of the concrete structure of 1,512 m asl to reduce the internal forces of the walls.

Table 11-14: Results overview desander

Load Case		Sliding SF_S		Rotation			Flotation SF_F		Bearing Pressure (kPa)	
Condition	Combination	Actual	Req.	Max. eccentricity	Base in com-pression Actual (%)	Base in com-pression Req. (%)	Actual	Req.	Max	Allow
Usual	LC1 - Normal	1.53	1.5	Middle third = L/6	100	100	1.70	1.3	148	400
Unusual	LC2 - Maintenance	1.40	1.3	Middle half = L/4	90	75	1.62	1.2	141	460
Unusual	LC3 - OBE	1.56	1.3	In base = L/2	100	75	2.48	1.2	259	460
Extreme	LC4 - DBE	1.24	1.1	In base = L/2	100	>0	2.39	1.1	296	600
Extreme	LC5 - Flood	1.46	1.1	In base = L/2	130	>0	1.62	1.1	143	600

11.8 Standards, Codes and Guidelines

The following appropriate international standards, manuals and guidelines have been used for the diversion dam civil design works of the Feasibility Study.

11.8.1 Hydraulic Dam Design

- Bollrich. 1996. Technische Hydromechanik. Verlag für Bauwesen. Berlin.
- Chow, V.T. 1959. Open Channel Hydraulics.
- Giesecke, J. 2005. Wasserkraftanlagen. 4th edition.
- Minor, H.-E. 1988. Design of spillways for large dams. Reprinted from Indian Journal of Power & River Valley Development, March 1988.
- Mosonyi, E. 1991. Water Power Development, Volume Two, High-Head Power Plants. Akadémiai Kiado. Budapest.
- Ortmanns, C. 2006. Entsander von Wasserkraftanlagen. Mitteilung Nr. 193. Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, Eidgenössische Technische Hochschule. Zürich.

- USBR. 1978. Design of Small Canal Structures. United States Department of the Interior, Bureau of Reclamation. A Water Resources Technical Publication.
- USBR. 1990. Criteria and guidelines for evacuating storage reservoirs and sizing low-level outlet. Bureau of Reclamation, Denver, CO. Assistant Commissioner - Engineering and Research.

11.8.2 Pre-Cofferdams and Embankment Dam Design

- Fell, R., MacGregor, P., Stapledon, D., and Bell, G. 2005. Geotechnical engineering of dams.
- FEMA. 2005. Federal Guidelines for Dam Safety. Earthquake Analyses and Design of Dams. Federal Emergency Management Agency.
- FEMA. 2005. The National Dam Safety Program Research Needs Workshop- Seepage Through Embankment Dams. Federal Emergency Management Agency
- ICOLD Bulletin 91: Embankment Dams - Upstream Slope Protection. International Commission on Large Dams. 1993.
- ICOLD Bulletin 95: Embankment Dams - Granular Filters and Drains. International Commission on Large Dams. 1994.
- ICOLD Bulletin 148: Selecting seismic parameters for large dams. International Commission on Large Dams. 2010.
- Kutzner, C. 1996. Earth and Rockfill Dams, Principles for Design and Construction.
- Seed, B., Wong, R., Idriss, I. M., and Tokimatsu, K. 1984. Moduli and damping factors for dynamic analyses of cohesionless soils.
- Seed, B., Golesorkhi, R. and Sun, Joseph I. 1988. Dynamic moduli and damping ratios for dynamic analyses of cohesive soils. Earthquake engineering research center.
- USACE. 1984. A. G. Franklin, Mary E. Hynes-Griffin. US Army Corps of Engineers. Rationalizing the seismic coefficient method. Misc. Pap. GL-84-13.
- USACE. 2003. EM 1110-2-1902. Slope Stability. U.S. Army Corps of Engineers, Engineering and Design.
- USACE. 2004. EM 1110-2-2300. General Design and Construction Considerations for Earth and Rockfill Dams. U.S. Army Corps of Engineers, Engineering and Design.
- USSD. 2007. Strength of materials for embankment dams. United States Society on Dams.

11.8.3 Stability Analysis

- ASCE. 2010. Minimum design Loads for Buildings and Other Structures. American Society of Civil Engineers.
- ASTM. Testing specifications.
- USACE. 2005. EM-1110-2-2100. Stability Analysis of Concrete Structures. U.S. Army Corps of Engineers, Engineering and Design. American Society for Testing and Materials.

12 Civil Design - Lower Gabarband Intake

Corresponding Drawings

LSG-FS-070-001	Lower Gabarband Intake, General Arrangement, Overview Plan
LSG-FS-070-002	Lower Gabarband Intake, General Arrangement, Plan View
LSG-FS-070-003	Lower Gabarband Intake, Flushing Channel, Section A-A
LSG-FS-070-004	Lower Gabarband Intake, Spillway, Section B-B
LSG-FS-070-005	Lower Gabarband Intake, Desander & Forebay, Sections C-C & D-D
LSG-FS-070-006	Lower Gabarband Intake, Weir, Desander and Forebay, Sections 1-1 to 4-4
LSG-FS-070-007	Lower Gabarband Intake, Excavation, Plan View
LSG-FS-070-008	Lower Gabarband Intake, Excavation, Sections E1-E1 & E2-E2
LSG-FS-070-009	Lower Gabarband Intake, General Arrangement, Construction Phasing - Sheet 1/2
LSG-FS-070-010	Lower Gabarband Intake, General Arrangement, Construction Phasing - Sheet 2/2

12.1 Introduction

This chapter describes the civil structures of the Lower Gabarband Intake and their design, including the spillway, flushing channel, desander intake and desander. More detailed design criteria and comprehensive calculations performed as basis for the Feasibility Study design are compiled in Volume 7 – Project Design.

12.2 Location

The location of the Lower Gabarband Intake, especially the desander and Gabarband Intake Tunnel portal has been questioned by the Panel of Experts. Overall the location of the Lower Gabarband Intake is at the most optimal location considering the maximum upsurge water levels, length of Gabarband Intake Tunnel, width of the valley, scree areas and the upstream village. The position of the portal has been decided taking into account all possible geological risks, including the risk of rock falls and larger instabilities. The ancient rock fall zone present in the area does not show evidence of any recent activity. The large blocks accumulated at the base of the slope in the portal are the results of an ancient event and not of an ongoing process. The actual morphology of the area and the vegetation cover both indicate that the area is stable and does not anymore represent a risk for the structures. Active or recent rock fall areas, characterized by lack of vegetation formation of detrital cones are on the other hand observed upstream of the selected weir-intake area and the structures have been located and designed to avoid these areas. Per the Panel of Expert's comments it is recommended to validate the location in the next Project design stage.

12.3 Reservoir Characteristics

The weir generates a very small reservoir on the Gabarband River. Reservoir volume-area-curves have not been developed due to its negligible dimensions but the general characteristics of the reservoir are listed in Table 12-1.

Table 12-1: Main characteristics of Lower Gabarband reservoir

Reservoir	
Normal Operating Level (NOL)	1,553.00 m asl
Reservoir volume at NOL	4,000 m^3
Surface area at NOL	1,700 m^2
Backwater length at NOL	65 m

12.4 Hydraulic Design Weir

12.4.1 Introduction

This chapter describes the layout planning and design of the Lower Gabarband Intake. The concept for river diversion during construction is also discussed. This hydraulic design chapter contains the design description and the hydraulic design.

12.4.2 General Layout

The flow diverting Lower Gabarband Intake consists of an ungated spillway, gated flushing channel and an intake diverting flow to the Power Waterway. The flushing channel consists of one bay and shall be capable of sediment flushing.

During the construction period, the river shall be diverted through the main river channel (construction stage 1) and the flushing channel (construction stage 2). The spillway's crest is proposed at the Normal Operating Level (NOL).

Table 12-2 lists the general characteristics of the Lower Gabarband Intake.

Table 12-2: Main characteristics of Lower Gabarband Intake

Reservoir	
Normal Water Level (NOL)	1,553.00 m asl
Water level - design flood (1,000-year)	1,556.77 m asl
Water level - check flood (10,000-year)	1,558.28 m asl
Water level - safety flood (1,000-year, n-1)	1,557.66 m asl
Spillway	
Location	Main river channel
Crest elevation	1,553.00 m asl
Foundation elevation	1,538.50 m asl
Crest length	20.5 m
Flushing Channel	
Location	Left bank
Sill crest elevation	1,548.00 m asl
Type of gate	Radial gate
Gate dimensions (WxH)	4.00 m x 7.08 m
Top of parapet wall	1,560.30 m asl
Crest elevation	1,559.40 m asl
Foundation elevation	1,538.50 m asl
Crest length	9 m

12.4.3 Design Criteria

12.4.3.1 Basic Data

Floods

The flood peak discharges at the intake site on the Gabarband River are given in Table 5-7. The low-flow season in the Project area has been assumed from October to March.

Topography

The survey information given as summarised in Chapter 4 and presented in more detail in Volume 2 – Topography was used.

Geology

The intake site is mainly located on top of river deposits and slope wash river sediments and scree while the bedrock is mainly amphibolite as described in Chapter 6 and further documented in Volume 4 – Geology.

12.4.3.2 Hydraulic Design Criteria

The main requirement of the Lower Gabarband Intake is to divert water to the Gabarband Intake Tunnel and Power Waterway.

The intake will consist of a spillway, flushing channel and desander. The whole structure shall mainly be founded on sediments.

The following load cases for the hydraulic design of the weir are defined:

- Design flood: 1,000-year flood
- Check flood: 10,000-year flood
- Safety flood: Design flood with the flushing channel gate not operational (n- 1 rule)

The 1,000-year flood with the n-1 criterion was selected instead of the PMF as the safety flood because the weir is a small structure according to ICOLD (2016). Furthermore, the small concrete weir with minimal reservoir results in minimal consequences in case of a failure. Additionally, the concrete weir can sustain overtopping.

The flushing channel will also be used to periodically clear the bed load and debris from the front of the desander intake and to act as a river bypass during construction.

The weir height is determined based on topographic, hydraulic and freeboard requirements.

The spillway capacity is determined using standard dam-discharge relationships and appropriate discharge coefficients.

A freeboard of 1.12 m to the weir crest has been provided for the check flood condition. Minimum freeboards of 1.0 m to the underside of the bridge have been checked to be available for the critical safety flood event where the gate is not operational and sufficient clearance for debris shall be available.

A variable flow ranging from 0.23 to 0.33 m^3/s is released as residual flow through a valve-controlled by-pass, which is installed in the left flushing channel pier next to the desander, and discharges into the concrete flushing channel downstream of the gate.

12.4.3.3 Diversion during Construction Criteria

The Lower Gabarband Intake structure will be constructed in two main phases. The initial construction works in the river bed as well as the placing of the cofferdams will be carried out during the low-flow seasons. According to the USBR (1990) criterion, the flood should generally be approximately five times the duration of the construction period. With a construction duration of about one year for each stage, this criterion gives a 5-year flood. The construction pits shall therefore be designed to be safe against floods up to a 5-year return period.

During stage 1, structures at the left bank, i.e. the flushing channel, desander intake and desander shall be constructed while the river is being diverted within the natural main river bed. The construction site will be protected by the intermediate pier between the spillway and flushing channel as well as upstream and downstream cofferdams.

During stage 2, which comprises the completion of the spillway, the river will be diverted through the completed flushing channel at the left river bank.

12.4.4 Hydraulic Design

12.4.4.1 General

The main requirement of the Lower Gabarband Intake is to divert water to the Power Waterway. In particular, the following requirements have to be met by the intake:

- Enable a certain water level at the desander intake to catch the river flows up to the design diversion discharge,
- Allow flushing of sediments in front of the desander intake,
- Passing of floods, and avoid blockage due to floating tree branches and logs during floods,
- Ensure a residual flow in the Gabarband River downstream of the intake site during all hydrological conditions.

12.4.4.2 Outline Design

The Lower Gabarband weir is a concrete structure with a total crest length of about 31.0 m (including the flushing channel and spillway bay, piers and side walls) and a maximum height of 20.9 m (measured from the deepest foundation level to the dam crest top level excluding the parapet wall).

Apart from the desander intake, the weir comprises two separate hydraulic sections. The left multifunctional gated flushing channel is an open channel with an overall length of 54.5 m and the spillway is an ungated flood discharge structure.

The weir includes one 20.5 m wide spillway bay with a crest elevation at 1,553.00 m asl at the NOL, and one 4 m wide flushing channel bay with a radial gate and the gate sill level at 1,546.42 m asl. The flushing channel is designed with a steep slope invert to allow for easy and effective release of the sediment. The invert inclination of the flushing channel is 13.90%. The spillway bay width has been selected to provide enough room for safe passage of floating tree logs.

The flushing channel radial gate hydraulic cylinder mounting position has been designed to keep the respective position out of the discharging flows.

Stoplog grooves and stoplogs are provided upstream of the flushing channel radial gate. No stoplogs are needed on the downstream side of the flushing channel radial gate because of the low downstream water level. The stoplogs will be placed by a mobile crane.

The flushing channel provides a number of important functions: (a) second stage construction diversion water passage, (b) flood control incorporation, (c) maintain the intake free of bed load, (d) allow sediment and debris flushing from the reservoir to maintain its storage and (e) help in release of excess flows during normal operation above the NOL as well as during floods.

The intermediate pier between the flushing channel and the spillway is continued towards upstream as this pier will be used as part for the closure of the upstream cofferdam during the construction phase. In addition to its function during the construction/diversion phase, the intermediate pier will also improve the sediment flushing efficiency of the flushing channel and guide the water and the sediments through the bay.

The spillway has an ogee crest with an inclined upstream face to facilitate the removal of accumulated sediments during floods.

12.4.4.3 Hydraulic Design

The flushing channel has been designed to safely pass a design flood of 530 m^3/s, equivalent to a 1,000-year flood event, and was checked for a 10,000-year flood of 850 m^3/s without any weir overtopping.

The flow in the Gabarband River downstream of the weir is supercritical and is not causing any backwater effect which could have a negative impact on the discharge capacity of the weir.

With the flushing channel gate fully open, the discharge through the flushing channel will be free-surface flow with critical depth formed at the sloped channel inlet. For the operation of the flushing channel with the gate fully open and the operation of the spillway, the estimated headwater levels for the 1,000-year design flood and the 10,000-year check flood will be at elevations 1,556.77 m asl and 1,558.28 m asl, respectively. With the flushing channel gate closed (n-1 criterion), the headwater level for the 1,000-year flood will reach the elevation of 1,557.66 m asl.

The rating curves for the combined spillway and the flushing channel operation with the gate fully open is shown in Figure 12-1.

Due to the low tailwater levels and super-critical flow regime within the natural downstream river, no hydraulic jump shall take place in the flushing channel or downstream of the spillway. The provided inclined concrete channel is to protect the flushing channel foundation from erosion.

The weir structure at the Lower Gabarband Intake including the spillway and flushing channel is deemed not to impact the sediment transport regime of the river remarkably. With the proposed structures the sediment shall be transported to the downstream river reach during annual floods.

To clean up the desander intake area from sediment, the flushing channel needs to be operated at least once a year during the high-flow season floods. The flushing channel is however planned to be operated more often than that in order to regulate the reservoir water level for small floods.

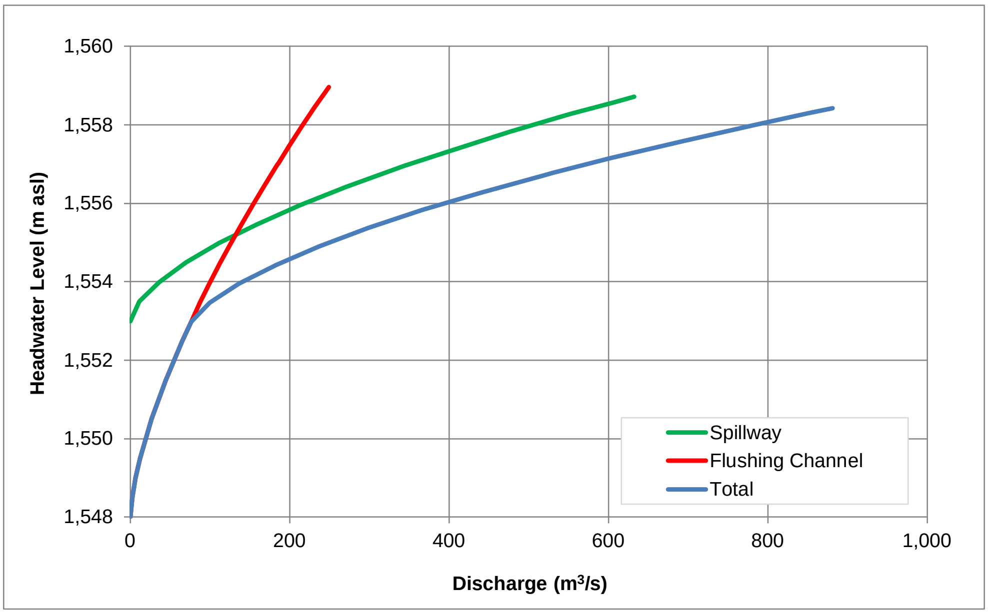


Figure 12-1: Headwater rating curves for combined operation of spillway and flushing channel (gates fully open)

12.4.4.4 Design Floods and Freeboard

As mentioned in Chapter 12.4.3.2, the design of the weir is carried out for the following load cases:

1) Design flood, which corresponds to the 1,000-year flood with the flushing gate fully open,
2) Check flood, which corresponds to the 10,000-year flood with the flushing gate fully open,
3) Safety flood, which corresponds to the 1,000-year flood with the flushing gate closed (n-1 criterion).

The defined load cases lead to the following headwater levels in the reservoir:

- Design flood (HQ1,000, n): 1,556.77 m asl
- Check flood (HQ10,000, n): 1,558.28 m asl
- Safety flood (HQ1,000, n-1): 1,557.66 m asl

Generally, an adequate freeboard represents an adequate safety margin during severe floods. A minimum freeboard of 1.12 m to the weir crest has been provided for the check flood condition. With the weir crest level at 1,559.40 m asl, freeboards of 1.24 m and 1.74 m are available during the design and safety flood events respectively. Wave run-up and wind setup has also been taken into account for the design flood event. The freeboard to the underside of the bridge during the safety flood is 1.24 m.

12.4.4.5 Residual Flow Outlet

The residual flow requirement at the Lower Gabarband Intake resulted to 0.23 to 0.33 m^3/s. The residual flow is released through a pipe of 0.30 m diameter embedded in the left flushing channel pier. A gate valve (0.30 m diameter) is provided to control the discharge at various operating levels. The residual flow valve opening will be adjusted through automatic control from SCADA based on the headwater level to release the required amount of flow.

The residual flow pipe discharges into the flushing channel comprising of high-strength concrete.

12.4.5 Tailwater Rating Curve

The Gabarband River water surface profile analysis has been carried out using the 1D HEC-RAS model developed by USACE. The river Manning's roughness coefficients were estimated utilising well-known hydraulic references such as Chow's Open Channel Hydraulics (1959). Manning roughnesses of n=0.05, n=0.065 and n=0.014 were estimated for the river main channel, overbanks and concrete surfaces, respectively. The model geometry is based on the detailed topography from the 2010 Feasibility Study.

The Lower Gabarband Intake tailwater levels for different discharges are shown in Figure 12-2.

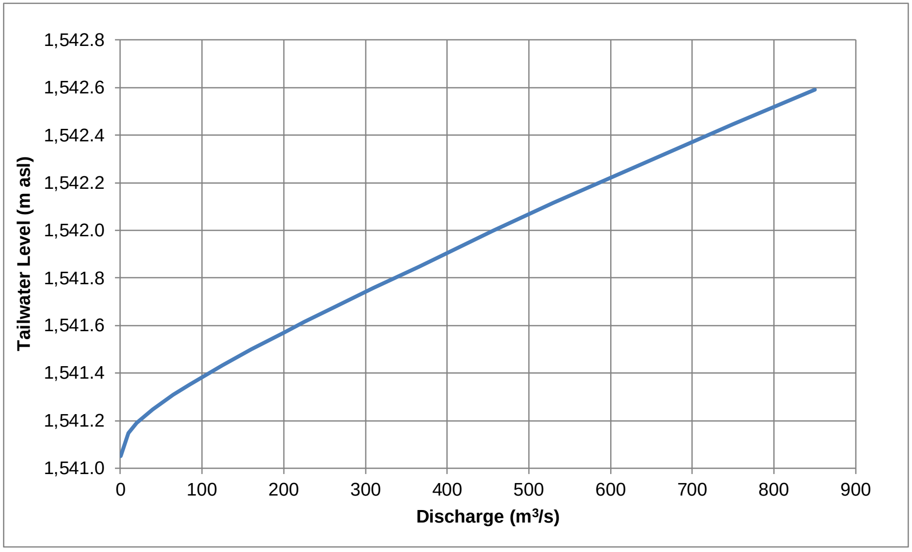


Figure 12-2: Lower Gabarband Intake tailwater level

12.4.6 Concept of River Diversion during Construction

Water needs to be diverted during construction to allow the weir and desander to be built in dry conditions. The purpose of the Lower Gabarband Intake construction diversion concept discussed in this section is not to describe how the construction is to be carried out. However, the purpose is to demonstrate that the construction diversion is feasible and to recommend reasonable diversion floods that are typically acceptable to investors and insurers.

The high-flow season is from April to September with the most severe floods between May and July. A two-stage construction procedure is proposed for the Lower Gabarband Intake. The proposed diversion concept is illustrated in Figure 12-3 and further discussed in the following sections.

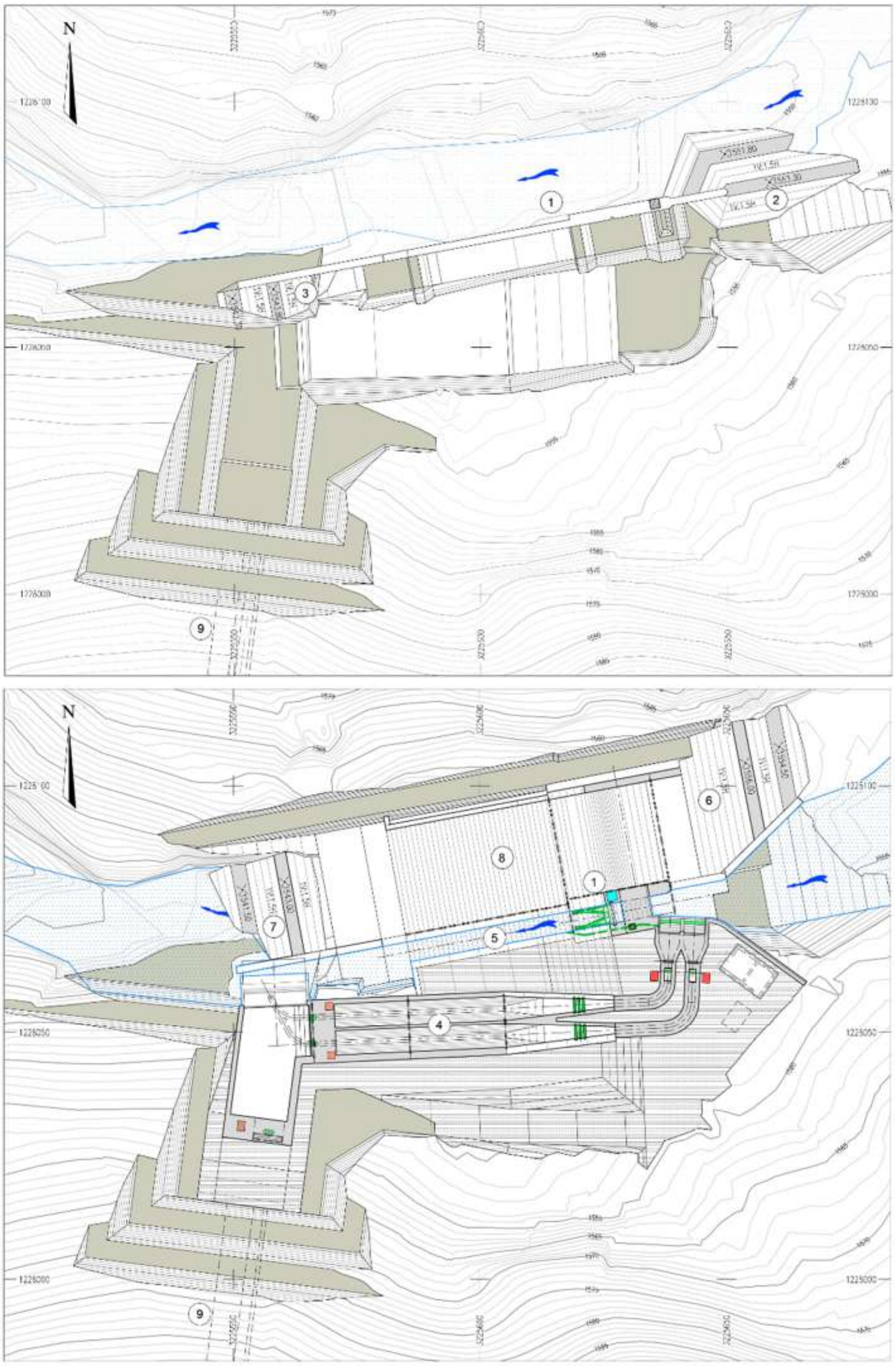


Figure 12-3: Dam construction stage 1-A (top) and 2 (bottom)

After some initial works, construction of the Lower Gabarband Intake will be done during two main construction stages:

- Stage 1: Construction of left bank structures
- Stage 2: Construction of spillway and right abutment

Stage 1 works will be carried out along the left bank and the river will be allowed to follow in its natural course at the weir site, i.e. along the main channel and right bank. During this stage the intermediate pier, cofferdams, flushing channel, desander intake, desander and forebay will be constructed. The stage 1 works can only start when the excavation and lining of the Lower Gabarband Intake tunnel is complete because the tunnel serves as access for the Lower Gabarband Intake. The intermediate pier and flushing channel slab as well as the subsequent cofferdam construction will have to be carried out during the low-flow season. The remaining structures can then be completed during the high-flow season.

The stage 2 works will be carried out at the river main channel and the right bank and the river will be diverted to flow through the flushing channel constructed in Stage 1. The removal of the stage 1 cofferdam and placement of the stage 2 cofferdams will be done in the second low-flow season of the Lower Gabarband Intake construction. The construction of the spillway and right abutment can then start and be completed at the end of the low-flow season.

12.5 Hydraulic Design Desander

12.5.1 Introduction

This chapter present the hydraulic design of the desander including the desander intake and the desander flushing channel. The design of the forebay and Gabarband Intake Tunnel downstream of the desander end sill is presented in the chapter of the Power Waterway (Chapter 13).

This chapter only presents the design particular to the desander and is to be read in conjunction with other civil design chapters such as for the weir and Power Waterway and the Volume 7 – Project Design providing more detailed information about the way the structure has been hydraulically designed.

12.5.2 General Layout

The layout of the desander consists of an intake section and desander itself. The intake conveys the water from the reservoir to the desander. At the downstream end of the desander, the water flows over an end sill into the forebay of the Gabarband Intake Tunnel while sediments will remain at the bottom of the desander basins, to be flushed back into the river through the flushing channels. The desander is designed with two basins, and an intake and intake channel each.

Table 12-3 lists the general characteristics of the intake and desander.

Table 12-3: Main characteristics of Lower Gabarband Intake desander and basins

Discharge	
Design discharge Q_d	10.0 m^3/s
Intake	
Type	Lateral
Inlet sill level	1,551.00 m asl
Inlet size (W x H)	Two 4.20 m x 2.00 m
Intake Channel	
Width	1.40 m
Water depth at NOL & Q_d	1.7 m
Length calming section upstream basins	7.00 m
Invert upstream of basins	1,550.95 m asl
Transition Zone	
Length	22.25 m
Vertical and lateral slope	1:5 (V:H) or less steep

Calming racks	Three rows for each basin
Desander Basins	
Number	2
Design grain size	0.3 mm
Length	39 m
Dimensions (W x H) at beginning	4.9 m x 6.2 m
Flushing channel width	1 m
Flushing channel slope	3%
Flushing gate	Sluice
Desander End Sill	
Type	Broad-crested
Crest level	1,552.06 m asl

12.5.3 Design Criteria

The design grain size for the desander basin design shall be 0.3 mm (see Chapter 8.3.1). The functional design criteria of the desander are as follows:

1. A trash rack shall be foreseen at the intake to prevent any floating debris from entering it. A concept for the removal of material from the trash rack in case of clogging is to be foreseen.
2. The desander shall be designed so that each basin can be flushed independently while allowing for continuous operation of the power plant at proportionally reduced plant discharges.
3. The desander shall be able to operate and flush sediment back into the river up to a design flood.

The following criteria are applied to hydraulic design of the desander.

1. Reservoir level — At spillway crest for design discharge
2. Gross approach velocity of trash rack — 0.60 m/s
3. Intake channel
    - Length of straight section — L > 5*W
    - Maximum Froude number — 0.65
4. Desander basins
    - Grain size to remove — d = 0.3 mm

12.5.4 Design

The purpose of the desander is to remove sediment particles with a diameter of d = 0.3 mm or more from the water before it is conveyed to the forebay and the Gabarband Intake Tunnel. The desander is provided in order to avoid deposition in the subsequent waterways and abrasion of the turbines.

The design discharge of the desander system equals the diversion discharge of 10 m^3/s.

12.5.4.1 Intake

The intake to the desander is located next to the sediment flushing channel of the weir on the left river bank and is designed to divert the water into the waterway with as little coarse sediment as possible. The pier between the flushing channel and the spillway improves the flow conditions towards the intake. In order to not entrain sediment which settled upstream of the radial gate, the invert of the intake is at an elevation of 1,551.00 m asl, which is about 4 m above the flushing channel invert. The sediment entry into the desander is expected to be reduced because of the elevated intake. The intake dimensions were determined with the recommended maximum velocity at the trash racks of 0.6 m/s, which is also suitable to reduce the entrainment of fine gravel by turbulence. Two intakes are foreseen, and a width of 4.20 m and a height of 2.00 m per intake fulfil this criterion.

A vertical coarse steel trash rack will be fitted to the intake openings to prevent large debris from entering the waterway system. Entering of larger debris and large sediments will be prevented and will be flushed downstream through the sediment flushing gate.

The flow area downstream of the intake is gradually reduced to the size of the intake channel to increase the flow velocity. After the contraction, a fixed-wheel gate will be provided for each intake. The gates have the following functions:

- Revision of desander and Power Waterway: If the desander or Power Waterway need to be emptied for a revision, the gates can be closed.
- Flood event: When the water level rises too much above the NOL during a flood event, then the gates are closed completely. The power generation might continue depending on the flood conditions at the Lower Spat Gah Headworks. The river contains a high concentration of sediments during those flood events, so closing the gates and stopping the operation has additional benefits. This prevents an excessive sediment load entering and settling in the desander and waterway as well as minimises abrasion at the turbines.
- Flushing of desander basin: The gates will be operated during flushing of the basins.

Just upstream of each gate will be a slot for stoplogs. They will be manually lowered into the slot for revisions of the gate or if the gate cannot be closed.

12.5.4.2 Intake Channels

Two intake channels are foreseen between the intake and the transition zone at the beginning of the desander basins, one for each basin. The purpose of the channels is to guide the flow to the desander basins in a uniform flow with no turbulences.

The velocity in the intake channels is such that sediment deposition is avoided. The minimum velocity is determined with the Zanke criterion to prevent a deposition of sediments.

The critical velocity vcr will be approximately 2 m/s. With the width of the channel of 1.40 m and a flow depth of 1.7 m, the critical flow velocity can be adhered to. For hydraulic stability reasons the Froude number should not exceed 0.65, which is kept with the 2.1 m/s flow velocity and corresponding water depth.

To achieve uniform approach flow conditions for the desander basins, a straight section of 7 m is foreseen upstream of each transition zone. The commonly applied criterion to determine this length is five times the channel width, which is fulfilled with the foreseen length.

12.5.4.3 Transition Zone

The purpose of the transition zone at the beginning of the desander is the adjustment from the intake to the basin cross section.

For the proper operation of the desander the flows have to be calmed and uniformed as much as possible and the installation of three calming racks is therefore foreseen in the transition zone.

12.5.4.4 Desander Basins

The desander system is designed to remove particles with a diameter of 0.3 mm for the diversion design discharge of 10 m^3/s (5 m^3/s per desander basin). The operation water level at the overflow crest with the design discharge of 5 m3/s is at 1,552.68 m asl. In order to avoid re-suspension of the settled particles, the flow velocity v in the desander basins should not exceed the critical velocity v_{cr} of the design particle. To avoid the re-suspension of a particle with a diameter of 0.3 mm from a sand bed according to Zanke, the critical velocity v_{cr} is 0.19 m/s.

The geometric ratios of the basin are designed to avoid irregular flow patterns. The flow velocity criterion is fulfilled with a selected width of each basin of b = 4.9 m and a water depth of h = 6.2 m, not including the flushing channel height. The flow velocity v in each basin results to 0.18 m/s and does not exceed the critical velocity v_{cr} = 0.19 m/s.

The length of the desander basins results from the classic sand trap design approach: A particle with the design grain size entering the desander basin at the water surface shall sink to the basin's bottom while travelling through the basin, considering a constant sinking velocity over the basin length. The resulting length of the desander is 39 m. This length also fulfils the L ≥ 8 * width criterion.

12.5.4.5 Desander End Sill

At the downstream end of the desander is an overflow crest to divert the water into the forebay of the Intake Tunnel. The overflow height is determined with the formula according to Poleni. An overflow height of 0.62 m is needed to convey 5 m^3/s per basin.

A reduced basin width of 4.7 m was taken into account to consider the contractions due to the flushing gate rods. It is assumed that no submergence occurs from the downstream tunnel and the overflow is not reduced by the downstream water level. The water level in the desander is thus hydraulically independent of the water level in the Gabarband Intake Tunnel.

The crest elevation is at 1,552.06 m asl, resulting in a water level at the downstream end of the desander basins of 1,552.68 m asl.

12.5.4.6 Forebay Overflow Section

An overflow section is foreseen at the forebay to return the flow entering the desander back into the river after a load trip while the desander intake gates are closing. The crest level of the spillway is foreseen at 1,552.90 m asl with crest length of 12.00 m.

12.5.4.7 Flushing Channel

A flushing channel is located at the bottom of each basin. A sliding gate is located at the downstream end, after which the channel conveys the sediment back to the river. The wetted surfaces will be specially treated with a special protection against abrasion.

The elevation of the flushing channel invert at the gate is 1,545.33 m asl, which allows the operation of the flushing channel even during large flood events.

12.5.4.8 Water Level from Intake to End Sill

The water level from the end sill to the intake was determined taking friction and local losses into account. The friction losses were calculated with the equation from Manning.

The results of the water level surface calculations for the diversion discharge conditions are compiled in Volume 7 – Project Design, Annex 2.4. The losses along Channel 1 and 2 differ slightly because of the different intake channel lengths and bends.

12.5.4.9 Flushing of Desander Basins

While one basin is flushing, the other basin remains in operation. The discharge in the Gabarband Intake Tunnel will then be half of the available capacity.

The flushing procedure for one desander basin is as follows:

- Closing of the intake gate
- Opening of the flushing gate
- When the water level in the chamber is down, open the intake gate slightly to provide for free-surface flushing
- Re-operate

12.6 Concrete Structures Stability

12.6.1 Introduction

This chapter presents a summary of the stability checks performed as basis for the Feasibility Study design of the Lower Gabarband Intake flushing channel, spillway and desander structures.

The following checks have been performed to verify the overall stability of the Lower Gabarband Intake concrete structures:

- Flotation (buoyancy)
- Sliding
- Rotation (overturning)
- Bearing capacity

The Lower Gabarband Intake flushing channel and spillway are a water retaining control structure that control the reservoir water level either with radial gate or with the overflow crest and a channel alike structure downstream that channels the flow and protects the headworks from erosion. The stability analysis is limited to the control structure, proofing that this structure is stable for the below defined load cases without relying on force transmission to the channel structure, except specifically mentioned. More information and details results have been compiled in Volume 7 – Project Design.

12.6.2 Design Criteria

Refer to Chapter 11.7.2.

The following design water levels have been considered for the Lower Gabarband Intake:

- Upstream
  - NOL: 1,553.00 m asl
  - 1,000-year flood (n-1): 1,557.88 m asl
  - 10,000-year flood: 1,558.28 m asl
- Downstream
  - Normal operation: 1,541.35 m asl (0.3 m above concrete)
  - 1,000-year flood: 1,544.38 m asl
  - 10,000-year flood: 1,545.20 m asl

12.6.3 Loading Combinations

An overview of the investigated load case combinations is provided in Table 12-4 and Table 12-5 for the flushing channel/spillway and the desander respectively.

Table 12-4: Load condition category flushing channel /spillway

Load Condition Category	Load Case Description	Upstream Water Level	Gate
LC1-Usual	Operating situation	NOL	closed
LC2-Unusual	Earthquake – OBE	NOL	closed
LC3-Extreme	Earthquake – SEE	NOL	closed
LC4-Extreme	Flood	10,000-yr	Closed
LC5-Post SEE	Normal condition, residual shear strength parameter, no uplift pressure reduction	FSL	closed

Table 12-5: Load condition category desander

Load Condition Category	Load Case Description	Hillside Water Level	Gate	Channel
A1-Usual	Operating situation	High	Opened	Filled
A2-Unusual	Maintenance	Normal	Closed	Emptied
B1-Extreme	Flood	Top of structure	Closed	Emptied
C1-Unusual	Earthquake – OBE	Normal	Opened	Filled
C2-Extreme	Earthquake – DBE	Normal	Opened	Filled

12.6.4 Stability Analysis Results

12.6.4.1 Flushing Channel

The computed safety factors for the flushing channel structure are presented in Table 12-6. The detailed calculations are compiled in Volume 7 – Project Design, Annex 2.1.

All requirements stipulated in the above Design Criteria are met.

Table 12-6: Results overview flushing channel

Load Case		Sliding SF_S		Rotation			Flotation SF_F		Bearing Pressure (kPa)	
Condition	Combination	Actual	Req.	Max. eccentricity	Base in com-pression Actual (%)	Base in com-pression Req. (%)	Actual	Req.	Max	Allow
Usual	LC1 - Normal	5.52	1.5	Middle third = L/6	100	100	2.60	1.3	204	400
Unusual	LC2 - OBE	1.52	1.3	Middle half = L/4	77	75	2.34	1.2	315	460
Extreme	LC3 – SEE	1.14	1.1	In base = L/2	52	>0	2.23	1.1	449	600
Extreme	LC4 - Flood	1.96	1.1	In base = L/2	88	>0	1.76	1.1	226	600
	LC5 – Post SEE (informative)	3.85	1.1	In base = L/2	100	>0	2.34	1.1	197	600

12.6.4.2 Spillway

The computed safety factors for the spillway structure are presented in Table 12-7. The detailed calculations are compiled in Volume 7 – Project Design, Annex 2.2.

For all considered load case combinations, the safety against flotation and rotation is fulfilled. In case of global sliding the required safety factors are met except for the extreme load case combination considering the SEE. According to international standards this can be accepted if no uncontrolled water release happens during and after an SEE event. Preliminary permanent sliding calculations have been performed for this phase but more detailed calculations need to be executed during the Detailed Design phase of the Project based on conventional Finite Element Model(s). However, the permanent sliding displacements are conservatively calculated as 16 cm, which is not critical.

The calculated bearing pressures are well below the allowed values.

Table 12-7: Results overview spillway

Load Case		Sliding SF_S		Rotation			Flotation SF_F		Bearing Pressure (kPa)	
Condition	Combination	Actual	Req.	Max. eccentricity	Base in com-pression Actual (%)	Base in com-pression Req. (%)	Actual	Req.	Max	Allow
Usual	LC1 - Normal	3.28	1.5	Middle third = L/6	100	100	2.68	1.3	153	400
Unusual	LC2 - OBE	1.30	1.3	Middle half = L/4	100	75	2.34	1.2	155	460
Extreme	LC3 – SEE	0.77	1.1	In base = L/2	100	>0	2.20	1.1	189	600
Extreme	LC4 - Flood	1.17	1.1	In base = L/2	100	>0	1.76	1.1	100	600
Extreme	LC5 – Post SEE	2.04	1.1	In base = L/2	100	>0	2.11	1.1	131	600

12.6.4.3 Desander

The computed safety factors for the desander structure are presented in Table 12-8. The detailed calculations are compiled in Volume 7 – Project Design, Annex 2.3.

The desander structure is safe for all considered load case combinations including the DBE since it is not a water retaining structure (gates at intake) that is safety critical.

Table 12-8: Results overview desander

Load Case		Sliding SF_S		Rotation			Flotation SF_F		Bearing Pressure (kPa)	
Condition	Combination	Actual	Req.	Max. eccentricity	Base in com-pression Actual (%)	Base in com-pression Req. (%)	Actual	Req.	Max	Allow
Usual	LC1 - Normal	7.45	1.5	Middle third = L/6	100	100	3.90	1.3	199	400
Unusual	LC2 - Maintenance	5.83	1.3	Middle half = L/4	100	75	3.26	1.2	167	460
Unusual	LC3 – OBE	2.59	1.3	In base = L/2	100	75	3.47	1.2	224	460
Extreme	LC4 - DBE	1.16	1.1	In base = L/2	86	>0	1.99	1.1	184	600
Extreme	LC5 – Flood	4.76	1.1	In base = L/2	100	>0	2.24	1.1	147	600

12.7 Standards, Codes and Guidelines

The following appropriate international standards, manuals and guidelines have been used for the Lower Gabarband Intake civil design works of the Feasibility Study:

- Bollrich. 1996. Technische Hydromechanik. Verlag für Bauwesen. Berlin.
- Chow, V.T. 1959. Open Channel Hydraulics.
- Giesecke, J. 2005. Wasserkraftanlagen. 4th edition.
- ICOLD Bulletin 157: Small dams: Design, Surveillance and Rehabilitation. International Commission on Large Dams. 2016
- Mosonyi, E. 1991. Water Power Development, Volume Two, High-Head Power Plants. Akadémiai Kiado. Budapest.
- Ortmanns, C. 2006. Entsander von Wasserkraftanlagen. Mitteilung Nr. 193. Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, Eidgenössische Technische Hochschule. Zürich.
- USBR. 1978. Design of Small Canal Structures. United States Department of the Interior, Bureau of Reclamation. A Water Resources Technical Publication.
- USBR. 1990. Criteria and guidelines for evacuating storage reservoirs and sizing low-level outlet. Bureau of Reclamation, Denver, CO. Assistant Commissioner - Engineering and Research.

13 Civil Design - Power Waterway

Corresponding Drawings

LSG-FS-080-001	Power Waterway, General Arrangement, Overview Plan
LSG-FS-080-002	Power Waterway, General Arrangement, Longitudinal Profile
LSG-FS-080-003	Power Waterway, General Arrangement, Projected Underground Facilities
LSG-FS-080-004	Power Waterway, Gabarband Intake Tunnel, Plan View & Detail Junction
LSG-FS-080-005	Power Waterway, Gabarband Intake Tunnel, Longitudinal Profile & Typical Section
LSG-FS-080-006	Power Waterway, Gabarband Crossing, Plan, Profile & Details
LSG-FS-080-007	Power Waterway, Gabarband Crossing Adits, Plan, Profile & Typical Sections
LSG-FS-080-008	Power Waterway, Surge Shaft & Upper Erection & Gate Chamber, Layout & Sections
LSG-FS-080-009	Power Waterway, Access Tunnel to Upper Erection & Gate Chamber / Access Tunnel to Surge Shaft, Plan, Profile & Typical Section / Rock Support
LSG-FS-080-010	Power Waterway, Penstock & Lower Erection Chamber, Plan, Profile & Typical Section
LSG-FS-080-011	Power Waterway, Tailrace Tunnel & Tailrace Outlet Structure, Profile & Typical Section
LSG-FS-080-012	Power Waterway, Rock Support Classes, Headrace Tunnel & High Pressure Tunnel
LSG-FS-080-013	Power Waterway, Rock Support Classes, Gabarband Intake Tunnel
LSG-FS-080-014	Power Waterway, Rock Support Classes, Surge Shaft
LSG-FS-080-015	Power Waterway, Rock Support Classes, Pressure Shaft
LSG-FS-080-016	Power Waterway, Rock Support Classes, Penstock
LSG-FS-080-017	Power Waterway, Rock Support Classes, Tailrace Tunnel
LSG-FS-080-018	Power Waterway, Final Lining Classes, Typical Sections

13.1 Introduction and General Layout

This chapter describes the civil structures of the Power Waterway design. More detailed design criteria and comprehensive calculations performed as basis for the Feasibility Study design are compiled in Volume 7 – Project Design.

The Power Waterway is located on the right side of the Spat Gah valley. It connects the intake area at the Lower Spat Gah Headworks with the Tailrace Tunnel Outlet Structure in the Indus River valley. An additional lateral intake tunnel is connected to the Headrace Tunnel and will divert water from the Gabarband valley.

The Power Waterway consists of the following sub-structures:

- Forebay including intake,
- Headrace Tunnel,
- Lower Gabarband intake tunnel including maintenance valve at its downstream end,
- Surge Shaft,
- Emergency gate valve,
- Pressure Shaft,
- High Pressure Tunnel,
- Tailrace Tunnel.

The main characteristics of the Power Waterway are given in Table 13-1.

Table 13-1: Main characteristics of the Power Waterway

Headrace Tunnel (HRT)	
Length	10,894 m (start after inlet to Upper Erection and Gate Chamber), thereof: - 9,457 m concrete lining - 626 m foil lining - 724 m steel lining - 87 m steel at Gabarband crossing
Slope	1.5/12.0/0.75%
Flow conditions	Pressurised flow
Excavation method	Drill and Blast
Tunnel profile	Horseshoe
Excavation diameter	6.50 - 6.90 m
Lining type	Concrete and steel lined sections
Lining thickness	0.50 m
Inner lining diameter	5.30 m
Invert level at forebay	1,486.35 m asl
Invert level at Pressure Shaft	1,259.05 m asl
Gabarband Intake Tunnel	
Length	2,364 m (portal to chamber)
Slope	9.2%
Flow conditions	Free-flow in upstream part and pressurised flow in downstream part of pipe
Excavation method	Drill and Blast
Tunnel profile	Horseshoe
Lining type	Shotcrete GRP pipe on the side
Pipe diameter	GRP pipe 2.1/1.9/1.7 m Steel pipe 1.5 m
Pipe invert level at forebay	1,548.50 m asl
Pipe invert level at start chamber	1,335.11 m asl
Surge Shaft	
Bottom elevation	1,259.03 m asl
Top elevation	1,653.00 m asl (invert adit)
Slope	Vertical
Excavation method	Drill and Blast
Shaft profile	Circular

Excavation diameter	7.50 - 8.00 m
Lining type	Concrete lining
Lining thickness	0.50 m
Inner lining diameter	6.50 m
Pressure Shaft	
Length	463 m (bottom upper chamber to top lower chamber)
Slope	Vertical
Flow conditions	Pressurised flow
Excavation method	Drill and Blast
Shaft profile	Circular
Excavation diameter	5.30 - 5.50 m
Lining type	Steel lining
Inner lining diameter	4.00 m
High Pressure Tunnel	
Length	69 m (lower erection chamber to first bifurcation)
Slope	0.5%
Flow conditions	Pressurised flow
Excavation method	Drill and Blast
Tunnel profile	Horseshoe
Excavation size	Same as HRT
Lining type	Steel lining
Inner lining diameter	4.00 m
Invert level at Pressure Shaft	763.90 m asl
Invert level at penstock	763.61 m asl
Penstocks	
Length	D=3.25 m: 27 m / D=2.3 m: 133 m
Slope	0.5%
Flow conditions	Pressurised flow
Excavation method	Drill and Blast
Tunnel profile	Horseshoe
Excavation size	Same as HRT
Lining type	Steel lining
Inner lining diameter	3.25/2.3 m
Tailrace Tunnel (TRT)	
Length	1,312 m (from pit below unit 3 to outlet structure)
Slope	0.1%
Flow conditions	Free-flow
Excavation method	Drill and Blast

Tunnel profile	Horseshoe
Lining type	Concrete lining
Lining thickness	0.50 m
Inner lining diameter	6.50 m / 7.50 m
Invert level outlet structure	756.32 m asl

13.2 Design Criteria

The Power Waterway shall comply with the criteria listed in the following sections.

13.2.1 Functional Design Criteria

1. The Power Waterway shall convey water from the Lower Spat Gah Headworks desander and the Lower Gabarband Intake desander to the Powerhouse. The alignment, cross sections, excavation concept and lining concept of the waterways will be optimised to achieve reliability over the requested design life and to maximise the overall economic benefit considering construction cost, maintenance cost, energy delivery and operational aspects.
2. In order to prevent air entrainment into the Headrace Tunnel and the draining of the Lower Spat Gah forebay, the control system shall initiate an emergency shutdown when the water level in the Lower Spat Gah forebay reaches MOL.
3. A concept for permanent access to the tunnels for inspections and maintenance shall be incorporated into the design.
4. A maintenance and emergency valve shall be incorporated into the design at the downstream end of the Headrace Tunnel.
5. A maintenance and emergency valve shall be incorporated into the design at the junction of the Gabarband Intake Tunnel with the Headrace Tunnel.
6. All tunnel cross sections shall be determined with an economic optimisation.

13.2.2 Hydraulic Design Criteria

13.2.2.1 Determination of Forebay Volume and Operation Levels

1. The Lower Spat Gah Headworks (flushing channels, reservoir, intake, desander basins and forebay) shall be designed to ensure sub-critical flow between the forebay and the reservoir.
2. The Gabarband Intake Tunnel invert shall be chosen to ensure hydraulic decoupling of the forebay and the desander during normal operation. The Lower Gabarband forebay volume shall be chosen in a way that the water from the Gabarband Intake Tunnel does not backflow into the desander basins under transient conditions.
3. The critical submergence of the Headrace Tunnel intake shall be determined by the Knauss condition based on the MOL. The Knauss condition is defined in Figure 13-1.
4. The minimum pressure above the Power Waterway crown shall not be less than 6.0 m during transient load cases.

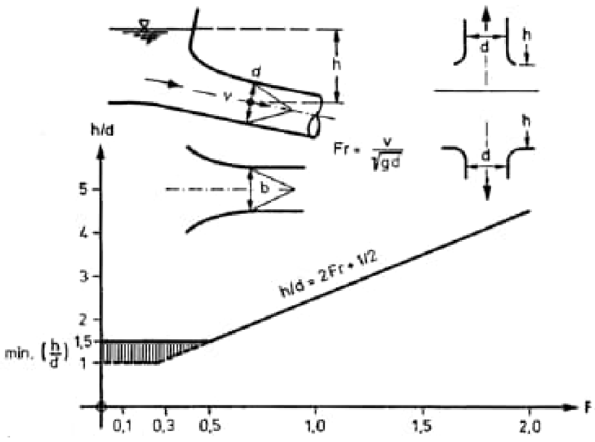


Figure 13-1: Knauss condition for intake submergence (reprinted from Knauss)

13.2.2.2 Vertical Setting of Tunnel Alignment

1. The vertical setting of the Headrace Tunnel shall be determined in order to (i) provide sufficient submergence of the intake at the MOL; (ii) prevent any negative pressures within the Power Waterway; (iii) prevent fully draining the Surge Shaft at maximum down surge; and (iv) prevent high internal pressure at the Headrace Tunnel valve excluding the use of a butterfly valve.
2. In addition to the hydraulic aspects outlined in the above item, the vertical layout of underground structures shall be chosen in order to minimise costs and risks with regard to rock support and hydraulic confinement.

13.2.2.3 Transient Design

1. The mechanical part of the generating equipment of the Project consists of Pelton turbines.
2. The following standard load cases shall be considered for the design of the Power Waterway, Surge Shaft and of the hydro-mechanical equipment:
    - Standstill to full load,
    - Full load rejection,
    - Turbine opening and closing to and from critical nozzle stroke,
    - Emergency closure with main inlet valves,
    - Full load rejection and subsequent full load acceptance at the highest inflow discharge from the Surge Shaft,
    - Full load acceptance and subsequent full load rejection at the highest outflow discharge from the Surge Shaft,
    - Full load acceptance and subsequent full load rejection at the highest inflow discharge into the Surge Shaft,

    To remain consistent with the 2010 Feasibility Study, the two following exceptional load cases have also been evaluated to determine the highest and lowest pressures and Surge Shaft water levels:
    - Full load rejection and subsequent full load acceptance at the highest outflow discharge from the Surge Shaft and subsequent load rejection at the highest inflow discharge to Surge Shaft,
    - Full load acceptance and subsequent full load rejection at the highest inflow discharge into the Surge Shaft and subsequent full load acceptance at the highest outflow from the Surge Shaft.

3. The boundary conditions for each load case shall be chosen so that the most critical condition to be investigated with each load case is achieved.
4. The arrangement of the Surge Shaft is to be designed so that Thoma criterion is satisfied with a safety factor of 1.9.

13.2.2.4 Roughness

The design values for hydraulic roughness of the wetted perimeter of the waterways in Table 13-2 will be applied. The design values for hydraulic roughness generally presume good workmanship and internationally accepted construction practices as may be expected from an experienced Contractor.

Table 13-2: Design values for equivalent sand grain roughness

Surface	Equivalent Sand Grain Roughness
In-situ concrete lining	0.6 mm
Steel lining	0.06 mm
GRP Pipe	0.1 mm

13.2.2.5 Flow Velocities in Waterways

1. The maximum flow velocity of concrete lined tunnel sections shall not exceed 4 m/s.
2. The maximum flow velocity of steel lined tunnel and shaft sections shall not exceed 7 m/s.

13.2.3 Tunnel Diameter and Construction Issues

1. The minimum excavation diameter of the tunnel shall be chosen so that: (i) construction ventilation can be provided with reasonable measures, (ii) efficient equipment can be utilised for the construction works, (iii) overall construction cost and duration are optimised, and (iv) volume of concrete is minimised.
2. Adits shall be included in the design if they are required for any of the following purposes: (i) construction feasibility or optimisation, (ii) achievement of key dates in the overall Project implementation schedule and (iii) to indicate access roads, spoil areas and installation areas on the drawings for inclusion in environmental impact assessments and in concession agreements.
3. Adits shall be located to optimise the length of drives for each face in order to meet the Project overall construction schedule. Adit portals shall be located in favourable geological conditions and as close to existing roads and usable installation areas as possible above flood water level. The length of adits shall be kept to a minimum. The longitudinal slope of adits shall not exceed 12% for the current design phase, except where clearly justified for construction optimisation.
4. Adit portals shall be located in such a way that they are safe against the 50-year flood, in line with the design criteria of the access roads.
5. A minimum longitudinal slope of 0.5% shall be provided to ensure gravity drainage during excavation whenever possible

13.2.4 Design Criteria for Excavation and Primary Support

This chapter describes the design methods that will be used in the design of underground works and rock mechanics issues. In general, the design of underground and surface excavations is done according to the recommendations for Geotechnical design given by the Austrian Society for Geomechanics (ÖGG).

13.2.4.1 Excavation Procedure

All underground structures, tunnels, shafts and caverns are planned to be excavated by drill and blast according to the New Austrian Tunnelling Method (NATM). The New Austrian Tunnelling Method constitutes a method where the surrounding rock or soil formations of a tunnel are integrated into an overall ring-like support structure.

While driving a tunnel, the existing primary balance of forces in the rock mass will be changed into a new secondary and also stable state of balance. This can only be achieved through a succession of intermediate stages accompanied by various stress redistribution processes. The NATM aims at getting under control these transitional processes, while still taking into account economic and safety considerations. The method also wants to check rock deformation on the following lines.

- On the one hand, deformation should be kept to a minimum so that the primary state of stability and the compressive strength of the rock are not weakened more than is inevitable,
- On the other hand, deformation is actually wanted to the extent that the rock formation itself acts as an overall ring-like support structure, thus minimising costs for excavation and supports.

13.2.4.2 Implementation

The NATM treats the ground surrounding the tunnel or other underground structure not just as a load, but as a load-bearing element of support. In combination with the time-dependent development of ground reactions as a result of tunnel excavation, the type and quantity of the support elements required are systematically adjusted. The ground reactions, taking the form of lining deformations and lining pressures, are measured and the stability of the excavation is confirmed by frequent monitoring.

The cross-section shape of the tunnel and also changing of the tunnel shape along the alignment is not constrained by the method allowing the shape optimised for the stress distribution, but also for the final tunnel serviceability. Also, the local changing of the tunnel shape such as junctions and niches can be constructed easily and without big additional effort.

Typical support activities in NATM are the systematic application of shotcrete and rock anchors to allow controllable deformation of the rock mass. Steel ribs or lattice girders provide limited support before the shotcrete hardens and ensure correct profile geometry. Face bolts sealing shotcrete, spiles or pipe canopies are installed in ground conditions where the stability of the excavation face cannot be achieved and a support in-front the excavation face is required.

In case of expected large deformations caused by bed ground conditions or high overburden, longitudinal gaps in the shotcrete lining can be ordered allowing bigger deformation of the lining without overstressing. With so-called lining stress controller elements installed in the gaps in the shotcrete lining a controlled load transfer between shotcrete arches and better bearing capacity can be achieved.

13.2.4.3 Rock Support System for Tunnels

The rock support for the tunnels has been calculated with the ground reaction / support interaction method, developed by Fenner (1968) and Pacher (1964) as schematically shown in Figure 13-2. This method allows the calculation of the applied support measure (shotcrete, steel sets, yield steel elements) and the required rock bolt length.

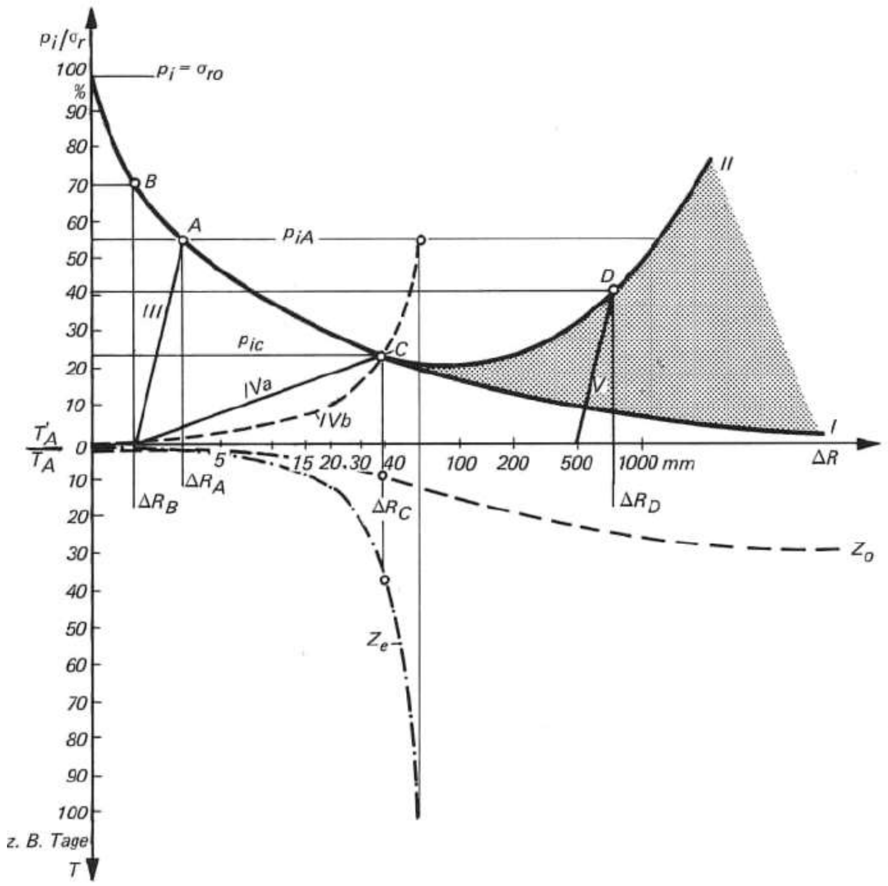


Figure 13-2: Principles of the ground reaction / support interaction curves (Müller 1978)

where:

σ_r	Radial stress at the excavation surface
p_i	Strength of support resistance
ΔR	Radial deformation at the excavation surface
Curve I	Ground reaction
Curve II	Ground reaction including dilatation
Curve III, IV,V	Excavation support lines

13.2.5 Concrete Lining

13.2.5.1 Confinement Criteria

The confinement criteria defined by the tunnel cover requirements need to suppress hydro-jacking of the surrounding rock mass. Leaking water can cause hydro-jacking of the surrounding rock mass if the confinement (the ability of rock mass to withstand internal pressure) is too low. Leaking water in case of unlined tunnels or lined with shotcrete or plane and reinforced, therefore, cannot be omitted. The minimal in-situ stress in the rock mass, independent of the direction, must be higher than the maximal internal water static pressure in the tunnel. Under such conditions leaked water will not be able to open existing joints and discontinuities causing higher water losses or possible instabilities on the surface.

The minimal state of stress is mostly unknown at the beginning of the design and the tunnel layout is checked for confinement by one of the rock cover criteria. For a power tunnel situated in a mountain flank or a ridge, the confinement criteria become a critical issue for alignment and also for the design and selection of the lining system. In the early stage of the Project the minimal primary stress $\sigma_{min,rock}$ and the direction of the joint systems are mostly unknown and the confinement criteria can be written in the form defined as a safety factor SF:

$$SF = \frac{\sigma_{min,rock}}{\sigma_{\max(pi)}} \approx \frac{\gamma_r h_r k_0}{\gamma_w h_w}$$

Where:

$\sigma_{max(pi)}$:	maximum stress outside the tunnel caused by leakage water (MPa)
γ_r:	unit weight of the rock mass (kN/m^3)
γ_w:	unit weight of the water (kN/m^3)
h_r:	overburden height (m)
h_w:	distance from the tunnel axis to the maximal static water pressure in the tunnel
k_0:	ratio between the minimum and maximum in-situ primary state of stress

Under the condition that the direction of the joints and the minimal primary stress is not known and the minimal primary state of stress in flank or ridge has approximately half the value of the vertical stress defined by overburden height, the criteria can be visualised as a circle around the tunnel with a radius similar to the internal water head h_w. If such a circle does not intersect the rock surface, the criteria are satisfied with a factor of safety of approximately 1.25 ($SF = \gamma_r\ k_0\ /\ \gamma_w$) in the static case. The required radius (minimum distance to the ground surface) is then calculated as follow.

$$R_{min,rock} = \frac{SF \times \gamma_w \times h_w}{k_0 \times \gamma_R}$$

which is basically a development of the minimum stress criteria after Schleiss (1988). Such simple geometric consideration simplify the alignment design in the first Project stages and should be carefully analysed in detail during the following stages by in-situ tests (e.g. hydro fracturing) tests. Therefore, the length of the steel lining shall be viewed with caution at the Feasibility Study stage and it cannot be ruled out that the length may have to be increased at a later design stage based on the results of the in-situ tests.

On the portion of the tunnel where the confinement criteria are not satisfied, a tight tunnel lining has to be designed. In the transition zone a section with a thin tightening element – plastic foil, fiberglass or thin steel lining – can be used as a cost-saving alternative to relatively expensive steel lining.

13.2.5.2 Rock Mass Resistant on Erosion and Slaking

In case the tunnel is unlined or lined by shotcrete lining, the surrounding rock mass will be exposed to the oscillating water pressure. Oscillation of the water pressure and water circulation into and out of the tunnel can cause washing out of the joint fillings or slaking of the surrounding rock mass.

Such a process is not favourable for the tunnel stability and may cause degradation of the integrity of the tunnel surrounding and instabilities on the tunnel walls resulting in serious problems in the operation.

13.2.6 Concrete Lining and Water Loss Criteria

For the design of the Power Waterway final lining concept, the geological knowledge is essential but is not limited to the parameters crucial for the excavation and primary support. The design process also requires an understanding of a number of geological variables including rock modulus and strength, rock mass permeability, the resistance of rock mass to erosion and slaking, the minimal in-situ rock stress and ground-water levels in operation. These additional design key parameters are specified in Table 13-3.

Therefore, an exploration programme for the design of the Power Waterway will have to be prepared during the Detailed Design phase with special care and with sufficient time for the definition of all required design parameters. The design parameters will have to be verified and confirmed/updated during the construction period. Restrictions in the exploration programme and insufficient time for their realisation during the pre-construction phase could later lead to cost overruns or operational problems.

Table 13-3: Some of the design key parameters different in primary support and final lining design

Primary Support Design	Final Lining Design
Primary state of stress	Minimal primary stress
Strength of rock mass	Deformability of rock mass
Maximal groundwater level	Minimal groundwater level
Water inflow in the tunnel	Permeability of rock mass

A number of fundamental design criteria and other important considerations have to be defined, identified and selected during the design phase. In Figure 13-3, a flow chart defining design criteria that has to be proved during the Power Waterway design, resulting in a suggested final lining type is presented. The flowchart can be applied to each section along the Power Waterway and has to be included in the design of the vertical and horizontal tunnel alignment.

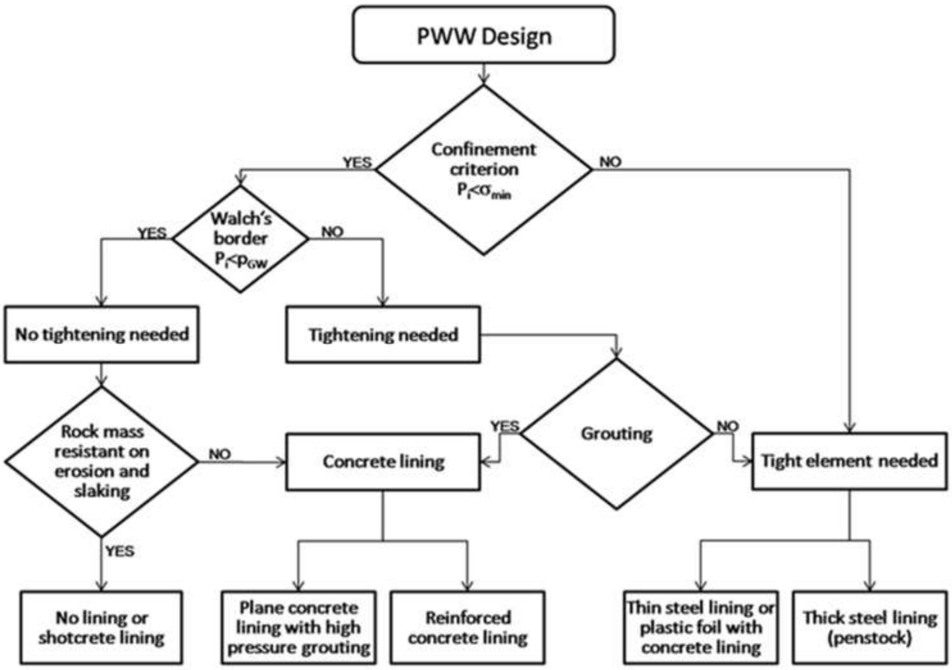


Figure 13-3: Geotechnical Power Waterway design considerations (Marence 2009)

An important criterion for the design of the concrete tunnel lining is the amount of water that could leak out of the tunnel in operation. Leaked water could not only be a problem for the rock mass around the tunnel but also represents lost water and at the end lost energy that could be generated. Therefore, often pressurised concrete lined tunnels means technically tight tunnel lining. The technically tight tunnel is a tunnel where the losses along the concrete lined sections are less than 1-2 l/km/s/bar.

13.2.7 Design Criteria for Steel Lining

13.2.7.1 General

The steel penstock is used as a lining of the waterway where the surrounding rock mass is no longer sufficient to withstand the internal pressure loading. The steel penstocks can be constructed as free-standing penstocks or embedded in the concrete and surrounding rock mass. In the case of the embedded penstock, the load from the internal water pressure could be carried by the steel pipe alone or by the steel and surrounding concrete and rock mass depending on their stiffnesses.

The design of the penstock is determined by guidelines of the steel construction and traditionally takes place with the involvement of the cooperative for workload cases, exceptional load cases and disaster load cases. Of course, it is only possible to take into account the effect of the impact if the steel material used and the weld metal is characterised as having sufficient expansion behaviour (uniform elongation, impact strength, fracture toughness).

For the static dimensioning of the penstock pipe on internal pressure, proofs of tension according to the global safety concept are traditionally carried out by means of the following two stress categories:

- Verification of primary stresses (I): refers to the equilibrium stress and membrane stresses from global constraints (such as the membrane stresses of the pipe under internal pressure, as well as those from transverse contraction or temperature change).
- Verification of secondary stresses (II): relates to the sum of the stresses resulting from equilibrium and compatibility conditions (such as the membrane plus bending stresses in the pipe wall on a stiffening ring or segmental bend) as determined by elasticity theory.

The design for external groundwater pressure is based on the buckling evidence according to Jacobsen/Amstutz. For the load case groundwater pressure, boundary conditions are defined project-specific (safety factor for exposure, out of roundness, gap width between steel lining and surrounding backfill concrete). In case that the designed smooth pipe cannot resist the external pressure, steel stiffening rings have to be installed. Reduction of the external pressure could also be achieved by pressure relief valves. The pressure relief valve has a characteristic that is tight from inside to outside, but relief water in the pipe if the pressure outside pipe is higher than the pressure inside the pipe.

13.2.7.2 Application of Confinement Criterion for Steel Lined Sections

Checking of the tunnel alignment and the related overburden was done with the confinement criteria to determine the required steel liner length in the tunnel alignment at the Gabarband Crossing and confirm that no additional steel liner is needed in the Headrace Tunnel except downstream of the Surge Shaft.

13.2.7.3 Design Requirements

Minimal steel thickness

The minimal steel thickness is calculated according the US Bureau of Reclamation:

$$s_{min} = \frac{D_i}{400} + 2\,mm$$

where:

s_{min} minimum steel thickness (mm)

D_i internal diameter (mm)

Internal water pressure

For the inner pressure the envelope of the maximum pressure lines for several load cases is used for the design of the steel lining. The calculations for the internal water pressure are executed using the method of Seeber (1982).

External water pressure

For the external pressure line the assumed groundwater pressure is extracted from the geological investigations.

The calculations for the external water pressure are executed using the method of Amstutz (1969). Depending on the external water pressure, stiffener rings are used. The safety factor against buckling has to be at least 1.5. For calculating the gap occurring from the cooling-effect during filling, a temperature difference of $\Delta T = 25°$ C is assumed. The resulting relative gap is 0.0003.

In the absence of reliable/direct information, the groundwater pressure was taken at the elevation of the natural ground to be on the safe side. This might be optimised at a later stage based on the results of drillholes and ground water measurements.

Surrounding rock mass

For the calculation the surrounding rock module (given by geological investigations) is reduced. The reduced module chosen for calculation is 5.0 GPa which is a conservative assumption based on the available geological data.

Secondary, the lining is also conservatively checked not taking the surrounding rock into account, due to failure. This calculation is an extreme load condition with reduced safety factors for the lining design.

Corrosion margin

Additional to the calculated lining thickness a corrosion margin of 1 mm is added.

Injections

The injection pressure between the steel lining and the fill concrete (contact grouting) is at least 3 bars to ensure a good performance.

13.2.7.4 Steel Lining Material

The steel qualities in Table 13-4 have been considered for the pre-design of the steel lining. The following additional values are used:

E-modulus: E_{st} = 210,000 N/mm²

Poisson: v = 0.33

Table 13-4: Steel specification

Steel Quality	Thickness t (mm)	Minimum Yield Strength for Calculation σ_y (N/mm²)	Upper Yield Point (min.) ReH (N/mm²)
S460M	≤ 16 ≥ 17	460 440	460
S550M	≤ 16 ≥ 17	550 530	550

13.2.7.5 Load Cases and Safety Factors

Internal water pressure

The calculations for the steel lining are executed for two main load cases. One is taking the surrounding rock into account (usual load case). The second load case foresees that the surrounding rock mass fails (extreme load case). Therefore the safety factors in Table 13-5 are used.

Table 13-5: Safety factors

Section	Usual Load Cases	Extreme Load Cases
Headrace Tunnel, Pressure Shaft and High Pressure Tunnel	1.5	1.1
Penstock	2	-

External water pressure

The safety factor against buckling is independent of the load case and has to be at least 1.5.

13.2.8 Initial Filling and Dewatering of the Waterway

Initial filling and also dewatering of the tunnel both represent critical loading cases for the tunnel lining. Therefore the processes have to be performed with special care and in predefined steps.

For the filling and also dewatering of the Power Waterway a pressure change of 2-3 bar in 24 hours is suggested. Normally this means filling of 20-30 m height of the Power Waterway in 12 hours and 12 hours waiting time for consolidation. If possible, especially in the horizontal tunnel sections, during the 12 hours waiting time the losses could be measured in the Surge Shaft.

13.2.9 Emergency Closing

The pressurised Power Waterway is equipped with four emergency closing systems including a wheel intake gate at the Lower Spat Gah Headworks and at the Lower Gabarband Intake, a butterfly valve at the top of the Pressure Shaft, a butterfly valve at the downstream end of the Gabarband Intake Tunnel and three Powerhouse spherical valves.

All seven gates have emergency and operational functions. The intake gates close the entire Power Waterway and disconnect the two reservoirs from the Power Waterway. After emptying of the Power Waterway inspections are possible along the entire tunnel length with four possible access points (Lower Spat Gah forebay, Lower Gabarband Intake forebay, Gabarband crossing adits and Upper Erection and Gate Chamber).

The Powerhouse valves disconnect the turbine from the Power Waterway and allow turbine maintenance.

The gate situated in the Upper Erection and Gate Chamber directly downstream of the Surge Shaft has a safety function and disconnects the Pressure Shaft and the High Pressure Tunnel from the Headrace Tunnel. In case of failure in the steel penstock the water situated in the long Headrace Tunnel will not flow out and additionally endanger the steep mountain flank with the penstock and Powerhouse. With this valve, it will also be possible to inspect the steel lined section of the Pressure Shaft without having to dewater the Headrace Tunnel. The valve has to be equipped with aeration valves working in both directions opening in case of under pressure (fast emptying) and air evacuation during the penstock filling.

13.3 Tunnel Alignment

During the Inception Phase, several tunnel layouts were studied and a preferred alignment was chosen which enables on the one hand a relatively short connection between Powerhouse and intake, but on the other hand considers local geological and geomorphological settings (faults, lineaments, valley crossings, overburden) as far as possible.

13.3.1 Changes Since Previous Design Phase

The excavation of the Headrace Tunnel in the 2010 Feasibility Study was elaborated for both TBM and D&B design solutions. The alternative had a Headrace Tunnel length of approximately 12.6 km and crossed the Gabarband valley next to the Lower Gabarband Intake location. Therefore, no intake tunnel was required and a small vertical shaft as previously foreseen was sufficient. A major disadvantage of this alternative was the long tunnel alignment section parallel to the lineament 4.

The new layout is an optimised tunnel alignment with regards to geological risk, constructability, internal pressure and construction time. The tunnel routing is feasible for D&B as well as for TBM excavations.

For this study, the D&B (NATM) methodology was selected. A main advantage besides the low internal pressure over the whole Headrace Tunnel length is the classification as medium geological risk. Furthermore, the location of the Gabarband valley crossing has been designed to reduce the required length of steel lining because of more favourable side burden.

13.3.2 Headrace Tunnel Forebay Portal

The location of the Headrace Tunnel portal is determined by the desander and the forebay of the Lower Spat Gah Headworks.

13.3.3 Horizontal Alignment of Headrace Tunnel

Various different alternatives for the Power Waterway layout were evaluated during the Alternatives Study and one has been selected as the preferred alternative, and is elaborated in the Feasibility Study. The alignment at the Gabarband Crossing has been further optimised based on the 2020/2021 geological investigation results.

The tunnel starts in the Spat Gah valley and diverts the water. The tunnel then runs relatively straight for a distance of approximately 5.7 km through the first mountain, named Kiru Sequence. The tunnel is then crossing the Gabarband valley between downstream of Thoki village. Here, the Gabarband Crossing is located.

A cut and cover section of 86.5 m enables the crossing of the valley, and a steel lined section of approximately 760 m is required because of the confinement criteria. Afterwards the Headrace Tunnel is leading through the second mountain area, the Kamila Sequence, for a distance of about 5.1 km to the top of the Pressure Shaft.

13.3.4 Alignment of Gabarband Intake Tunnel

The Gabarband Intake Tunnel shall convey water from the Lower Gabarband Intake to the Headrace Tunnel. The confluence point of both tunnels was chosen around chainage 5,400 m of the Headrace Tunnel to minimise costs.

After excavation, a glass-reinforced plastic (GRP) pipe installed on supports on the side of the tunnel is envisaged. The excavated cross section is 8.3 m wide and 5.65 m high and the width for traffic will be 4.5 m.

13.3.5 Vertical Alignment

13.3.5.1 General

The vertical alignment can mainly be differentiated into four parts: the parts upstream of the Powerhouse (cavern solution) are as described: a relatively long low-pressurised Headrace Tunnel, a Pressure Shaft and a short High Pressure Tunnel to avoid highly stressed concrete sections, high pressures at the emergency gate location and long steel lined sections to minimise cost. Downstream of the Power Cavern the water is flowing through a free-flow Tailrace Tunnel with a constant inclination.

The vertical alignment has been determined under the consideration of the following factors:

- Lower Spat Gah forebay portal: Operating water levels of the forebay and required intake submergence,
- Headrace Tunnel
    - Crossing under the Gabarband valley to allow a cut-and-cover construction,
    - A minimal elevation and thus maximal internal pressure at the downstream end to allow the installation of a butterfly valve as the maintenance and emergency valve.
- Surge Shaft junction: Sufficient submergence of the junction during down surges of the Surge Shaft,
- Turbine axis elevation: The turbine axis elevation is set by the future Patan reservoir FSL and the hydraulic conditions in the Tailrace Tunnel,
- Minimisation of total construction costs.

13.3.5.2 Elevation of Gabarband Crossing

The Gabarband Crossing is located at a centreline elevation of about 1,299.6 m asl.

13.3.5.3 Inclination of Headrace Tunnel

The inclination of the Headrace Tunnel is comprised between 1.5% at the beginning of the Headrace Tunnel and 0.75% downstream of the Gabarband River crossing. A maximum slope of 12.0% has been allowed for the tunnel directly upstream of the Gabarband Crossing for construction reasons in order to allow for efficient mucking and installation of concrete and steel lining.

13.3.5.4 Elevation and Location of the Top and Bottom of the Pressure Shaft

The Pressure Shaft consists of a vertical alignment with a total length of 494 m between the Headrace Tunnel and High Pressure Tunnel centrelines. The top elevation is located at a centreline elevation of 1,261.05 m asl and the bottom centreline elevation is 766.7 m asl.

The shaft height between the bottom of the Upper Erection and Gate Chamber at 1,256.05 m asl and the top of the Lower Erection Chamber at 782.6 m asl is 473 m. The static pressure at the top results to 24.4 bar and allows for a butterfly valve type for the maintenance and emergency Headrace Tunnel valve.

13.3.5.5 High Pressure Tunnel

Right at the bottom of the vertical Pressure Shaft follows the horizontal High Pressure Tunnel with an inclination of 0.5% and a length of 95 m from the Pressure Shaft axis to the first bifurcation. The distance from the Lower Erection Chamber to the first bifurcation is 69 m.

13.3.5.6 Tailrace Tunnel

The Tailrace Tunnel is a free-flow tunnel. It is upwards inclined with 0.1% towards the powerhouse. The invert elevation at the outlet structure is 756.32 m asl. The overall length from the pit below unit 3 to the Tailrace Tunnel Outlet Structure is 1,302 m.

The tunnel has a horseshoe section with an inner height of 7.0 m and an invert width of 5.1 m.

The maximum flow velocity shall reach around 3 m/s for the design discharge. A maximum tunnel filling degree of 70% is considered for the design discharge assuming an aged/slimed tunnel for the water surface profile calculation purposes. This is to address uncertainties, and accommodate waves and surges created from the turbine flow splashing onto the tailrace pit water cushion.

13.3.6 Tailrace Outlet Structure

The structure is located on the Indus River with an invert elevation of 756.40 m asl. It is a reinforced concrete structure founded on rock. The energy dissipation is partly achieved by means of a reinforced stepped spillway. The bottom of the steps needs has been assumed at elevation 735 m asl based on preliminary water level information available to the Consultant but will have to be confirmed during the Detailed Design phase based on records of water levels in the Indus River during low flow season.

Stoplog slots are foreseen on both sides of the separation pier to be able to close the Tailrace Tunnel for maintenance purposes in the event the Patan HPP is built in the future.

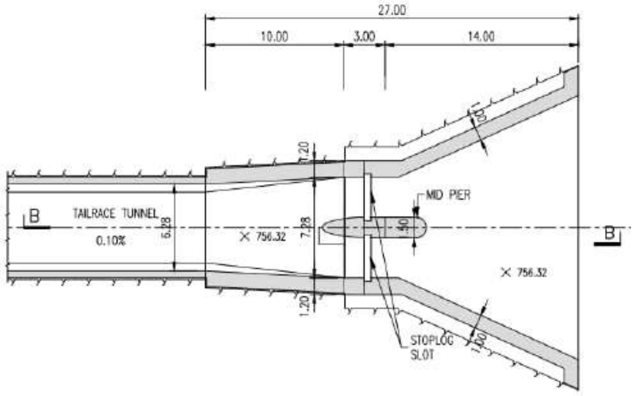


Figure 13-4: Outlet structure layout

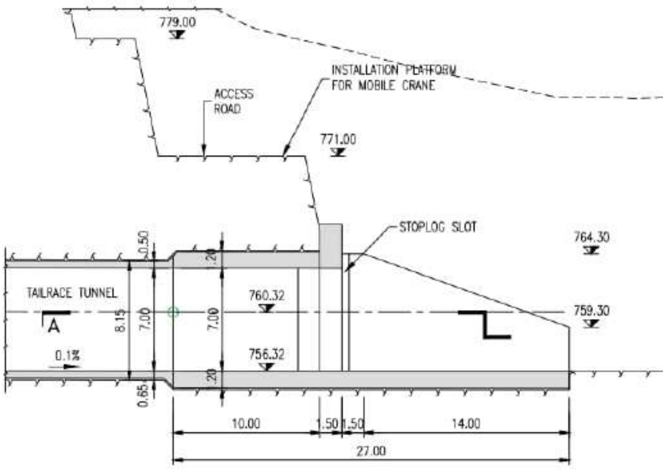


Figure 13-5: Outlet structure section

13.4 Temporary Rock Support

The primary support definition follows the New Austrian Tunnelling Method (NATM) philosophy and divides the rock mass dependent on the rock type, quality and overburden in five support classes. The support measures used in the tunnel are the standard measures such as shotcrete reinforced by welded wire meshes, rock bolts and in case of weak rock and large deformations additionally steel arches and/or yielding elements. The use of fibre reinforced shotcrete is currently not foreseen but may be proposed by the Contractor during construction to potentially optimise cost and reduce construction time.

The first three classes I, II and III are determined for good and sound rock, depending on the overburden situation and geologic formation. The classes include a bottom slab for ease of constructability.

Class IVa foresees longer anchors, more shotcrete efforts and a concrete slab for the invert and is meant to be used in moderate squeezing conditions.

For the portal areas and zones of weaker rock and debris mass or transition areas of different rocks a special class IVb with spiles is foreseen.

Class V is designed for fault zone material (which is to a certain grade expected) in combination with high stress zones due to a large overburden, which is mainly the case in the Kiru Sequence (overburden 1,500 – 1,800 m).

The support classes have been defined following the support/underground interaction curves for the following tunnel sections. The detailed calculations are compiled in the Volume 7 – Project Design, Annex 3.2.

- Headrace Tunnel,
- Gabarband Intake Tunnel,
- Pressure Shaft,
- Surge Shaft,
- Tailrace Tunnel,
- Main Access and Power Evacuation Tunnel ,
- Emergency and Ventilation Tunnel.

13.4.1 Headrace Tunnel

The support classes for the Headrace Tunnel are defined in Table 13-6.

Table 13-6: Rock support classes for Headrace Tunnel

Rock Support Class	Rock Support
I	- Maximum excavation length 3.0 m - Spot bolting, 3.0 m long bolts - 5 cm shotcrete in the crown area for safety reasons
II	- Maximum excavation length 3.0 m - Systematic bolting with 3.0 m long bolts, pattern 2.0*2.0 m in crown - Spot bolting in walls - 7.5 cm shotcrete in the crown area, 1 layer wire mesh
III	- Maximum excavation length 3 m - Systematic bolting with 3.0 m long bolts, pattern 1.5*1.5 m in crown and walls - 10 cm shotcrete in crown and walls, 1 layer wire mesh
IVa	- Maximum excavation length 2.0 m - Systematic bolting with 4.0 m long bolts, pattern 1.5*1.5 m in crown and walls - 15 cm shotcrete in crown and walls, 2 layer wire mesh - 20 cm reinforced concrete invert slab (flat)
IVb	- Support anchors shotcrete) as IVa - Additional: spiles in roof, l = 4.00 m, s = 30 cm

V	- Maximum excavation length 1.0 m - Separate top (heading) and bench excavation - Systematic bolting with 5.0 m long bolts, pattern 1.0*1.0 m in crown and walls - 30 cm shotcrete in crown and walls, 2 layer wire mesh - 30 cm reinforced concrete invert slab (curved) - Steel profiles, TH36 - If required: yielding elements (deformation gaps) in shotcrete

13.4.2 Gabarband Intake Tunnel

The support classes for the Gabarband Intake Tunnel are defined in Table 13-7.

Table 13-7: Rock support classes for Gabarband Intake Tunnel

Rock Support Class	Rock Support
I	- Maximum excavation length 3.0 m - Spot bolting, 4.0 m long bolts - 5 cm shotcrete in the crown area for safety reasons
II	- Maximum excavation length 3.0 m - Systematic bolting with 4.0 m long bolts, pattern 2.0*2.0 m in crown - Spot bolting in walls - 7.5 cm shotcrete in the crown area, 1 layer wire mesh
III	- Maximum excavation length 3 m - Systematic bolting with 4.0 m long bolts, pattern 1.5*1.5 m in crown and walls - 10 cm shotcrete in crown and walls, 1 layer wire mesh - 15 cm reinforced concrete invert slab (flat)
IVa	- Maximum excavation length 2.0 m - Systematic bolting with 5.0 m long bolts, pattern 1.5*1.5 m in crown and walls - 15 cm shotcrete in crown and walls, 2 layer wire mesh - 30 cm curved shotcrete invert, 2 layer wire mesh
IVb (portal)	- Support anchors shotcrete) as IVa - Additional: spiles in roof, l = 4.00 m, s = 30 cm
V	- Maximum excavation length 1.0 m - Separate top (heading) and bench excavation - Systematic bolting with 5.0 m long bolts, pattern 1.0*1.0 m in crown and walls - 30 cm shotcrete in crown and walls, 2 layer wire mesh - 30 cm curved shotcrete invert, 2 layer wire mesh Steel profiles every 1.0 m, TH36 - If required: yielding elements (deformation gaps) in shotcrete

13.4.3 Pressure Shaft

The support classes for the Pressure Shaft are defined in Table 13-8.

Table 13-8: Rock support classes for Pressure Shaft

Rock Support Class	Rock Support
I	- Maximum excavation depth 2.0 m - 7.5 cm around circumference, 1 layer wire mesh - Systematic bolting with 2.0 m long bolts, pattern 2.0*2.0 m
II	- Maximum excavation depth 1.5 m - 10 cm around circumference, 1 layer wire mesh - Systematic bolting with 2.0 m long bolts, pattern 1.5*1.5 m
III	- Maximum excavation depth 1.5 m - 15 cm around circumference, 2 layer wire mesh - Systematic bolting with 3.0 m long bolts, pattern 1.5*1.5 m
IV	- Maximum excavation depth 1.0 m - 25 cm around circumference, 2 layer wire mesh - Steel profiles; HEB 200 - Systematic bolting with 3.0 m long bolts, pattern 1.0*1.0 m

13.4.4 Surge Shaft

The support classes for the Surge Shaft are defined in Table 13-9.

Table 13-9: Rock support classes for Surge Shaft

Rock Support Class	Rock Support
I	- Maximum excavation depth 2.0 m - 7.5 cm around circumference, 1 layer wire mesh - Systematic bolting with 4.0 m long bolts, pattern 2.0*2.0 m
II	- Maximum excavation depth 1.5 m - 10 cm around circumference, 1 layer wire mesh - Systematic bolting with 4.0 m long bolts, pattern 1.5*1.5 m
III	- Maximum excavation depth 1.5 m - 15 cm around circumference, 2 layer wire mesh - Systematic bolting with 4.0 m long bolts, pattern 1.5*1.5 m
IV	- Maximum excavation depth 1.0 m - 25 cm around circumference, 2 layer wire mesh - Steel profiles; HEB 200 - Systematic bolting with 5.0 m long bolts, pattern 1.0*1.0 m

13.4.5 Tailrace Tunnel

The support classes for the Tailrace Tunnel are defined in Table 13-10.

Table 13-10: Rock support classes for Tailrace Tunnel

Rock Support Class	Rock Support
I	- Maximum excavation length 3.0 m - Spot bolting, 4.0 m long bolts - 5 cm shotcrete in the crown area for safety reasons
II	- Maximum excavation length 3.0 m - Systematic bolting with 4.0 m long bolts, pattern 2.0*2.0 m in crown - Spot bolting in walls - 7.5 cm shotcrete in the crown area, 1 layer wire mesh

III	- Maximum excavation length 3 m - Systematic bolting with 4.0 m long bolts, pattern 1.5*1.5 m in crown and walls - 10 cm shotcrete in crown and walls, 1 layer wire mesh
IVa	- Maximum excavation length 1.5 m - Systematic bolting with 4.0 m long bolts, pattern 1.5*1.5 m in crown and walls - 15 cm shotcrete in crown and walls, 2 layer wire mesh - 20 cm reinforced concrete invert slab (flat)
IVb	- Support anchors shotcrete) as IVa - Additional: spiles in roof, l = 4.00 m, s = 30 cm
V	- Maximum excavation length 1.0 m - Separate top (heading) and bench excavation - Systematic bolting with 5.0 m long bolts, pattern 1.0*1.0 m in crown and walls - 25 cm shotcrete in crown and walls, 2 layer wire mesh - 25 cm reinforced concrete invert slab (curved) - Steel profiles, TH36 - If required: yielding elements (deformation gaps) in shotcrete

13.4.6 Main Access and Power Evacuation Tunnel of Power Cavern

The support classes for the Main Access and Power Evacuation Tunnel are defined in Table 13-11.

Table 13-11: Rock support classes for Main Access and Power Evacuation Tunnel to Power Cavern

Rock Support Class	Rock Support
I	- Maximum excavation length 3.0 m - Spot bolting, 4.0 m long bolts - 5 cm shotcrete in the crown area for safety reasons
II	- Maximum excavation length 3.0 m - Systematic bolting with 4.0 m long bolts, pattern 2.0*2.0 m in crown - Spot bolting in walls - 7.5 cm shotcrete in the crown area, 1 layer wire mesh
III	- Maximum excavation length 3 m - Systematic bolting with 4.0 m long bolts, pattern 1.5*1.5 m in crown and walls - 10 cm shotcrete in crown and walls, 1 layer wire mesh
IVa	- Maximum excavation length 1.5 m - Systematic bolting with 5.0 m long bolts, pattern 1.5*1.5 m in crown and walls - 15 cm shotcrete in crown and walls, 2 layer wire mesh - 20 cm reinforced concrete invert slab (flat)
IVb	- Support anchors shotcrete) as IVa - Additional: spiles in roof, l = 4.00 m, s = 30 cm
V (if necessary)	- Maximum excavation length 1.0 m - Separate top (heading) and bench excavation - Systematic bolting with 5.0 m long bolts, pattern 1.0*1.0 m in crown and walls - 25 cm shotcrete in crown and walls, 2 layer wire mesh - 25 cm reinforced concrete invert slab (curved)

	- Steel profiles, TH36 - If required: yielding elements (deformation gaps) in shotcrete

13.4.7 Emergency and Ventilation Tunnel to Power Cavern

The support classes for the Emergency and Ventilation Tunnel to the Power Cavern are defined in Table 13-12.

Table 13-12: Rock support classes for Emergency and Ventilation to Power Cavern

Rock Support Class	Rock Support
I	- Maximum excavation length 3.0 m - Spot bolting, 2.5 m long bolts - 5 cm shotcrete in the crown area for safety reasons
II	- Maximum excavation length 3.0 m - Systematic bolting with 2.5 m long bolts, pattern 2.0*2.0 m in crown - Spot bolting in walls - 7.5 cm shotcrete in the crown area, 1 layer wire mesh
III	- Maximum excavation length 3 m - Systematic bolting with 2.5 m long bolts, pattern 1.5*1.5 m in crown and walls - 10 cm shotcrete in crown and walls, 1 layer wire mesh
IVa	- Maximum excavation length 2.0 m - Systematic bolting with 3.0 m long bolts, pattern 1.5*1.5 m in crown and walls - 15 cm shotcrete in crown and walls, 2 layer wire mesh - 20 cm reinforced concrete invert slab (flat)
IVb	- Support anchors shotcrete) as IVa - Additional: spiles in roof, l = 4.00 m, s = 30 cm
V (if necessary)	- Maximum excavation length 1.0 m - Separate top (heading) and bench excavation - Systematic bolting with 3.0 m long bolts, pattern 1.0*1.0 m in crown and walls - 30 cm shotcrete in crown and walls, 2 layer wire mesh - 30 cm reinforced concrete invert slab (curved) - Steel profiles, TH36 - If required: yielding elements (deformation gaps) in shotcrete

13.4.8 Rock Support Class Distribution Forecast

In Table 13-13 to Table 13-17 the assumed excavation class distribution is given. The tables are compiled from upstream to downstream. The rock support distribution has been estimated based on the available geological information, overburden, presence of pre-identified faults based on satellites information and the tunnel rock support measures.

The rock support class distribution forecast is also shown on the related geological drawing.

Table 13-13: Rock support distribution Headrace and Tailrace Tunnels

Formation	Length (m)	Support Class Distribution (%)					
		I	II	III	IVa	IVb	V
Headrace Tunnel (excluding 45 m Gabarband Crossing in RMT 2)							
RMT 2 (Mandraza Amphibolit, Kiru Seq.)	5,734	20	42	30	4	2	2
RMT 1 (Keyal Gabbro, Kiru Seq.)	1,623	18	18	27	17	10	10
RMT 3 (Amphibolites, Kamila Seq.)	2,472	10	40	35	9	3	3
RMT 4 (Plagioclase granite, Kamila Seq.)	979	20	40	18	10	6	6
Tailrace Tunnel							
RMT 4 (Plagioclase granite, Kamila Seq.)	1,285	20	40	18	10	6	6

Table 13-14: Rock support distribution vertical shafts

Formation	Length (m)	Support Class Distribution (%)			
		I	II	III	IV
Pressure Shaft					
RMT 4 (Plagioclase granite, Kamila Seq.)	463 m	60	30	8	2
Surge Shaft					
RMT 4 (Plagioclase granite, Kamila Seq.)	395 m	40	50	8	2

Table 13-15: Rock support distribution High Pressure Tunnel

Formation	Length (m)	Support Class Distribution (%)					
		I	II	III	IVa	IVb	V
RMT 4 (Plagioclase granite, Kamila Seq.)	69 m	10	34	34	10	6	6

Table 13-16: Rock support distribution Main Access and Power Evacuation Tunnel

Formation	Length (m)	Support Class Distribution (%)					
		I	II	III	IVa	IVb	V
RMT 4 (Plagioclase granite, Kamila Seq.)	1,212 m	20	40	18	10	6	6

Table 13-17: Rock support distribution Emergency and Ventilation Tunnel

Formation	Length (m)	Support Class Distribution (%)					
		I	II	III	IVa	IVb	V
RMT 4 (Plagioclase granite, Kamila Seq.)	1,167 m	20	40	18	10	6	6

Table 13-18: Rock support distribution Gabarband Intake Tunnel

Formation	Length (m)	Support Class Distribution (%)					
		I	II	III	IVa	IVb	V
RMT 2 (Mandraza Amphibolit, Kiru Seq.)	2,364 m	20	38	34	4	2	2

13.5 Lining Design

13.5.1 Overview

The final linings of the tunnel sections are shown in the Power Waterway drawings. Table 13-19 gives an overview of the applied lining type for each tunnel part.

Table 13-19: Overview of applied lining types

Tunnel part	Lining
Forebay including intake	Concrete
Headrace Tunnel (except Gabarband Crossing)	Concrete
Headrace Tunnel at the Gabarband Crossing (760 m)	Steel
Gabarband Intake Tunnel	GRP / Shotcrete
Surge Shaft	Concrete
Surge Shaft throttle	Steel
Emergency gate valve	Steel
Pressure Shaft	Steel
High Pressure Tunnel	Steel
Tailrace Tunnel	Concrete

13.5.2 Hydraulic Confinement

13.5.2.1 General

The hydraulic confinement was checked with the Austrian method described in the design criteria chapter 13.2.5.1. It must however be emphasised that the most important input parameters such as the rock mass density, the ratio of horizontal / vertical in-situ stress (k_0 value) remain largely unknown at this stage.

Furthermore, the used Airbus topography has some uncertainties in the steeper sections and will have to be confirmed by means of a terrestrial survey as recommended in the Chapter 24.

Thus, the calculations performed below are to be viewed very cautiously. The required length of steel liner will have to be re-evaluated after the results of the hydrocracking tests have become available at a later design stage and it cannot be excluded that a longer steel lining and highly reinforced concrete lining may be required during Project execution.

- Assessed rock mass density: γ_r = 28 kN/m^3
- Projected range of horizontal / vertical stress ratio: k_0 = 0.5 – 0.6
- Factor of safety static: FS_s = 1.3
- Factor of safety dynamic: FS_d = 1.00

The calculation results are compiled in Annex 3.1 of Volume 7 - Project Design.

13.5.2.2 Confinement at the Pressure Shaft

At the chosen location of the Pressure Shaft, the minimum required overburden elevation is 1,492 m asl for static and 1,514 m asl for dynamic loading.

The elevation of natural ground being in the range of 1,696 m asl in this location, the confinement criteria are checked and reinforced concrete lining can be applied upstream of the Surge Shaft location.

13.5.2.3 Confinement at the Gabarband Crossing

Based on the results of the head loss and water hammer calculations, the required overburden elevation was calculated to 1,498 m asl for static and dynamic loadings respectively upstream of the Gabarband Crossing. Similarly, the required overburden elevation was calculated to 1,495 m asl and 1,487 m asl for static and dynamic loading downstream of the Gabarband Crossing.

As a matter of fact, the evaluation of the hydraulic confinement and therefore the definition of the minimum length of steel lining required at the Gabarband Crossing is not a straightforward task especially considering the uncertainties associated with the rock mass parameters, the groundwater level and the available satellite data that are already known to be of limited accuracy/reliability in steep valleys. Based on the above assumptions, it can be reasonably assumed that the theoretical length of the Headrace Tunnel lying outside of the confined area is around 1,400 m.

To minimise cost and in the absence of direct and reliable data, it was chosen at the Feasibility Study stage to systematically apply a steel lining whenever the minimum vertical stress criteria was not fulfilled (e.g. for the sections of the tunnel where the theoretical load from the vertical overburden of the rock is lower than the static internal water pressure). Thus, the length of the steel lining at the Gabarband Crossing was taken as 762 m.

For the transition zones located upstream and downstream of the steel lining and outside of the confinement zones with a total length of 626 m, a combination of a tight element (PVC foil) and a reinforced concrete lining with a higher reinforcement ratio was proposed. The upstream and downstream transition zones were defined in such a way that both the vertical and horizontal confinement criteria were fulfilled for a rock mass density 28 kN/m^3 and a k0 value conservatively taken as 0.5.

13.6 Design of the Reinforced Concrete Lining

13.6.1 General

The underground design must achieve the functionality, stability, and safety of the underground openings during and after construction and for as long as the underground structure is expected to function.

Power tunnel structures, additionally to stability and safety in the operation and maintenance, should be designed to minimise leakage. Accordingly, a design method should be used that will eliminate wide cracks and other potential sources of leakage.

Reinforcement concrete lining cannot prevent the formation of cracks. Only better crack distribution by an increase in a number of cracks and limitation of crack width is achieved by reinforcing the concrete tunnel lining.

In general, reinforcement in the concrete is required along the waterway when the following conditions are encountered:

- Upstream of steel lined part of power tunnels, in order to have gradual changes of permeability from pervious un-reinforced concrete to impervious steel lined parts of power tunnels,
- In areas where there is weak rock with high permeability,
- In areas where the rock is susceptible to erosion,

- In areas where seepage into the tunnel through altered or fractured zones can cause washing out of joint filing and accordingly invoke cavities behind the lining and so endanger long-term stability,
- In areas where leakage from the tunnel to the ground surface can result in instability and landslides,
- In areas where the long-term stability may be endangered by dynamic water pressures.

Reinforcement in the concrete lining additionally prevents the formation of loose concrete pieces formed by local cracks caused by changing internal loads and dynamic pressures (water hammer) in the system.

Modern and economic design of the reinforced concrete lining can be done by the method developed by Schleiss (1997). This method considers the forces due to seepage through the lining and rock as well as the deformation – dependent permeability of the lining.

In Chapter 13.6.6, a discussion about the different possibilities of the tunnel lining is held and the conclusions to continue with a reinforced concrete lining for the whole Headrace Tunnel are drawn.

13.6.2 Calculations

For the parts of the tunnel where the confinement criteria is fulfilled, the concrete lining design was calculated with Excel spread sheets following the theory of Seeber (1982) and the approach of Schleiss (1997).

First, the thickness of the lining was evaluated and chosen to be 50 cm based on the excavated diameter and the type of rock and overburden. The area between the lining and surrounding rock must be treated with grouting.

Calculations following the theory of Seeber (1982) introduced that grouting injections with the pressures in the defined range of maximum 10bar would not be sufficient to avoid cracking of the concrete. Hence, the lining shall be reinforced.

The results are provided in Figure 13-6 and also in Volume 7 – Project Design. A preliminary definition of grouting measures to be applied is given in Chapter 13.11.

CONCRETE LINING DESIGN (Seeber Theory)

PROJECT: Lower Spat Gah — Area: Head race tunnel

INPUT PARAMETERS:		
Geometry:		
External tunnel radius:	3,15	[m]
Lining thickness:	0,50	[m]
Internal tunnel radius:	2,65	[m]
Overburden:	1800,00	[m]
Groundwater height:	215,00	[m]
Rock mass:		
Elasticity modulus:	15000	[N/mm²]
Poisson's ratio:	0,20	[-]
Unit weight:	25,00	[kN/m³]
Horizontal stress ratio:	0,50	[-]
Deformation modulus(Lame)	12500	[N/mm²]
Concrete lining:		
Concrete quality:	C25/30	
Elasticity modulus:	30000	[N/mm²]
Poisson's ratio:	0,20	[-]
Thermal coefficient	1,20E-05	[1/°C]
Strength:	25,00	[N/mm²]
Max. allowed strain:	6,42E-04	[-]
Internal water pressure:	2,50	[N/mm²]
Reduction and safety factors:		
Concrete strength reduction	0,77	[-]
Concrete strain reduction	0,77	[-]
Safety factor	1,35	[-]
Pressure loss:		
on pump	0	%
Creep and shrinkage	30	%
Temperature	10	°C

CALCULATION:			
Primary stresses in rock mass:			
Vertical	σ_v=	45	[N/mm²]
Horizontal	σ_h=	22,50	[N/mm²]
Loading case - Empty tunnel			
Groundwater pressure	p_{gw}=	2,11	[N/mm²]
Concrete strain	ε_b^{out}=	-3,97E-04	[-]
	ε_b^{in}=	-4,81E-04	[-]
Minimal thickness	t_{min}=	0,49	[m]
Loading case - Injection			
Pressure on pump	p_{pump}=	1,00	[N/mm²]
Max. allow. pressure on lining	p_{max}=	2,81	[N/mm²]
Injection pressure on lining	p_{inj}=	1,00	[N/mm²]
Minimal thickness	t_{min}=	0,17	[m]
Concrete strain	ε_b^{out}=	-1,88E-04	[-]
	ε_b^{in}=	-2,21E-04	[-]
Loading case - Operation			
Inj. pressure losses (creep)	Δp_c=	-0,30	[N/mm²]
Inj pressure losses (temp.)	Δp_t=	-0,64	[N/mm²]
Remain. inj. pressure	p_{rem}=	0,06	[N/mm²]
Remain. concrete strain	$\varepsilon_b^{out,r}$=	-1,17E-05	[-]
Pressure taken by rock	p_{rock}=	0,15	[N/mm²]
Maximal allowed pressure	p_{tot}=	0,21	[N/mm²]
Internal pressure (calcul.)	p_i^{out}=	2,84	[N/mm²]
Concrete strain	ε_b^{out}=	4,95E-04	[-]
	ε_b^{in}=	6,00E-04	[-]

Figure 13-6: Concrete lining design Headrace Tunnel

13.6.3 Water Losses Through Concrete Lining when Subject to Internal Pressure

13.6.3.1 Results

The water losses in the Power Waterway were calculated with the method after Schleiss (1997) which considers the effect of seepage forces in the reinforced concrete lining, the surrounding rock and the deformation-dependent permeability of the lining.

A sensitivity analysis has been performed considering different E-moduli of the surrounding rock, different permeabilities based on the rock mass classification which can be found in Volume 4 - Geology of this Feasibility Study Report and various internal pressure stages up to 30 bar.

The detailed calculation results are compiled in Volume 7 – Project Design, Annex 3.3. The results for an average E-modulus of 30 GPa can be found in Table 13-20 to Table 13-22.

Table 13-20: Water losses for E-modulus of rock mass of 30 GPa

E-modulus Rock (GPa)	Permeability (m/s)	Water losses	Water pressure (bar)			
			10	15	20	30
30	10^{-7}	(l/s/km)	12.5	22.9	32.0	47.4
		(l/s/km/bar)	1.2	1.5	1.6	1.6
Crack series			1st			

Table 13-21: Water losses for E-modulus of rock mass of 15 GPa

E-modulus Rock (GPa)	Permeability (m/s)	Water losses	Water pressure (bar)					
			5.8	15	20	28	28	30
15	10^{-8}	(l/s/km)	1.3	2.8	3.5	4.6	4.6	4.9
		(l/s/km/bar)	0.2	0.2	0.2	0.2	0.2	0.2
15	10^{-7}	(l/s/km)	9.3	27.3	34.9	46.0	45.4	48.2
		(l/s/km/bar)	1.6	1.8	1.7	1.6	1.6	1.6
15	10^{-6}	(l/s/km)	36.9	229.7	320.8	445.5	410.7	442.8
		(l/s/km/bar)	6.3	15.3	16.0	15.9	14.7	14.8
Crack series			1st				2nd	

Table 13-22: Water losses for E-modulus of rock mass of 2 GPa

E-modulus Rock (GPa)	Permeability (m/s)	Water losses	Water pressure (bar)									
			2	4	4.5	5.2	5.2	7	10	16.2	16.2	25
2	10^{-7}	(l/s/km)	6.0	10.2	11.2	12.5	12.5	20.6	30.0	30.0	42.3	20.6
		(l/s/km/bar)	2.9	2.6	2.5	2.4	2.4	2.2	2.1	1.9	1.8	1.7
Crack series			1st				2nd			3rd		

13.6.3.2 Interpretation

Evaluation of E-moduli of surrounding rock:

Assuming an E-modulus of 30 GPa for the rock mass, the first crack series initiates at 10 bar inner pressure, and up to an investigated range of 30 bar no second crack series occurs.

Assuming an E-modulus of 15 GPa for the rock mass, the first crack series initiates at 5.8 bar inner pressure. At 28 bar the second crack series occurs theoretically, however, the vertical alignment of the Power Waterway has been designed such that the concrete lined section is not subjected to a higher inner pressure of 20 bar in static and a maximum of ~25 bar in dynamic loading.

At the assumed fault zone material with E-modulus of 2 GPa, the first series of cracks initiates at 2 bar inner pressure. The second crack series initiates at 5.2 bar and reaches up to 16.2 bar. The third crack series is propagating up afterwards. At the point of the highest investigated internal pressure of 25 bar the tensile stress of the concrete in the lining between the cracks (3rd series) is ~0.6 MPa, hence still not exceeded.

Evaluation of rock mass permeabilities:

A common criterion for water losses in power waterways is 1-2 l/s/km/bar internal pressure.

Assuming a permeability of k=10-8 m/s the water losses are around 0.2 l/s/km/bar, hence significantly below 1 l/s/km/bar. These very favourable conditions would mean a technically tight system. The absolute water losses at 20 bar pressure would be 3.5 l/s/km.

Assuming a permeability of k=10-7 m/s the water losses would be in a range of 1.6 – 1.8 l/s/km/bar, hence acceptable. The absolute water losses at 20 bar pressure would be 35 l/s/km.

Assuming a permeability of k=10-6 m/s the water losses are 6.3 – 16 l/s/km/bar, hence significantly above the required range of 1-2 l/s/km/ bar. The absolute water losses at 20 bar pressure would be 321 l/s/km.

Under these unfavourable conditions (e.g. k > 10-7 m/s), additional measures (e.g. grouting) would have to be taken to reduce the permeability of the rock mass.

Conclusions:

50 cm of reinforced concrete lining with a moderate reinforcement grade are sufficient to limit the cracks to a reasonable range up to an internal operation pressure of 25 bar for the averaged assumed rock conditions.

A closed contact for the structural interaction between the lining and the surrounding rock mass is a precondition for the application of the chosen calculation method.

Therefore, void filling and contact grouting of the lining is mandatory along the whole lining. The necessity of consolidation grouting around the tunnel is also expected locally especially in the higher rock support classes (no systematic consolation grouting foreseen).

Rock mass permeabilities of k=10-7 m/s to 10-8 m/s result in water losses between 1 and 2 l/s/km/bar, which is a commonly accepted range. Higher permeabilities of the rock mass would have to be treated accordingly with grouting.

13.6.4 Reinforced Concrete Lining at the Gabarband Crossing

Upstream and downstream of the steel lined section at the Gabarband Crossing, a transition zone has been introduced including a watertight sealing element in combination with a concrete lining that has a higher reinforcement ratio.

Preliminary structural calculations show that the required reinforcement reduces with increased loads transferred from the lining to the surrounding rock mass, which is related to the rock mass' stiffness. However, the rock mass classification shows generally very high stiffness moduli for the geological units and to conservatively account for partially weaker and loosened up zones at the edges of the mountain near the valley crossing, a relatively low spring stiffness has been considered in the analysis.

The required reinforcement area in transversal direction (ring reinforcement) is approximately 60 cm^2/m. Possible reinforcement raster are 2 layers of DB30/200mm (2 x 35 cm^2/m = 70 cm^2/m) or DB32/200mm (2 x 40.2 cm^2/m = 80.4 cm^2/m) on the inside and outside. D32/200mm has been assumed inside and outside for the quantity take-off.

13.6.5 Empty Concrete Lining Subject to External Water Pressure

Several lining thicknesses were evaluated and at the end it was decided to proceed with the design with a concrete liner thickness of 50 cm. One of the main reasons for this was the loading condition "empty tunnel". In case of dewatering/tunnel emptying the outer groundwater pressure is acting against the tunnel and the only parameter, which can improve the safety against outer water pressure is the thickness of the lining.

The geological interpretation of the Project area gives reasons to believe that a relatively high ground water level will be encountered, hence the selected lining thickness is on the upper edge of the evaluated range of lining thicknesses.

A 50 cm thick lining can take about 215 m of external water pressure considering a factor of safety of 1.35. If higher groundwater pressures are effectively encountered especially along faults connecting the tunnel with high external pressure, additional constructive measures like consolidation grouting or dewatering valves can be foreseen. A description of this feature can be found in Schleiss (2005).

13.6.6 Unlined (Shotcrete) versus Concrete Lining in Power Waterways

13.6.6.1 General Discussion

Unlined tunnels are tunnels that in operation remain unlined or are just lined by the primary lining (e.g. rock support) that takes the function of the final lining. In contrast to transfer tunnels or access tunnels, the particular challenge posed by the fact that the water flow and frequent pressure fluctuations favor the falling out of blocks, which can lead to the damage of turbines and with progressive failure to a clogging of the tunnel.

Also the excavation method has an impact on whether a tunnel is left unlined in operation. Since NATM driven tunnels have a significantly higher roughness, larger flow losses will occur. These higher losses could be compensated with larger excavation sections that again increase the construction costs.

The question of unlined tunnels arises only in the very good mountains, characterised on the one hand by solid rock (not changeable in contact with fluctuating water), low separation surface frequency and good interfacial properties (no washable fillings) and enough internal stress suppressing opening of joints by internal water pressure.

Waterways that are completely or partially unlined have to be equipped with rock traps. The sand or rock trap has the function to accumulate the fallen pieces of rock before they can reach the turbine and cause damages.

Therefore, the selection and decision to use unlined Headrace Tunnel must be made considering all these influences and needs very good rock mass.

At the current stage of this Project the level of information about the rock mass is not sufficient and the risk to suggest the construction of the Headrace Tunnel as unlined is perceived as high. Therefore, the selection is made to line the entire length with reinforced lining.

If during the excavation of the Powerhouse and Upper Erection and Gate Chamber access tunnels and various construction adits the conditions required for the unlined tunnel will be met, then the design could be adopted and sections that could stay unlined or just shotcrete lined could be defined accordingly. The decision must be approved during the excavation process and the final decision will have to be made after excavation.

13.6.6.2 Rock Trap

In case that in later Project stages it is decided that a part of the Headrace Tunnel is left unlined or lined just by shotcrete lining, losing of small parts of lining and rock mass pieces could not be excluded. These fragments could be transported along the tunnel and represent a risk for the turbines. Therefore these parts must be trapped in order not to endanger the turbine.

A rock trap, which is basically a collecting basin, has then to be foreseen at the downstream end of the unlined section, before the start of the steel lined section. Implementation of such a feature can be done easily. Access to the rock trap and a possibility to clean it must be assured.

13.7 Steel Lining and Gabarband Intake Steel Pipe

For the design of the steel lining of the Headrace Tunnel, Pressure Shaft and High Pressure Tunnel, the external water pressure is decisive. For the penstock at the downstream end of the GRP pipe in the Gabarband Intake Tunnel internal water pressure is decisive.

The lining thickness for the 4.00 m inner diameter Pressure Shaft and High Pressure Tunnel ranges from 17 mm up to 38 mm and relies on the use of stiffener rings to optimise cost. In a first attempt, stiffener rings have only been assumed where necessary, i.e. for lining thicknesses over 36 mm to remain on the safe side and allow for site conditions that are potentially less favourable during Project implementation especially at the Gabarband Crossing with longer steel lining required.

The systematic use of stiffener rings has the advantage of lower overall steel quantities and thus costs but has the disadvantage of a more complicated handling and thus longer construction time. The lining of the Pressure Shaft is not on the critical path of the construction schedule and stiffener rings could even be used on thinner plates. However the final design and consideration of costs vs. construction time remains with the Contractor, a brief sensitivity analysis has been maximising the use of stiffener rings to optimise the steel quantities.

A steel quality of S460M up to S550M is used. The total steel amount for the Pressure Shaft steel and High Pressure Tunnel lining can be given with 2,074 tons in case no stiffener rings are used.

The lining thickness for the 4.00 m inner diameter Headrace Tunnel at the Gabarband Crossing ranges from 16 mm up to 36 mm. A steel quality of S460M is used. The total steel amount for the 720 m of steel lining is 1,365 tons in case no stiffener rings are used

The lining thickness for the cone (diameter 5.2 - 4.0 m), the horizontal section and the elbow at the downstream Headrace Tunnel ranges from 17 mm up to 22 mm. The total steel amount is 159 tons in case no stiffener rings are used.

The amount of steel for the penstock is 422 tons.

For the Gabarband Intake Tunnel pipe P355N steel quality is used. The penstock cone thickness is 8 mm for a diameter of 1.5 m. The total steel amount is 10 ton.

Table 13-23: Results of the pre-design of the steel lining

Tunnel Section	P355N	S460M	S550M	Total
Headrace Tunnel – Gabarband Crossing		1,365 t	-	1,365 t
Surge Chamber, Cone, downstream, upper pressure tunnel		159 t		159 t
Pressure Shaft		422 t	1,251 t	1,673 t
High Pressure Tunnel		-	401 t	401 t
Penstock		-	422 t	422 t
Gabarband Intake Tunnel Penstock	10 t			10 t
Total	10 t	1,946 t	2,074 t	4,030 t

As described above, this design was made in the absence of reliable/direct information about the groundwater levels. The layout shall be further optimised at a later stage based on detailed information from excavation, hydro fracturing tests and ground water measurements.

The detailed results for both load cases for the Gabarband Crossing, Pressure Shaft and High Pressure Tunnel are compiled in Volume 7 – Project Design, Annex 3.4.

A preliminary sensitivity analysis has been performed for the Pressure Shaft (steel grade S500M and generalised use of stiffeners for all plates thickness) and the Gabarband Crossing considering stiffener rings to have a first estimate of the potential savings of steel should the length of the steel lining need to be extended at the Gabarband Crossing during the next design stage. It is assumed that circa 490 tons of steel could be saved which is also circa 150 m of steel lining at the Gabarband Crossing.

13.8 GRP Pipe

The water in the Gabarband Intake Tunnel will be conveyed within a GRP pipe mounted on concrete supports. The pipe has been divided into 3 equally long sections with an inner diameter of 2.1 m in the upstream section, 1.9 m in the middle section and 1.7 m in the downstream section. This allows for a segment stacking of the different pipe diameters into one shipping unit for the transport from the manufacturer to Pakistan, and thus reduces the transport cost to 1/3.

In order to protect the pipe against the sediments in the flow, high abrasion resistant pipes have been selected.

Due to the increasing internal pressure, the pipe is generally divided into three pressure sections, taking into account the transient results from Chapter 13.12.4.11. The most upstream section will be designed for an internal pressure of 10 bar, the middle section for 16 bar and the most downstream section for 25 bar. Because the pipe is mounted on supports and has thus no external pressure and with the selected pipe segment length of 5.7 m, the stiffness of the pipe could be selected at 5,000 N/m^2.

The velocity in the 1.7 m diameter pipe section is 4.4 m/s at the design discharge of 10 m^3/s. During the relevant transient event, the flow increases to 21 m^3/s, resulting in a velocity of about 9 m/s. The selected pipe diameter therefore adhere to the velocity requirements.

A manhole in the middle of the GRP pipe is foreseen to allow for inspection of the pipe in addition to the entry from the Lower Gabarband forebay and the manhole in the steel section just upstream of the Headrace Tunnel junction. The manhole will be located in the PN 16 section for cost purposes because manholes in PN 20 or PN 25 segments are fairly costly. The steel section will also contain a butterfly valve which can isolate the GRP pipe for maintenance purposes or in emergency situations such as a leak of the GRP pipe.

The preliminary material parameters in Table 13-24 have been provided by a pipe supplier.

Table 13-24: Preliminary material parameters of GRP pipe

Parameter	Unit	Upper Section	Middle Section	Lower Section
Nominal diameter	(mm)	2,100	1,900	1,700
Nominal pressure	(bar)	10	16	25
Stiffness	(N/m^2)	5,000	5,000	5,000
Minimum thickness	(mm)	29.5	24.3	21.0
Circumferential tensile modulus	(GPa)	13.0	20.0	30.0
Longitudinal tensile modulus	(GPa)	7.0	8.0	10.0
Circumferential tensile strength	(N/mm^2)	172.4	296.9	454.6
Longitudinal tensile strength	(N/mm^2)	25.2	33.4	43.9

13.9 Surge Shaft

The Surge Shaft is located upstream of the Upper Erection and Gate Chamber, at chainage 10,852 m of the Headrace Tunnel. The top of the tank is below the surface and can be reached via an access tunnel to the surge shaft chamber.

The design foresees a solution in the form of a shaft with an offset in the layout relative to the tunnel axis, which is beneficial for the construction. The inner diameter of the shaft is 6.50 m. A 0.50 m thick reinforced concrete lining is foreseen also for the Surge Shaft over its full height, the outer diameter is then 7.50 m. The proposed solution for the construction of the shaft is the Raise Drill procedure with glory hole and enlarging.

The throttle of the Surge Shaft will have to be steel lined, as well as the whole section of the tunnel down to the MIV.

13.10 Operational Aspects

During the operation the tunnel will be exposed to large internal pressure and also transient pressures caused by changing of the flow regime in the tunnel. The designed lining system must be able to manage the static pressure as well as pressure fluctuation without damage of the lining and the surrounding rock mass.

Filling and especially emptying of the Power Waterway are the most extreme loading conditions for the lining and also for the surrounding rock mass. Therefore, both processes have to be done with special attention and the filling/emptying speed should not be higher than the specified values.

Too fast filling or emptying of the system could cause a strong increase of the stresses in the lining and in the surrounding rock mass and could result in serious cracks and even collapses.

It must be mentioned that in recent years the hydropower industry has suffered from several damages of power tunnels in that context.

13.11 Grouting

13.11.1 General

Grouting is an injection of fluid medium particles into the rock voids improving the rock mass characteristics. Around the pressure tunnels grouting is performed mainly to increase the rock mass stiffness, to reduce the rock mass permeability and to achieve a contact between rock mass and the final tunnel lining. For concrete lined tunnels three types of grouting can be distinguished:

- Void filling caused by the concreting process - mostly in the tunnel crown,
- Contact grouting achieving continuous contact around the tunnel,
- Consolidation grouting improving the rock mass characteristics around the tunnel.

Void grouting involves filling of the voids between the cast-in-place concrete lining and surrounding rock mass. Fluid fresh concrete tends to maintain horizontal surfaces and voids can occur on the highest point. The voids also develop due to the presence of trapped air, a poor concrete placement procedure, insufficient concrete slump or unstable concrete. The voids have to be filled with low-pressure grout or mortar substituting missing concrete lining.

Contact grouting around the tunnel has the function of filling possible air traps in overbreak areas and other irregularities occurred by pouring process, fill bleeding and shrinkage gap. Also a gap between the lining and the rock mass caused by temperature changing – cooling of the concrete lining – can occur. The contact grouting is performed around the tunnel through prepared or drilled boreholes with a minimal length of 50 cm into the surrounding rock mass. Grouting mix and pressure have to be defined based on the Project settings, with grouting pressures up to 5 - 10 bar being usual.

The function of the consolidation grouting is to improve the physical characteristics of the surrounding rock mass – an increase of the rock mass stiffness, and reduction of the rock mass permeability. The consolidation grouting is performed in a radial direction or perpendicular to the dominant joint system. The length and pattern of the consolidation boreholes are dependent on the geological conditions and the targets that should be achieved. The length of boreholes is mostly in the range of the tunnel radius to tunnel diameter with one borehole per approximately 10 m2 of the tunnel lining. Grouting pressures are normally 5-10 bar except in case of pre-stressing of the plane concrete lining where high pressures up to 30 bar are usual. In case that the grouting packer is situated in the concrete lining, the consolidation grouting and the contact grouting can be performed in the same stage.

13.11.2 Concrete Lining Grouting

13.11.2.1 Contact Grouting / Void Grouting

This grouting measure shall assure a close contact of the tunnel lining with the surrounding rock and enable full load transfer between concrete and rock. The shrinkage gap between lining and surrounding rock must be closed along the whole tunnel lining.

6 holes with a shallow depth (~50 cm into the rock) along the circumference of the lining are required for the Headrace Tunnel. The longitudinal distance for the contact grouting is 3 m.

7 holes with a shallow depth (~50 cm into the rock) along the circumference of the lining are required for the Surge Shaft. The longitudinal distance for the contact grouting is 3 m.

Contact grouting is done with pressures of ~8-10 bar.

In case where consolidation grouting is applied through the radial holes and the packer is set in the concrete the contact, grouting could be performed together with the consolidation grouting.

13.11.2.2 Consolidation Grouting

Consolidation grouting is applied to increase the stiffness (E-modulus) of the rock mass and to decrease the permeability.

This grouting shall be done with pressures of ~8-10 bar, 6 holes with drilling depth of 3 m into the rock for the Headrace Tunnel, 6 holes with drilling depth of 3 m into the rock for the Tailrace Tunnel and 4 m into to the rock for the Surge Shaft, a horizontal distance of 3 m is foreseen, with staggered boreholes.

Following assessments for the required consolidation grouting are made:

- Class I and II: no consolidation grouting required
- Class III: consolidation grouting required along 30% of the length
- Class IV and V: systematic consolidation grouting required

In class III, the areas where consolidation will be performed will be defined based on encountered geological conditions (rock mass classification during excavation) and based on the grout take tests that will be performed during drilling works.

13.11.3 Steel Liner Grouting

Systematic contact (or "skin") grouting behind the steel liner is necessary in order to fill voids and guarantee good contact between steel and surrounding concrete. After the filling with the surrounding concrete, grout is injected through openings (valves) behind the steel liner. An exact procedure shall be determined in a subsequent design phase.

13.12 Hydraulic Design

13.12.1 General

The hydraulic design of the Power Waterway considers three main aspects:

- General verification for the Power Waterway and its appurtenant structures as fit for purpose,
- Hydraulic losses along the Power Waterway,
- Transient analysis of the Power Waterway.

Each of these aspects is presented in a separate sub-chapter of this chapter.

13.12.2 General Verification for the Waterway

Due to the long Power Waterway of the Lower Spat Gah scheme, a surge facility is required as the water starting time (Tw=6.1 s) of the waterway system is far higher than the critical limits recommended in different criteria.

In order to increase the hydraulic stability of the pressurised system of the Power Waterway, the surge facility should be as close as possible to the Powerhouse. For this purpose, the surge facility has been located at the downstream end of the Headrace Tunnel just upstream of the Pressure Shaft upper bend.

13.12.2.1 Surge Shaft Area

The hydraulic stability of the pressurised Power Waterway system is expressed by the Thoma criterion. As the waterway downstream of the Surge Shaft is quite long, the Thoma criterion has to be corrected by the Evangelisti factor.

The minimum area of cross section of a Surge Shaft results from Thoma's condition for the stability of surge shafts. Thoma showed that with automatically governed turbines, the Surge Shaft will only be hydraulically stable if the horizontal cross sectional area of the tank exceeds a certain minimum value F_{Th}:

$$F_{Th} = \frac{L \cdot f \cdot {v_0}^2}{2g \cdot h_0 \cdot (H_0 - h_0)}$$

where:

- F_{Th}: Minimum area of Surge Shaft after Thoma (m^2)
- L: Length of equivalent headrace tunnel (m)
- F: Area of the equivalent tunnel section (m^2)
- v_0: Velocity in the tunnel at flow design discharge (m/s)
- g: Acceleration due to gravity (9.81 m/s^2)
- H_0: Total head (m)
- h_0: Head loss upstream of Surge Shaft (m)

The Evangelisti correction factor is:

$$F_{min} = F_{Th} \cdot \frac{1 + \frac{L_d \cdot f}{L \cdot f_d}}{1 - 3 \cdot \frac{\Delta z_{do}}{H_{Br} - \Delta z_{do}}}$$

where:

- F_{Th}: minimum area of Surge Shaft after Thoma (m2)
- F_{min}: minimum area of Surge Shaft after Thoma corrected by Evangelisti (m^2)
- v_o: velocity in the Headrace Tunnel (upstream of surge tank) (m/s)
- L: length of Headrace Tunnel (m)
- F: cross-section area of Headrace Tunnel (m^2)
- Δz_o: head losses in Headrace Tunnel (m)
- H_{Br}: total head (m)
- L_d: total length of waterway (m)
- F_d: cross-section area (m^2)
- Δz_{do}: total head losses of waterway (m)

For the hydraulic characteristics of the Lower Spat Gah Power Waterway, the Thoma criterion would result in a Surge Shaft minimum diameter of about 4.00 m. However, after applying a safety factor of 2.0 as well as the Evangelisti correction factor due to the relatively long waterway length between the Surge Shaft and Powerhouse, the minimum stable Surge Shaft diameter would increase to about 6.1 m.

Eventually, a throttling Surge Shaft with internal diameter of 6.50 m has been selected as the surge relief facility. A short steel tunnel with a diameter of 2.50 m which will act as the throttling orifice connecting the Surge Shaft to the steel lined Headrace Tunnel.

The shaft inlet is throttled to improve the dampening of the oscillations by offering greater resistance. As a rule of thumb, the area of the orifice of a throttled Surge Shaft should not be larger than 40% of the area of the branching tunnel because large sizes will not provide effective pressure dampening. The Headrace Tunnel as the branching tunnel with a diameter of 4.00 m results in an orifice diameter of 2.50 m. This size was checked in the transient analysis (Chapter 13.12.4) to provide a balanced head design so that the maximum tunnel pressure below the Surge Shaft nearly equals the maximum upsurge level caused by a full load rejection.

13.12.2.2 Headrace Tunnel Intake Submergence

The submergence of the Headrace Tunnel intake has been determined with the Knauss condition, which is shown graphically in Chapter 13.2.2.1. The required submergence is determined based on the MOL of the Lower Spat Gah forebay. The MOL is determined in the desander hydraulic design chapter and is the level corresponding to the reservoir MOL minus the losses in the desander. The resulting submergence factor (h/d) is in the range of 1 to 1.5. The turbine governor will regulate the turbine discharge so that the water level is maintained between the FSL and MOL. With a required submergence factor of 1.24 the minimum allowable water level in the forebay would be 1,495.6 m asl.

Table 13-25: Verification of the minimum allowable water level in the Lower Spat Gah forebay

Parameter	Value
Axis elevation of Headrace Tunnel	1,489.00 m asl
Diameter of Headrace Tunnel (height)	5.30 m
Width of gate section	5.30 m
Considered discharge at MOL	75 m^3/s
Flow velocity at the intake	2.7 m/s
Froude number	0.37
Required submergence factor h/d	1.24
Minimum submergence from intake/tunnel axis	6.6 m
Minimum allowable water level in forebay	1,495.6 m asl

However, a submergence factor of about 2.0 is selected for the determination of the vertical setting of the Headrace Tunnel intake to cover any non-symmetric approach flow condition within the forebay.

The corresponding minimum allowable water level in the forebay to achieve sufficient intake submergence is 1,499.6 m asl, which equals the MOL of the forebay.

The axis level of the Headrace Tunnel intake is additionally checked to adequately satisfy the minimum required pressure on the crown of the Headrace Tunnel starting reach during transient conditions. This criterion is also fulfilled.

13.12.2.3 Gabarband Intake Tunnel Flow Regime

A mixed flow regime is expected along the Gabarband Intake Tunnel (pipe) during water transmission. The water level in the pipe is dictated by the operational regime within the Power Waterway in terms of Powerhouse discharge as well as headwater level at the Lower Spat Gah Headworks. Due to the steep slope of the Gabarband Intake Tunnel (pipe), a supercritical flow shall form between the pipe inlet and the downstream dictated boundary condition. The flow regime transition shall take place through a hydraulic jump where the supercritical free-flow meets the downstream water table. The free-flow parts of the pipe need to be well aerated. For this purpose a separate aeration is foreseen downstream of the pipe intake gate.

The flow velocity for the design discharge of 10.0 m^3/s along the pipe part with free-flow regime would reach about 7.3 m/s with a normal depth of around 0.9 m. In the pressurised reach the flow velocity is around 3.2 m/s.

During load trips there will be backflow surges within the pipe which would lead to water spilling out into the forebay. Therefore, the size of the forebay is determined such as not to have flow returning back into the desander with some adequate freeboard allowance.

13.12.3 Hydraulic Losses

13.12.3.1 Approach

The head losses have been defined as the sum of friction and form losses.

The friction losses are calculated considering the length, diameter and roughness of the concrete lined as well as the steel portions of the Power Waterway for a design discharge of 25.0 m^3/s per unit.

Form losses consist of losses related to inlet structure, stoplogs/gate grooves, transitions, bends, mitres, valve, bifurcations etc.

The friction losses in the waterway are calculated using the Darcy-Weisbach formula, where the Darcy's friction factor is calculated using the Colebrook-White equation.

New Conditions: Roughness heights of 0.6 mm and 0.06 mm have been assumed for in-situ concrete lining and steel lined or penstock sections, respectively, according to recommendations of ASCE 1989.

Old Conditions: In order to quantify the sensitivity of the friction head losses as well as to assess the effect of long-term operation and sliming of the waterway system, the roughness heights have been increased to 2.0 mm for the in-situ concrete lining and 0.15 mm for steel lined or penstock sections. Such roughness assumptions are associated with remarkably deteriorated surfaces as they may prevail after several decades of operation.

13.12.3.2 Results

For *New Conditions*, the applied roughness values lead to a total head loss of 22.50 m for the design discharge.

For *Old Conditions*, the applied roughness values lead to a total head loss of 27.16 m for the design discharge.

The detailed loss calculation including form and friction losses (New Conditions) for different components of the waterway at rated condition is presented in Table 13-26.

The results for the minor loss calculation are shown in Table 13-27.

Table 13-26: Friction losses between Lower Spat Gah forebay and main inlet valve of Unit 2 for design discharge (New Condition-all units in operation)

Segment Name	Rough-ness Height (mm)	Q (m^3/s)	V (m/s)	Equi-valent n	S_f	L (m)	ΔH_f (m)	% of Total Friction Loss	ΔH_f / km
Concrete Lined Headrace Tunnel, D=5.3 m	0.6	75	3.40	0.0132	0.001373	10,100.7	13.87	68.6%	1.37
Steel Lined Headrace Tunnel, D=4.0 m	0.06	75	5.97	0.0107	0.004058	831.8	3.38	16.7%	4.06
Steel lined Shaft & High-Pressure Tunnel, D=4.0 m	0.06	75	5.97	0.0107	0.004058	594.3	2.41	11.9%	4.06
Steel Penstock, D=3.25 m	0.06	50	6.03	0.0105	0.005267	26.1	0.134	0.7%	5.27
Steel Penstock, D=2.3 m	0.06	25	6.02	0.0102	0.007858	32.3	0.25	1.3%	7.86
Steel Penstock to MIV, D=2.0 m	0.06	25	7.96	0.0100	0.016044	10.1	0.16	0.8%	16.04
Total Friction Loss (m)							20.21	100%	

Table 13-27: Minor losses considered for the Power Waterway along the unit 2 branch for the design discharge

Segment Name	Q (m^3/s)	V (m/s)	Loss Coefficient, k_i	$v^2/2g$ (m)	ΔH_f (m)	Reference
Inlet Mouth	75	1.0	0.160	0.05	0.008	Design of Small Dams, Table 10.1
Stoplogs slot	75	2.7	0.100	0.36	0.036	Design of Small Dams, Page 460
Emergency Gate Slot	75	2.7	0.100	0.36	0.036	Design of Small Dams, Page 460
Intake Transition Rectangle to Circular Section	75	3.4	0.007	0.59	0.004	Crane TP-410
Gabarband Intake Tunnel Junction	75	3.4	0.050	0.59	0.029	Miller's Internal Flow Systems, Figure 13.23
Headrace Concrete to Steel Lined Section Contraction	75	6.0	0.028	1.82	0.050	Crane TP-410
Headrace Steel to Concrete Lined Section Expansion	75	6.0	0.039	1.82	0.070	Crane TP-410
Headrace Concrete to Steel Lined Section Contraction	75	6.0	0.028	1.82	0.050	Crane TP-410
Headrace Vertical Mitre in Concrete Section	75	3.4	0.020	0.59	0.012	Crane TP-410
Headrace Vertical Mitre in Steel Section	75	6.0	0.020	1.82	0.036	USACE EM 1110-2-1602, Plate C-11
Horizontal Bend, R=30 m & θ=4.5°	75	3.4	0.009	0.59	0.005	USACE EM 1110-2-1602, Plate C-10
Horizontal Bend, R=600 m & θ=50.8°	75	6.0	0.030	1.82	0.055	USACE EM 1110-2-1602, Plate C-10
Horizontal Bend, R=2,000 m & θ=27.8°	75	3.4	0.015	0.59	0.009	USACE EM 1110-2-1602, Plate C-10
Surge Shaft Junction	75	6.0	0.050	1.82	0.091	Miller's Internal Flow Systems, Figure 13.23
Butterfly Valve	75	6.0	0.150	1.82	0.272	Design of Small Dams, Page 460
Vertical Bend, R=15 m & θ=90°	75	6.0	0.110	1.82	0.200	USACE EM 1110-2-1602, Plate C-10
Vertical Bend, R=15 m & θ=90°	75	6.0	0.110	1.82	0.200	USACE EM 1110-2-1602, Plate C-10
Bifurcation 1, Main Conduit, θ=70°	75	6.0	0.020	1.82	0.036	I.E.Idel'chik, Diagram 7.23
Bifurcation 2, Branch Conduit, θ=70°	50	6.0	0.570	1.85	1.055	I.E.Idel'chik, Diagram 7.22
Steel Penstock Contraction	25	8.0	0.009	3.23	0.027	Crane TP-410
Total Form Loss (m)					2.285	

13.12.3.3 Total Head Losses

The total head losses for the waterway between the Lower Spat Gah forebay and the main inlet valve of Unit 2 correspond to 22.50 m when all three units are operating at the design discharge. The total head losses are shown in Figure 13-7 as a function of the total plant discharge. The head losses can be approximated with the following relation:

$$\Delta h = 0.0039993 \cdot Q_{tot}^2$$

where Q_{tot} is the total waterway discharge.

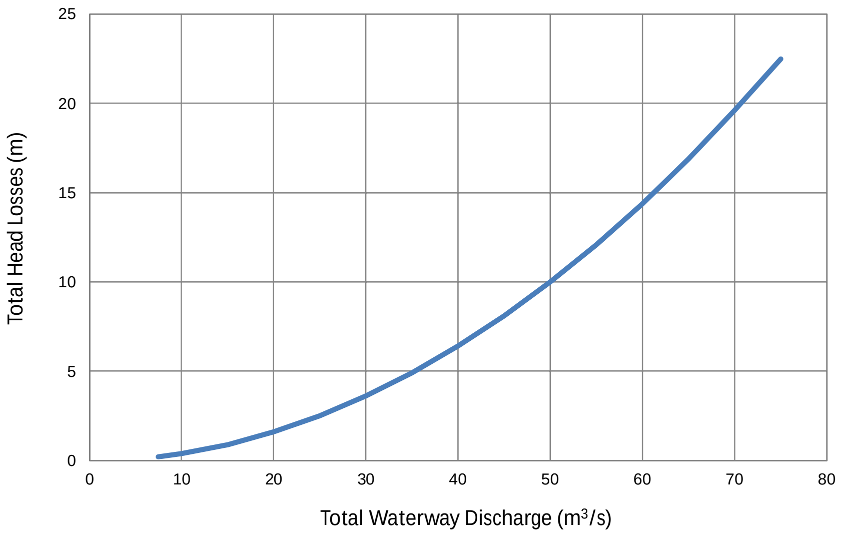


Figure 13-7: Total hydraulic head losses between the forebay and the turbine distributor

13.12.4 Transient Calculations

13.12.4.1 Approach

For the proposed Lower Spat Gah Project hydraulic layout, a preliminary transient analysis has been performed. The aim of this study is the following:

- Simulation of normal and exceptional load cases and evaluate the impact on the proposed waterway,
- Definition of the maximum and minimum dynamic pressure along the Power Waterway as well as maximum upsurge and minimum downsurge inside the Surge Shaft.

13.12.4.2 Software Applied

Bentley HAMMER was used for the transient analysis. HAMMER is an advanced, interactive software package to support hydraulic analysis and simulates the dynamic behaviour of fluids in branched and looped pipelines and full flowing tunnel systems with robust capabilities to model transient behaviour of pumps and turbines.

13.12.4.3 Numerical Model

A numerical model has been elaborated in HAMMER that represents all the relevant characteristics of the waterway. The model starts at the Lower Spat Gah forebay and ends at the turbine nozzles of the Pelton units. It also includes the Gabarband Intake Tunnel starting at the forebay. The forebay is represented as a fixed head at the Full Supply Level and Minimum Operating Level, as these will lead to the highest and lowest dynamic pressures/surges respectively along the waterway and Surge Shaft. The topology of the model is shown in Figure 13-8.

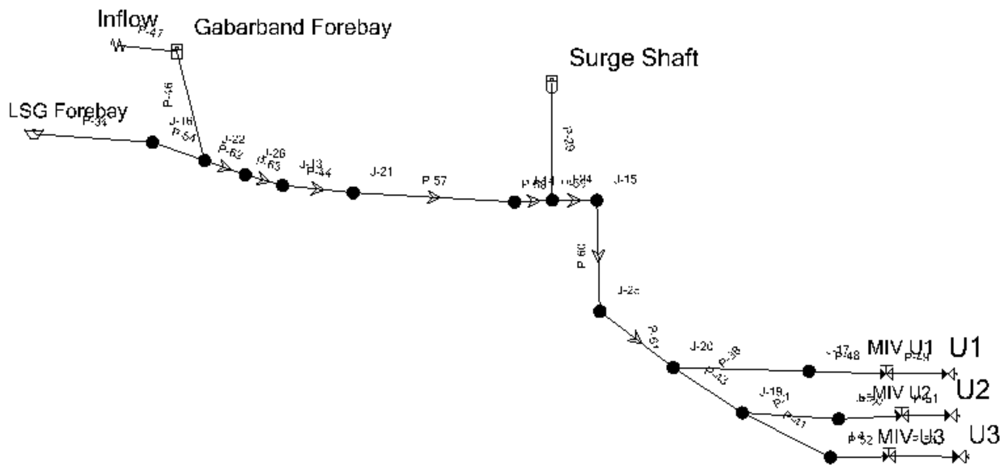


Figure 13-8: Numerical model elaborated for the Power Waterway

13.12.4.4 Waterway Layout

The final layout and characteristics of the Power Waterway with three (3) units, as per the waterway drawings and given in Table 13-28, have been taken as basis to define the model geometry for the water hammer model.

Table 13-28: Waterway characteristics used for the transient analysis

Structure	Parameter	Value
Waterway – Headrace Tunnel; concrete Lined	Type: Diameter (internal):	Circular, in-situ concrete-lined 5.30 m
Waterway – Headrace Tunnel, Pressure Shaft & High Pressure Tunnel; steel lined	Type: Diameter (internal):	Circular, steel 4.00 m
Lower Gabarband Intake Tunnel Pipe	Type: Diameter (internal): Type: Diameter (internal):	Circular, GRP 2.10 / 1.90 / 1.70 m Circular, steel 1.50 m
Penstocks d/s Y-branch 1	Type: Diameter (internal):	Circular, steel 3.25 m
Penstocks d/s Y-branch 2	Type: Diameter (internal):	Circular, steel 2.30 m
Penstocks u/s units	Type: Diameter (internal):	Circular, steel 2.00 m
MIV	Inlet diameter	2.00 m
Turbine	Axis elevation:	765.40 m asl

13.12.4.5 Wave Celerity of Waterways

The average wave celerity in the different parts of the Power Waterway is assessed as follows:

- Concrete lined Headrace Tunnel (D=5.3 m): 1,187 m/s,
- Steel lined Power Waterway sections (D=4.0 m): 940 m/s,
- Penstock (D=3.25 m): 1,097 m/s,
- Penstock (D=2.3 m): 1,177 m/s,

- Penstock (D=2.0 m): 1,207 m/s,
- GRP pipe (D=2.1 m): 348 m/s,
- GRP pipe (D=1.9 m): 344 m/s,
- GRP pipe (D=1.7 m): 343 m/s,
- GRP pipe (D=1.5 m): 1,179 m/s.

The wave celerity depends on various factors such as the definitive lining thicknesses, and Young's modulus of both the lining and the supporting rock mass. The wave celerity values above are to be verified in the subsequent Project phases once the rock parameters are better known and the definitive length of the steel liner has been determined.

13.12.4.6 Closing Laws for Turbines and Valves

The dynamic pressures and mass oscillations resulting from the closing of either the main inlet valve or the turbine will be calculated considering a linear nozzle stroke over the closing time specified. The discharge will then be determined in function of the nozzle stroke according to generic closing laws for Pelton turbines and ball valves. The applied valve's standard characteristic curves are shown in Figure 13-9.

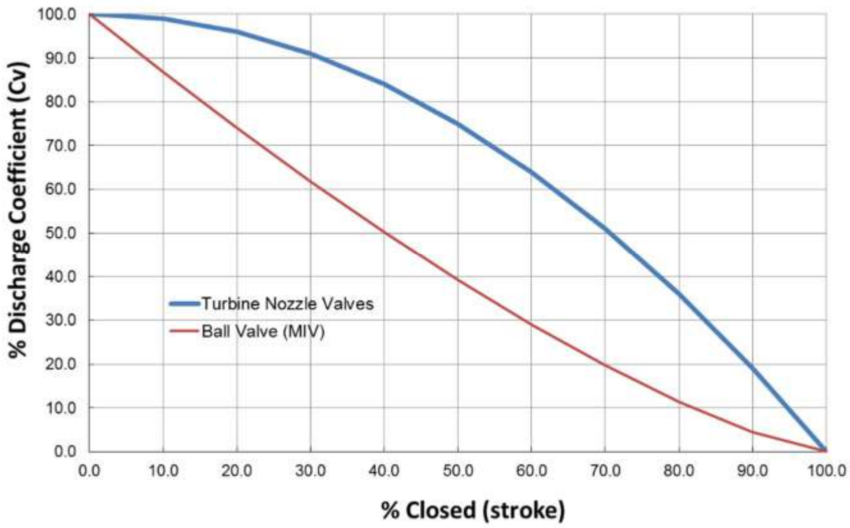


Figure 13-9: Applied valves standard characteristic curves

It is noted that the water hammer calculations are dependent on the closing laws applied. The equipment suppliers shall therefore verify during the tendering stage that the design pressures of the waterways are not exceeded with the closing times specified.

13.12.4.7 Water Hammer Reflection Time and Critical Nozzle Stroke

Load cases LC-3 and LC-4, as defined in Chapter 13.12.4.10, consider the absence of negative wave interference or the positive wave interference of the water hammer shock waves respectively. In order to construct these load cases the reflection time of the waterway between the turbine nozzle and the surge tunnel has to be calculated, which is 1.52 s.

13.12.4.8 Closing Time for Pelton Turbines

A closing time of 40 s has been considered for the turbine nozzle valves in accordance with the 2010 Feasibility Study, which results in admissible dynamic pressures based on the load case simulated. It is recommended to approach NTDC during the next design stage to ensure that such a closure time is acceptable by the grid.

13.12.4.9 Performance Criteria

The applied performance criteria for minimum pressure along the Power Waterway is summarised in Table 13-29. The recommended minimum pressure values are common practice considering the existing range of velocities along the waterway system.

Table 13-29: Applied performance criteria

Structure	Parameter	Value
Waterway	Minimum pressure	58.5 kPa (6.0 m WC) above tunnel soffit

An error margin has been applied to the raw computed data before the comparison with the above performance requirements. Extreme pressures and rotational speed include additional computation uncertainty margin. The uncertainty margin corresponds to 10% of the variation of the examined quantity between its initial condition value and the extreme transient value, to be added to the maximum transient values or subtracted from the minimum transient values.

13.12.4.10 Load Cases for Transient Calculations

The following load cases will be considered for transient calculations:

- LC-1: Full load rejection, while headwater at Lower Spat Gah forebay at FSL,
- LC-2: Standstill to full load, while headwater at Lower Spat Gah forebay at MOL,
- LC-3: Opening and closing in reflection time to and from critical nozzle stroke, while headwater at Lower Spat Gah forebay at FSL,
- LC-4: Emergency closure with main inlet valves, while headwater at Lower Spat Gah forebay at FSL,
- LC-5: Full load rejection and subsequent full load acceptance at the highest inflow discharge from the Surge Shaft, while headwater at Lower Spat Gah forebay at MOL,
- LC-6: Full load acceptance and subsequent full load rejection at the highest outflow discharge from the Surge Shaft, while headwater at Lower Spat Gah forebay at FSL,
- LC-7: Full load acceptance and subsequent full load rejection at the highest inflow discharge into the Surge Shaft, while headwater at Lower Spat Gah forebay at FSL.

To remain consistent with the 2010 Feasibility Study, the two following exceptional load cases have also been evaluated to determine the highest and lowest pressures and Surge Shaft water levels:

- LC-8: Full load rejection and subsequent full load acceptance at the highest outflow discharge from the Surge Shaft and subsequent load rejection at the highest inflow discharge to Surge Shaft, while headwater at Lower Spat Gah forebay at FSL,
- LC-9: Full load acceptance and subsequent full load rejection at the highest inflow discharge into the Surge Shaft and subsequent full load acceptance at the highest outflow from the Surge Shaft, while headwater at Lower Spat Gah forebay at MOL.

All the load cases are carried out under the most adverse headwater levels at the Lower Spat Gah Headworks.

All the load cases have been repeated for the maximum inflow contribution of 10 m^3/s through the Gabarband Intake tunnel to capture the most critical pressure/surge condition in throughout different components of the Power Waterway.

Since the closing time for the desander intake gates is several times longer than the turbine nozzle closing time, no load cases considering the flushing of desander bays need to be considered.

The initial state of the following components is determined based on a steady-state simulation of the initial conditions above:

- Gabarband Intake Tunnel water level,

- Surge Shaft water level.

13.12.4.11 Summary of Results of Transient Calculations

A summary of the maximum and minimum values for critical components along the Power Waterway is presented in Table 13-30. As expected, load case LC-7 is decisive for the maximum overpressures at the turbine distributors, which equals the target dynamic pressure rise of 118% of the gross static head at the main inlet valve. The results of LC-7 for the location of the main inlet valve are shown in Figure 13-10. The figures showing the results of the transient analysis of the critical components in Table 13-30 are presented in Volume 7 – Project Design.

Table 13-30: Summary of results from the transient analysis for critical waterway components

Location	Case	Unit	Raw data	With error margin	Require-ment	Load Case	Remarks
Waterway at most upstream (upper) mitre (at Chainage 4+730.0 m)	Maximum Pressure	m WC	146.7	152.2	-	LC-7	-
	Minimum Pressure	m WC	15.2	9.0	6.0	LC-9	-
Lower Gabarband Intake forebay / Gabarband Intake Tunnel pipe	Maximum Forebay Water Level	m asl	1,550.2	-	-	LC-7	Available freeboard to desander crest level 1.9 m
	Minimum Water Level along Pipe	m asl	1,460.4	1,456.5	-	LC-9	-
Surge Shaft	Maximum Water level	m asl	1,637.1	1,649.8	-	LC-7	Available freeboard to Surge Shaft adit invert about 3 m
	Minimum Water Level	m asl	1,343.3	1,327.7	6.0	LC-9	Available freeboard to Headrace Tunnel junction crown level about 65 m
Headrace Tunnel valve	Maximum Pressure	m WC	375.8	388.5	-	LC-7	-
	Minimum Pressure	m WC	80.6	64.9	6.0	LC-9	-
Upstream of units (MIV)	Maximum Pressure	m WC	873.1	886.1	-	LC-7	-
	Minimum Pressure	m WC	575.9	560.2	6.0	LC-9	-

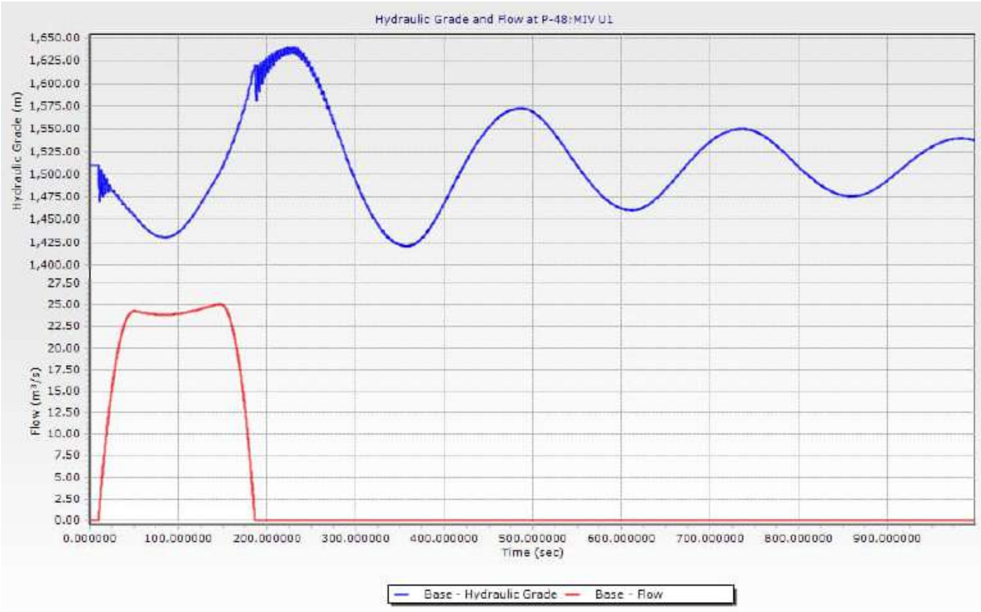


Figure 13-10: Highest dynamic hydraulic grade line (HGL) and discharge at the main inlet valve of Unit 1 (LC-7)

13.12.4.12 Conclusion

The hydraulic transient modelling was undertaken considering the proposed arrangement of the waterway and machines of the Lower Spat Gah Project. The following can be concluded:

- The results of hydraulic transient simulations show the minimum pressures at control points are within the range of the recommended performance criteria,
- The maximum overpressure upstream of the units would reach around 118% of the static pressure.

More detailed modelling, calculations and analysis of the hydraulic transient processes will need to be performed during the Detailed Design phase by the E&M Supplier, taking into consideration all design parameters, all combinations of operating modes and related unit performance data. During the tender process the bidding E&M suppliers shall confirm the suitability of the actual Power Waterway by their own modelling and simulation.

13.13 Gabarband Crossing of Headrace Tunnel

13.13.1 Design Concept

The Headrace Tunnel crosses the Gabarband valley over a length of 86.5 m with an inclination of 0.75% at an axis elevation of about 1,299.6 m asl in the middle of the crossing. This tunnel section has to be protected against erosion triggered from water (Gabarband River) and must be able to tolerate deformations resulting from settlements over the whole service period.

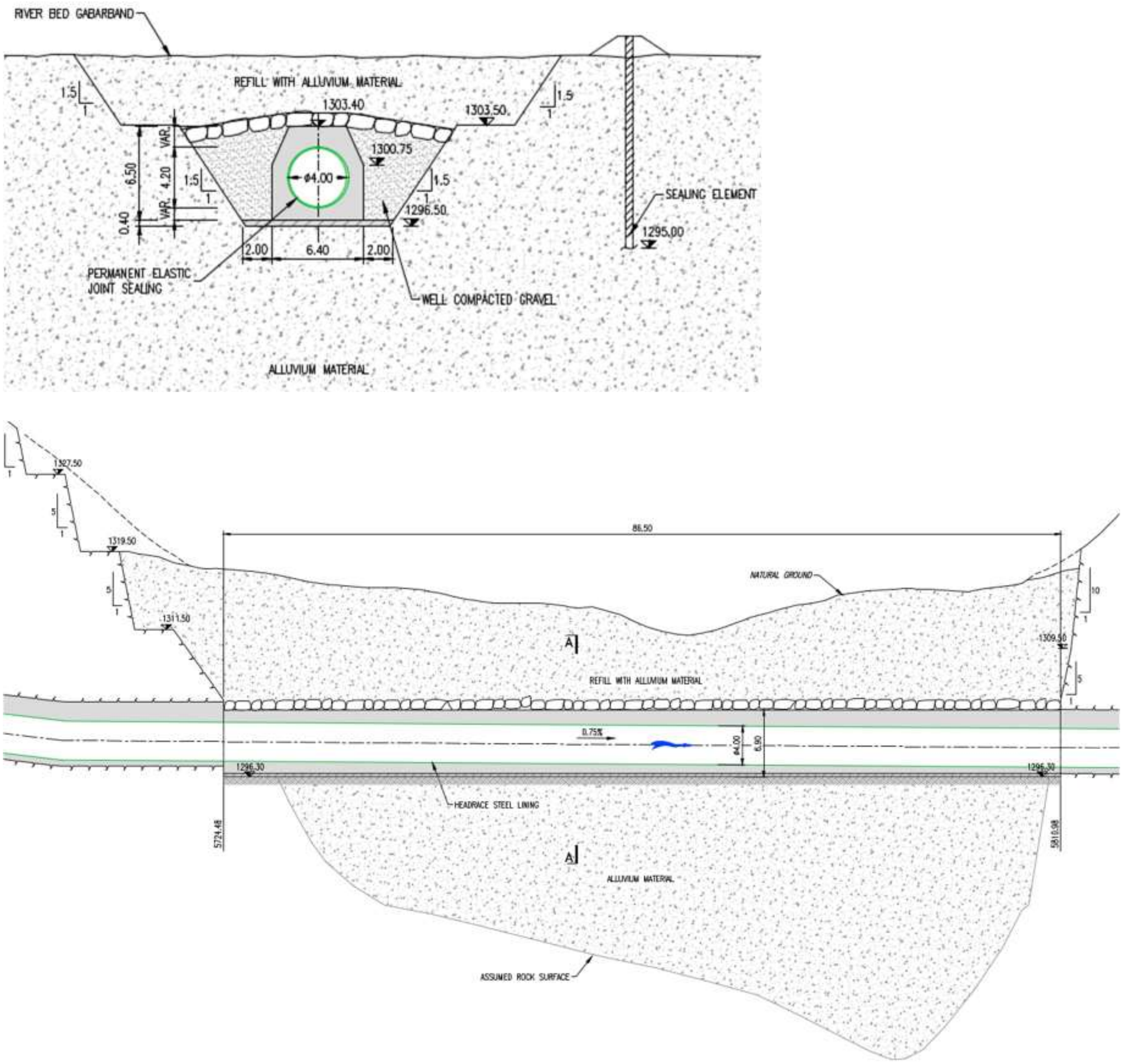


Figure 13-11: Cross section (top) and longitudinal section (bottom) and of Gabarband valley crossing

The Gabarband Crossing design is based on the information from the 2020/2021 geological investigation. Based on the rock outcroppings on both valley sides and the reached bedrock in one borehole, the rock surface in the Gabarband valley is at 30 m and deeper. Because the sound rock is not reachable with a reasonable effort, the Gabarband River will be crossed using a conventional and tailored suited cut and cover solution as follows:

- On both sides of the valley the excavation down to the tunnel level will be in the sound rock such that a temporary tunnel portal can be established.
- The steel pipe with an inner diameter of 4.00 m will be supported by a reinforced concrete cover.
- The reinforced concrete cover/sections with a width of 6.4 m will rest on levelling concrete and well compacted gravel will be backfilled on the side. The subgrade for the gravel consists of well compacted alluvial fill material. Rip rap will be placed on top of the section as a protection. The remaining excavated area will be refilled with alluvium material to restore the natural river course.

- Between the steel pipe and the reinforced concrete cover a permanent elastic joint sealing will be foreseen to tolerate differential settlements and resulting rotations of the concrete cover blocks.

13.13.2 Construction Sequence

A construction in two stages with a river diversion is foreseen. Because of the high permeability of the river deposits and because of space limitations, sealing elements (i.e. diaphragm wall or secant concrete piles) are currently and conservatively foreseen. Even though the works in the river bed is only planned for the dry season, the required river diversion cross section for both phases has conservatively been calculated for a flood event with a return period of 20 years, which is 212 m^3/s.

A cross section with 8 m bottom width and 2H:1V side slopes has been foreseen. The diversion starts about 35 m upstream of the Gabarband Crossing pipe and is released back into the river about 45 m downstream. During the right side works (stage 1), a canal is dredged on the left most side of the valley as shown in Figure 13-12. During the left side works (stage 2), a canal is formed in the re-filled river bed. It is recommended to conduct terrestrial survey at the crossing area to verify the topography and confirm the diversion concept.

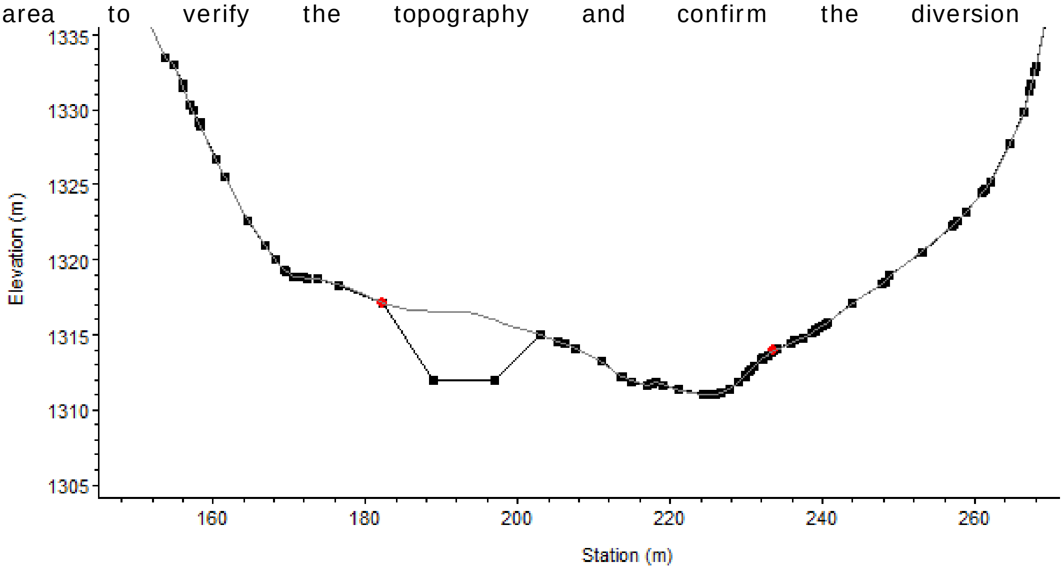


Figure 13-12: Dredging canal cross section during stage 1

Based on the above calculations, a two stage construction sequence is proposed as follows:

- Stage 1: A sealing element upstream and parallel to the crossing as shown in Figure 13-11 starting from the natural ground surface is constructed to seal the open surface excavation pit. The length of this element is assumed to a final elevation of 1,295 m asl but shall be determined in further design stages. A second sealing element is constructed along the river. The Headrace Tunnel section can then be constructed in a dry excavation pit.
- Stage 2: The element which is located parallel to the Headrace Tunnel has to be removed in the upper part to enable the river diversion stage 2. After the successful diversion of the river and the excavation of a dry open surface excavation pit by using sealing elements, the remaining sections of the Headrace Tunnel can be constructed.

13.14 Constructional Aspects

13.14.1 Construction Risks

In order to comply with the Project objectives and as an important part of a cost estimate the risk assessment for the Project shall be carried out in each design stage. Potential hazards and their consequences should be identified. The time and cost impact of risks is evaluated and measures are foreseen to mitigate these risks. Particular attention is paid to the geotechnical risk for which a detailed geotechnical safety management plan is to be elaborated. The results of the risk assessments have to be examined with respect to avoiding, transferring or accepting particular risks. Risk management shall cover possible deviations from the Project objectives. The potential for deviation depends on the particular Project stage and decreases with the degree of completion of the Project. The cost estimate produced at a particular design stage must appreciate the result of the risk assessment. A certain amount of provisions shall be allocated to the identified risks.

For all risks which have to be evaluated in the Project, a risk scenario shall be defined. The incident, its reasons and the consequences have to be identified. To evaluate the risk and to identify the associated cost and/or time implication, a definition of the standard project parameters and the particular case which occurs as a result of the risk incident shall be provided.

Table 13-31 includes the most important risks for the waterway that have to be managed in this Project.

Table 13-31: Waterway excavation risks, consequences and mitigation measures

Risk	Impact	Mitigation Measure
Unforeseen subsurface conditions e.g. misjudgement of ground properties.	Increased construction time, higher costs	Thorough geological and geotechnical investigation programme, provide adequate contingencies
Unexpected system behaviour (ground-support interaction)	Overstressing, damage, defective materials, collapse of excavation face, excessive ground surface settlement	Adjustment within the chosen construction method (adapt support class)
High ground water level	Water inflow, unforeseen water chemical action, unforeseen water level, wells	Grouting of tunnel face in advance of excavation
Large overburden	Rock bursting and rock squeezing caused by high primary stress	Additional support of tunnel side walls with wire mesh for better support classes.

13.14.2 Minimum Cross Section for Construction

For the construction a minimum section of 4 m width and height with bypass niches is required to ensure sufficient space for manoeuvring and proper ventilation.

An exception is the mucking tunnel for the Surge Shaft where the cross section was decreased as much as possible to minimise the concrete volume of the plug. Because of the short length (<50 m) an inner cross section of 3.50 m width and height is found sufficient for construction purposes.

13.14.3 Planned Construction Sequence

The Headrace Tunnel shall be excavated from 4 faces in parallel: i) from the Lower Spat Gah Headworks area in the downstream direction, ii) from the two construction adits in the Gabarband valley crossing in the upstream and the downstream directions, as well as iii) from the Upper Erection and Gate Chamber at the downstream end of the Headrace Tunnel in the upstream direction.

The Surge Shaft and the Pressure Shaft shall both be excavated with the vertical raise drill method.

The Pressure Shaft shall be excavated with the same cross section as the Headrace Tunnel. The steel liner shall be erected using an erection crane at the Upper Erection and Gate Chamber and the remaining area of the cross section shall be backfilled with unreinforced concrete.

The Tailrace Tunnel shall be excavated from downstream to upstream starting from the Tailrace Tunnel Outlet Structure at the Indus River at an elevation that is currently well above normal and flood water levels.

13.14.4 Construction Adits and Access Roads

13.14.4.1 Gabarband Valley Adits

A construction adit is foreseen at the right bank (Adit Tunnel RB). This tunnel will only be in use during the envisaged construction time.

- Length: 136 m,
- Inclination: 12.0%,
- Cross section: 4.30 m width / 4.40 m height.

The adit portal location has been optimised based on the geological conditions. The invert of the portal is at 1,310.10 m asl, which is above the 50-year flood of 1,306.69 m asl.

The adit will be plugged at the end of the construction works. The 24 m long concrete plug is located next to the Headrace Tunnel.

At the left bank an adit is foreseen which shall be used for construction, but will also serve as the dry access tunnel to the Gabarband Intake Tunnel during operation of the power plant (Adit Tunnel LG/ Access Gabarband Intake).

- Length: 442 m,
- Inclination: 12.0/2.0%,
- Cross section: 5.50 m width / 5.25 m height.

The location of the adit portal has been selected based on the topographic and geological conditions at the crossing. The adit portal invert has been placed at 1,306.40 m asl, which is above the 50-year flood level of 1,304.50 m. The tunnel runs parallel to the valley at an inclination of 12.0% in order to cross the Headrace Tunnel at a minimum vertical distance of 20 m for stability purposes. The crossing distance is considered adequate because the Headrace Tunnel is fully lined in this area and thus the adit is not draining the pressurised Headrace Tunnel. After the crossing the adit has an inclination of 2.0% to connect to the junction chamber of the Gabarband Intake Tunnel with the Headrace Tunnel. The vertical layout of the adit allows for natural drainage of the adit itself but also from the Gabarband Intake Tunnel.

13.14.4.2 Adit to Upper Erection and Gate Chamber

An emergency butterfly valve is located in the Upper Erection and Gate Chamber at the upper part of the Pressure Shaft. An adit tunnel shall provide access for construction purposes of the Headrace Tunnel and Pressure Shaft but shall also serve as permanent access to the chamber during the operation of the plant.

- Length: 470 m,
- Inclination: 1.0%,
- Cross section: 5.50 m width / 5.25 m height.

13.14.4.3 Adit to Surge Shaft Chamber

A construction adit is required to build the chamber at the top of the Surge Shaft and construct the surge shaft. This tunnel will used during the construction and for maintenance during operation as required.

- Length: 44 m,
- Inclination: 10%,
- Cross section: 5.50 m width / 5.55 m height.

13.14.4.4 Passing and Turning Niches

Passing and turning niches are foreseen every 500 m (not shown on the drawings) for the Headrace Tunnel, Tailrace Tunnel and Emergency & Ventilation Tunnel. However, this will strongly depend on the needs of the construction company and whether conveyor systems will be used or not. Also, equipment niches will be based upon the contractor's preference.

13.14.5 Care of Water

Water shall be harnessed with mats and pipes and diverted into the longitudinal channel situated on one side of the tunnel. In case of downwards excavation, pumps need to be installed and the drained water has to be pumped out of the tunnel.

13.14.6 Required Site Installations and Installation Areas

An overview of all construction camps and spoil areas with the related areas is provided on the Project layout drawing.

At the Lower Spat Gah Headworks, a construction camp is foreseen at the right bank downstream of the Dar-Mose area.

On the right bank of the Gabarband valley a construction camp is planned near Sachoi village.

13.14.7 Spoil Area Requirements

At Upper Erection and Gate Chamber adit portal a disposal area is foreseen (Area #1).

At the Indus River left bank between the Tailrace Tunnel and the Powerhouse Cavern Main Access and Power Evacuation Tunnel two disposal areas are planned (Area #2 and 3).

At the Gabarband valley a disposal area between the villages of Sachoi and Thoki on the right bank is foreseen (Area #4)

At the Lower Spat Gah Headworks an additional spoil area (Area #5) is foreseen because a part of the excavated tunnel material is planned to be used as fill material for the dam.

All spoil disposal areas are next to the rivers and not partially in them. They will be designed and built such that the mucking material will also not end up in the river.

13.15 Standards, Codes and Guidelines

The following appropriate international standards, manuals and guidelines have been used for the Headrace Tunnel civil design works of the Feasibility Study:

- Amstutz. 1969. Das Einbeulen von Schacht- und Stollenpanzerungen. Schweizerische Bauzeitung.
- ASCE. 1989. Civil Engineering Guidelines for Designing and Planning Hydroelectric Developments Volumes 2.
- ASCE. 1995. Guidelines for Design of Intakes for Hydroelectric Plants.
- ASCE. 2003. Journal of Hydraulic Engineering, Boes R.M. and Hager W.H., Hydraulic design of stepped spillway.
- Brox, D. 2018. Hydropower tunnel failures – risks and causes. London engineering group conference 2018 – Chesham, England, October 18.-19., 2018.
- Fenner, R. 1938. Untersuchungen zur Erkenntnis des Gebirgsdrucks. Glückauf, Jg. 74.
- Jacobsen, S. 1974. Buckling of circular rings and cylindrical tubes under external pressure. Water Power, Volume 26.
- Marence, M. 2010. Geotechnical input essential for power waterway design. Rock engineering in difficult ground conditions – Vrkljan. Taylor & Francis Group, London, 2010.
- Müller, L. 1978. Der Felsbau – Band 3 Tunnelbau – Ferdinand Enke Verlag, Stuttgart.

- Pacher, F. 1964. Deformationsmessungen im Versuchsstollen als Mittel zur Erforschung des Gebirgsverhaltens und zur Bemessung des Ausbaus. Felsmechanik und Ing. Geologie.
- Schleiss, A 2005. Bemessung von Entlastungsventilen zur Beulsicherung von Druckschacht-Panzerungen gegen Außendruck. Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie, Festkolloquium 7.Oktober 2005, 75 Jahre VAW.
- Schleiss, A. 1988. Design criteria applied for the low pressure tunnel of the North Folk Stanislaus River Hydroelectric Project in California. Rock Mechanics and Rock Engineering 21, 161 – 181 , Springer 1988.
- Schleiss, A. 1997. Design of reinforced concrete linings of pressure tunnels and shafts. Hydropower and dams, Issue three, 1997.
- Seeber, G. 1982. New ways for the construction of pressure tunnels. ISRM Symposium Aachen, 1982.
- USACE. 1980. EM 1110-2-1602. Hydraulic Design of Reservoir Outlet Work. U.S. Army Corps of Engineers. Washington D.C.
- USACE. 1997. EM 1110-2-2901. Tunnels and Shafts in Rock. U.S. Army Corps of Engineers. Washington D.C.
- USBR. 1987. Design of Small Dams. United States Department of the Interior, Bureau of Reclamation. A Water Resources Technical Publication.

14 Civil Design – Powerhouse

Corresponding Drawings

LSG-FS-090-001	Powerhouse, Layout, Overview Plan
LSG-FS-090-002	Powerhouse, Layout, Plan View
LSG-FS-090-003	Powerhouse, Tailrace Tunnel, Plan View at El. 757.60 m asl
LSG-FS-090-004	Powerhouse, MIV Floor, Plan View at El. 762.40 m asl
LSG-FS-090-005	Powerhouse, Turbine Floor, Plan View at El. 768.00 m asl
LSG-FS-090-006	Powerhouse, Generator Floor, Plan View at El. 772.60 m asl
LSG-FS-090-007	Powerhouse, Machine Hall Floor, Plan View at El. 778.60 m asl
LSG-FS-090-008	Powerhouse, GIS Floor and Machine Hall Crane Floor, Plan View at El. 790.50 m asl
LSG-FS-090-009	Powerhouse, Section A-A, Unit Axis
LSG-FS-090-010	Powerhouse, Section B-B, Penstock and Turbine Axis
LSG-FS-090-011	Powerhouse, Section C-C, Main Access and Power Evacuation Tunnel
LSG-FS-090-012	Powerhouse, Main Access & Power Evacuation Tunnel, Profile & Typical Section
LSG-FS-090-013	Powerhouse, Emergency and Ventilation Tunnel, Profile and Typical Section
LSG-FS-090-014	Powerhouse, Rock Support and Excavation Sequence, Typical Sections
LSG-FS-090-015	Powerhouse, Excavation - Schematic Sequence, Step 00 - Step 03
LSG-FS-090-016	Powerhouse, Excavation - Schematic Sequence, Step 04 - Step 06
LSG-FS-090-017	Powerhouse, Excavation - Schematic Sequence, Step 07 - Step 10
LSG-FS-090-018	Powerhouse, Excavation - Schematic Sequence, Step 11 - Step 12
LSG-FS-090-019	Powerhouse, Rock Support Classes, Main Access & Power Evacuation Tunnel
LSG-FS-090-020	Powerhouse, Rock Support Classes, Emergency & Ventilation Tunnel / Emergency & Power Evacuation Tunnel

14.1 Introduction

The Lower Spat Gah HPP involves the construction of an underground Powerhouse complex with 470 MW Installed Capacity that is located at the left bank of the Indus River about 1.3 km upstream of the confluence with the Spat Gah River and 800 m below natural ground level including the following structures:

- Machine hall with dimensions of 91.2 m length, 45.1 m height and 31.9 m span (26.5 m span between EOT crane superstructure) housing three machine bays, one erection and unloading bay and one dewatering pit,
- Transformer Cavern with dimensions of 88.7 m length, 17.1 m height and 17.95 m span (16.3 m span between columns) housing three three-phase transformer cells 9.1 m wide each, and the 15.5 m long and a gas insulated switchyard (GIS),
- Three (3) Insulated Phase Busbar (IPB) galleries with dimensions of 48.0 m length, 7.70 m height and 8.20 m span each and three (3) Tailrace Tunnels merging into one tunnel.

The main purpose of the Powerhouse is to house the mechanical and electrical equipment required for the three Pelton turbine sets with a spacing of 25 m between units. The above and the layout of the caverns complex in general are indicative at this stage and shall be viewed with caution. As usual in the hydropower industry, the layout of both caverns will be subject to a final space-proofing assessment after contract awards in close cooperation with the appointed E&M supplier.

14.2 Design Criteria

This chapter outlines the particular functional and operational requirements of the Powerhouse.

14.2.1 General Arrangement

The Lower Spat Gah Powerhouse will be a drained underground facility comprising:

- A Power Cavern housing three Pelton turbines generating units blocks, a control room and all associated electro-mechanical auxiliaries required for operation of the power station. The erection bay will allow the indoor pre-assembly of the generator rotor and stator during installation and maintenance of the equipment,
- A Transformer/GIS Cavern housing the three station’s transformers, power transmission equipment and the GIS,
- Three IPB galleries connecting both caverns.

Caverns having straight walls appear feasible for the expected geological conditions, however, preference has been given to caverns having slightly curved walls to offer more flexibility in design in the event the geological conditions are worse than currently expected and to take advantage of the space left available between the structural C line and the columns supporting the concrete structures above the machine hall and transformers hall floors above.

For the purpose of the caverns and main equipment layout, it was considered that the Project will use a rated head difference of 722.08 m between the Lower Spat Gah Headworks forebay and the Tailrace structure to produce 478.0 MW at the turbine shaft in generation mode at a rated discharge of 75 m^3/s and that the three Pelton units will operate at a speed of 428.57 rpm. Accordingly, the Powerhouse has been designed around the following main electro-mechanical equipment:

- Turbine: 3 Pelton units with vertical axis
- Centre line: 765.40 m asl
- Tailrace water level: 762.40 m asl
- Main inlet valve: 3 spherical valves, diameter 2,000 mm
- Generator: 3 synchronous generators, 428.57 rpm
- Main transformer: 3 step-up transformers, 190 MVA, 220 kV
- Machine hall crane: 1 indoor overhead bridge crane, 300 t

The elevation of the Powerhouse was defined by the centre line of the three Pelton units set out at 765.40 m asl. In the close vicinity of the caverns complex, steel lined High Pressure and concrete lined free-flow Tailrace Tunnels will be provided to connect the Headrace and the Tailrace Tunnels respectively and prevent high leakages from entering the caverns.

In the lower section (up to elevation 778.60 m asl) the interior concrete work of the Power Cavern will consist of reinforced concrete in which the three units will be embedded allowing a safe and efficient transfer of turbine and generator loads to the surrounding rock mass.

From elevation 778.60 m asl upwards, reinforced concrete columns and machine hall crane beams will have to be constructed. The loads from the machine hall crane will be directly transferred to the reinforced concrete sections below and the rock mass via the crane beam supported on columns.

Following the notification of the exact loads from the selected E&M supplier, a detailed structural analysis of the whole structure shall be carried out during detailed design stage and therefore it cannot be excluded that some of the concrete thicknesses will have to be adjusted accordingly.

14.2.2 Main Access and Power Evacuation Tunnel

The Main Access and Power Evacuation Tunnel (MAPET) shall be sized to be sufficient for construction, operation and maintenance activities as it must be capable of accommodating all equipment and plant required to enter the station, water discharge and firefighting pipework, lighting, power evacuation cables and/or ventilation ducts. The Main Access and Power Evacuation Tunnel was also sized to bring in the steel pipes to be installed at the High Pressure Tunnel.

As the Main Access and Power Evacuation Tunnel approaches the caverns, it will branch to permit vehicular access to the erection bay at the machine hall floor of the two caverns. The tunnel shall also be sized to facilitate the removal of all items of plant and equipment transiting and/or being installed at the Power Caverns complex.

14.2.3 Emergency and Ventilation Tunnel

The Emergency and Ventilation Tunnel shall be sized to permit vehicular access being understood that major equipment and plant will not enter via this route and be sufficient for emergency and ventilation purposes. The Emergency and Ventilation Tunnel enters the Transformer Cavern along the edge furthest from the generating unit No. 1.

14.2.4 Access in General

Hatches

The machine bays will be provided with easily accessible removable hatches for all floors above the MIV floor level to allow loads and large equipment to be moved by the main EOT crane through all levels of the station.

Egress Paths

All areas will be provided with at least two paths of egress where there exists a feasible event that could cause one egress route to become impassable. Services will not be located along arterial egress paths which have to be arranged in a way so that an intuitive path is provided.

Ladders

The use of ladders to provide access to areas and/or particular equipment and plant shall be avoided as much as possible. Where this is not practically possible, ladders have been proposed.

Elevators For Access Paths

The Power Cavern will be provided with stairwells and one liftwell providing access through all levels below the machine hall floor. In addition, two stairwells located at both ends of the Transformer Cavern will provide access through the two floors of this cavern.

Influence of Structural Arrangement

The structural arrangement will ensure that sufficient space is provided to key areas (e.g. generator lower guide, thrust bearing and brake area and upper generator rotor) around equipment and plant to facilitate maintenance tasks without requiring significant disassembly. The top of the transformers shall be accessible via integrated access system to facilitate inspection and maintenance of components such as seals, fasteners and instrumentation.

14.2.5 Power and Transformer Caverns

In addition to the general requirements outlined above, the power and the GIS/Transformer Cavern shall be designed in such a way that:

- The arrangement of mechanical and electrical equipment will be unitised and physically separated in order to, as much as possible, promote correct identification of plant and make simple exclusion during maintenance activities,
- A unitised arrangement shall be provided as much as possible whereby all associated auxiliary equipment can be located within the same bay,
- It is accessible from the MAPET and incorporates one erection/unloading bay aligned along the edge furthest from the generating unit No. 1,
- The hydraulic layout of the plant shall be symmetric,

- All three three-phase transformers will be located in individual fire-separated enclosures with a removable and re-constructible front fire and explosion resistant walls to facilitate maintenance,
- The transformers will be able to be relocated from their enclosure in the transformers cavern into the machine hall via mobile shifting tracks,
- The Emergency and Ventilation Tunnel will meet the station complex at the western end of the Transformer Cavern,
- The Emergency and Power Evacuation Tunnel will meet the station complex at the eastern end of the Transformer Cavern near the GIS to minimise the length of and the complexity of electrical cables and busbars.

The permanent main station crane (EOT crane) will be supported by a system of reinforced concrete beams and columns. It is advised to construct a temporary crane beam anchored to the rock with post tensioned tendons and install one or two temporary cranes to accelerate the works and bring the completion date of the Power Caverns complex forward.

14.2.6 Layout and Rooms

The final caverns complex arrangement shall be based on the minimum room area and height requirements. It is noted that a preliminary space proofing has been undertaken by the Consultant to obtain the dimensions of all main generating equipment and electrical and mechanical balance of plant defined in chapter 15 as basis for the plant layout.

14.2.7 Plant Maintenance

The structural arrangement of the caverns complex shall enable:

- All plant is provided with access that will facilitate periodic inspection, maintenance and testing,
- Maintenance of plant can be undertaken without requiring the disassembly of un-associated generation equipment,
- The removal of the turbine to the machine hall floor without requiring the removal of the generator through the incorporation of an intermediate shaft and suitable handling equipment,
- Auxiliary equipment located within the transformer enclosure to be removed without requiring the removal of the transformers.

14.3 Powerhouse Layout

14.3.1 General

The general layout of the Powerhouse is shown in the Figure 14-1 to Figure 14-4.

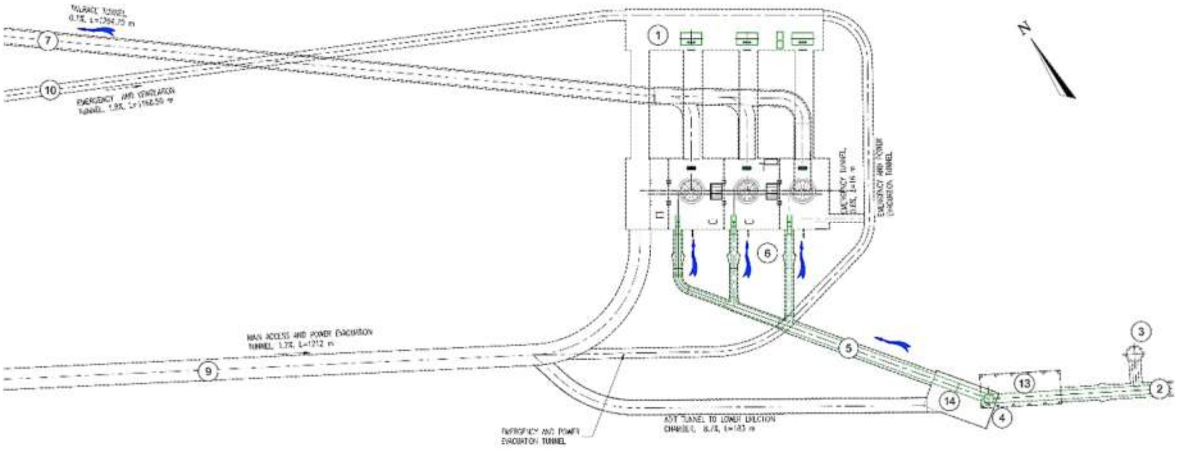


Figure 14-1: Powerhouse layout and plan view

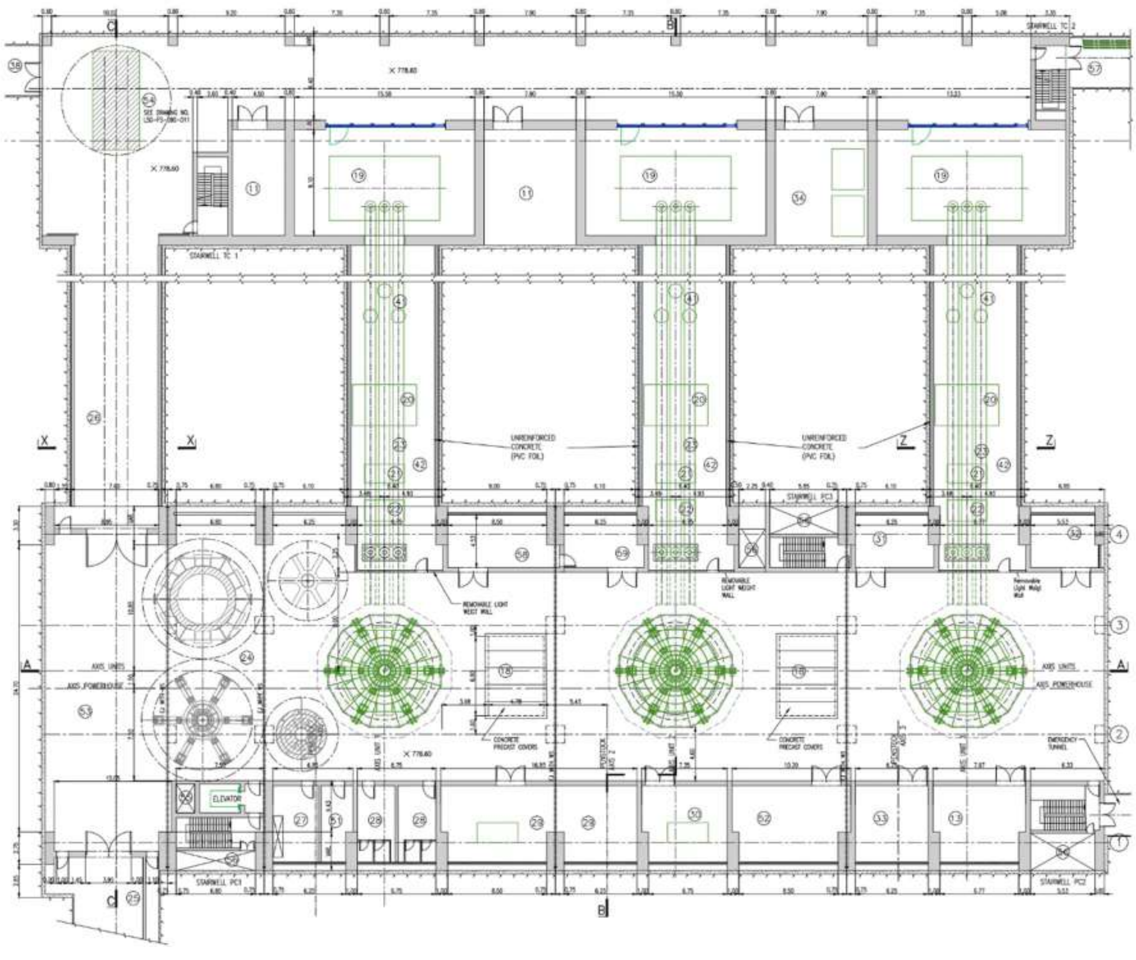


Figure 14-2: Machine hall floor - plan view at elevation 778.60 m asl

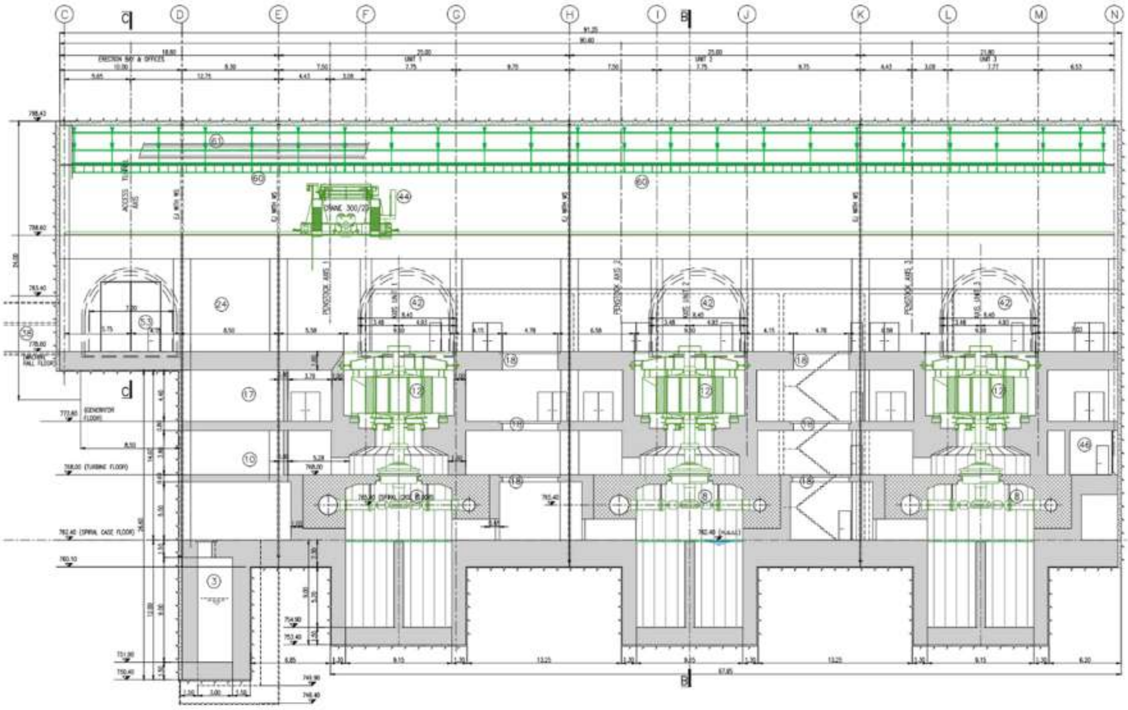


Figure 14-3: Section A-A – unit axis

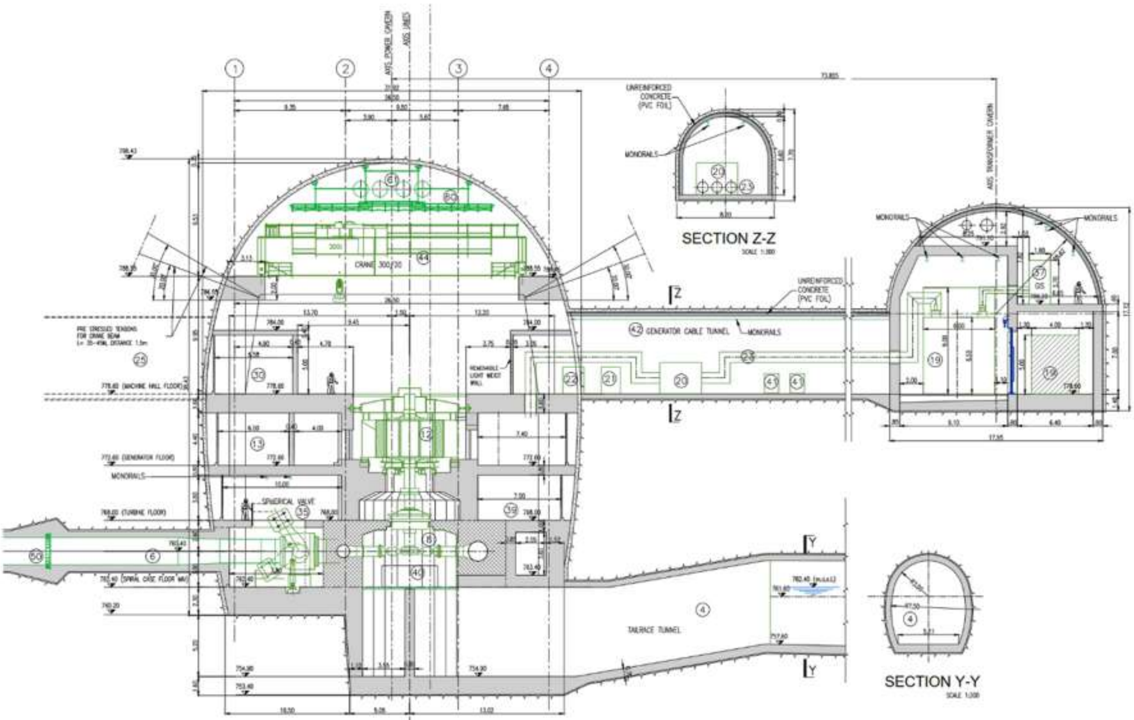


Figure 14-4: Section B-B – Powerhouse and Transformer Caverns

14.3.2 Vertical Connections

The different floors will be connected with stairwells or ladders as follows:

- Stairwells: Three main stairwells above the MIV floor in the Power Cavern and two above the machine hall floor in the Transformer Cavern,
- Ladders: The dewatering and drainage sump, the oil separator and the machine hall crane will be accessible using steel ladders after the removal of concrete pre-cast hatches at the bottom of the cavern,
- Hatches and erection openings: The Power Cavern will be provided with two hatches installed between units 1-2 and 2-3 for the installation and maintenance of the main inlet valves using a system of rails and monorails fixed to the bottom of the turbine floor above. These hatches will also be used for the maintenance of the runner and all other smaller equipment found at the MIV floor. A third larger hatch will be provided in the Transformer Cavern for the erection of the GIS.

14.3.3 Horizontal Layout

The horizontal layout with a list of all main plant components per floor is given in Table 14-1 and Table 14-2 for the Power Cavern and the Transformer Cavern/IPB Tunnels respectively.

Table 14-1: Horizontal layout of Power Cavern

Floor Level	Rooms and Equipment
Tailrace Tunnel El. 757.60 m asl	- Turbine Pit U1-3 - Tailrace Tunnel U1-3 - Drainage and Dewatering Sump - Oil Separator
MIV Floor El. 762.40 m asl	- Inlet Valves U1-3 - Turbine Spiral Case and Runner U1-3 - Runner Maintenance Shaft
Turbine Floor El. 768.00 m asl	- Cooling Water Equipment - HPU for Turbines U1-3 - HPU MIV U1-3 - Low Compressed Air Room - Lubrication Oil Storage - Firefighting Room - Industrial and Domestic Water Distribution
Generator Floor El. 772.60 m asl	- Generators U1-3 - MV Switchgears - LV Switchgears - MV Transformers - Battery Room - HVAC Room
Machine Hall Floor El. 778.60 m asl	- Erection Bay - Unloading Bay - Control Room - Server Room - Mechanical Workshop - Electrical Workshop - Medical Supply / Emergency / First Aid Room - Lockers - Toilets Male/Female

Floor Level	Rooms and Equipment
	- Meeting Room / Office - Kitchen / Dining Room - LV Switchboard
Machine Hall Crane Floor El. 790.50 m asl	- Machine Hall Crane

Table 14-2: Horizontal layout of Transformer Cavern and IPB Tunnels

Floor Level	Rooms and Equipment
Machine Hall Floor El. 778.60 m asl	- Excitation Transformer - Breaking Switch - Generator Circuit Breaker - Isolated Phase Bus Duct - 3 Phased Transformer - Fire Fighting System Transformer - Transformer Rotating Area
GIS Floor El. 786.20 m asl	- GIS

14.4 Health, Fire Life Safety and Emergency Considerations

14.4.1 Fire Hazard and Smoke Extraction

It was briefly checked that the volumes inside the caverns shall be sufficient to accommodate the main ducts for fresh air supply and smoke extraction.

A smoke extraction system will collect smoke at any level and extract it to surface via the Main Access and Power Evacuation Tunnel. A separate smoke extraction shaft will be provided inside the Power Cavern near the stairwell No. 1.

14.4.2 Medical and First Aid Room

The medical supply, emergency and first aid room will be located at the machine hall level near the Main Access and Power Evacuation Tunnel.

14.4.3 Fire Zones

The Powerhouse complex will be divided into fire zones by incorporating fire barriers, separated by fire and pressure retaining doors. Each floor will be a separate fire zone and all vertical openings shall be closed with fire-proof and smoke-proof material. A physical separation between the units is not foreseen. The main hatches will be closed with removable pre-cast concrete covers.

The following design philosophy was followed by the Consultant for space proofing assessment and layout arrangement of the caverns complex based on experience gained on similar projects:

- Stairwells: All stairwells will be separate fire zones with concrete casing and pressurised ventilation to be designed by the E&M supplier,
- MIV floor: No separation between the units and between upstream and downstream,
- Turbine floor: No separation between the units. The turbine pit will be a separate fire zone separated from the upstream and the downstream areas. Low compressed air and lubrication oil storage rooms will also be separate fire zones,

- Generator Floor: No separation between the units. The generator pit will be a separate fire zone and the downstream and upstream areas will be separate fire zones as well. Separate zones are foreseen for the mechanical and electrical balance of plant equipment such as the HVAC room, battery room, LV/MV/switchboard and MV transformers. The generator room will form a separate fire zone for each unit with a separate fire extinguishing concept,
- Machine hall floor: No separation between the units and to the erection/unloading bay foreseen. The unit control and protection rooms, the electrical and mechanical workshops, the control room, and other rooms (e.g. office, meeting room, toilet, locker, kitchen, storage, etc.) at the Power Cavern will be separate fire zones,
- Each and every IPB gallery will form a fire zone separated from the Power and Transformer Caverns,
- The Transformer Cavern will house three transformer cells which will be a separate fire zone with its own extinguishing concept. The GIS floor will also be a separate fire zone.

14.4.4 Stairwells and Escape Routes

A modern powerhouse requires a redundant access system in case the main entrance is blocked. In accordance with international standards, the Power Cavern will be provided with three stairwells giving access through all levels above the MIV floor and two of them will be located at both ends of the cavern with direct access to the main access and the Emergency and Ventilation Tunnel. Similarly, the Transformer Cavern will be equipped with two stairwells with direct access to the Emergency and Ventilation Tunnel. All stairwells will be pressurised and closed with concrete walls.

Panels and emergency lights throughout all floors of the Powerhouse will indicate the closest stairwell. Stairwells will be constantly kept under light and over-pressure from the HVAC system, preventing smoke from entering.

In case of an emergency evacuation several escape routes can be used. The Main Access and Power Evacuation Tunnel will be provided with a separated walkway for evacuation to the surface safe from smoke inhalation. In addition an Emergency and Power Evacuation Tunnel with three access points at the opposite side of the caverns is designed which is connected to the Main Access and Power Evacuation Tunnel. A third escape route is provided by the Emergency and Ventilation Tunnel.

14.4.5 Anchoring of the MIV Forces

The MIV forces resulting from the closure of the MIV will be transferred to three anchor blocks made of reinforced concrete located circa 15.0 m upstream of the Power Cavern via the steel penstock and stiffener ring(s). From this anchor block on, the force will be transferred to the surrounding rock.

The final location of the anchor blocks will have to be coordinated with the E&M supplier and the designer of the steel lining to ensure that the walls of the Power Cavern are not stressed beyond their expected design capability.

14.4.6 Main Access and Power Evacuation Tunnel

The main dimensions of the Main Access and Power Evacuation Tunnel have been selected in such a way to guarantee the transport of the largest equipment parts into the cavern and the lower erection chamber, the main transformer in this case as shown as the red line in Figure 14-5. The Main Access and Power Evacuation Tunnel to the Power Cavern will house physically separated evacuation tunnel and smoke extraction ducts, power evacuation cables, the cavern exhaust air, the firefighting pipe and several other supply cables and pipes.

The portal of the Main Access and Power Evacuation Tunnel will be located close to the construction camp and will connect to the erection/unloading bay of the Power Cavern. It has a length of 1,212 m between the portal and the Power Cavern, and a downwards slope to the cavern of 1.7%.

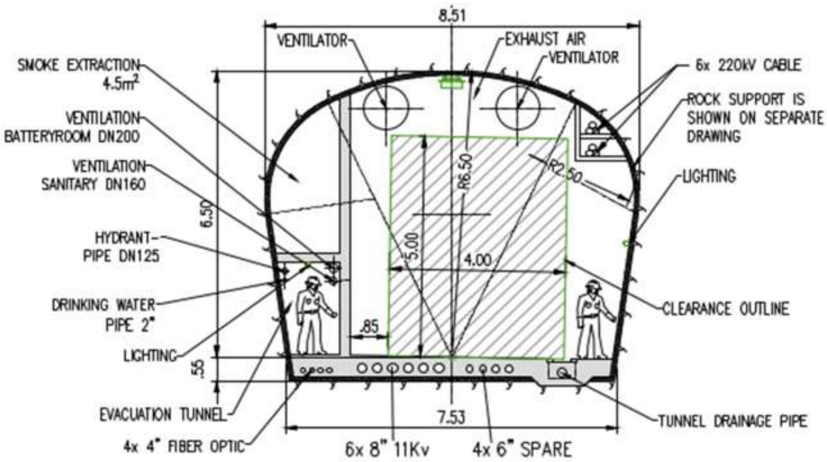


Figure 14-5: Main Access and Power Evacuation Tunnel – typical section

The layout of the Main Access and Power Evacuation Tunnel is shown on the overview drawing while the profile and the typical section are shown on the respective drawing of the powerhouse feature in Volume 14 of this Feasibility Study. The excavation of the tunnel will be executed with the conventional drill and blast method. The excavation support classes are also shown on the respective powerhouse drawing.

14.5 Emergency and Ventilation Tunnel

The main dimensions of the Emergency and Ventilation Tunnel have been selected in such a way to provide vehicular access and space for ventilation as shown in Figure 14-6.

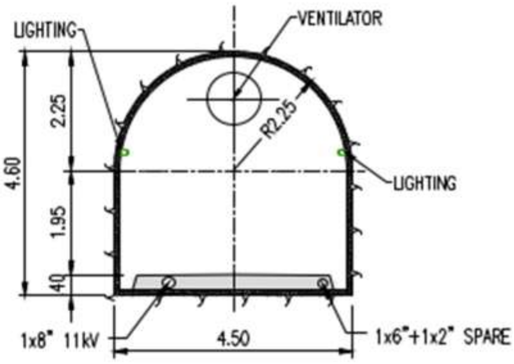


Figure 14-6: Emergency and Ventilation Tunnel – typical section

The layout of the Emergency and Ventilation Tunnel is shown on the overview drawing while the profile and the typical section are shown on the respective drawing of the powerhouse feature in Volume 14 of this Feasibility Study.

The portal of the Emergency and Ventilation Tunnel will be located close to the construction camp and will connect to the Transformer Cavern. It has a length of 1,167 m between the portal and the Power Cavern, and a downwards slope to the cavern of 1.8%.

The excavation of the tunnel will be executed with the conventional drill and blast method. The excavation support classes are also shown on the respective powerhouse drawing.

14.6 Emergency and Power Evacuation Tunnel

The main dimensions of the Emergency and Power Evacuation Tunnel have been selected in such a way to provide vehicular access and space for ventilation as well as the 220 kV cables as shown in Figure 14-7.

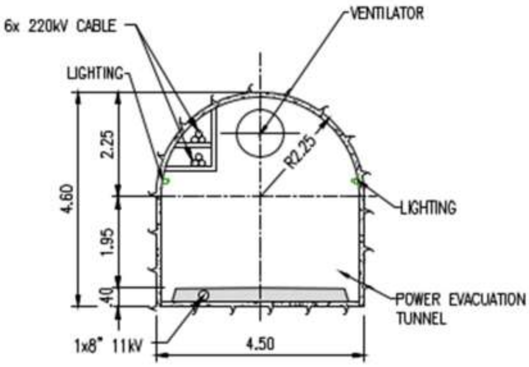


Figure 14-7: Emergency and Power Evacuation Tunnel – typical section

The layout of the Emergency and Power Evacuation Tunnel is shown on the overview drawing while the profile and the typical section are shown on the respective drawing of the powerhouse feature in Volume 14 of this Feasibility Study.

The tunnel has a length of 260 m between the eastern end of the Transformer Cavern and the Main Access and Power Evacuation Tunnel, and a downwards slope to the cavern of 0.5%.

The excavation of the tunnel will be executed with the conventional drill and blast method.

14.7 Emergency Tunnel

The main dimensions of the Emergency Tunnel have been selected in such a way to provide vehicular access and space for ventilation as shown in Figure 14-8.

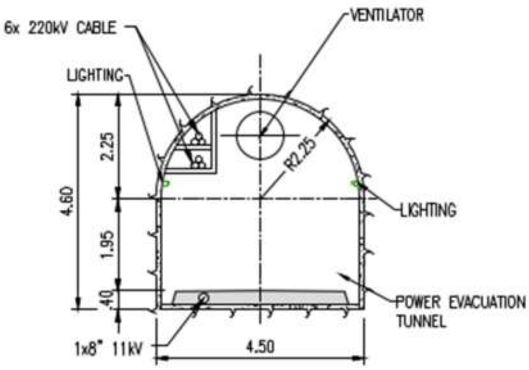


Figure 14-8: Emergency Tunnel – typical section

The layout of the Emergency Tunnel is shown on the overview drawing while the profile and the typical section is the same as for the Emergency and Power Evacuation Tunnel shown on the respective drawing of the powerhouse feature in Volume 14 of this Feasibility Study.

The tunnel has a length of 16 m between the eastern end of the Transformer Cavern and the Emergency and Power Evacuation Tunnel, and a downwards slope to the cavern of 0.6%.

The excavation of the tunnel will be executed with the conventional drill and blast method.

14.8 Tailrace Tunnel

The Tailrace Tunnels of each unit will merge into one free-flow Tailrace Tunnel common to all three units and the turbined water will be returned to the Indus River. It has a length of 1,312 m between the unit 3 pit and the Tailrace Tunnel Outlet Structure, and a slope of 0.1%. A surface outlet structure is foreseen at its downstream end to safely dissipate the energy of the water and prevent regressive erosion.

The layout of the Tailrace Tunnel is shown on the overview drawing of the powerhouse features and the profile and typical section are shown on the respective drawing of the power waterway feature in Volume 14 of this Feasibility Study (refer also to Figure 14-9).

The excavation of the tunnel can be executed with the conventional drill and blast method. The excavation support classes can also be seen in the respective power waterway drawing. Six support classes (shotcrete, wire mesh and rock bolts) are designed.

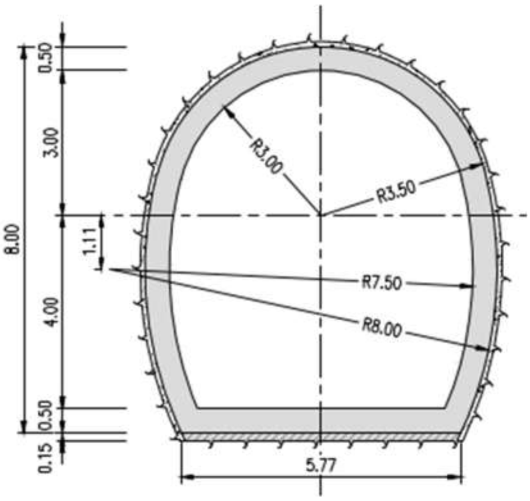


Figure 14-9: Tailrace Tunnel – typical section

14.9 Plant Construction, Installation and Maintenance Concept

14.9.1 Excavation Sequence and Rock Support

Excavation

The excavation of the caverns will be executed with the conventional drill and blast method. The proposed rock support and excavation sequence are shown on the respective drawings of the powerhouse feature in Volume 14 of this Feasibility Study.

It is foreseen that the excavation of the caverns will be carried out using ramps inside the caverns starting at the crown area of the caverns. Smooth blasting will be required in the close vicinity of the final walls of the two caverns.

Two glory holes connecting the Tailrace Tunnel to the machine and Transformer Caverns may be planned for the mucking of the excavated material through the Tailrace Tunnel for ease of logistics at the Main Access and Power Evacuation Tunnel.

Finite Element Analysis

A preliminary and simplified finite element analysis has been performed for the excavated cavern cross section in order to assess the expected stresses and deformations, estimate the required support measures (anchor lengths, need for post-tensioning system) and verify the chosen distance between the Power Cavern and the Transformer Cavern.

The rock mass parameters were defined for stress-dependent shear strength parameters (Mohr-Coulomb) with the software RocLab. The finite element analysis was performed with the software Examine 2D as presented in Volume 7 – Project Design.

Rock Wedges Stability Analysis

The orientation of the discontinuities was investigated for the 2010 Feasibility Study and the main findings are presented in Volume 4 - Geology.

Preliminary rock wedge analyses have been performed for the unsupported excavation and after implementation of the rock support measures defined in chapter for the three pre-identified main discontinuities and the assumed properties presented in Volume 7 – Project Design.

Results

The results of the Power Cavern calculations are compiled in Volume 7 – Project Design.

There is a reasonable distance between the zones around the cavern with a strength factor < 1 (plastic zone). As a consequence, the chosen distance between the two caverns of 1.5 x $_{\text{Dmain cavern}}$ (or 73.50 m between axes) is deemed appropriate. The depth of the plastic zone is approximately 3.5 m. A systematic rock bolting of 6 m depth with a grid of 2.0 m x 2.0 m is foreseen to cover that zone, allowing for a minimum of 2.5 m of anchor length which is also deemed appropriate for the proposed rock mass parameters.

The results of these analyses are the calculated factors of safety for the identified wedges. A summary of the calculated safety factors and the detailed graphic output are compiled in the Volume 7 – Project Design demonstrating the suitability of the proposed rock support.

Excavation Support

The following support system is envisaged for the main cavern excavation.

A 35 cm thick shotcrete layer is foreseen at the crown until the elevation of the crane beam is reached. A shotcrete layer with 30 cm thickness is proposed to be applied at the lateral walls. Systematic rock bolts with a length of 6 m and a grid of 2.0 m x 2.0 m and pre-stressed thread bar anchors with a length of 15 m and a grid of 4.0 m x 4.0 m are proposed to be applied to stabilise the surrounding rock area during construction and operation of the plant.

Next, the application of temporary pre-stressed tendons at the crane beam elevation, with a length of 35-45 m and a spacing of 1.5 m in order to fix the crane beam before construction of the columns underneath in order to use a temporary crane for all excavation and concrete works before the construction of the machine hall columns/beams.

A 25 cm thick shotcrete layer and systematic rock bolting with a length of 6 m and a 2 x 2 m grid is currently envisaged for the Transformer Cavern excavation.

14.9.2 Construction Phases

The construction schedule developed in Chapter 20 for the Power Cavern considers a sequence of hand overs from bottom to top with first stage and second stage concrete activities by the civil Contractor proceeding in parallel to the installation of the main equipment by the E&M supplier.

Chapter 20 presents the concreting and E&M installation sequences assumed by the Consultant for planning purposes based on the Power Cavern complex arrangement. The sequence of events and the critical path can be described as follows:

- Following the completion of excavation phases I and II with ramps inside the cavern, the crane beam will be casted and supported by pre-stressed tendons as shown on the respective powerhouse drawings and required for the installation of a temporary (approximately 18 ton) auxiliary crane,
- Completion of the remaining excavation phases III to VII until the excavation in full of the Power Cavern is complete for the concrete works to start,
- Concreting of the Tailrace Tunnel, dewatering sump, MIV floor and foundations available for steel lining and the spiral case installation,
- Installation of the high pressure steel lining and the spiral case followed by their subsequent embedment in concrete,
- Concreting of the turbine floor, generator floor and foundations, machine hall floors, erection bay and the machine hall superstructure above supporting the EOT crane beam,

- Installation of the steel drip shield and the EOT crane and completion of all sensitive concrete activities to provide a dust free working area to the main supplier for the subsequent installation of the generator and the MIV,
- Installation of the generator and the remaining sensitive electrical auxiliaries,
- Commissioning activities.

The sequence of events is much simpler at the Transformer Cavern and the interfaces between civil Contractor and E&M supplier are as follows:

- Concreting of the machine floor and the transformer foundation for subsequent installation,
- Concreting of the GIS and GIS foundation available for subsequent installation.

14.9.3 Main Mechanical Equipment

Auxiliary Crane

There will be an (approximately 18 ton) auxiliary crane installed on temporary crane beams anchored to the surrounding rock mass used for the first stage concrete activities of the Power Cavern.

EOT Main Crane

The erection of the main EOT crane using a mobile crane can only start after the first stage concrete has reached the elevation of the machine hall crane rail beam. Following the erection and the commissioning of the EOT crane all major station equipment can be lifted directly from the transportation trucks to the related equipment positions or erection openings.

It is noted that the pre-assembly and the installation of the generators can only start following the erection of the main EOT crane in a dust free environment and is not feasible using the auxiliary crane.

Spiral Case Installation

The foundation of the generator floor above sitting on top of the concrete around the spiral case, the spiral case shall be installed and embedded into the concrete without the main EOT crane available.

This will however require the timing of the spiral case installation to be coordinated with the ongoing concreting activities, the main drawback being that the spiral case will be on the critical path. Space permitting at the Power Cavern, it may be an option to weld the two pieces of the spiral case at the erection bay and lift the spiral case down to the MIV floor using a large mobile crane.

After lifting, the spiral case element(s) will be moved across the machine bays with a rails system and the help of auxiliary crane to its final installation position for welding if not already pre-assembled.

Turbine Runner

The turbine runner and other parts will be delivered through the Main Access and Power Evacuation Tunnel and further distributed to their final installation using the EOT crane.

For maintenance and inspection works on the turbine runner, the current design allows for an easy and quick dismantling from below through the MIV access corridor without removing the motor-generator and the runner will be moved to the machine floor via one of the two hatches that will be closed with precast elements after the successful completion of the operation. This procedure allows the plant Operator to inspect and maintain the main important parts of the turbine in an efficient and convenient way with the objective to deliver a plant with high availability.

Main Inlet Valves

The MIVs will be transported to site in one piece and will be lowered through the hatches to the MIV floor.

The MIV transport from the central hatches to the final erection location will be done with a rail transport device. The erection and dismantling of the counterweights will be done with local monorail cranes and ceiling lifting hooks.

14.9.4 Main Electrical Equipment

Generator

The pre-conditions to the generator installation are as follows:

- Complete erection bay floor,
- All Power Cavern openings closed,
- Main EOT crane ready for operation,
- Access to the Assembly Bay for unloading heavy equipment,
- Architectural works largely complete, generator pit dry, clean and dust free.

In line with common practise in the hydropower industry, the erection bay has been sized to allow for parallel pre-assembly and maintenance works on the below four components:

- Stator: frame assembly; core stacking (possible also in the pit),
- Rotor: Rim stacking; pole mounting,
- Lower bracket/bearing: guide bearing, lower bracket; shaft,
- Upper bearing/bracket: combined bearing; upper bracket, thrust collar, shaft.

Due to the size and the weight of the generator it will be transported to the site in separate pieces. The main parts are the frame parts of the stator as well as the solid rotor body. The rotor will be assembled at the erection bay and after that the complete rotor will be lifted into the unit pit with the EOT crane.

In case of failure or during maintenance works at the generators, the rotor of the unit can be lifted for maintenance at the erection bay. All stator correlated repair or maintenance works will be made in the generator pit. Single poles can be dismantled without rotor lifting.

Unit Transformers

The unit transformers will be transported through the Main Access and Power Evacuation Tunnel with a self-propelled transporter that is a proven solution which has been executed at several projects where the Consultant was involved. The transporter will able to unload the unit transformer on the steel plates prepared for rotating the transformer by 90 degrees. To reach the final position the transformer will be pushed via mobile equipment on shifting tracks to its final location.

The main benefit of such transport solution as opposed to a conventional flatbed trailer is that excavation savings are possible upstream of the erection bay at the machine hall floor of the Power Cavern. The use of such transportation method will however need to be confirmed by the appointed E&M supplier.

In the event of major maintenance or repair works in the factory, the transformers will be transported in the same way out of the cavern.

220 kV GIS

The heaviest component of the GIS equipment will be one complete feeder delivered via trailer. The complete feeder will be delivered to site using the MAPET and lifted using the local monorail crane and ceiling lifting hooks installed at the crown of the Transformer Cavern. The remaining parts and interconnections will be brought in the same way. The components will then be moved using the same monorail crane. In case of equipment failures the faulty component will be replaced and it will not be necessary to dismantle the whole feeder. The HV cable systems between the unit transformers and GIS will be installed with correspondent cable pulling machines and track rollers.

Generator Switchgear Equipment

The main part of the generator switchgear with the biggest dimensions is the generator circuit breaker (GCB). It will be loaded/unloaded using the EOT crane at the Power Cavern and transported on transport trolleys to its final location inside the IPB galleries. During maintenance works the respective parts from the GCB will be replaced.

14.10 Standards, Codes and Manuals

The following appropriate international standards, manuals and guidelines will be used for the Powerhouse civil design works of the Feasibility Study:

- ACI American Concrete Institute
- ANSI American National Standards Institute
- ASTM American Society for Testing and Materials
- BSI British Standards Institution
- EN European Standard (all related Eurocode standards)
- USACE United States Army Corps of Engineers
- USBR United States Bureau of Reclamation

15 Hydro-Mechanical Equipment

15.1 Introduction

This chapter gives a general description of the hydro-mechanical equipment of the Lower Spat Gah Project placed at the following locations and provides a summary of Volume 8 – Mechanical and Electrical Equipment.

- Lower Spat Gah Headworks including flushing channel and desander,
- Lower Gabarband Intake,
- Power Waterway.

The arrangement and the general dimensions of the equipment are shown on the drawings which are presented in Volume 14 –Drawings. The technical data of the hydro-mechanical equipment can be found in the Volume 8 – Mechanical and Electrical Equipment.

15.2 Lower Spat Gah Flushing Channel

The Lower Spat Gah flushing channel is located to the left of the desander intake at the right bank. In addition to its flood protection purposes, the Lower Spat Gah flushing channel is also used for the flushing of sediments in front of the desander intake area and is equipped with three (3) separate flushing channels. Further also the equipment for residual flow discharge is part of the flushing channel structure.

15.2.1 Flushing Channel Radial Gates with Flap

For sediment flushing purposes and water discharge in case of a flood event, the Lower Spat Gah flushing channel will be equipped with three (3) independent radial gates. Each gate is 9.50 m wide and 23.71 m high including the 80 cm above the FSL or 6 cm above 10,000-year flood and will be operated by two double acting hydraulic cylinders. In order to flush floating debris, the installed radial gate No. 3, which is the closest to the desander intake, will be equipped with a flap gate at its top with approximately 7.50 m width and 4.00 m height.

The radial gates shall be designed to be able to close by their own weight in full flow condition and shall be designed for the static pressure of the reservoir maximum flood water level and hydrodynamic pressure due to earthquake conditions (SEE with 3,000-year return period). To guarantee tightness of the gate, the radial gates will be supplied with rubber seals at both sides as well as at the bottom. The sealing of the gates shall be designed to withstand the abrasive water flow during flushing of the sediments in front of the desander intake.

15.2.2 Flushing Channel Stoplogs

For repair and maintenance purposes, the flushing channel radial gates will be provided with upstream and downstream stoplog elements. The upstream and downstream stoplog will normally be kept in their storage position in the stoplog slots or above the slots at deck elevation.

For lifting and lowering of the gates, a semi-automatic lifting beam will be supplied enabling manipulation of the gates using the flushing channel stoplog traveling gantry crane. However, at any time that a maintenance operation is required on one of the flushing channel radial gates, the stoplog set will be placed into the stoplog slot of the respective bay, making an effective water retaining barrier for working safely on the radial gates.

The stoplogs shall be designed to be able to close and open in balanced condition and shall be designed for the static pressure of the reservoir FSL and hydrodynamic pressure due to earthquake conditions (DBE for upstream gate and OBE for downstream gate). This pressure equalised opening condition will be obtained by lifting the upper stoplog element in filling position.

15.2.3 Residual Flow Equipment

The residual flow will be released through a pipe embedded in the right abutment of the flushing channel structure.

The intake for the residual flow release will be located in the left wall behind the trash rack of the left most desander intake. The outlet will be located downstream of the flushing channel radial gate in the right channel wall.

The right abutment of the flushing channel will be supplied with a shaft for installation of the valve for regulation of the residual flow velocity as well as the maintenance valve.

15.2.4 Flushing Channel Gantry Crane

For handling of the flushing channel stoplogs in case of inspection, maintenance and repair works, the flushing channels of the Lower Spat Gah HPP will be supplied with their own gantry crane.

The gantry crane shall be installed at the top of the flushing channel structure and is intended for the lifting and lowering operation of the stoplog elements in the upstream and downstream stoplog slots at the three (3) flushing channel bays. The same gantry crane will also be used for erection and maintenance of the three (3) radial gates. In addition the railing system for lateral moving of the gantry crane will be extended in the direction of the desander intake area for unloading of trucks and storage of the stoplog elements. DBE earthquake conditions will be considered in the design.

15.3 Lower Spat Gah Desander

To increase the lifetime of the turbines and avoid significant O&M costs, a large desander structure will have to be designed and constructed at the right abutment to remove all particles with design grain size higher than 0.3 mm for the Minimum Operating Level.

Channels at the downstream end of the desander bays shall be foreseen to allow the flushing of the settled sediments back to the Spat Gah River downstream of the Lower Spat Gah Headworks.

15.3.1 Desander Intake Trash Rack and Trash Rack Cleaning Machine

15.3.1.1 Intake Trash Rack

The intake structure will consist of three (3) separate intakes protected with 80° inclined trash racks to prevent trees and other floating debris from entering the desander system.

The single welded panels of the trash racks are bolted on supporting beams and braced to the steel side frame. Each panel will consist of vertical flat steel bars, horizontal bar spacers which also interconnect the single panels and are used for lateral bracing to the embedded frame.

The design, fabrication and installation shall be done to withstand respective loads resulting from the trash accumulated in front of the rack panels and to also avoid vibration. Clearance between the rack elements and the need for intermediate beams will have to be finalised in discussion with the chosen E&M supplier to minimise risk of passing trash and vibrations respectively.

15.3.1.2 Intake Trash Rack Cleaning Machine

The trash racks will be cleaned by a gantry type rope system trash rack cleaning machine (TRCM). The rope type TRCM will be operated in automatic, semi-automatic and manual mode and will be supplied with containers and an additional revolving hydraulic standard truck loading crane for manual large trash handling. For trash handling and loading into the containers, an additional loading crane will also be supplied with a grab.

The TRCM will mainly consist of the TRCM rail installation, embedded parts for water pressure sensors installation, a supporting movable steel structure (gantry), a winch house with the hoisting unit, a swivelling trash rake, an operator’s cabin, an additional loading crane and a control and power supply unit. The design of the TRCM shall comply with international standards.

The proposed trash rack cleaning system shall be able to remove various kind of debris such as wood sticks, branches, medium sized logs and stumps, plastic bottles and civilisation trash from the racks and ensure that the intake areas are clear of floating and submerged debris. DBE earthquake conditions will be considered in the design.

15.3.2 Desander Intake Gates

The intake area of the desander will be supplied with service gates for the protection of the desander itself as well as the other hydro-mechanical structures and equipment of the Lower Spat Gah desander.

The service gates will be of the fixed-wheel gate type acting as an emergency closure device to cut off the flowing water flow into the desander. The fixed-wheel gates shall be designed to be able to close by their own weight in full flow condition and can also be opened without equalised pressure between the upstream and downstream side of the gate.

They will be designed with skin plate and rubber seals on the upstream side of the gate. The bottom edge of the roller gate leaf shall be shaped for low vibration lowering the fixed-wheel gate in running water or under full load. The two elements of the intake fixed-wheel gates will be equipped with stainless steel fixed-wheel and connected by bolts.

The gates shall be designed for the static pressure of the reservoir maximum flood water level and hydrodynamic pressure due to earthquake conditions (SEE with 3,000-year return period).

15.3.3 Desander Intake Stoplogs

For inspection and maintenance purposes, each of the three (3) desander intakes will be supplied with stoplog slots located upstream of the intake service gates.

The intake stoplogs (one set will be provided) will be of the sliding gate type with lifting beam and the stoplog elements will normally be kept in their storage rack at the storage area or at the upper end of the stoplog slot. However, at any time that a maintenance operation may be required on the service gate, the stoplog set will be placed into the stoplog slot making an effective water retaining barrier.

The stoplogs will be placed in the slot only under balanced head conditions for opening and closing and shall be designed for the static pressure of the reservoir Full Supply Level and hydrodynamic pressure due to earthquake conditions (OBE). This pressure equalised opening condition will be obtained using a by-pass valve system incorporated at the upper stoplog element.

The stoplogs will be operated by a standard truck loading crane with installed rope hoist installed at the trash rack cleaning machine of the desander intake. For lifting and lowering of the stoplog parts into the slot, the rope hoist of the loading crane will be coupled with a semi-automatic lifting beam.

15.3.4 Calming Racks

The desander transition zones downstream of the desander intake channels are each equipped with calming racks to calm the inflows into the desander basins. Each basin will have three consecutive racks with a decreasing spacing between the bars. The calming racks will consist of welded steel V-shaped vertical beams that are laterally braced to the embedded frame.

The racks shall be designed for the differential head resulting out of the head loss calculations and possible additional trash load. The design, fabrication, and installation shall be done to avoid vibration.

15.3.5 Desander Basin End Sill Gates

In order to hydraulically uncouple the desander of the Lower Spat Gah Headworks from the forebay area during flushing, the end of each desander basin will be supplied with additional desander basin end sill gates on top of the end sills.

The desander basin end sill gates will be of the slide gate type, able to close and open in balanced condition and hydrodynamic pressure due to earthquake conditions (OBE). The gate body shall be designed as rigid steel construction.

Sealings will be provided at upstream side and at the bottom and the head of the gates to guarantee total tightness of the gates when the gates are in the closed position.

15.3.6 Desander Basin Flushing Gates

Each basin of the desander will be supplied with its own flushing gate at the downstream end of the desander basin. The flushing gates will be of the sliding type with 1.30 m width and 1.40 m height and will be kept in the closed position during normal operation of the desander.

For flushing purposes of the desander basins the flushing gates will be opened by means of a spindle, a gear box and an electric actuator.

The steel structure and the electric actuator will be placed directly at the top level of the desander bridge structure at 1,512.00 m asl. The sealing design of the gates shall take the high abrasive water flow into consideration.

The sliding gates shall be designed to be able to open and close (under their own weight) the flushing channel under full flow conditions for all possible levels between FSL and MOL without equalisation of the water pressure between the upstream and downstream side of the gate and hydrodynamic pressure due to earthquake conditions (OBE).

15.4 Lower Gabarband Intake

15.4.1 Flushing Channel Radial Gate

For flushing purposes and water discharge in case of a flood event, the Lower Gabarband weir will be equipped with one (1) independent radial gate. The gate will have a size of 4.00 m width and 7.08 m height including 50 cm above the NOL and will be operated by two double acting hydraulic cylinders.

The gate shall be designed to close by its own weight in full flow condition and static pressure of the reservoir maximum flood water level. The gate shall also be designed to withstand hydrodynamic pressure due to earthquake conditions (SEE with 1,000-year return period). To guarantee the tightness of the gate, the gate body will be supplied with rubber seals at both sides and at the bottom of the steel structure. The sealing of the gate shall be designed to withstand the abrasive water flow during flushing of the sediments in front of the desander intake.

A mobile crane will be needed for maintenance of the gate in the absence of gantry crane.

15.4.2 Flushing Channel Stoplogs

For repair and maintenance purposes, the flushing channel radial gate at the Lower Gabarband flushing channel will be provided with a set of upstream stoplogs. The stoplogs will normally be kept in their storage position in the stoplog slot or above the slot at deck elevation.

For lifting and lowering of the stoplogs, a semi-automatic lifting beam will be supplied enabling manipulation of the stoplogs via a mobile crane. However, at any time that a maintenance operation is required on the flushing channel radial gate, the stoplog set will be placed into the stoplog slot making an effective water retaining barrier for working safely on the radial gate.

The stoplogs will be placed in the slot only under balanced head conditions for opening and closing and shall be designed for the static pressure of the reservoir NOL and hydrodynamic pressure due to earthquake conditions (DBE). This pressure equalised opening condition will be obtained by lifting the upper stoplog element in filling position.

15.4.3 Residual Flow Equipment

The residual flow will be released through a pipe embedded in the left flushing channel wall.

The intake for the residual flow release will be located in the right wall behind the trash rack of the right desander intake and the outlet structure will be located downstream of the flushing channel radial gate (left abutment of the spillway channel).

The abutment of the flushing channel will be supplied with a shaft for installation of the valve for regulation of the residual flow velocity.

15.4.4 Desander Intake Trash Rack and Trash Rack Cleaning Machine

15.4.4.1 Intake Trash Rack

The intake structure of the Lower Gabarband desander will be protected with 75° inclined trash racks to prevent trees and floating debris from entering the desander system.

The single welded panels of the trash racks will be bolted on supporting beams and braced to the steel side frame. Each trash rack panel will be made of vertical flat steel bars and horizontal bar spacers which also interconnect the single panels and are used for lateral bracing to the embedded frame.

The design, fabrication, and installation shall be done to withstand respective loads resulting to trash in front of the rack panels as well as to avoid vibration. Clearance between the rack elements will have to be finalised in discussion with the chosen E&M to minimise risk of passing trash.

15.4.4.2 Intake Trash Rack Cleaning Machine

The trash racks will be cleaned by a gantry type rope system trash rack cleaning machine (TRCM). The rope type TRCM will be operated in automatic, semi-automatic and manual mode and will be supplied with containers and an additional revolving hydraulic standard truck loading crane for manual large trash handling. For trash handling and loading into the containers, an additional loading crane will also be supplied with a grab.

The TRCM will mainly consist of the TRCM rail installation, embedded parts for water pressure sensors installation, a supporting movable steel structure (gantry), a winch house with the hoisting unit, a swiveling trash rake, an operator’s cabin, an additional loading crane and a control and power supply unit. The design of the TRCM shall comply with international standards.

The proposed trash rack cleaning system shall be able to remove various kind of debris such as wood sticks, branches, medium sized logs and stumps, plastic bottles and civilisation trash from the racks and ensure that the intake areas are clear of floating and submerged debris. DBE earthquake conditions will be considered in the design.

15.4.5 Desander Intake Gates

The intake area of the desander will be supplied with service gates which will normally be kept inside their slot at the lower end, right above the gate opening. During larger flood conditions when the power plant is not operating, the gates are lowered to stop diverting water.

The service gates will be of the fixed-wheel intake gate type acting as an emergency closure device to cut off the water flow into the desander. The fixed-wheel gates shall be designed to be able to close by their own weight in full flow condition and can also be opened without equalised pressure between the upstream and downstream side of the gate.

They will be designed as roller type emergency gates with skin plate and rubber seals on the upstream side of the gates. The bottom edge of the roller gate leaves shall be shaped for low vibration when lowering the roller gates in running water or under full load. The intake roller gates will be equipped with stainless steel rollers and connected by bolts.

The gates shall be designed for the static pressure of the reservoir maximum flood water level and hydrodynamic pressure due to earthquake conditions (OBE).

15.4.6 Intake Stoplogs

For inspection and maintenance purposes, each of the two (2) desander intake service gates will be supplied with stoplog slots located upstream of the service gates.

The intake stoplogs will be of the sliding gate type with lifting beam and the stoplog elements will normally be kept in their storage rack at the storage area or at the upper end of the stoplog slot. However, at any time that a maintenance operation may be required on the service gates, the stoplog set will be placed into the stoplog slot of the intake making an effective water retaining barrier.

The stoplogs will be placed in the slot only under balanced head conditions for opening and closing and hydrodynamic pressure due to earthquake conditions (OBE). This pressure equalised opening condition will be obtained using a bypass valve system incorporated at the upper stoplog.

Sliding type stoplogs with skin plate and rubber seals on the downstream side of the stoplogs are foreseen.

15.4.7 Calming Racks

The desander transition zones downstream of the desander intake channels are each equipped with calming racks to calm the inflows into the desander basins. Each basin will have three consecutive racks with a decreasing spacing between the bars. The calming racks will consist of welded steel V-shaped vertical beams that are laterally braced to the embedded frame.

The racks shall be designed for the differential head resulting out of the head loss calculations and possible additional trash load. The design, fabrication, and installation shall be done to avoid vibration.

15.4.8 Desander Basin Flushing Gates

Each basin of the desander will be equipped with its own flushing gate at the downstream end of the desander basin. The flushing gates will be of the sliding type with dimensions of 1.00 m width and 1.00 m height and will be kept in the closed position during normal operation of the desander.

For flushing purposes of the desander basins, the flushing gates will be opened by means of a spindle, a gear box and an electric actuator.

The steel structure and the hoisting cylinders will be placed directly at the top level of the desander bridge structure at 1,554.00 m asl. The sealing design of the gates shall take the high abrasive water flow into consideration.

The sliding gates shall be designed to be able to open and close (under their own weight) the flushing channel under full flow conditions for all possible levels between NOL and low flood levels without equalisation of the water pressure between upstream and downstream side of the gate and hydrodynamic pressure due to earthquake conditions (OBE).

15.4.9 Forebay Intake Gate

The intake area located immediately downstream of the Lower Gabarband desander will be equipped with one (1) service gate for protection of the Gabarband Intake Tunnel as well as for maintenance purposes.

The fixed wheel gate will act as an emergency closure device designed to be able cut off the water flow by its own weight in case of failure/defect of the Gabarband Intake Tunnel or Headrace Tunnel.

For opening of the fixed-wheel gate, pressure at the upstream and the downstream side of the gate has to be equalised and the gate will therefore be supplied with a manually operated valve. The valve will be activated by the opening mechanism of the gate structure itself.

The gate structure will be designed with skin plate and rubber seals on the upstream side of the gate. The bottom edge of the fixed-wheel gate leaf will be shaped for low vibration when lowering the gate in running water or under full load.

The gate will be designed for the static pressure of the forebay maximum water level (1,554.00 m asl) and hydrodynamic pressure due to earthquake conditions (OBE).

15.5 Power Waterway

15.5.1 Lower Spat Gah Forebay Emergency Gate

The intake area located at the forebay of the Lower Spat Gah Headworks will be equipped with one (1) service gate for protection of the Headrace Tunnel and all other hydro-mechanical structures and equipment of the Lower Spat Gah HPP.

The fixed wheel gate will act as an emergency closure device designed to be able cut off the water flow in case of failure/defect of the Headrace Tunnel. In addition it will also be used to seal off the Headrace Tunnel to enable maintenance or inspection of the tunnel, Surge Shaft and butterfly emergency valve from upstream. The emergency gate of the fixed wheel gate type will be able to close by its own weight in full flow condition.

For the opening of the fixed wheel gate, pressure at the upstream and the downstream side of the gate has to be equalised and the gate will therefore be supplied with a manually operated valve for filling of the Headrace Tunnel before opening. The filling valve will be activated by the opening mechanism of the gate structure itself.

The gate structure will be designed as fixed wheel type emergency gate with skin plate and rubber seals on the upstream side of the gate. The bottom edge of the fixed wheel gate leaf will be shaped for low vibration when lowering the fixed wheel gate in running water or under full load. The two parts of the intake fixed wheel gate will be equipped with stainless steel rollers and connected by bolts.

The gate will be designed for the static pressure of the reservoir maximum flood water level and hydrodynamic pressure due to earthquake conditions (OBE).

15.5.2 Lower Spat Gah Forebay Stoplogs

For inspection and maintenance purposes of the forebay emergency gate, upstream stoplogs of the sliding gate type will provided. The forebay stoplogs will normally be kept at the upper end of the stoplog slot. However, at any time that a maintenance operation may be required on the forebay emergency gate, the stoplog set will be placed into the stoplog slot of the intake making an effective water retaining barrier.

The stoplogs will be placed in the slot only under balanced head conditions for opening and closing and shall be designed for the static pressure of the reservoir maximum flood water level and hydrodynamic pressure due to earthquake conditions (OBE). This pressure equalised opening condition will be obtained using a by-pass valve system inside the top stoplog element.

The stoplog set will be stored directly inside the stoplog shaft at its upper end, held in position by means of interlocking devices. In case of needed inspection and maintenance of the forebay emergency gate, the stoplogs shall be lowered into closed position via mobile crane with sufficient lifting capacity. For easy manipulation of the stoplog set, a semi-automatic lifting beam will be coupled to the hook of the mobile crane.

Alternatively it would also be possible to install electric actuators or to use single acting hydraulic cylinder powered by the high pressure oil unit foreseen for operation of the forebay stoplog gate.

15.5.3 Power Waterway Steel Liner and Gabarband Intake Tunnel Pipe

The technical details of the steel liner in the Power Waterway and the pipe in the Gabarband Intake Tunnel are discussed in Chapter 13.7.

15.5.4 Headrace Tunnel Emergency and Maintenance Valve

The power waterway of the Lower Spat Gah HPP will be supplied with an emergency and maintenance valve located downstream of the Surge Shaft and upstream of the vertical Pressure Shaft.

To protect the mechanical equipment of the Power Cavern in case of a failure of the turbine and to enable inspection and maintenance of the Pressure Shaft, High Pressure Tunnel, penstock and the spherical valves of the Power Cavern without having to empty the whole Power Waterway, the Headrace Tunnel will be supplied with an emergency and maintenance valve installed in a valve chamber located downstream of the Surge Shaft at the top of the Pressure Shaft.

The emergency closing function will be achieved by a butterfly valve with valve disc of the double decker type. The design of the butterfly valve will be done in respect to the water hammer calculations of the total hydraulic system and will be supplied with weights for automatic closing function, following a defined closing scheme if necessary.

The 4.00 m diameter butterfly valve will be installed at elevation 1,261.05 m asl (referring to the pipe centreline) and will be pressurised with a nominal static 2.44 MPa (24.4 bar). The maximum dynamic pressure is expected to be in the range of 3.81 MPa (38.1 bar). OBE earthquake conditions will be considered in the design.

It is noted that the dimensions and weight of the butterfly valve components will have to be taken into account for the confirmation of the final design of the access road, adit tunnel and gate chamber layout during Project execution.

It is currently foreseen to extend the emergency and maintenance valve chamber downstream and construct an Upper Erection and Gate Chamber that will subsequently be used for the erection of the Pressure Shaft steel liner.

15.5.5 Upper Erection and Gate Chamber Bridge Crane

The Upper Erection and Gate Chamber will be supplied with its own overhead travelling bridge crane. The bridge crane will be used for erection and maintenance of the emergency and maintenance butterfly valve and shall have therefore have a sufficient capacity to handle the heaviest parts during installation as well as during maintenance.

For the erection of the Pressure Shaft steel lining, the valve chamber will be extended towards the downstream to form an Upper Erection and Gate Chamber used for excavation and the unloading and the installation of the Pressure Shaft steel liner. It is currently foreseen that steel cans will be directly transported to the Upper Erection and Gate Chamber where a temporary erection gantry crane with sufficient lifting capacity and stroke length (not shown on the drawings as it is a temporary structure to be designed by the Contractor) will have to be installed.

15.5.6 Tailrace Outlet Structure Stoplogs

The turbined water will be returned to the Indus River by a free-flow Tailrace Tunnel that will be provided with a Tailrace Outlet Structure and a stepped spillway at its downstream end to ensure a safe energy dissipation in the absence of the future Patan reservoir.

The Tailrace Outlet Structure will be provided with stoplog slots enabling the installation of sliding type stoplogs with a mobile crane to allow inspection and maintenance should the Patan reservoir will be built in the future.

The stoplogs themselves and the equipment required for lifting and lowering of the stoplogs are currently not included in the scope of supply and will have to be supplied at a later stage only in case the Patan HPP is built in the future. OBE earthquake conditions will be considered in the design.

15.5.7 Gabarband Intake Tunnel Emergency and Maintenance Valve

The Gabarband Intake Tunnel will be supplied with an emergency and maintenance valve located at the downstream end of the Gabarband Intake Tunnel pipe and just upstream of the connection with the Headrace Tunnel.

To prevent excessive water spill from the Headrace Tunnel into the Gabarband Intake Tunnel in case of a Gabarband Intake Tunnel pipe failure and to enable inspection and maintenance of Gabarband Intake Tunnel pipe without having to empty the Headrace Tunnel, the Gabarband Intake Tunnel will be supplied with an emergency and maintenance valve.

The emergency closing function will be achieved by a butterfly valve. The design of the butterfly valve will be done in respect to weights for automatic closing function, following a defined closing scheme if necessary.

The butterfly valve opening shall be accomplished by mobile hydraulic power unit. The overspeed device shall be purely mechanical, and it shall initiate closing of the valve in case the pipe bursts. The overspeed device will be installed in the direction that activates the device, that menas in flow direction from the Headrace Tunnel to the Gabarband Intake Tunnel.

The 1.50 m diameter butterfly valve will be installed at elevation 1,335.96 m asl (referring to the pipe centreline) and will be pressurised with a nominal static 1.71 MPa (17.1 bar). The maximum dynamic pressure is expected to be in the range of 2.10 MPa (21.0 bars). OBE earthquake conditions will be considered in the design.

15.5.8 Gabarband Junction Chamber Intake Chain Hoist

The Gabarband Junction Chamber monorail crane will be supplied with its own hand chain hoist. The hoist will be used for erection and maintenance of the emergency and maintenance butterfly valve and shall therefore have a sufficient capacity of 15 ton to handle the valve during installation as well as during maintenance.

15.6 Powerhouse Main Inlet Valve

The main inlet valve is described in Chapter 16.3.2.

15.7 Standards, Codes and Guidelines

The following relevant international standards, manuals and guidelines have been used for the hydro-mechanical design of the Feasibility Study:

- DIN 19704-1 Hydraulic steel structures – Part 1: Criteria for design and calculation

16 Electro-Mechanical Equipment

Corresponding Drawings

LSG-FS-090-021	Powerhouse, Governor Oil Pressure System, Schematic Diagram
LSG-FS-090-022	Powerhouse, MIV Oil Pressure System, Schematic Diagram
LSG-FS-090-023	Powerhouse, Unit Lubrication System, Schematic Diagram
LSG-FS-090-024	Powerhouse, Cooling Water System, Schematic Diagram
LSG-FS-090-025	Powerhouse, Fire Fighting System and Service Water Supply System, Schematic Diagram
LSG-FS-090-026	Powerhouse, Wastewater Treatment System, Schematic Diagram
LSG-FS-090-027	Powerhouse, Drainage and Dewatering System, Schematic Diagram
LSG-FS-090-028	Powerhouse, Low Pressure Compressed System, Schematic Diagram
LSG-FS-090-029	Powerhouse, Fire Fighting System in the Powerhouse, Schematic Diagram
LSG-FS-090-030	Powerhouse, HVAC System, Schematic Diagram
LSG-FS-090-031	Powerhouse, Symbols Legend
LSG-FS-090-032	Powerhouse, Main Single Line Diagram, Schematic Diagram
LSG-FS-090-033	Powerhouse, Protection Main / GIL / Trafo, Schematic Diagram
LSG-FS-090-034	Powerhouse, GIS protection, Schematic Diagram
LSG-FS-090-035	Powerhouse, Motor Control Center, Schematic Diagram
LSG-FS-090-036	Powerhouse, Primary Distribution System, Schematic Diagram
LSG-FS-090-037	Powerhouse, DC UPS SLD, Schematic Diagram
LSG-FS-090-038	Powerhouse, Route of Cable and IPB Generator Floor, Plan View at El. 772.60 m asl
LSG-FS-090-039	Powerhouse, Route of Cable and IPB Machine Floor, Plan View at El. 778.60 m asl
LSG-FS-100-001	Control, Instrumentation & Power Supply, MV/LV Single Line Diagram, Schematic Diagram
LSG-FS-100-002	Control, Instrumentation & Power Supply, Control System Topology, Schematic Diagram
LSG-FS-100-003	Control, Instrumentation & Power Supply, Power Supply to Project Structures, General Layout
LSG-FS-100-002	Control, Instrumentation & Power Supply, Power Supply to Project Structures, Power Cavern

16.1 Introduction

This chapter gives a general description of the electrical and mechanical equipment of the Lower Spat Gah Project and provides a summary of Volume 8 – Mechanical and Electrical Equipment.

The arrangement and general dimensions of the individual items of equipment are shown on the drawings listed above and given with this Feasibility Study. The main connection of the different equipment is also shown on the system schematics given on the drawings. It is noted that non-binding technical and financial proposals have been received from at least two international electro-mechanical suppliers which also formed the basis for the selection of the turbine speed, the technology in general and the layout/space proofing of the Powerhouse.

16.2 Design Criteria

The main hydraulic data used for the layout and dimensioning of the turbines is summarised in Table 16-1.

Table 16-1: Hydraulic input data

Lower Spat Gah Forebay Water Levels	
Full Supply Level (FSL)	1,509.98 m asl
Minimum Operating Level (MOL)	1,499.65 m asl
Tailwater Level	
Patan reservoir Full Supply Level	760.00 m asl
Maximum operation level (future Patan reservoir at 761 m asl plus design discharge flow)	762.40 m asl
Turbine Level	
Centreline	765.40 m asl
Head	
Maximum gross head	744.58 m
Rated gross head	744.58 m
Rated net head (QT=75.0 m^3/s, all three unit turbines running)	722.08 m
Minimum gross head	734.25 m

16.3 Mechanical Equipment

16.3.1 Turbines and Valves

16.3.1.1 Turbine

For the given head range and the chosen Installed Capacity of the plant, a Pelton turbine is the only reasonable possibility as outlined in Chapter 8.7.1.

The Pelton turbines are impulse type turbines that require a certain freeboard from the maximum tailwater level. The layout of the turbines and the Powerhouse are also designed to operate up to that level of 762.4 m asl. The required freeboard to the bottom of the wheel is in the range of circa 2.5 m.

It has been assumed that certain turbine parts such as the runner with its buckets are coated as a protection against abrasion, for example with wolfram carbide. The coating will have to be determined by the turbine supplier based on the sediment characteristics in a next Project stage.

The selected Pelton turbine is a vertical-shaft type machine with six jet nozzles (25 m^3/s each) with deflectors, however final number of nozzles will be confirmed by the Supplier. An illustration of a vertical 6-nozzle Pelton turbine is shown in Figure 16-1.

Figure 16-1: Picture of a vertical 6 nozzle Pelton turbine

16.3.1.2 Turbine Speed

The speed selection of the unit is primarily determined by the given head, tail water levels, number of units, available flow and desired operating regime.

Generally a higher speed leads to smaller turbine and generator dimensions which is directly reducing the cost of the equipment and the civil structures. Therefore, it is generally preferable to select a synchronous speed as high as possible. The budgetary proposals received from international E&M suppliers confirmed the selection of the synchronous speed of 428.57 rpm based on the design for the prevailing hydraulic conditions (Chapter 8.7.4). In case the Suppliers offer a five-nozzle turbine the number of rotations could also change.

16.3.1.3 Turbine Sizing and Layout

The main turbine characteristics resulting from the hydraulic conditions defined for the Feasibility Study are shown in Table 16-2.

Table 16-2: Turbine characteristics

Turbine Characteristics	
Rated net head	722.08 m
Rated discharge per unit	25 m^3/s
Discharge at maximum net head	24.2 m^3/s
Discharge at minimum net head	25 m^3/s
Maximum turbine capacity at shaft	159.3 MW
Synchronous speed	428.57 rpm
Runner pitch diameter D2	2,510 mm
Centreline elevation	765.40 m asl
Minimum clearance of the wheel	> 2.5 m

16.3.2 Main Inlet Valve

Turbine inlet valves are needed for turbine isolation and as a secondary turbine shut-off device in case of failure of the deflector or failure of the Pelton nozzle-needle. Motor actuated bypass valves provide the ability of controlling the filling of the Pelton turbine ring pipe and equalising the pressure prior to the opening of the main valve.

The main inlet valve shall be designed to close against flow for a safe shutdown in case of an emergency especially during power failure. It shall also be able to close safely even in case of maximum turbine flow.

Considering the high water pressure at main inlet valve, a spherical valve will be provided and it will be equipped with its own hydraulic system for opening and weights for emergency closing purpose. The three valves will be installed upstream of the each of the three turbines. Each turbine will be provided with a spherical type main inlet valve (MIV) with a diameter of approximately 2.00 m.

16.4 Electrical Equipment

16.4.1 Synchronous Generator

The main generator technical data resulting from the Feasibility Study conditions are shown in Table 16-3. In the next Project phase when the efficiencies for the turbine and generator are available from binding supplier proposals, the rated power will have to be confirmed and it can be discussed if the generator should be slightly over dimensioned, as it can be expected to favourably increase the long term availability and reliability of the plant according to the Consultant’s experience.

Table 16-3: Technical data for the generators

Generator Data	
Number of units	3
Rated output per unit	190 MVA
Power factor	0.8 lagging / 0.9 leading
Maximum output per unit	195 MVA
Nominal voltage	15.75 kV[1]
Frequency	50 Hz
Nominal speed	428.57 rpm
Maximum runaway speed	750 rpm
Bearing arrangement	IM 8425 (W41)
Weight Rotor approximately	270 ton
Weight Stator approximately	200 ton

The main criteria for the selection of the generator dimensions are the speed and the maximum power.

The generators will have a state-of-the-art mica/epoxy type insulation system, allowing the operation at class F temperature rise, as this is defined in the IEC No. 60034. The long-term performance of the insulation system is affected by the maximum operating temperature of the windings.

The air-cooled generators will be equipped with air-water heat exchangers, connected to a closed-loop cooling water system. This type of cooling concept is common practice for cavern powerhouses and for this size of generators and shall considerably reduce the maintenance activities.

[1] Nominal voltage of generator depending on manufacturer design process

Each generator will be equipped with pneumatically operated brakes of sufficient capacity to stop the rotor and the turbine from about one third of the synchronous speed to standstill. The main dimensions for the generators are shown Figure 16-2.

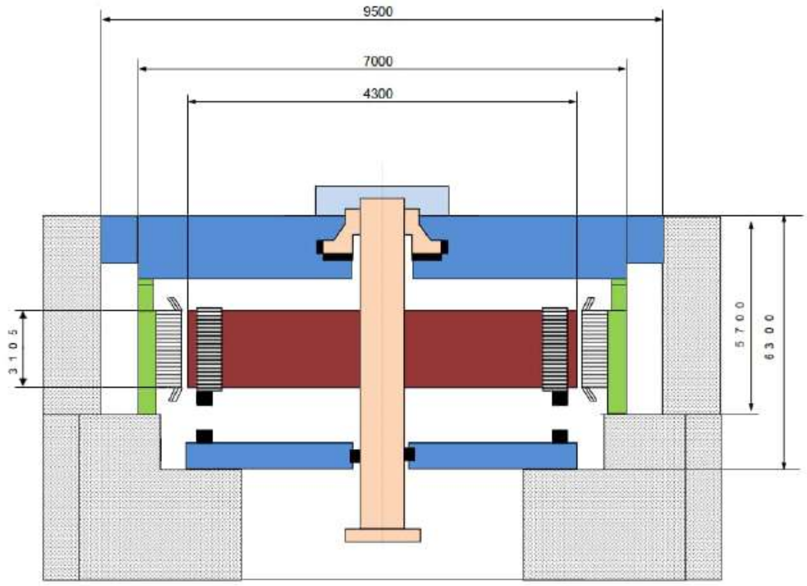


Figure 16-2: Main dimensions of the generator

16.4.2 Excitation System

The excitation system for each generator will be of a fully static type. The system will include digital voltage regulator, thyristor/diode rectifiers and field suppression equipment. The excitation energy will be drawn from the main leads through a dry-type excitation transformer, placed in a separate metallic housing. All components will have to be accommodated in cubicles. Each generator will be equipped with its proper excitation system.

16.4.3 Generator Switchgear

16.4.3.1 Insulated Phase Busbar

The connection between the generators, generator switchgear and step-up transformers will be made via Insulated Phase Busbar (IPB) with integrated instrumentation transformers and all necessary switching and protecting devices.

The system is specified as naturally cooled since the rated full load current is below the accepted limit of accepted capacity for natural cooling. To prevent ingress of pollution all enclosures will be maintained at a nominal pressure above atmospheric pressure by dry air circulation and make-up systems.

The excitation transformer and the current limiting reactor for the MV station supply will be connected by branch connections.

Table 16-4: Technical data for the generator switchgear

Generator Switchgear Data	
Number of units	3
Nominal voltage	15.75 kV
Insulation level	17.5 kV
Frequency	50 Hz

Generator Switchgear Data	
Maximum continuous current	10 kA
Maximum symmetrical 3-phase short circuit current	100 kA
Maximum symmetrical 3-phase short circuit current at tapping	120 kA

16.4.3.2 Generator Circuit Breaker

For synchronisation and protection reasons of the unit a Generator Circuit Breaker (GCB) will be specified. The GCB shall be able to open the circuit for each load case. The circuit breaker will consist of a mechanical spring mechanism and shall be specifically designed for breaking short-circuit currents close to the generator.

The GCB will be installed between the generator terminals and the main step-up transformers. The voltage rating of the circuit breaker will be in accordance with the terminal voltage of the generators.

In addition to the common protection and synchronising equipment of the main circuit breaker unit, disconnecting and earthing switches, surge arresters, current and voltage transformers etc. shall be foreseen.

16.4.3.3 Braking Switch

The braking switch will allow short-circuit between the phase terminals of the generator in order to brake the generator-turbine unit from nominal speed to one third of the speed, where the pneumatically operated brakes take over. Besides braking it will also protect the generator during commissioning and maintenance works.

16.4.3.4 Step-up Transformers

For each generator unit a three-phase step-up transformer for energy dissipation to the assumed 220 kV transmission grid will be installed. Each step-up transformer will be fixed in a separate transformer box closed by fire and explosion resistant doors in the Transformer Cavern.

On the low voltage (LV) side the connection from the generators will be made via isolated phase busbars. On the HV side the transformers will be connected to the high voltage gas-insulated switchgear (GIS) with corresponding GIS transformer connection components.

Each transformer will be protected by a firefighting system as described in the relevant mechanical balance of plant chapter.

Table 16-5: Technical data for the step-up transformers

Step-up Transformer Data	
Design	Three-phase oil immersed
Number of units	3
Rated unit output	190 MVA
Maximum unit output	195 MVA
Primary voltage	220 kV
Tap changer	On load
Secondary voltage:	15.75 kV
Frequency	50 Hz
Cooling system	ODWF or OFWF
Winding connection	YNd11

16.4.4 Gas-Insulated Switchgear

The 220 kV gas-insulated switchgear (GIS) will be located at the Transformer Cavern on a floor above the step-up transformers. The connection between each step-up transformer and the switchgear will be achieved by GIS transformer connection components.

The auxiliary distribution boards as well as the control and protection panels will be located in the GIS room and will be supplied by the station service of the Powerhouse. The control and protection of the GIS will be linked to the plant system and the remote 765/220 kV Connection Switchyard, at which the Project interfaces with NTDC.

Table 16-6: Technical data for the GIS

GIS Data	
Nominal voltage	220 kV
Maximum operation voltage	245 kV
Rated lighting impulse withstand voltage	1,050 kV
Rated power frequency withstand voltage	460 kV
Rated current for bus bar	2,000 A, 40 kA 1 s
Rated current for unit/cable feeders	1,250 A
Bus bar arrangement	Double system
Feeder	3 transformer feeders 3 cable feeders 1 bus coupler 1 measurement equipment

16.5 Mechanical Balance of Plant

16.5.1 Cooling System

There will be one central cooling system for all units installed in the Lower Spat Gah Power Cavern, consisting of a primary and a secondary water loop and supplying cooling water for the following components:

- Turbine bearings,
- Governors,
- Lower generator bearings,
- Upper generator bearings,
- Generator cooling,
- HVAC system,
- Transformers,
- Other consumers.

The raw water for supply of the system will be taken from the Tailrace Tunnel common to all three units via independent loops. Thus, full redundancy will be provided for all the components.

The primary loop will be connected to the tailrace of the units. It will be equipped with three automatic back flash filters, three circulating pumps and three heat exchangers, as a thermal connection to the secondary loop.

The secondary loop will be executed as a closed loop. The circulation of the water will be achieved by three circulating pumps of the same type as for the primary loop, for keeping the maintenance costs low.

It is noted that the type and functionality of the cooling water system are mainly driven by the way the power plant will be operated. At this stage of the Project, and because a synchronous condenser mode of the turbine is not foreseen, it was assumed that no cooling water will be needed in the shut off mode of the turbine when there is no water at the Tailrace Tunnel.

16.5.2 Drainage and Dewatering System

To keep the Power Cavern water-free and to enable dewatering of the turbines, a combined drainage and dewatering system will be installed in the Power Cavern.

Drainage System

To keep the Power Cavern water-free, all drainage water will be collected and directed over a sludge sump and an oil/water separator directly to the main drainage sump pit.

The drainage pit will be located at the lowest point of the Power Cavern. The collected water will be automatically pumped and returned to the Tailrace Tunnel after reaching the limit water level in the pit. The installed submersible pumps for transfer of the drainage water shall have a full redundancy.

The pump sump shall have an overflow pipe that shall prevent flooding in case of an emergency (e.g. failure of MIV's by-pass valve or pipe). The valve shall be motor and hand operated and remotely controlled.

Dewatering System

The penstock dewatering shall be done via the turbines directly into the Tailrace Tunnel.

Additional prevention has to be foreseen to enable dewatering of both loops of the cooling water system on the lowest point of each loop. If there are some additive in the water of the secondary loop (e.g. glycol), it is not allowed to lead the water into the sump pit. In this case, the secondary loop shall be dewatered to a separate tank.

16.5.3 Powerhouse Crane and Other Hoisting Equipment

The power craven will be supplied with its own machine hall crane enabling handling of heavy equipment and parts during erection and operation. Different types of lifting equipment will have to be installed in the Power Cavern and each crane shall be designed in accordance with the latest standards and requirements.

The required total lifting capacity for the main machine hall crane at the Power Cavern is determined by the weight of the rotor of the generator which will be approximately 270 ton with two 150 ton bridge cranes using a lifting beam for tandem operation. Furthermore, a 20 ton auxiliary bridge crane travelling underneath the main bridge cranes is foreseen for the Power Cavern.

The GIS, the IPB bust ducts, the MIV and the electrical and mechanical workshops of the Power Cavern will also be supplied with their own monorail cranes with sufficient lifting capacity. Minor other monorails (not shown) will be provided for quick installation and maintenance of the electrical and mechanical balance of plant as required.

16.5.4 Elevator

For transportation of people and material between the different floors, the machine hall cavern will be equipped with its own elevator. The elevator will have a capacity of 1,150 kg or 15 persons. The design of the elevator shall be in accordance with the latest standards and regulations.

16.5.5 Heating, Ventilation and Air-Conditioning Systems

The heating, ventilation and air conditioning (HVAC) system will provide suitable conditions for human work activities, heat evacuation and sensitive electronic equipment, avoid high concentration of polluting or harmful substances and evacuate smoke and heat in case of fire. The fire will have to be isolated into fire rated compartments by the automatic closure of smoke and fire dampers.

The HVAC room of the Power Cavern will be equipped with a central air handling unit purifying the recirculating air which will be automatically distributed to the respective areas and rooms of the Power Cavern as well as to the access tunnels of the Power Cavern. Polluted air will also be transferred to the outside automatically.

In order to keep the duct dimensions small, the power plant will be equipped with its own an air conditioning system to evacuate extensive heat from particular electrical equipment. In respect to the event of a fire hazard, the whole Power Cavern and the access/escape tunnels will be supplied with its own fire smoke extraction and fresh air supply system, guaranteeing smoke free escape ways.

16.5.6 Fire Protection, Fire Detection and Firefighting System

The firefighting system of the Power Cavern shall protect staff and equipment inside and outside of the cavern, as well as the access tunnels. In general the firefighting, fire detection and fire protection system of the Lower Spat Gah HPP will consist of an automatic fire detection and alarm system and fire extinguishing equipment for both automatic and manual operation in the event of fire.

The access tunnels connecting the Power Cavern to the surface will be supplied with an adequate amount of fire hydrants and water sprinkler fire extinguishing system. Areas inside the Power Cavern will be equipped with fire hoses and chemical extinguishers at every floor of the plant. The water based firefighting system will be fed by the firefighting water tank, located close to the portal area of the Main Access and Power Evacuation Tunnel. The firefighting water tank will have two separate chambers each with sufficient capacity in accordance with latest standards. Recharging of the firefighting tanks will be done by pumps, following a 100% redundancy policy, tapping the water out of the Indus River by a pumping station. Furthermore, the water tank shall be horizontally divided into two sections. The service water can only be provided with raw water for supply of the Industrial and Domestic Water System from the upper section of the head reservoirs.

In the lower reservoir section, the firefighting water is stored. This design ensures that at any time enough firefighting water is available.

For emergency cases and during revision works on the elevated firefighting water reservoir, one (1) electric motor driven firefighting pump, located in the Power Cavern and connected to safe power supply, will draw fire fighting water from the Tailrace Tunnel and shall supply it through the fire service main to the hose stations and water spray fixed systems.

The firefighting system will be connected to the firefighting tank via supply pipes installed in the Main Access and Power Evacuation Tunnel of the Power Cavern and raw water will be taken from the Indus River nearby. Rooms with sensitive equipment will be supplied with automatic chemical fire extinguishing systems of the FM200 type. For the generators, a gaseous extinguishing system (INERGEN) is currently foreseen.

The main transformers will be equipped with independent firefighting equipment for fire hazard purpose. The fire protection system of the transformers will be realised as a high pressure water mist system, according to state-of-the-art standards. Each main transformer will be equipped with spray nozzles, fire detectors, hot dip galvanised piping systems, and hydraulic remote control valve sets. The high pressure/compressor unit will be located in the Transformer Cavern next to the main transformers. The needed water reservoir will be designed for an operation time of 30 min for one transformer in total.

16.5.7 Low Pressure Compressed Air

The Power Cavern will be equipped with a low pressure air system to provide pressurised air to the following consumers:

- Generator brakes,
- Maintenance seal of spherical valves (if required),
- Service air within the Powerhouse.

The system will operate with approximately 10 bars. The system will consist of a central arrangement in the machine hall cavern with redundant air compressors, pressure tanks, pipes, valves, instruments, anchors and all necessary accessories.

16.5.8 Industrial and Domestic Water System

For the supply of treated water and the storage/removal of the waste water, the power plant will be supplied with its own industrial and domestic water system.

The industrial and domestic water system for the Lower Spat Gah HPP will be supplied with raw water out from firefighting water tank. The industrial and domestic water system installed in the Power Cavern shall be equipped with its own water treatment plant for purification of the raw water.

The different consumers installed inside the Powerhouse will be supplied with cold and hot water through this system.

The waste water of the different rooms will be collected by its own piping system. For storage of the collected sewage water of the different consumers the Power Cavern shall be supplied with a wastewater storage treatment package.

16.5.9 Oil Treatment Plant

For filtration, dehydration and degassing of the different oil systems, a mobile oil treatment plant will be provided. The oil treatment plant will be of the mobile type to be used for the equipment installed in the Power Cavern of the Lower Spat Gah Project.

In addition also a mobile oil tank of sufficient capacity to store oil of one complete governing system or of turbine and generator bearings of one unit will be provided.

16.5.10 Mechanical Workshop

A mechanical workshop will be provided inside the Power Cavern enabling smaller maintenance and repair works without the need to transport parts to a local workshop.

The mechanical workshop will be provided with its own monorail hoist crane type and will further also be equipped with all necessary tools needed for execution of smaller repair works.

16.6 Electrical Balance of Plant

16.6.1 Station Service and AC Power Supply

Under normal operation, the station service power supply in the Powerhouse will be ensured by two medium voltage station service transformers, connected to the 24 kV medium voltage switchgear. This switchgear will be fed by branches of the isolated busbars. For limiting the short circuit power corresponding limiting reactors are foreseen.

The 400 V AC main distribution boards will be fed from Unit 1, 2 or Unit 3. The main distribution will be separated in non-essential and essential supply. In case of failure of this energy supply, all essential loads will automatically be fed by an emergency diesel generator unit. Alternatively, an additional/backup power supply may also be provided by a direct connection to the local 11 kV medium voltage grid, if available.

The 400 V AC main distribution panels and the motor control centres will be of the modular type with circuit breakers that can be withdrawn for the main circuits and a proven design will be employed.

The power supply of the Lower Spat Gah Headworks and Lower Gabarband Intake areas will be provided by local medium or low voltage grid connection. Two small emergency power generators and DC/UPS systems for control, protection and measuring equipment will ensure essential power supply at these two areas.

For the power supply of the portal/access area a low voltage cable connection from the Power Cavern is foreseen. A small DC/UPS system for control, protection and measuring equipment will ensure essential power supply.

16.6.2 DC Power System and Uninterruptable Power Supply

The DC power system will have a voltage level of 220 V for feeding the plant control system equipment, the uninterrupted AC power supply (UPS) and the emergency lighting.

A 220 VDC system in the Power Cavern will be installed to provide power supply for control, monitoring and protection systems. The DC system will consist of a set of batteries, a twin rectifier unit and distribution panels. The 220 VDC system together with the emergency diesel generator will be designed to provide back-up energy for black start capability.

The main 220 V bus will be divided into two parts that will be linked by a bus coupling switch. Each bus section will be fed by a set of batteries and a battery charger. The main DC consumers will be fed from both bus sections. The bus coupling switch will be open in normal conditions. If one part of the bus is disconnected from this source, due to an error in charger or related battery, the bus coupling switch to the bus will be automatically closed. Both batteries will be sized to provide emergency power continuously for at least 8 hours. The total battery capacity is roughly estimated to be 1,600 Ah.

Furthermore, a UPS system will be provided to ensure 220 V AC power supply at all times to essential equipment such as computers, monitors, etc. in case of failure of the main 400 V AC system.

16.6.3 Emergency Diesel Generators

To provide emergency power supply of essential consumers within the Powerhouse a diesel generator set will be foreseen. The size of the diesel unit shall enable starting one unit without auxiliary power supply. The generator unit of approximately 1,000 kVA power will be located outside of the Power Cavern at the portal area.

Additional diesel generator sets are also considered at the Lower Spat Gah Headworks and Lower Gabarband Intake areas to provide reliable power supply for the control system and essential loads.

16.6.4 Control and Monitoring System

State-of-the-art automation systems will be provided for all plant equipment to allow both local control and control from the control room and/or load dispatch centre. It will comprise local and remote control, display and data logging facilities of the whole process.

The proposed topology is considering a process and computer local area network (LAN). On the process level all automation unit and station controllers will be connected via ring bus system.

The unit controller will take care of the interaction between the several sub-systems of a unit. The station service/auxiliaries controller will operate and control all switchgears, switchgear sections and auxiliary services located in the Powerhouse. Joint-control will manage the common operation modes of the units.

The control room will be located in the Powerhouse and will be equipped with two operator stations and one engineering station. For local control a touch panel is considered on controller level.

The Upper Erection and Gate Chamber, the Lower Spat Gah Headworks and Lower Gabarband Intake areas will be connected to the Powerhouse using fibre optical communication medium and devices.

A metering system will count the energy at the generator terminals and at the 220 kV GIS switchgear terminals.

16.6.5 Protection System

The protection system for the power plant encompasses the unit protection, mechanical protection, hydraulic protection and the electrical protection system. The task of the protection system is to monitor the unit for unallowable operating conditions, detect malfunctions at an early stage, and safely stop the unit and corresponding systems if necessary.

The electrical protection will be realised by microprocessor-based protection relay systems for each of the units and/or components, such like generator, step-up transformer, GIS switchyard and for the outgoing HV cable connection to the Connection Switchyard. The protection relays will be assembled in two independent groups as main and backup.

For data exchange, signalling and monitoring the protection system will be interconnected with the control system.

16.6.6 Grounding & Lightning Protection

One complete interconnected grounding system will be provided for the Powerhouse and all other areas. Depending on the earth electrode resistance, the mesh width will be determined. For reaching a low grounding resistance, all electric conductible equipment will be connected together and to the grounding mesh.

16.6.7 Illumination and Small Power Installations

The design and the location of the equipment will be defined by the purpose of the rooms/structures at the Powerhouse, Lower Spat Gah Headworks and Lower Gabarband Intake areas. All installations will be carried out in accordance with best modern construction practice. The lighting and socket outlet system will be 400/230V AC, three-phase, four-wire with a separate grounding wire and solidly-grounded neutral.

16.6.8 Communication Systems and Security Systems

The power plant will be equipped with a telephone, clock and public address system.

An integrated security and surveillance system will be installed to achieve a good level of protection against all potential risks of intrusion and to contribute to the process, equipment, and personnel safety through IP based Video Surveillance System (VSS) via a Closed Circuit TV System (CCTV). All these systems will be fed by the correspondent station service supply.

16.6.9 Electrical Workshop

An electrical workshop will be provided inside the Power Cavern enabling smaller maintenance and repair works without the need to transport parts to a local workshop.

The workshop will be provided with its own crane of monorail hoist crane type and will further also be equipped with all necessary tools needed for execution of smaller repair works.

16.7 Standards and Regulations

The equipment and systems will be designed in compliance with Codes and Standards applicable in Pakistan.

- American National Standards Institute (ANSI)
- American Society for Testing and Materials (ASTM)
- Institute of Electrical and Electronics Engineers (IEEE)
- International Electrotechnical Commission (IEC)
- American Society of Mechanical Engineers (ASME)
- Insulated Cable Engineers Association (ICEA)
- National Electrical Code (NEC)

- National Electrical Manufacturers Association (NEMA)
- National Fire Protection Association (NFPA)
- Steel Structures Painting Council (SSPC)
- National Association of Corrosion Engineers (NACE)
- American Institute of Electrical Engineers (AIEE)
- Illumination Engineering Society (IES)

17 Transmission Line and Interconnection

17.1 Introduction

This chapter summarises the power systems study conducted to evolve an interconnection scheme between the Lower Spat Gah HPP and the National Grid, for stable and reliable evacuation of electrical power generated from this Project. The complete report is attached in Volume 9 – Transmission Line Studies.

17.2 Interconnection Scheme

The proposed interconnection scheme is to Loop In and Out Lower Spat Gah HPP on the proposed 765 kV line connecting Dasu and Mansehra with an assumed looping length of 10 km. The length has to be confirmed once the transmission line survey data and the Dasu-Mansehra transmission alignment is available.

In order to connect the Lower Spat Gah Project to the 765 kV Dasu-Mansehra transmission line, a 765/220 kV Connection Switchyard located near the Powerhouse access tunnel portals will have to be constructed. The Connection Switchyard will consist of the 765 kV outdoor GIS yard, one auto transformer bank 570 MVA 765/220 kV, and a 220 kV GIS yard for connecting the three high voltage cable systems from the power cavern. The technical data is listed in Table 17-1.

Table 17-1: Technical data for the 765/220 kV Connection Switchyard

Main Data	
765 kV Yard	765 kV outdoor GIS, 1.5 CB, 4000 A 2 Line bays with reactors, AIS HV line equipment 1 Transformer feeder
Auto Transformer Bank	3 x 190 MVA single-phase transformers 765/220 kV AIS HV equipment
220 kV Yard	220 kV in-/outdoor GIS, 1.5 CB, 2000 A 1 Transformer feeder 3 Cable bays, AIS HV cable equipment
Station Service	Common control building and infrastructure

17.3 Base Case 2030

The transmission network data beyond 2028 was not available from NTDC at the time of the study. The power systems studies are however carried out for the year 2030 when the Lower Spat Gah Project delivers power to the grid after COD. The power system studies cannot be carried out without the system model for the year 2030. The availability of the NTDC transmission expansion plan for 2030 was unclear at the start of the studies.

In agreement with NTDC and to facilitate these power system studies, PPI developed an interim Base Case for 2030 based on i) assumptions agreed with NTDC and ii) the approved load forecast until 2030 and system data (NTDC Transmission Plan & IGCEP). Once the NTDC transmission plan for 2030 is available, the power systems studies might have to be updated. This was done for the peak case as well as the off-peak case.

17.4 Load Flow Studies

Detailed load flow studies have been carried out for following scenarios:

- Peak load summer 2030,
- Off-peak load summer 2030.

The peak load case for summer 2030 has been studied in detail for both without and with the Lower Spat Gah HPP. It can be concluded from the analysis that the proposed interconnection scheme with all the proposed reinforcements and the protection schemes is adequate to evacuate the power of the Lower Spat Gah HPP under normal and contingency conditions. The interconnection ensures reliability and availability under all events of contingencies, i.e. planned or forced outages studied in this report for the base year. The bus bar voltages remain well within the permissible limits in all the contingency events.

17.5 Short Circuit Analysis

In order to assess the short circuit strength of the 765 kV network without the Lower Spat Gah HPP, three-phase and single-phase fault currents have been calculated for the NTDC network in the vicinity of the Lower Spat Gah HPP site for the year 2030. These levels will give the information of the fault levels without the Lower Spat Gah HPP, which can be used to determine the impact of the addition of the Project later on.

The total maximum fault currents for 3-phase and 1-phase short circuit at these substations are summarized in Table 17-2. The maximum calculated fault currents do not exceed the short circuit ratings of the equipment at these substations.

Table 17-2: Maximum short circuit levels without Lower Spat Gah HPP

Substation	3-Phase Fault Current (kA)	1-Phase Fault Current (kA)
Dasu 765 kV	11.35	12.06
Mansehra 765 kV	13.88	10.85
ISB-W 765 kV	15.12	13.39
ISBD-W 500 kV	47.92	40.53
Tarbela 500 kV	45.66	48.08
G. Brotha 500 kV	37.77	32.93
Gatti 500 kV	33.04	24.07
Rewat-N 500 kV	34.31	25.01
Gujranwala 500 kV	36.21	26.17
Maira-S/S 500 kV	33.26	27.97

Maximum fault currents have then been calculated for the electrical interconnection of the proposed scheme. A summary of fault currents at significant bus bars of interest are tabulated in Table 17-3. The comparison of Table 17-2 and Table 17-3 shows that results of short circuit levels for three-phase and single-phase faults improved due to the connection of the Lower Spat Gah HPP on the 765 kV bus bars, these fault levels are much below the rated short circuit values of the equipment installed at these substations.

The maximum short circuit levels at Lower Spat Gah 765 kV are 12.65 kA and 11.17 kA for 3-phase and 1-phase faults, respectively, in the year 2030. Therefore, industry standard switchgear of a short circuit rating of 63 kA would be sufficient for installation at 765 kV switchyard of Lower Spat Gah HPP, as the maximum short circuit levels for the year 2030 were also found to be within this range, taking care of any future generation additions and system reinforcements in its electrical vicinity and also fulfilling the NEPRA Grid Code requirements specified for 765 kV switchgears. There are no violations of the power rating of the equipment in the vicinity of Lower Spat Gah HPP in the event of fault conditions.

Table 17-3: Maximum short circuit levels with Lower Spat Gah HPP

Substation	3-Phase Fault Current (kA)	1-Phase Fault Current (kA)
Lower Spat Gah 765 kV	12.65	11.17
Dasu 765 kV	12.87	13.52
Mansehra 765 kV	15.08	11.42
ISB-W 765 kV	16.01	13.87
ISBD-W 500 kV	48.78	40.97
Tarbela 500 kV	46.07	48.38
G.Brotha 500 kV	37.96	33.06
Gatti 500 kV	33.01	24.05
Rewat-N 500 kV	34.59	25.12
Gujranwala 500 kV	36.12	26.08
Maira-S/S 500 kV	33.34	28.01

17.6 Dynamic Stability Analysis

The dynamic stability has been analysed to check if the interconnection withstands dynamic stability criteria of post fault recovery with good damping. Each simulation is run for its first one second for the steady state conditions of the system prior to fault or disturbance. This is to establish that the pre fault/disturbance conditions of the network under study were smooth and steady. Post fault recovery has been monitored for nineteen seconds. Usually, all the transients due to non-linearity die out within a few seconds after disturbance is cleared in the system.

Three-phase faults are considered as the worst disturbance in the system and line tripping has been simulated at the Lower Spat Gah HPP, Dasu HPP and Mansehra HPP bus bars.

The results of the dynamic stability carried out for summer 2030 show that the system is strong and stable for the proposed scheme for the severest possible faults of 765 kV systems near the Lower Spat Gah HPP under all events of disturbances. Therefore, there is no problem of dynamic stability for interconnection of the Lower Spat Gah HPP, it fulfils all the criteria of dynamic stability. The system is found strong enough to stay stable and recovered with fast damping.

17.7 Conclusion

The power systems study showed that the proposed scheme of interconnection has no technical constraints or problems, it fulfils all the criteria of reliability and stability under steady state load flow, contingency load flows considered, short circuit currents and dynamic/transient conditions.

18 Environmental and Social Impact Assessment

18.1 Introduction

This chapter is a summary of Volume 11 – Environmental and Social Impact Assessment, which presents the results of the Environmental and Social Impact Assessment (ESIA) and the Resettlement Action Plan (RAP) developed as part of the study.

The overall purpose of the ESIA is to identify the potential environmental and social impacts of the Project and evaluate them following a process which is acceptable to regulatory authorities in Pakistan and the Project Lenders. In this process, the ESIA identified measures to minimize any anticipated adverse impact of the Project, at least to the level that it meets the national and good international industry practice criteria for evaluation of environmental and social impacts, in particular the International Finance Corporation's (IFC) Standards and the Equator Principles.

Besides the standard evaluations and consultations, the ESIA also assessed whether:

- The Project would trigger Critical Habitat for any impacted flora or fauna species and to what extent modified and natural habitats are impacted. This assessment resulted together with the environmental flow assessment's conclusions in the preparation of a Biodiversity Action Plan,
- The Project would cause, reduce or increase cumulative impacts in combination with other existing and proposed large infrastructure in the region,
- Anticipated climate change impacts would cause any risks to the Project.

18.2 Stakeholder Consultation

The consultation process was designed to be consistent with relevant national legislation and the IFC Performance Standards.

Consultations with Project stakeholders were undertaken in October, November, and December 2020. A Background Information Document (BID) prepared in English and Urdu was shared with the stakeholders. The BID provided a background about the Project and informed the stakeholders about the ESIA process. A total of 11 local communities were consulted, and meetings with key institutional stakeholders were conducted. The main concerns expressed by the communities include the water usage, provision of health, education and access roads as well as the impact of the construction and people from outside the area.

18.3 Grievance Redress Procedure

A procedure will be adopted to resolve grievances received by the Grievance Redress Committees. The grievance mechanism will be made public through public consultations by the Environment and Social Unit of the Power Management Unit and the Consultant.

18.4 Baseline Studies

To assess the impact of the Project on the existing conditions, the baselines of the following environmental and social conditions were established:

- Physical environment: geology, soils, hazards, topography, land use, climate, air quality, sound levels, visual character, and the water resources of the study area.
- Ecology baseline: fish, macro-invertebrates, riparian vegetation, terrestrial flora, mammals, avifauna, and herpetofauna of the study area.
- Socioeconomic environment: narrative description of the socioeconomic zones, a description of the demographics, ethnicity, religion, governance, and administrative setup, social service infrastructure, physical infrastructure, local economy household socioeconomic conditions, indigenous people, and cultural heritage of the study area.

The impact of the Project design, construction, and operation on the physical, ecological and socioeconomic environment of the area is assessed in relation to the baseline studies.

18.5 Study of Alternatives

The study of alternatives identified and analyzed various alternatives to the Project and its design, this included ‘no project’ option, alternative technology and scale of power generation, alternative Project location and layout, peaking and non-peaking operation, environmental flow and management option, and options for equipment and supplies transportation.

Over the last decade, the Government of Pakistan prioritised hydropower development across all territories in its control to overcome massive shortfalls in power capacity which are estimated to have reached 8,500 MW in 2012. Pakistan is now on the path to successfully overcoming this energy crisis, through increase in generation as well as in transmission capacity. In 2016, the gap between supply and demand was over 2,600 MW according to PEDO. The proposed Project will contribute 470 MW to the supply of much needed power to reduce the current gap. Thus, in the absence of this Project, the gap in power supply and demand will continue to grow.

The alternatives to the proposed hydropower project include power generation from liquefied natural gas / imported natural gas based combined cycle gas turbines, coal fired steam plants, and fuel oil-based diesel engines. In addition, other technologies such as nuclear, and wind and solar renewable energy power plants could also be considered as alternatives. An analysis of the life cycle average cost of generation from the competing technologies was carried out by NEPRA to assess the least cost generation alternative of the Project.

The cost of power generation for the proposed large size run-of-river hydropower project is lower than that for LNG, and comparable to coal. Even though the cost of wind energy and solar projects is lower, the power generation is intermittent and weather dependent and requires back up fossil fuel-based power generation capacity or pumped storage projects to maintain supply in the grid.

18.6 Project Impacts

During the scoping stage of the ESIA process, several potential environmental and social impacts of the Project were identified. The baseline surveys were conducted keeping in consideration the potential impacts.

A summary of Project impacts is presented in Table 18-1, with probability being the likelihood of the impact based on Project information and expert judgement. All other environmental impacts are of minor or moderate significance. Only the impacts on aquatic biodiversity can be considered significant. These impacts will be mitigated by maintaining minimum environmental flow and implementing a Biodiversity Action Plan.

Major social impacts include acquisition of land which will require resettlement of some households. In addition, influx and exposure to outsiders during the construction and operation phase is also seen as a risk to the small yet culturally sensitive indigenous community.

The impact assessment show what mitigation measures are required and defines them further in the Environmental and Social Management Plan, the Biodiversity Action Plan and the Resettlement Action Plan.

Table 18-1: Summary of identified environmental and social impacts

ID	Aspect	Impact	Phase	Stage	Magnitude	Timeframe	Spatial Scale	Consequence	Probability	Significance	+/-	Confidence
1	Ambient air quality	Increase in ambient and ground level concentration of air pollutants from construction activities and vehicular movement may cause health impacts to the community.	C	Ini.	Moderate	Short Term	Inter-mediate	Medium	Possible	Medium	-	High
				Res.	Minor	Short Term	Small	Low	Possible	Low	-	High
2	Blasting and vibration	Vibration from blasting during the construction phase may disturb local communities.	C	Ini.	Moderate	Short Term	Inter-mediate	Medium	Possible	Medium	-	High
				Res.	Minor	Short Term	Small	Low	Possible	Low	-	High
3	Blasting and vibration	Blasting may pose a health hazard due to flying debris.	C	Ini.	Major	Short Term	Inter-mediate	Medium	Possible	Medium	-	High
				Res.	Minor	Short Term	Small	Low	Possible	Low	-	High
4	Hydrology and water quality	Alterations of natural passage of springs due to blasting for tunnels may disrupt the water supply for mountain spring users.	C, O	Ini.	Moderate	Long Term	Inter-mediate	High	Possible	High	-	High
				Res.	Minor	Long Term	Inter-mediate	Medium	Possible	Medium	-	High
5	Hydrology and water quality	Use of local water resources for construction activities may reduce the water availability for local communities.	C	Ini.	Moderate	Short Term	Inter-mediate	Medium	Possible	Medium	-	High
				Res.	Minor	Short Term	Small	Low	Unlikely	Low	-	High
6	Hydrology and water quality	Discharge from construction activities can potentially result in the contamination of groundwater and surface water.	C	Ini.	Moderate	Short Term	Small	Low	Possible	Low	-	High
				Res.	Minor	Short Term	Small	Low	Unlikely	Low	-	High

ID	Aspect	Impact	Phase	Stage	Magnitude	Timeframe	Spatial Scale	Consequence	Probability	Significance	+/-	Confidence
7	Construction noise	Increase in ambient noise levels due to operation of construction equipment, movement of construction traffic and blasting may create nuisance for nearby communities.	C	Ini.	Moderate	Short Term	Small	Low	Possible	Low	-	High
				Res.	Minor	Short Term	Small	Low	Possible	Low	-	High
8	Soil, topography, and land stability	Contamination of soil because of accidental release of solvents, oils and lubricants can degrades soil fertility and agricultural productivity.	C	Ini.	Moderate	Short Term	Inter-mediate	Medium	Possible	Medium	-	High
				Res.	Minor	Short Term	Inter-mediate	Low	Unlikely	Low	-	High
9	Soil, topography and land stability	Land clearing, excavation, tunnel boring and other construction activities may loosen the topsoil in the Project area resulting in loss of soil and possible acceleration of soil erosion and land sliding, especially in the wet season.	C	Ini.	Moderate	Short Term	Inter-mediate	Medium	Definite	Medium	-	High
				Res.	Minor	Short Term	Small	Low	Possible	Low	-	High
10	Soil, topography, and land stability	Failure of spoil dumping sites resulting in increased erosion and sediment load entering river.	C	Ini.	Moderate	Short Term	Inter-mediate	Medium	Definite	Medium	-	High
				Res.	Minor	Short Term	Small	Low	Possible	Low	-	High
11	Aesthetics	Deterioration of aesthetics and	C	Ini.	Minor	Short Term	Small	Low	Possible	Low	-	High

ID	Aspect	Impact	Phase	Stage	Magnitude	Timeframe	Spatial Scale	Consequence	Probability	Significance	+/-	Confidence
		visual amenity of nearby receptors due to construction activities, including vehicular movement on roads, may cause disturbance in aesthetics for tourists, businesses and nearby communities.		Res.	Minor	Short Term	Small	Low	Possible	Low	-	High
12	Aesthetics	Permanent change in aesthetics of the area due to the reservoirs and dam.	O	Ini.	Minor	Long Term	Inter-mediate	Medium	Possible	Medium	-	High
				Res.	Minor	Long Term	Small	Medium	Possible	Medium	-	High
13	Traffic and roads	Improved accessibility due to construction of Project access roads.	C, O	Ini.	Minor	Long Term	Intermediate	Medium	Definite	Medium	+	High
				Res.	Minor	Long Term	Intermediate	Medium	Definite	Medium	+	High
14	Traffic and roads	Increase in congestion, due to increased traffic volume will cause delays.	C	Ini.	Minor	Short Term	Small	Low	Possible	Low	-	High
				Res.	Minor	Short Term	Small	Low	Possible	Low	-	High
15	Traffic and roads	Increase in traffic volume will deteriorate the air quality.	C	Ini.	Minor	Short Term	Small	Low	Possible	Low	-	High
				Res.	Minor	Short Term	Small	Low	Possible	Low	-	High
16	Traffic and roads	Increased risk to community safety due to increased traffic volume during the construction phase near communities.	C	Ini.	Minor	Short Term	Small	Low	Possible	Low	-	High
				Res.	Minor	Short Term	Small	Low	Possible	Low	-	High
17	Traffic and roads	Degradation of the pavement due to use by heavy construction traffic.	C	Ini.	Minor	Short Term	Small	Low	Possible	Low	-	High
				Res.	Minor	Short Term	Small	Low	Possible	Low	-	High
18	Climate Change	GHG Emissions due to inundation of biomass in the Lower Spat Gah HPP Reservoirs	O	Ini.	Minor	Medium term	Inter-mediate	Low	Possible	Low	-	High
				Res.	Minor	Medium term	Inter-mediate	Low	Possible	Low	-	High

ID	Aspect	Impact	Phase	Stage	Magnitude	Timeframe	Spatial Scale	Consequence	Probability	Significance	+/-	Confidence
19	Climate Change	Embodied GHG emissions from construction materials will increase GHG concentration in the atmosphere thereby contributing to climate change.	C	Ini.	Minor	Short Term	Inter-mediate	Low	Definite	Low	-	High
				Res.	Minor	Short Term	Inter-mediate	Low	Definite	Low	-	High
20	Aquatic Ecology	Loss of Aquatic Biodiversity due to Creation of a Low Flow Section	C, O	Ini.	Moderate	Long Term	Small	Modera te	Definite	Medium	-	High
				Res.	Moderate	Long Term	Small	Modera te	Definite	Medium	-	High
21	Terrestrial Ecology	Terrestrial habitat loss due to development of Project infrastructure	C	Ini.	Minor	Short Term	Small	Low	Possible	Low	-	High
				Res.	Minor	Short Term	Small	Low	Possible	Low	-	High
22	Terrestrial Ecology	Decline in abundance and diversity of terrestrial flora and fauna caused by construction related activities.	C	Ini.	Minor	Short Term	Small	Low	Possible	Low	-	High
				Res.	Minor	Short Term	Small	Low	Possible	Low	-	High
23	Terrestrial Ecology	Project operation leading to animal disturbance, displacement and decline	O	Ini.	Minor	Long Term	Small	Mediu m	Possible	Medium	-	High
				Res.	Minor	Medium	Small	Low	Possible	Low	-	High
24	Employment	Direct, indirect and induced employment at the local levels, resulting in increased prosperity and wellbeing due to higher and stable incomes of people.	C, O	Ini.	Minor	Long term	Inter-mediate	Mediu m	Possible	Medium	+	High
				Res.	Moderate	Long term	Inter-mediate	High	Definite	High	+	Medium
25	Training and Skill Development	Increase in the stock of skilled human capital due to transfer of knowledge and skill under the Project resulting in enhanced productivity of the local labor.	C, O	Ini.	Minor	Long term	Inter-mediate	Mediu m	Possible	Medium	+	Low
				Res.	Moderate	Long term	Inter-mediate	High	Possible	High	+	Low

ID	Aspect	Impact	Phase	Stage	Magnitude	Timeframe	Spatial Scale	Consequence	Probability	Significance	+/-	Confidence
26	Land Acquisition	Loss of assets and livelihood because of land acquired for the Project.	C, O	Ini.	Major	Long term	Extensive	High	Definite	High	-	High
				Res.	Minor	Medium	Small	Low	Possible	Low	-	Low
27	Pressure on Social Infrastructure and Services	Increase in population due to in-migration of job seekers (in-migrants) leading to pressure on existing social infrastructure and services in the Study Area.	C	Ini.	Moderate	Medium	Inter-mediate	Medium	Possible	Medium	-	Medium
				Res.	Minor	Medium	Inter-mediate	Low	Possible	Low	-	Medium
28	Conflicts Due to Provision of Employment to Outsiders	Disputes over distribution of Project employment within and between Study Area inhabitants and the in-migrants resulting in social unrest.	C	Ini.	Moderate	Medium	Inter-mediate	Medium	Possible	Medium	-	High
				Res.	Minor	Short term	Inter-mediate	Low	Possible	Low	-	Medium
29	Conflicting Socio-Cultural Norms	Potential social unrest in the Study Area due to conflicting socio-cultural norms amongst the inhabitants and in-migrants.	C	Ini.	Minor	Short term	Small	Low	Possible	Low	-	Medium

C: Construction (and pre-Construction); O: Operation; Init: Initial; Res: Residual; Duration: Short (less than four years), Long (beyond the life of the Project)

Frequency: High (more than 10 times a year), Low (less than once a year)

18.7 Environmental Flow Impact Assessment

An environmental flow assessment for the Spat Gah and Gabarband Rivers, upstream and downstream of the Project was carried out as part of the ESIA. The objectives of the assessment were:

- To assess the environmental (ecological and social) implications of the operation of Lower Spat Gah HPP on the Spat Gah and Gabarband Rivers,
- Provide stakeholders with the above information to facilitate informed decision making for Project operation,
- Support the development of the Biodiversity Action Plan.

In addition to the flow and barrier related impacts on the aquatic biodiversity which will be caused by Project development, there are limited non-flow related pressures on the river ecosystem that are impacting the biodiversity. Due to the low levels of socioeconomic pressures, socioeconomic parameters were not included directly in the EFlow assessment.

The EFlow assessment paid particular attention to the impacts on the vulnerable and migratory Snow Trout which is a fish species of concern with regards to conservation significance. The impact of different flow scenarios on the fish population compared to the baseline was determined and the final decision on the environmental flow should be taken by the relevant Project stakeholders considering the trade-off to power generation and the survival of the species present in the river under advice from KP EPA.

18.8 Climate Change Risk Assessment

The climate change risk assessment was carried out to evaluate the assessment of anticipated future changes in climate and their impact on the Project.

The Climate Change Risk Assessment concluded that the Lower Spat Gah HPP, as currently planned, is unlikely to be impacted by climate related changes in the catchment and is unlikely to impact the downstream water availability.

18.9 Cumulative Impact Assessment

This Cumulative Impact Assessment was prepared as part of the ESIA, and the assessment followed the methodology of IFC's Good Practice Handbook on Cumulative Impact Assessment and Management, and guidance notes from IFC's Performance Standard 1.

Presently, 15 hydropower projects are in various development stages in the Spat Gah and Upper Indus Basin. These include three projects that are operational, two under construction, three projects at feasibility stage, and seven projects at Pre-Feasibility stage. The combined installed capacity of these projects is approximately 17,841 MW.

The following Valued Environmental and Social Components were prioritized after a detailed literature review, Project Feasibility studies, and information gathered from multiple site visits and stakeholder consultations:

- River ecology,
- Flow regime,
- Fish fauna.

Climate change, seismicity, unregulated fishing, and waste generation are the three external stressors impacting the VECs.

Based on the assessment under full development scenario, the main stream of the Indus River will be highly modified after completion of all 15 hydropower projects. However, relative contribution of Lower Spat Gah HPP in the cumulative impacts is considered low.

18.10 Biodiversity Action Plan

A Habitat Assessment for the Project site and vicinity was carried out as part of the ESIA of the Lower Spat Gah Hydropower Project according to the IFC's Performance Standard 6 (IFC PS6). It was determined that the Project lies in a Natural Habitat both for aquatic and terrestrial environment. This is because the water of the river is not regulated by dams, reservoirs, or barrages. Anthropogenic impacts such as sediment extraction from riverbed and banks (for construction) is limited, primarily because the Spat Gah Valley is difficult to access and demand for sediment is low.

In Natural Habitats, 'no net loss where feasible' is required for those values for which Natural Habitat has been designated under IFC PS6. The Biodiversity Action Plan (BAP) was prepared to meet the requirements of IFCs PS6.

The strategy and approach used for protecting the biodiversity included the following:

- Setting up an effective protection system that will help to reduce the existing anthropogenic pressures in the Area of Management which is central to keeping the integrity of the Area of Management of the BAP intact. This will:
    - o Curtail illegal fishing including non-selective fishing, fishing in breeding season of fish, fishing in river tributaries,

- o Regulate sediment mining to maintain it at sustainable levels and prevent sediment mining from ecologically sensitive locations,

- Promote environmental awareness among the local communities and engage them in protecting the ecological resources,
- Institutional strengthening of custodian government departments.

18.11 Resettlement Action Plan

A Resettlement Action Plan has been prepared for the Project to undertake the resettlement in a fair and open manner and to minimise social or economic impacts. The basic principles used for resettlement are derived from Pakistani laws, IFC Performance Standards and ADB's Safeguard Policy Statement 2009 so that the livelihoods and standards of living for all affected households are improved or at least restored.

A total of 90 households will be affected by the execution of the Project based on the resettlement field survey conducted in October and November 2020. Out of 90 households, 25 households' residences will be affected, 25 households' cultivated lands and crops will be affected, 82 households' uncultivated lands will be affected, 21 households will lose their fruit trees, and 74 households will lose their non–fruit trees. All the affected households losing any asset will be compensated according to the replacement cost. Every Project Affected Person losing their livelihood resources or places of income generation because of Project interventions will be supported with income and livelihood restoration assistance. Moreover, eligible PAPs will also receive resettlement allowances like relocation allowance, vulnerability allowance, severe impact allowance etc.

The Resettlement Action Plan also provides a grievance redress mechanism and a monitoring and evaluation system. It is also anticipated that the Project development will significantly contribute to the betterment of the socio-economic conditions in the Project area besides better connectivity and overall improvement of local and regional infrastructure.

19 Transportation Survey

19.1 Road Route

This transportation survey chapter is a summary of Volume 10 – Transportation Survey which presents the results of the route survey carried out for the Lower Spat Gah Project. It was assumed that the relevant equipment is transported from Port Qasim in Karachi to the Project site, and a viable transport route has been identified. The route shown in Figure 19-1 has been selected because it is the route used for the majority of heavy cargo transports in Pakistan. It is the most optimal, feasible and safe route as indicated by the many past heavy cargo transports using the presented road. The survey documents the obstacles such as bridges and overhead structures along the route as observed during the survey in October 2020.

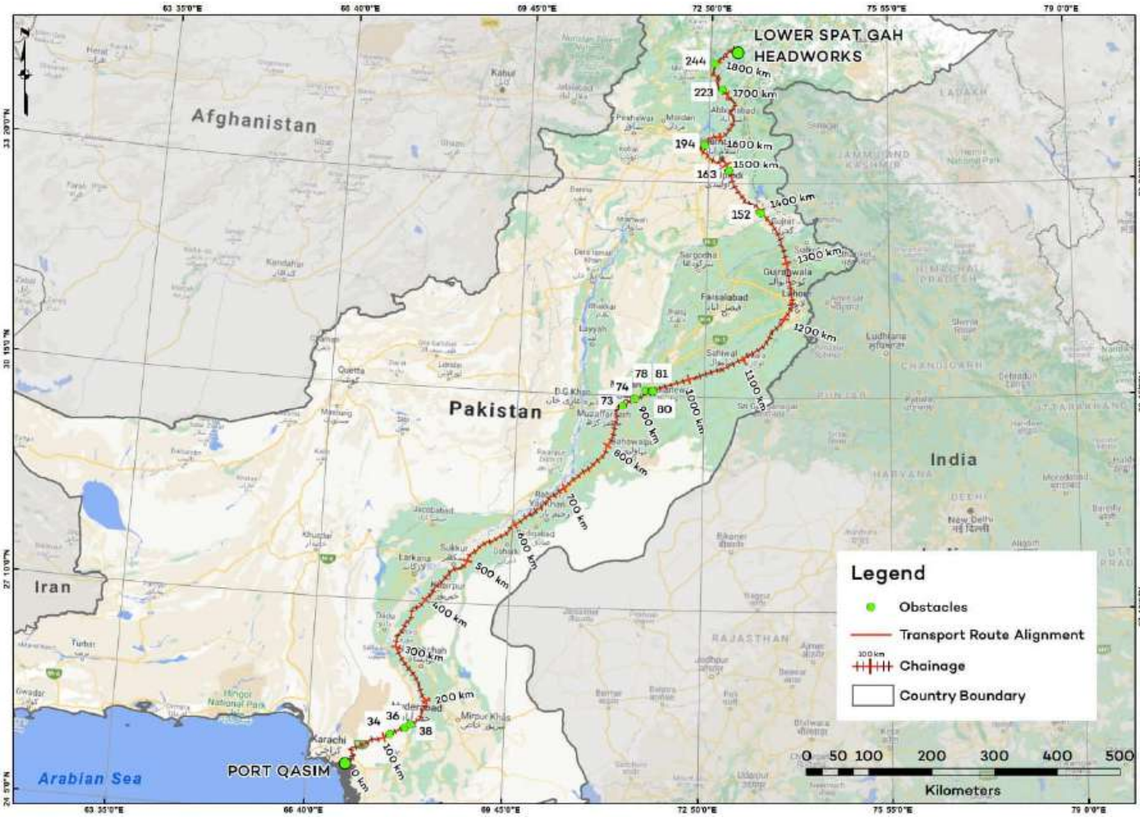


Figure 19-1: Route overview between Port Qasim, Karachi, and the Project site

19.2 Railway Route

There is a railway line between Karachi and Havelian station north of Islamabad. The only availability for cargo movement with the railway infrastructure is based on standard 20 or 40-foot containers with standard weight limitations of 15 tons per container. Because such options are not applicable for the transport of the heavy bulk equipment, the transportation survey only comprised road routes.

19.3 Relevant Equipment to be Transported

The heavy and large equipment to be transported to the site consists of turbines, generators, transformers and hydromechanical equipment. The equipment will mostly be manufactured outside of Pakistan and is expected to be unloaded in Karachi. The largest and heaviest cargo dimensions relevant for the route survey are given in Table 19-1.

Table 19-1: Overview of largest and heaviest cargo

Equipment	Transport Weight (tons)	Dimensions (m)	Remark
Turbine runner - outer diameter	-	3.2	
Generator			Generator design can be adopted to transport restrictions in a wide range, therefore not relevant
Transformer	125	8.5 x 4.0 x 4.0	Heaviest and largest cargo (without oil)
GIS	5	4.5 x 2.2 x 2.2	
Butterfly valve upstream of pressure shaft	60	4.0	
MIV upstream of powerhouse	70	2.0	

19.4 Trailer Categories in Pakistan

Table 19-2 lists the trailer categories in Pakistan. All provisioned details are as per Pakistan's Logistics Market Dynamics.

Table 19-2: Trailer categories in Pakistan

Description of Equipment	Axle based Composition	Trailer Capacity
Flat-bed trailer	Bi-axle based trailer	Max up to 20 ton
	Tri-axle based trailer	Max up to 35 ton
Low-bed trailer	Bi-axle based trailer	Max up to 60 ton
	Tri-axle based trailer	Max up to 120 ton
Specialized trailer / hydraulic multi-axle modular trailer	Multi-axle composition	Weight handling to be based on range from 100 to 500 ton average in Pakistan

19.5 Roads and Bridges along Route

As much information as possible about the minimum dimensions and maximum weight capacity of roads and bridges has been collected from the relevant authorities for this survey. However, information is often not available to the general public or firms for bridges located in the Northern Region.

Based on the route survey detailed in Volume 10 - Transportation Survey, the maximum weight and minimum road dimensions between Karachi port and the new Indus Bridge near the Lower Spat Gah Powerhouse area can be summarised as follows:

- Minimum road clearance: 3.5 m (min road width at 3.0 m) at one obstacle,
- Minimum road height: 5.1 m at nine obstacles,
- Maximum bridge pay load capacity (where known):
    - 150 ton, maximum span: 35 m at ten obstacles,
    - 140 ton, maximum span: 42.6 m at one obstacle,
    - 130 ton, maximum span: 9 m at one obstacle,
    - 128 ton, maximum span: 45 m at one obstacle.

While information could be retrieved from the National Highway Authority (NHA) for most of the bridges along the route, the nominated agent authorized for Project logistics by the EPC Contractor will have to approach NHA during Project execution to collect the missing information.

19.6 Conclusion

Based on the conducted survey, there is only one obstacle with a road width and clearance smaller than the largest equipment. Civil work may be required in the form of road extension / expansion over a length of 49 m. All other obstacles on the route to Dasu have a road clearance of at least 4.6 m.

Possible civil work due to minimum road height and bridge capacity will have to be evaluated by the logistics subcontractor during the Project execution when the final dimensions are known and the route feasibility is evaluated. It is recommended to not transport the relevant equipment in the monsoon season due to the risk of landslides.

It is expected that the transformers of the Dasu HPP, which are heavier and larger, will be using the same route. It is recommended to approach the Project Owners about their transportation concept and using synergies to be able to transport the Lower Spat Gah HPP equipment with minor or no adjustments to be borne by the Client for the Lower Spat Gah HPP.

20 Construction Procedure and Schedule

Corresponding Drawings

LSG-FS-040-001	Site Facilities, Site installations, Borrow & Disposal Areas, General Layout
LSG-FS-040-002	Site Facilities, Main Site Installation Powerhouse, Overview Map
LSG-FS-040-003	Site Facilities, Site Installation Lower Spat Gah Headworks, Overview Map
LSG-FS-040-004	Site Facilities, Site Installation Gabarband Crossing and Lower Gabarband Intake, Overview Map

20.1 General

The implementation of the Lower Spat Gah Project can be divided into the pre-award activities, early works (2 years), the construction phase and the commissioning phase (5.5 years) for an assumed total construction duration of 7.5 years. The pre-award activities consider the activities required for the development of the Project prior to execution such as further design activities including complementary site investigations, EPC tendering, negotiating the concession agreement, achieving financing and securing the power purchase agreement. The early works of the Project begin after the Client has taken the initial investment decision.

The early works will consist of the provision of site infrastructures as well as some of the access roads as an acceleration measure for the main works. The construction of the Lower Spat Gah HPP involves several different and independent construction sites spread out over a wide area. Therefore the construction of access roads and access tunnels to the different sites becomes an important and with regard to the schedule critical part of the construction works. The Project work can be divided into the following three main areas for the works:

- Lower Spat Gah Headworks comprising dam, flushing channels, desander intake, desander and Headrace Tunnel intake as well as Lower Gabarband Intake comprising weir, desander intake, desander and Gabarband Intake Tunnel intake, both with river diversion in two stages,
- Power Waterway including Headrace Tunnel, Pressure Shaft, Surge Shaft, penstock to Powerhouse and Gabarband Intake Tunnel,
- Powerhouse complex containing Powerhouse Cavern, Transformer Cavern, Tailrace Tunnel and access tunnels.

20.2 Project Milestones

It has been assumed to start construction of the main access roads in January of Year 1 after the approval of the Feasibility Study by the Korean and Pakistani governments. The finalisation of the access road to the Powerhouse portal together with the mobilisation of the EPC Contractor in the first half of Year 2 will allow for the start of the main works for the Powerhouse complex in the second half of Year 2.

Due to the required access roads the works for the Headrace Tunnel from the Gabarband Crossing will start at the end of Year 2 while the works for the Lower Spat Gah Headworks and the Headrace Tunnel from the Lower Spat Gah Headworks the works will start at the end of Year 3. This results in a Commercial Operation Date in the middle of Year 8. With this the total construction time is 7.5 years with 2 years of early works and 5.5 years of main construction and commissioning works.

The key Project milestones are listed in Table 20-1.

Table 20-1: Key Project planning milestones

Project Planning	
Commencement date of access road construction	January Year 1
Commencement Date of EPC Contract	January Year 2
Lower Spat Gah reservoir ready for Impounding	June Year 7
Waterway ready for Filling	October Year 7
Date of Completion	April Year 8
Commercial Operation Date	June Year 8

20.3 Early Works Activities

The early works activities comprise the Project access roads and the Owner's and Owner's Engineer's camp. Table 20-2 lists the access roads and for which works they are required.

Table 20-2: Summary of access roads and bridges

Access Roads and bridges	Enabling Works
Bridge across Indus River	All works of Project
Access roads to Tailrace Outlet Structure and Powerhouse access portals	Powerhouse Complex, Tailrace Tunnel, High Pressure Tunnel, Pressure Shaft
Access road to Dogah	All headworks and Headrace Tunnel
Access road and bridge from Dogah to Lower Spat Gah Headworks	Lower Spat Gah Headworks, Headrace Tunnel
Access road from Dogah to Gabarband Crossing/adits	Headrace Tunnel, Lower Gabarband Intake
Access road to Upper Erection and Gate Chamber	Headrace Tunnel, Pressure Shaft and Surge Shaft
Construction road to top of Surge Shaft	Surge Shaft

The access roads are critical for the schedule for both the Lower Spat Gah Headworks and also the Headrace Tunnel as they are required to start the respective works.

The progress rates for the opening of the access roads are estimated at 25 m/d and 10 m/d for easy and semi-difficult morphologies including bridge construction based on the design and quantities obtained from the specific access roads study and the construction preferences of the Early Work Contractor.

20.4 Progress Rates and Scheduling of Main Activities

For the preparation of the preliminary construction schedule, the construction sequence and progress rates have been examined carefully for the main activities listed hereafter:

- Construction of the Lower Spat Gah Headworks and Lower Gabarband Intake,
- Construction of the Power Waterway,
- Construction of the Powerhouse, cavern access tunnels and Tailrace Tunnel.

For each of those structures the construction procedure is briefly outlined hereafter and the assumed progress rates of the main activities are presented. The duration of time for critical tasks is determined by the comparison of principal quantities for the civil works and the average schedulable progress rates assumed for the construction schedule are indicated in Table 20-3. For all works, working times of 7 days per week and 365 days per year have been assumed.

Table 20-3: Average schedulable progress rates assumed

Activity	Average Progress Rate
Access road (easy morphology)	25 m/d
Access road (semi-difficult morphology)	10 m/d
Excavation of Headrace Tunnel	4 m/d
Tunnel concrete lining (per formwork carriage)	5 m/d
Shaft concrete lining	1.5 m/d
Tunnel finishing works	40 m/d
Placement, welding and backfilling of steel liner (tunnel and shaft)	1.5 m/d
Corrosion protection of steel liner and finishing works	10 m/d
Excavation of Powerhouse	220 m^3/d
Powerhouse concrete lining	30-60 m^3/d
E&M installation time	13 months total

20.4.1 Lower Spat Gah Headworks and Lower Gabarband Intake

Lower Spat Gah Headworks

The Lower Spat Gah Headworks are planned in two main stages to divert the river first on one side and for stage 2 on the other side as described in Chapter 11.5. For each stage the river will be diverted using the intermediate pier wall as a retaining structure for building the upstream and downstream cofferdams. The following works are planned for each stage:

Stage 1:

- Flushing channels No. 2 and 3,
- Desander intake structure,
- Desander,
- Forebay (concrete works after tunnelling complete).

Stage 2:

- Flushing channel No. 1,
- Dam.

The construction works for the cut-off wall and the cofferdams (for both stages) can only happen in the winter half year during the low-flow season. With the current optimised access road construction, the works for the Lower Spat Gah Headworks start approximately in October of Year 3.

For the construction works of the Headrace Tunnel one front will start from the forebay of the Lower Spat Gah Headworks. It was conservatively assumed that the concrete works for the forebay can only start when the construction works of the Headrace Tunnel from the desander are completed. Nevertheless, this may be optimised at a later Project stage.

Lower Gabarband Intake

The Lower Gabarband Intake is planned in two main stages to divert the river first on one side and for stage 2 on the other side as described in Chapter 12.4.6. For each stage the river will be diverted using the intermediate pier wall as a retaining structure for building the upstream and downstream cofferdams. The following works are planned for each stage:

Stage 1:

- Flushing channel,
- Desander intake structure,
- Desander,
- Forebay.

Stage 2

- Spillway.

The construction works for the cofferdams (for both stages) can only happen in the winter half year during the low-flow season. The works for the Lower Gabarband Intake can also only commence when the tunnel excavation and rock support to the Lower Gabarband Intake is complete. With the completion of the Gabarband Intake Tunnel excavation and rock support in December of Year 4, the works at the Lower Gabarband Intake, namely the intermediate pier and flushing channel slab, can start in October of Year 5.

20.4.2 Power Waterway

The Headrace Tunnel will be excavated and constructed from the following four fronts:

- Lower Spat Gah Headworks,
- Gabarband Crossing Left Bank,
- Gabarband Crossing Right Bank,
- Access tunnel to Upper Erection and Gate Chamber.

The excavation for all Headrace Tunnel sections as well as the Gabarband Intake Tunnel shall happen simultaneously as soon as the respective accesses to the fronts are available.

The Headrace Tunnel and Gabarband Intake Tunnel will be excavated by the drill and blast method. The Headrace Tunnel is concrete lined except for a 760 m long section at the Gabarband Crossing and for about 86.5 m at the downstream end of the Headrace Tunnel where a steel liner is required.

The Gabarband Intake Tunnel is excavated from the Headrace Tunnel junction towards the Lower Gabarband Intake. It is shotcrete lined and has a GRP pipe installed on supports on one side of the tunnel. The pipe can be installed after the completion of the Lower Gabarband Intake. Due to the scheduling of the Lower Gabarband Intake cofferdam in the low flow season, the pipe will be installed after the excavation of the tunnel.

The Pressure Shaft shall be excavated by the raise drill method. For the works to commence, the access tunnels to the upper and the lower erection chambers have to be completed. For the raise drill a small pilot hole is first drilled from the Upper Erection and Gate Chamber. Then the raise drill starting from the bottom to the top is used to excavate the Pressure Shaft while the excavated material drops to the lower erection chamber and has to be mucked from there. For the Pressure Shaft a steel liner is required.

The Surge Shaft is slightly offset to the Pressure Shaft and shall also be excavated by the raise drill method. For the works to start, the construction road to the surge shaft chamber, the surge shaft chamber and the access tunnel to the Upper Erection and Gate Chamber have to be completed. The mucking of the Surge Shaft and the Headrace Tunnel will be transported from the Upper Erection and Gate Chamber to the spoil area. For the Surge Shaft a concrete lining is foreseen.

20.4.3 Powerhouse and Tailrace Tunnel

The Main Access and Power Evacuation Tunnel to the Powerhouse Cavern shall be excavated at the same time as the Tailrace Tunnel that will be used for mucking. Alternatively, adits to the Power Cavern, Transformer Cavern and to the Tailrace Tunnel could be constructed from the Main Access and Power Evacuation Tunnel for access and mucking.

For both tunnels the permanent concrete tunnel lining at the bottom should be completed first to allow the vehicles driving to or from the Powerhouse to have a decent speed to allow sufficient progress rate for the works in the Powerhouse. Tunnels without concrete lining often have very uneven surfaces which considerably slow down the traffic. For the Main Access and Power Evacuation Tunnel a preliminary bottom slab will be constructed before the cavern works to allow for better driving conditions. The final bottom slab in the Main Access and Power Evacuation Tunnel and the concrete lining of the Tailrace Tunnel will however only be installed later.

The construction sequences for the excavation using ramps, concrete works and the interfaces of the Powerhouse and Transformer Caverns are described in detail in Chapter 14.9.

20.4.4 Manufacturing, Transport and Installation Sequence of the Electro-Mechanical Equipment

The construction sequence of the electro-mechanical equipment is described in detail in Chapter 14.9.

For the installation of the main inlet valves (MIV), Pelton turbines, turbine shafts, and generators a duration of 13 months is assumed.

For the commissioning of the machine unit 1 a duration of two months is considered. For the two following units a slightly shorter duration of one and a half months is assumed. The commissioning of the units is planned in consecutive order.

20.4.5 Switchyard and Transmission Line

For the switchyard and the transmission line for the tender, design, construction and commissioning a duration of 36 months is assumed in the schedule. This duration still has to be confirmed by the National Transmission & Despatch Company (NTDC).

In any case the switchyard and transmission line are not anticipated to be on the critical path.

20.5 Construction Schedule

For the complete construction schedule please refer to Annex 1 in this volume.

20.6 Critical Path

The works for the Powerhouse complex are on the critical path.

The works for the Headrace Tunnel and Gabarband Intake Tunnel are scheduled to be completed approximately seven months and two years respectively ahead of the Power Waterway filling. The Lower Spat Gah Headworks are scheduled to be completed about four months ahead of the Power Waterway filling. The Lower Gabarband Intake works will be completed seven months before the filling of the Power Waterway. However, the Lower Gabarband flushing channel, intake, desander and forebay are completed about twelve months before filling of the Power Waterway. If spillway works are not completed at the time of waterway filling, then the water could already be diverted into the Lower Gabarband Intake tunnel while the spillway construction is still ongoing.

However should there be any delay for the access roads, Headrace Tunnel, or Lower Spat Gah Headworks, then the critical path also could be for any of those structures.

21 Cost Estimate

21.1 General

The cost estimate is provided for the following main components:

- Direct costs comprising:
  - Access roads: All permanent access roads to the site and within the Project area including bridges as well as selected temporary construction access roads and bridges,
  - Site installations: Costs for preparatory works and construction of office space, camp, workshops, batching and crushing plants, spoil areas, quarries, other temporary construction roads, etc. are summarised under this item,
  - Civil works: The cost estimate for the civil works of all permanent structures is covered within this block,
  - Hydro-mechanical equipment: All hydro-mechanical equipment like gates, lifting equipment, stoplogs and trash rack inclusive embedded parts as well as the Headrace Tunnel and shaft steel liner are summarised under this item,
  - Electro-mechanical equipment: This item summarises the costs for all generating equipment like turbines, generators, main inlet valves, control equipment, transformers and switchgear, inclusive mechanical and electrical BoP in the Powerhouse as well as the GIS in the cavern and high-voltage cable in the tunnel and to the Connection Switchyard.
  - Grid connection: This item contains miscellaneous equipment for the Connection Switchyard, with the final cost allocation of the Connection Switchyard to be agreed with NTDC. The 765 kV transmission line is assumed to be paid by NTDC.
- Indirect costs comprising:
  - Project development costs: technical management costs pre-construction and Project administration costs after Financial Close,
  - Engineering & supervision: design review and site supervision services,
  - Financing and lender's fees: debt related financing fees,
  - Legal cost: fees for legal consultants and government fees,
  - Land acquisition & resettlement and environment: costs for purchase of land, relocation, and other environmental costs,
  - Insurance during construction: insurance premium during construction,
  - O&M mobilisation: costs for power plant operation team before commissioning,
  - Customs duties: customs on imported machinery,
  - Interest During Construction (IDC).

Note: VAT and other tax applicable in Pakistan, with the exception of sales tax, to be paid by the Contractors are included in the respective unit prices. Customs clearance/ duties have been taken into account separately in discussion with the Client.

Contingency provisions are included in each item, i.e. Lower Spat Gah Headworks, Lower Gabarband Intake, tunnels, Powerhouse, E&M, etc., as appropriate.

January 2022 has been applied as the reference date for the cost estimate of the Lower Spat Gah Project.

21.2 Unit Prices

The civil works are divided into the following main categories with respective pay items. The presented unit prices are based on current hydro IPP market construction costs in Pakistan.

Figure 21-1 indicates the percentage of the respective works on the overall estimated price of the civil works package without contingencies. The estimated costs for backfill (1.0%), O&M staff colony (1.0%), rockfill dam (1.1%), grouting works and cut-off walls (1.5%) , GRP pipe (1.7%), surface excavation support (1.8%), and surface excavation (6.6%) only represent a small share of costs. On the other hand the costs for preliminary works and camp (8.8%), underground support (9.6%), underground excavation (13.1%), surface concrete works (26.2%), and tunnel and cavern lining (26.3%) represent about 84% of the overall civil works costs.

It should be noted that the site installation costs are included in the unit prices of the major items of plant.

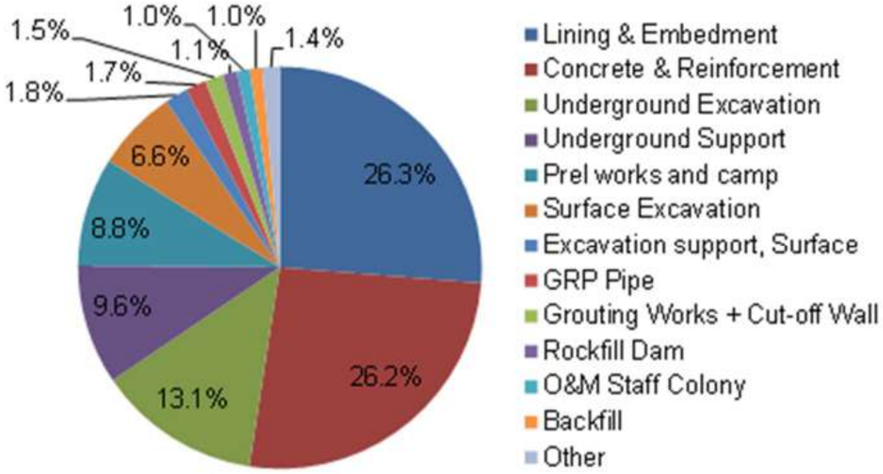


Figure 21-1: Percentage of specific works within the civil works (without contingencies)

21.3 Direct Costs

21.3.1 Infrastructure, Access Roads and Site Installations

Before the Civil Works Contractor arrives on site several pre-construction works are required to be completed.

- Access Roads

  The new bridge over the Indus River as well as the new access roads to the Powerhouse portal, Upper Erection and Gate Chamber, Lower Spat Gah Headworks and Gabarband Crossing will have to be constructed as part of the Early Works. The road from Dasu will only be used for the access road construction and is not included in the cost estimate. The cost are estimated based on current market conditions in Pakistan.

- Site Installations

  The costs for site installations are included in the price of major items and have therefore not been estimated separately.

21.3.2 Civil Works

The civil works cost estimate comprises the following main cost items:

- Lower Spat Gah Headworks

  The governing cost items for the dam are the excavation, clay, filter and rockfill as well as the cut-off wall. The governing cost items for the flushing channel structure, intake and desander are the structural concrete and reinforcement.

  The desander concrete and reinforcement are the largest cost of the Lower Spat Gah Headworks and is a result of the maximised peaking volume in the reservoir. This leads to a high dam and large desander volumes. The low MOL has been assumed because no confirmation regarding a minimum peaking output was available from PEDO and a conservative design has been selected at this stage. The provided reservoir storage for peaking may be optimised after a clear statement from the regulating agency regarding peaking requirements for the Lower Spat Gah Project.

- Lower Gabarband Intake

  The governing cost items for the weir, intake and desander are the structural concrete and reinforcement.

- Waterway

  The most relevant unit rates for the waterway are excavation, rock support and lining. The quantity of excavation material may be determined without major uncertainties based on the tunnels' cross sections and the proposed rock class distributions.

  The cost estimate of rock support is based on two to six predefined rock support classes as a result of the geological investigations with a respective forecast for the distribution and the length of the considered section of tunnels.

  For the Headrace Tunnel a systematic concrete lining is applied except for the crossing section where a steel lining is required. The Pressure Shaft and High Pressure Tunnel will be fully steel lined. In the Tailrace Tunnel a systematic concrete lining is again applied.

- Powerhouse and Transformer Caverns

  The most relevant unit rates for the Powerhouse and Transformer Caverns are excavation and concrete works. A different unit prices for excavation and structural concrete as for the tunnels have been used.

21.3.3 Hydro-Mechanical Equipment

The cost estimate for hydro-mechanical equipment is based on the mass of steel used for the respective equipment. The mass of steel to be used for the different sections of the works has been estimated based on the civil drawings and using empirical formulae. The price is based on cost estimates from hydro-mechanical suppliers.

A unit price of 6,900 to 28,900 USD per ton of steel for the main gates and 9,200 to 15,500 USD per ton of steel for stoplogs was applied. For the waterway steel lining 6,823 USD per ton of steel have been considered while a unit price of 2,675 USD per meter of pipe has been considered for the GRP pipe. The cost estimates include embedded parts, the hydraulic and control equipment, detailed design, supply, manufacturing and installation as well as corrosion protection and provision of basic spare parts.

The cost of the trash rack cleaning machines is estimated to 949,000 USD and 858,000 USD, based on prices from similar trash rack cleaning machines. A gantry crane estimated at 613,000 USD is foreseen for the Lower Spat Gah flushing channels. The butterfly valve and the bridge crane in the upper chamber have been estimated at 2.8 million USD and 135,086 USD. The butterfly valve at the downstream end of the Gabarband Intake Tunnel has been estimated to 209,345 USD.

21.3.4 Electro-Mechanical Equipment

The cost estimate for the generating equipment used for this Feasibility Study is based on budgetary proposals by several recognised international Suppliers. For the budgetary proposals a detailed scope of works for the mechanical and electrical equipment and the 220 kV GIS has been established comprising the design, manufacturing, transport and commissioning of the equipment as listed in Annex 2 in this volume and further documented in Volume 12 - Project Schedule and Cost Estimate. The costs for the 220 kV cable are based on similar projects in Pakistan.

21.3.5 Transmission Line and Connection to Grid

The cost estimate for the Project 11kV transmission lines are based on similar projects in Pakistan and the Consultant's database. A lump sum of 1.95 million USD has been assumed for miscellaneous equipment at the Connection Switchyard, for which adjustments might be needed depending on the NTDC's input for the transmission line studies.

The unit rate for the 11 kV project transmission lines of 143,500 USD/km in the tunnels and 37,200 USD/km are based on transmission line costs of similar projects in Pakistan, and amounts to total costs of about 2.0 million USD.

The 765 kV transmission line between the Connection Switchyard and the 765 kV Dasu-Mansehra transmission line is assumed to be paid by NTDC.

21.3.6 Design Studies and Field Investigations

A provision of 15 million USD has been made in the direct costs for the Basic Design and Detailed Design as well as for the geological and hydrological investigations.

21.3.7 Risks and Contingencies

In comparison to the Alternative & Optimisation Study documented in Volume 6, the contingencies have been reduced based as per Client's instruction because risks/uncertainties could be decreased significantly, mostly regarding quantities but to a certain extent also regarding pricing and design. In Table 21-1 the contingencies for the Feasibility Study in comparison to the previous phase are displayed.

Table 21-1: Contingencies applied in Alternatives & Optimisation Study and Feasibility Study

Item	Alternative & Optimisation Study	Feasibility Study
Underground works	25%	5%
Civil works	20%	5%
Hydro-mechanical works	20%	2.5%
Electro-mechanical works	20%	2.5%

21.4 Indirect Costs

Indirect costs include allowances for:

- Project development costs,
- Engineering & supervision,
- Financing and lender's fees,
- Legal cost,
- Land acquisition & resettlement as well as environment,
- Insurance during construction,
- O&M mobilisation,
- Customs duties,
- Interest During Construction (IDC).

These indirect costs were applied as certain percentages of the direct costs based on benchmarks of other ongoing hydropower projects in Pakistan.

21.4.1 Project Development Costs

An allowance of 4.7% of the direct costs has been applied for the costs associated with development of the Project including previous engineering phases, environmental and social studies, legal and financial support etc. This cost item also includes the Client's costs and efforts incurring throughout the construction of the Project.

21.4.2 Engineering & Supervision

An allowance of 4.3% of the direct costs has been applied for the costs associated with the engineering and supervision services during the pre-construction and construction phases. This includes previous engineering phases, tender engineering service, construction supervision etc. The costs for Basic Design and Detailed Design services are included as an item in the direct costs together with the field investigations.

21.4.3 Legal Costs

An allowance of 0.33% of the direct costs has been applied for the costs associated with the fees of the legal consultant and government fees required to be paid at various stages during the Project implementation.

21.4.4 Insurance During Construction

An allowance of 3.01% of the direct costs has been applied to cover the insurance costs during construction. This percentage is slightly higher than NEPRA approvals, but recent precedents indicate that the actual costs are higher than NEPRA approvals. This number may be revised upon receipt on firm EPC quotes and negotiations with insurance providers.

21.4.5 Financing / Lender's Fees

An allowance of 2.5% of the base loan amount (loan excluding IDC and financing charges) has been applied for the costs associated with the financing fees. These debt related financing fees include items such as lender's upfront fee, arrangement fee, working fee, commitment fee and various other fees related to the financing.

While NEPRA allows a maximum of 2% of the base loan amount, the feedback from several international banks was that recently it is difficult to procure large-scale financial resources at the 2% level. Therefore 2.5% is reflected as a compromise between bank's estimates and NEPRA allowance.

An additional allowance of 0.95% of the direct costs has been applied for agency and advisory costs, which includes costs associated with the security trustee, intercreditor agent, legal and financial advisors of both company and lenders.

21.4.6 Environmental and Social Impact Cost

The costs associated with the land acquisition and resettlement have been estimated by Hagler Bailly as part of the Environmental and Social Impact Assessment detailed in Volume 11, and amount to 7.8 million USD.

The costs for mitigation and other environmental and social management measures have been estimated as part of the Environmental and Social Impact Assessment detailed in Volume 11 for the construction and operation phase. It includes all environmental and social monitoring and implementations such as the biodiversity action plan, stakeholder engagement plan and other environmental and social management measures. The costs for the one time capital, construction duration and operation phase amount to 9.6 million USD.

21.4.7 O&M Mobilisation

An allowance of 0.57% of the direct costs has been applied for the costs associated with the mobilisation of the operation and maintenance team. This item covers the costs associated with the operator prior to the Commercial Operation Date (COD) for services such as operational design review, review of O&M manuals, witnessing of testing and commissioning.

21.4.8 Customs Duties

The relevant rules regarding customs duty on renewable energy power projects requires renewable energy projects to pay custom duty on the import of plant and machinery not manufactured locally. A custom duty at the rate of 5% as allowed by NEPRA and as well as infrastructure cess at the rate of 1.15% have been included, while sales tax is excluded. They have been applied on the off-shore part of the equipment which includes the electro-mechanical and hydro-mechanical equipment.

21.4.9 Interest During Construction

The Interest During Construction (IDC) represents the cost of financing the funds for the Project. It is based on the distribution of costs over the Project implementation phase, the duration of the construction activities and the annual interest rate for the funds.

The equity and loan drawdown pattern for the construction of the Lower Spat Gah Project foresees the use of equity for the works executed before Financial Close. The pattern also indicates a construction activity duration of 5 years after Financial Close. The annual interest rate has been provided by the Client and has been set at the LIBOR value of 0.34% per early January 2022 plus 4.6%.

With a debt ratio of 75% and the assumed disbursement schedule, the interest during construction amounts to 10.7%.

21.5 Disbursement Schedule

The disbursement schedule represents the distribution of costs over time. The distribution of Project costs over the Project implementation phase is relevant for the estimate of the financing costs of the Project. Generally payments in an early phase of the implementation are unfavourable compared to payments occurring at a later stage because of the interest rate on the loan for debt financing and rate of return for equity financing.

The equity and loan drawdown pattern for the construction period has been included in the financial analysis and is shown in Figure 21-2. The blue bars indicate the annual equity payments and the orange bars the annual debt payments. It can be noted that the pre Financial Close the first three years will be covered by equity and that debt will only incur during the construction works in months 31 to 90. The grey line displays the cumulative distribution of the incurring costs. According to the payment distribution the cumulative payments of the Early Works are 12%.

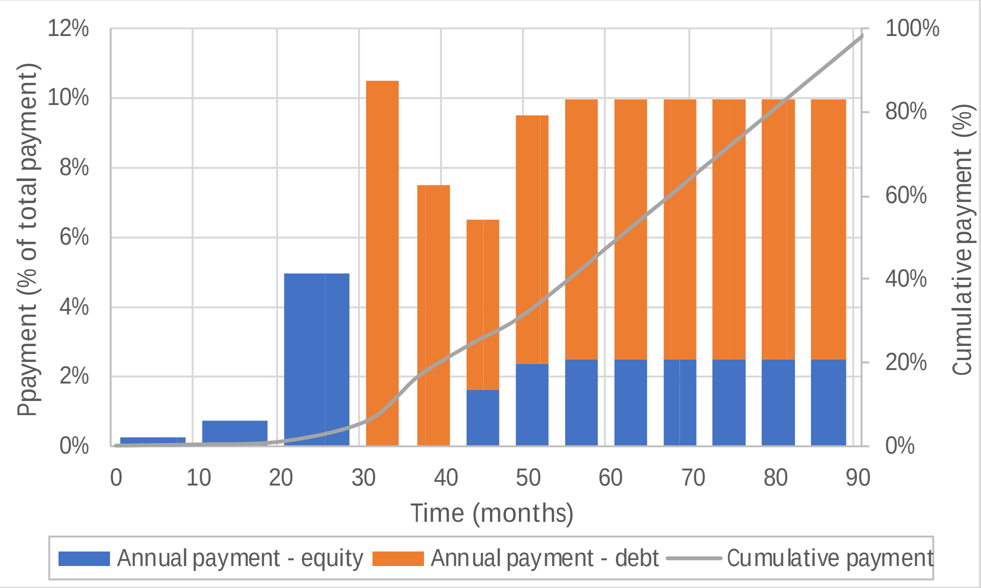


Figure 21-2: Preliminary disbursement schedule for Lower Spat Gah Project

21.6 Costs for Operation and Maintenance

Operation and Maintenance (O&M) costs comprise the total annual expenditure incurring during the operation of the Project. O&M costs are split into:

- Fixed O&M costs: Fixed operating expenses related to the type and size of the plant only, but not related to the output.
- Variable O&M costs: Expenses depending on the output of the plant.

  For hydropower plants the variable O&M costs are rather small compared to the fixed O&M costs. O&M costs typically include cost components for regular operation and maintenance, overhauls, staff, management, and administration and insurance and fees.

The estimate of the O&M costs includes the following cost items:

- Cost of Operation and Maintenance

  These are the costs related to the annual investment to be taken to keep the plant in operation. Spare parts of the E&M equipment as well as bigger overhauling of the civil and hydro-mechanical structures are not included.
- Cost of Staff

  This cost item considers the staff at site being responsible for the operation and maintenance of the plant.
- Costs for Management and Administration

  This cost item comprises the staff and environment needed for the operation of the plant. In general, this item considers the head office, including management, financial, invoicing and staff required to deal with the authorities.
- Insurance

  This cost item covers the insurance during the operation of the plant.
- Minor and Major Overhauls

  This cost reflects the annual expenditures based on the scheduled maintenance and major overhauls of turbines, generators and civil structures over the concession period.

The selection of the E&M equipment manufacturer as well as the selection of the civil Contractor may have a significant impact on the annual costs for O&M as lower costs are expected for equipment from Western and well-established suppliers.

The annual O&M costs assumed in the financial model were provided and amount to 35,800 USD/MW. With an Installed Capacity of 470 MW the annual O&M costs are 16.83 million USD. The variable portion has been set to 0.1006 US Cent/kWh and amount to 1.94 million USD of annual costs, which corresponds to about 12% of the total O&M costs.

21.7 Cost Estimate

The summary table of the direct cost estimate for the Lower Spat Gah Hydropower Project is displayed in Table 21-2. The detailed cost estimate is attached as Annex 2 in this volume and more information can also be found in Volume 12 – Project Schedule and Cost Estimate.

Table 21-2: Summary of direct cost estimate for Lower Spat Gah Project

Direct Cost Estimate Summary of Lower Spat Gah Hydropower Project

No.	DESCRIPTION	ESTIMATE			
		LCC		FCC	TOTAL AMOUNT LCC + FCC (USD)
		AMOUNT (PKR)	AMOUNT (Eq. USD)	AMOUNT (USD)	
A	**INFRASTRUCTURE & ROADS WORKS**	**16,698,142,171**	**93,678,217**		**93,678,217**
B	**CIVIL WORKS**	**65,335,460,022**	**366,538,345**	**38,423,402**	**404,961,747**
11	Lower Spat Gah Headworks	24,919,702,667	139,801,978	1,693,267	141,495,245
12	Lower Gabarband Intake	1,667,802,081	9,356,533	168,506	9,525,039
13	Power Waterway	27,143,803,283	152,279,401	11,332,568	163,611,969
14	Gabarband Crossing	603,950,230	3,388,220	54,804	3,443,024
15	Tailrace Outlet Structrure	312,814,808	1,754,922	112,327	1,867,249
16	Powerhouse and Transformer Caverns incl. Access Tunnels	7,748,969,823	43,472,481	2,879,569	46,352,050
17	Connection Switchyard Civil Works	105,000,000	589,060		589,060
18	O&M Staff Colony	713,000,000	4,000,000		4,000,000
19	EPC Contractor Preliminary Works and Camp Establishment Cost	2,120,417,129	11,895,748	22,182,362	34,078,110
C + D	**HYDROMECHANICAL & ELECTRO-MECHANICAL EQUIPMENT**			**299,466,920**	**299,466,920**
21	HM Lower Spat Gah Headworks			22,555,605	22,555,605
22	HM Lower Gabarband Intake			1,399,032	1,399,032
23	HM Power Waterway			32,809,884	32,809,884
31	Mechanical Equipment Powerhouse			83,674,535	83,674,535
32	Electrical Equipment Powerhouse			114,209,664	114,209,664
33	Switchyard/GIS			18,688,313	18,688,313
34	Auxiliary Supply Equipment Portal/Access Area			3,156,289	3,156,289
35	Auxiliary Supply Equipment Upper Erection Chamber/Surge Tank			161,238	161,238
36	Auxiliary Supply Equipment Lower Spat Gah Headworks			1,088,294	1,088,294
37	Auxiliary Supply Equipment Lower Gabarband Intake			2,132,772	2,132,772
	Delivery Cost Insurance Freight of HM & E&M Works			19,591,294	19,591,294
E	**DESIGN STUDIES AND FIELD INVESTIGATIONS**			**15,000,000**	**15,000,000**
F	**SITE SECURITY COST**	**289,872,604**	**1,626,214**		**1,626,214**
	Site Security Cost: 0.2% of EPC	289,872,604	1,626,214		1,626,214
	TOTAL EPC COST	**82,323,474,797**	**461,842,776**	**352,890,322**	**814,733,097**

Figure 21-3 indicates the percentage of the respective works on the overall estimated price of the direct costs.

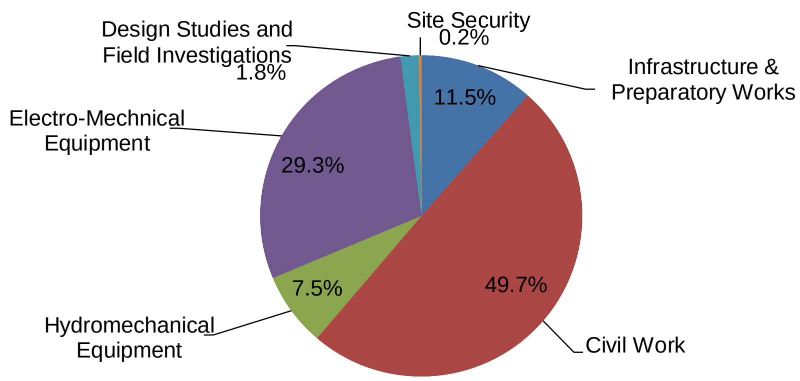


Figure 21-3: Percentage of cost allocation of all works

The uncertainties in cost estimates can have various causes, which are not under the control of the Consultant at this point. Based on the Consultant's experience, cost overruns are often caused by the following reasons:

- Changes in the quantities,
- Differences in unit rates,
- Variations and claims during construction,
- Time overrun (Interest During Construction).

Changes in the quantities can be caused by:

- Insufficient resources allocated to the Consultant to produce a tender design and a set of tender documents minimising risks,
- Design changes during the Detailed Design phase,
- Requests by the Client,
- Requests by authorities,
- Materialisation of risks (e.g. geological, flood risks), often combined with claims and time overrun.

Differences in unit rates can have various reasons:

- Contractor has other basis for his price calculation :
  - Contract conditions and risk provision,
  - General market conditions and economic situation in country/region, which might lead to price dumping (e.g. during crises) or excessive prices in overheated markets,
  - Order book and order stock of Contractors,
  - Perceived risks borne by the Contractor(s),
  - Owner's financial credit.
- Price fluctuation of commodities, e.g. steel, cement, energy (fuel):
  - Price difference between time of preparation of cost estimate and tendering,
  - Increase of prices during construction due to price escalation clauses,
- Speculative prices and other interests of the Contractor (e.g. market entry),
- A professional claim management (by the Client) during construction is in any case recommended for such type of Project. Possible claims cannot be predicted at the time of preparation of the cost estimate.

Uncertainties and risks are considered in the provision of contingencies. The impact of a cost overrun exceeding the contingency provision is considered as a case in the sensitivity analysis. However, it is recommended that the final investment decision should be based on binding offers for all works.

22 Financial Analysis

22.1 General

This chapter discusses the financial analysis for the Lower Spat Gah Hydropower Project. The analysis is carried out in US Dollars (USD). January 2022 has been applied as the reference date for the cost estimate of the Lower Spat Gah Project. Thus an exchange rate of 178.25 Pakistani Rupees per 1 USD as per 01 January 2022 has been assumed by the Client for the analyses. The period of the analysis spans the construction period of 7.5 years and the concession period of 30 years. All costs and benefits are compared and the Net Present Values of the cost and benefit flows are discounted.

The financial analysis indicates the attractiveness of the Project for an investor, analysing the cash flow from an investor's point of view. The Client has provided the financial model which AFRY has been using for the financial analysis.

A sensitivity analysis has been carried out on the key figures of the financial analysis to determine the robustness of the economics of the Project by varying the main input parameters and determining the impact on the financial key indicators of the Project.

22.2 Input Parameters

The main input parameters for the economic and financial analysis are the overall Project costs including indirect costs and other capital costs occurring in the concession period, the annual operation and maintenance costs (OPEX) and the revenues being based on the average yearly energy generation and the preliminarily agreed on energy tariff.

22.2.1 Capital Cost

The overall Project costs are based on capital costs for direct and indirect construction costs and the cost of capital lying idle during the time which the Project earns no revenue.

22.2.1.1 Construction Costs

The Project cost estimation which has been elaborated in Chapter 21 is used for the economic and financial analysis. It is defined as the Base Case cost scenario considering 100% of the construction costs (including contingencies). As part of the sensitivity analysis, the impact of varied capital costs is investigated.

22.2.1.2 Non-EPC Costs

The indirect costs which have been elaborated in Chapter 21.4 are used for the economic and financial analysis and are summarised in Table 22-1.

Table 22-1: Summary of indirect costs for Lower Spat Gah Project

Indirect Cost Item	Costs (million USD)
Lenders fees	18.0
Agency & advisory costs	7.8
Engineering & supervision	35.0
Land acquisition & resettlement	7.8
Insurance during Construction	24.8
O&M mobilization	4.6
Customs duties & taxes	16.6
Project development cost	39.0
Environment	9.6
Legal costs	2.7
Total	165.6

22.2.1.3 Construction Schedule and Disbursement Schedule

The construction schedule indicates a construction time of 7.5 years including Early Works (Chapter 20). After the construction period the plant will be up and running at its full capacity. The disbursement schedule indicates the distribution of costs over time and is presented in Chapter 21.5.

22.2.1.4 Interest During Construction

For the economic analysis Interest During Construction (IDC) has been considered. IDC is defined as the amount of interest arising on the expenses incurred for setting-up and building a Project to determine the total financial requirements. It covers the cost of capital lying idle during the time in which the Project earns no revenue.

Interest on the debt capital during construction is capitalised up to the time when the Project becomes revenue-earning. The capitalised interest is added to the capital required for building the scheme.

22.2.2 Operational and Maintenance Costs

Operation and maintenance costs comprise the total annual expenses occurring during the operation of the Project (Chapter 21.6). No price escalation has been considered in the financial model.

Table 22-2: Operation and maintenance costs

O&M Costs Item	Annual Cost (million USD)
Fixed cost	14.89
Variable cost	1.94
Total	16.83

22.2.3 Energy Generation

The energy simulation has been conducted according to Chapter 10. The mean annual net saleable energy for the base case is 1,925.5 GWh. The energy output is as measured at the Connection Switchyard and includes the plant losses as well as the production losses.

Any potential reduction in energy generation due to minor and major overhauls has been included in the O&M costs.

22.2.4 Energy Tariff

According to the Power Generation Policy 2015 by the Government of Pakistan, the energy tariff comprises the Energy Purchase Price (EPP) and the Capacity Purchase Price (CPP) as shown in Figure 22-1.

The Energy Purchase Price includes the water use charge as well as the variable O&M component and is expressed in Rupees per kWh. According to the Power Generation Policy 2015 by the Government of Pakistan, a water use charge of 0.425 Rupees/kWh has to be paid to the province.

The Capacity Purchase Price includes the fixed O&M, insurance, return on equity including return on equity during construction, debt servicing and the cost of the working capital and is expressed in Rupees per kW.

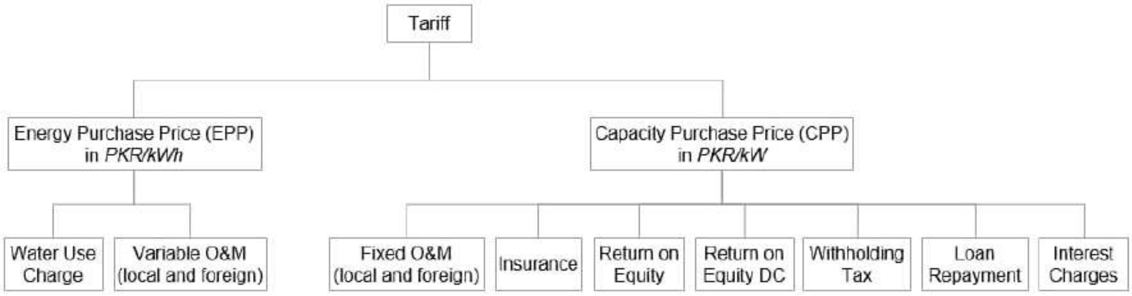


Figure 22-1: Components of energy tariff

22.2.5 Input Parameters for the Financial Analysis

The financial model prepared for Lower Spat Gah Project is based on a project financing approach. The project financing structure involves an equity investor (sponsor) and lending institutions providing loans. The non-recursive loans are paid entirely from the project cash flow, rather than from the other assets or credit worthiness of the project sponsors. The financing is secured by the project assets, including the off-take contracts (if any). The parameters of the financial model have been given by the Client together with the model. An equity IRR of 17% has been assumed as granted for hydropower project by NEPRA.

Table 22-3: Parameters for financial model

Financial Parameters	
Operation period	30 years from COD
Equity / debt ratio	25% / 75%
Discount rate NPV	10.0%
Interest on loan	4.9%
Price inflation	0%
Loan maturity	12 years
Depreciation period (=operation period)	30 years
Equity IRR	17%
Exchange rate USD/PKR	1 USD = 178.25 PKR

22.3 Financial Analysis

22.3.1 Introduction

The financial analysis evaluates the Project's profitability from the investor's perspective, as well as the ability to pay its obligation to creditors. Compared to an economic analysis, additional information relevant to the Project sponsor and financing structure as well as depreciation are applied to the cash flow model for the financial evaluation of a Project.

The results of the financial analysis are indicators measuring the profitability of the investment, and the ability to produce enough cash for debt servicing (interest and loan payments) and other obligations (liquidity or solvency of the Project).

The profitability of the Project from the investor's point of view is measured by the following financial indicators:

- Return on Equity (ROE) shows how well the investment of the sponsors is used to generate profits.
- Internal Rate of Return (IRR) measuring the profitability of an investment The IRR is determined based on the financial cash-flow on equity.
- Payback Period is the time required to earn the funds spent for the Project (to reach break-even), without taking into account the time value of money.

The liquidity (solvency) of the Project analyses the credit quality of the Project from a lender's perspective. It is analysed by the financial indicators DSCR and LLCR, ratios measuring the ability to pay the obligations to the creditors from the cash flow generated by the Project. The ratios used measure the ability of the Project to produce enough cash for debt services (to pay the obligations to the creditors):

- Debt Service Coverage Ratio (DSCR) is the ratio of net operating income and the debt services of a period.
- Loan Life Coverage Ratio (LLCR) is defined as the ratio of the net present value of the cash flow available for debt services (measured until the maturity of the debt tranche) and the outstanding debt in the period.

The financial model determines the tariff required to achieve an equity IRR of 17%. The model indicates the corresponding energy tariffs for the debt repayment tenure in years 1-12, the energy tariff in the remaining concession period in years 13-30 as well as the levelized tariff over the complete concession period.

22.3.2 Results

The results of the financial cash-flow analysis are indicators measuring the attractiveness and the credit quality (solvency/liquidity) of the Project.

The model assumption sheets of the financial analysis including the key Project indicators are attached as Annex 3 in this volume. The profitability indicators in Table 22-4 and Table 22-5 as well as the energy tariffs in Table 22-6 are obtained as a result of the financial analysis.

Table 22-4: Main indicators of financial cash-flow analysis

Key Financial Figures	
Return on Equity (ROE)	17.0%
Equity NPV	256.1 million USD
Equity payback period	3.4 years of operation
Project IRR	9.6%
Project NPV	111.5 million USD
Project payback period	6.8 years of operation

Table 22-5: Credit quality indicators

Key Financial Figures	Minimum
Debt Service Coverage Ratio (DSCR)	1.77
Loan Life Coverage Ratio (LLCR)	1.87

The two ratios DSCR and LLCR indicating the credit quality of the Project are bigger than one for the whole loan period. This indicates that enough cash is available for the debt services and no restructuring of the financial arrangement is required (e.g. increase of the equity portion of the investment).

Table 22-6: Energy tariffs

Key Financial Figures	
Energy tariff	Year 1-12: 9.87 US cent/kWh Year 13-30: 5.31 US cent/kWh Levelized: 8.61 US cent/kWh
Energy tariff	Year 1-12: 17.60 PKR/kWh Year 13-30: 9.47 PKR/kWh Levelized: 15.35 PKR/kWh

22.4 Sensitivity Analysis

22.4.1 Introduction

In order to determine the Project's robustness towards hydrological variability, construction costs variability, or OPEX costs, several sensitivity analyses are performed as implemented in the financial model. The sensitivity analysis focuses on the levelized tariff.

For the sensitivity analysis the following input parameters of the financial model are modified:

- Annual energy production due to hydrological variability (inflow),
- Annual energy generation due to head loss variability,
- Construction costs,
- OPEX costs.

22.4.2 Hydrological Variability

The average annual energy production increases in case of favourable hydrological conditions and vice versa. Therefore the base case assumption of the mean natural inflow is varied by ±10% and the resulting variation of the levelized energy tariff.

Table 22-7: Sensitivity analysis on varied inflow conditions with tariff adjustment

Scenario	Net Saleable Energy (GWh)	Levelized Energy Tariff (US cent/kWh)	Levelized Energy Tariff (PKR/kWh)
Inflow +10%	2,118	7.85	13.99
Base case	1,925	8.61	15.35
Inflow -10%	1,733	9.54	17.00

22.4.3 Head Loss Variability

The average energy production decreases with an aging Power Waterway and its associated higher head losses. The impact of the head loss conditions along the Power Waterway is addressed through a sensitivity analysis of the form loss by varying the roughness of the waterway. The assumed roughness values for the head loss calculation and the resulting head losses for the new and old conditions are described in Chapter 13.12.3. An average scenario with a roughness of 1 mm for concrete and 0.1 mm for steel was also simulated for the sensitivity analysis.

Table 22-8: Sensitivity analysis on varied head loss conditions with tariff adjustment

Scenario	Net Saleable Energy (GWh)	Levelized Energy Tariff (US cent/kWh)	Levelized Energy Tariff (PKR/kWh)
New conditions (base case)	1,925	8.61	15.35
Average	1,921	8.63	15.38
Old conditions	1,915	8.66	15.43

22.4.4 Variability Construction Cost

Escalating construction costs lead to a decreased profitability of the Project. The impact of a 10% cost increase and decrease of the total costs on the energy tariff is therefore investigated in the sensitivity analysis.

Table 22-9: Sensitivity analysis on construction costs with tariff adjustment

Scenario	Direct Costs (million USD)	Levelized Energy Tariff (US cent/kWh)	Levelized Energy Tariff (PKR/kWh)
Increased costs (+10%)	894.2	9.35	16.66
Base case	814.7	8.61	15.35
Decreased costs (-10%)	733.3	7.87	14.03

22.4.5 Variability OPEX Costs

An increase in the operation and maintenance costs has impacts on the Project's profitability. The impact of a 10% increase and decrease of the OPEX costs on the energy tariff is therefore investigated in the sensitivity analysis.

Table 22-10: Sensitivity analysis on OPEX costs with tariff adjustment

Scenario	OPEX Costs (million USD)	Levelized Energy Tariff (US cent/kWh)	Levelized Energy Tariff (PKR/kWh)
Increased OPEX (+10%)	18.30	8.68	15.46
Base case	16.83	8.61	15.35
Decreased OPEX (-10%)	15.32	8.54	15.22

22.4.6 Combined Variabilities

The combined sensitivity of the levelized energy tariff in US cent/kWh based on the construction costs and net saleable energy available and an equity IRR of 17% is displayed in Table 22-11. The combined sensitivity of the equity IRR without a tariff adjustment based on the construction and OPEX costs is displayed in Table 22-12.

Table 22-11: Sensitivity on construction costs and annual energy with tariff adjustment

Levellized Energy Tariff (US cent/kWh)		Construction Costs				
		110%	105%	100%	95%	90%
Net Saleable Energy (GWh)	1,733	10.36	9.95	9.54	9.13	8.72
	1,829	9.83	9.44	9.05	8.66	8.27
	1,925	9.35	8.98	8.61	8.24	7.87
	2,022	8.91	8.56	8.21	7.86	7.51
	2,118	8.52	8.18	7.85	7.51	7.18

Table 22-12: Sensitivity on construction costs and OPEX costs with tariff adjustment

Levellized Energy Tariff (US cent/kWh)		Construction Costs				
		110%	105%	100%	95%	90%
OPEX Costs	110%	9.41	9.04	8.68	8.31	7.94
	105%	9.38	9.01	8.64	8.27	7.91
	100%	9.35	8.98	8.61	8.24	7.87
	95%	9.31	8.94	8.58	8.21	7.84
	90%	9.28	8.91	8.54	8.17	7.80

22.4.7 Lower Gabarband Intake

The Alternatives Study in Volume 6 documents the economic assessment of various diversion discharges at the Lower Gabarband Intake including no diversion considering the Lower Spat Gah Project as stand-alone or within a cascade. The results showed that for the stand-alone Lower Spat Gah Project, having a diversion at the Gabarband River has a higher IRR than not having a Lower Gabarband weir and Gabarband Intake Tunnel. It was therefore recommended to divert water at the Gabarband as long as the Lower Spat Gah Project will be operated as a stand-alone scheme for at least a few years. A diversion discharge of 10 m^3/s has been selected for the Feasibility Study design.

The more detailed cost estimate from this Feasibility Study based on the drawings showed much higher costs than previously estimated on preliminary quantities when the diversion discharge was determined. A sensitivity analysis was therefore conducted to determine the economic viability of the diversion in comparison to the no diversion case.

Based on the design and cost estimate of the Lower Gabarband Intake and Gabarband Intake Tunnel as and considering a lateral intake at the Lower Gabarband Intake, the civil cost of the Lower Gabarband Intake and Gabarband Intake Tunnel structures are estimated to be 28.6 million USD including contingencies and the hydro-mechanical and transmission costs are estimated to be 4.1 million USD including contingencies.

The energy simulation of the Feasibility Study with a diversion design discharge of 10 m^3/s at the Lower Gabarband Intake resulted in an average annual energy of 1,925 GWh and 1,931 GWh for the stand-alone operation and cascade operation of the Project, respectively. The energy simulation was also carried out assuming that no water is diverted from the Gabarband River, resulting in an average annual energy generation of 1,744 GWh and 1,825 GWh for the stand-alone operation and cascade operation of the Project, respectively.

The financial model has been run with the construction cost and energy generation input and the results for the 17% equity IRR are shown in Table 22-13. The resulting levelized tariff of the stand-alone operation without a Lower Gabarband diversion at 9.02 US cent/kWh is higher than the layout with a diversion (levelized tariff 8.61 US cent/kWh) due to the 9% decrease of energy generation compared to 6% cost decrease. If the Lower Spat Gah scheme is operated as part of the cascade, the impact of the Lower Gabarband Intake is much smaller and not having a diversion results in a 0.3% decrease of energy while reducing the costs by 6%. As a result the levelized energy tariff at 8.19 US cent/kWh is lower than the layout with a diversion (levelized tariff 8.61 US cent/kWh). To the Consultant's knowledge there is currently no progress on the upper Spat Gah cascade projects and it is therefore likely that the Lower Spat Gah Project will be operated as a stand-alone scheme for at least a few years.

The financial analysis also shows that the direct costs of the layout with the diversion would have to increase by another 45.4 million USD to reach the levelized energy tariff of 9.02 US cent/kWh of the stand-alone operation without the diversion.

Table 22-13: Sensitivity of financial parameters to Lower Gabarband intake diversion

Characteristic	With 10 m^3/s Lower Gabarband Diversion	No Lower Gabarband Diversion – Stand-alone Operation	No Lower Gabarband Diversion – Cascade Operation
Total Project costs (million USD)	1,085.2	1,024.7	1,024.7
Energy generation			
Total stand-alone (GWh/yr)	1,925.5	1,743.5	
Total cascade (GWh/yr)	1,931.3		1,924.7
Peaking stand-alone (GWh/yr)	518 (65.5 m^3/s)	463 (58.6 m^3/s)	
Peaking cascade (GWh/yr)	652 (75 m^3/s)		652 (75 m^3/s)
Financial parameters			
Equity NPV (million USD)	256	242	242
Equity payback (years)	3.4	3.4	3.4
Project IRR (%)	9.6	9.6	9.6
Project NPV (million USD)	112	105	105
Project payback (years)	6.8	6.8	6.8
Levelized tariff (US cent/kWh)	8.61	9.02	8.19
Levelized tariff (PKR/kWh)	15.35	16.08	14.61

22.5 Conclusion

The following conclusions can be made from the financial analysis:

- The cash flows for the base case scenario are adequate to meet the annual payments on interest and loan paybacks which is a good precondition for the negotiations with the lenders,
- The sensitivity analysis showed that the net saleable energy due to hydrological variability has a significant impact on the energy tariff,
- A variation of the head losses in the Power Waterway has a minor impact on the energy tariff,
- A variation of construction costs has a substantial impact on the energy tariff,

- The variation of the O&M costs has a minor impact on energy tariff,
- The sensitivity analysis of the Lower Gabarband Intake showed that having a Lower Gabarband diversion with 10 m^3/s is beneficial if the plant is operated as a stand-alone Project and is not beneficial if the plant is operated within the Spat Gah cascade.

23 Re-Openers for Final Design & Construction Stage

23.1 General

Tariff for hydropower IPPs is allowed in three stages. Feasibility Stage Tariff is determined based on the Feasibility Study cost with certain re-openers available at EPC Stage.

EPC Stage Tariff is determined at Financial Close based on firm costs while typical adjustments are allowed at Commercial Operations Date which includes variation in tunnel (rock type), civil works costs, resettlement costs, exchange rates, interest rates, changes in assumptions, etc.

23.2 Definition of Re-Openers Verifier

The EPC price includes an estimated amount on the basis of relevant indices, to compensate the Contractor for (i) changes in cost of civil work on account of cement, steel, fuel and labour, and (ii) changes in cost of tunnelling works due to geological conditions which shall be allowed and paid to the Contractor in accordance with the approved NEPRA mechanism and base data provided in Chapter 23.4.2.1, with the Client being allowed to commensurate adjustment in tariff at Commercial Operation Date (COD) therefore not included in the EPC cost as claimed in this EPC stage Tariff Proposal.

This inclusion in the EPC Contract is necessary to allow for financing of this cost and seamless, uninterrupted construction activities.

23.3 Scope of Items to be included in Re-Opener during Final Design & Construction Stage

The EPC Contractor would execute the “Works” in accordance with the Project requirements of the EPC Contract, on a lump sum fixed price – time certain basis with the following re-openers in the EPC Price at Commercial Operation:

- Changes in prices of cement, steel, labour and fuel,
- Variation in rock type/classification in tunnelling works,
- Withholding taxes on onshore works in excess of seven percent (7%),
- Any sales tax paid by Contractor on invoices issued under EPC Contract in Pakistan/KPK.

The Re-Opener Verifier shall, amongst others, be required to prepare monthly reports up to the completion of the civil and tunnelling works (the "Re-Opener Reports") in accordance with terms of reference including an assessment or valuation or payment (provisional or final) of any reasonable and prudently incurred costs by the Client for such Re-Openers. The Re-Opener Reports shall be in a form acceptable to the Parties and include all necessary details along with supporting documents.

23.4 One Time Adjustments Procedure for EPC Re-Opener

23.4.1 General

The Project cost and the reference tariff at EPC stage shall be adjusted for the items (below) at COD (“One- time Adjustment”).

The reference local civil work costs under the EPC Construction Contract will be adjusted on account of variation in the price index of construction materials i.e. steel, cement, fuel and labour, in accordance with the NEPRA mechanism, with details provided in Chapter 23.4.2.1.

The reference tunnel cost shall be adjusted for the variations in cost due to geological conditions related to tunnelling as verified by Re-Opener Verifier, appointed pursuant to the terms of the power purchase agreement and NEPRA mechanism. The reference tunnel tables are provided in Chapter 23.4.2.1.

Any withholding tax, in excess of seven percent (7%), on onshore works under the EPC Construction Contract, in Pakistan or KPK, shall be allowed and adjusted in the Project cost and reference tariff.

No provision has been made for (i) general sales tax or provincial sales tax on the construction contract and (ii) withholding tax, general sales tax or provincial sales tax on offshore supply contract. Any variation in the Project cost on account of applicable withholding tax or sales tax on the construction or offshore supply contract shall be allowed with adjustment in the project cost and reference tariff.

Actual stamp duty, registration and similar charges paid on the (i) land lease documents in Pakistan and KPK; and (ii) land security documents, in the form acceptable to the project lenders, in Pakistan and KPK pursuant to applicable law, shall be adjusted in the project cost and reference tariff.

Cost of land acquisition and resettlement claimed by the Client will also be adjusted based on actual incurred cost in accordance with NEPRA mechanism for determination of tariff for hydropower projects including the costs related to raising or replacement of bridges, relocation of public infrastructure (electricity poles, roads etc.), tree planting, compensation for loss of livelihood, households, residential and commercial structures.

This chapters presents the NEPRA mechanism for adjustments in cost of civil works escalation and tunnelling/underground works due to geological conditions. The other items are not presented in this Report and will have to be addressed separately in the Tariff Petition.

23.4.2 Adjustments Under NEPRA Mechanism

23.4.2.1 Adjustments in Cost of Civil Works Escalation

The cost of civil works will be adjusted due to variation in the prices/indices of a selected number of cost elements. The method is set out hereunder for adjusting the Contract Price for changes in costs for cement, fuel, reinforcement and labour obtained and utilized by the Contractor in Pakistan.

The changes in costs shall only be adjusted in local currency portion on the basis of "rise and fall" of the prices of the above specified materials and labour. The formula by which the indexations are applied is given below:

$$P_n = a + b \cdot \frac{C_n}{C_o} + c \cdot \frac{S_n}{S_o} + d \cdot \frac{F_n}{F_o} + e \cdot \frac{L_n}{L_o}$$

Where:

"P_n" is the adjustment multiplier to be applied to the estimated contract value attributable to the civil works, in the relevant currency of the work carried out in period "n", this period being a month;

"a" is a fixed coefficient equivalent, stated

"b", "c", "d", “e” are coefficients representing the proportion of each cost element related to the execution of the Work,

"C_n", "S_n", “F_n”, "L_n" are the current cost indices for Cement, Steel, Fuel, and Labour respectively for month "n", expressed in Pakistani Rupees, each of which is applicable to the relevant tabulated cost element in the relevant month; and

"C_o", "S_o", “F_o”, " L_o” are the base cost indices for Cement, Steel, Fuel, and Labour respectively, expressed in Pakistani Rupees, each of which is applicable in the month 28 days prior to tendering.

For labour (L), the index shall be the wages applicable for the “Construction Wage Rates” of Consumer Price Index Number by Major Groups and Selected Commodities presently in Table 23-1, of the Monthly Bulletin of Statistics, published by the Pakistan Bureau of Statistics, Statistics Division, of the Government of Pakistan.

<u>For cement (C),</u> the cost index shall be the index number applicable to "Cement" as given under Index Numbers of Wholesales Prices by Commodities - Other Transportable Goods, presently in Table 23-1, of the Monthly Bulletin of Statistics, published by the Pakistan Bureau of Statistics, Statistics Division, of the Government of Pakistan.

<u>For fuel (F),</u> the index shall be the index number applicable to "Diesel Oil" as given under Index Number of Wholesale Prices by Commodities-Other Transportable Goods, presently in Table 23-1, of the Monthly Bulletin of Statistics, published by the Statistics Division, Pakistan Bureau of Statistics, of the Government of Pakistan.

<u>For steel (S),</u> the cost index shall be the index number applicable to "Iron Bars & Sheets" as given under Index Numbers of Wholesales Prices by Commodities-Metal Products, Machinery and Equipment, presently in Table 23-1, of the Monthly Bulletin of Statistics, published by the Statistics Division, Pakistan Bureau of Statistics, of the Government of Pakistan.

The reference material cost escalation table as proposed by the EPC Contractor will be as given in Table 23-1.

Table 23-1: Reference material cost escalation table

Month after Commence-ment Date	Amount (PKR)					Coefficients					
	Fixed	Cement	Steel	Fuel	Labour	Fixed	Cement	Steel	Fuel	Labour	Total
						a	b	c	d	e	
1						0.60 0.60	0.14 0.11	0.12 0.08	0.08 0.07	0.06 0.14	1.00 1.00
2						0.60	0.14	0.12	0.08	0.06	
3						0.60	0.14	0.12	0.08	0.06	
-						0.60	0.14	0.12	0.08	0.06	
-						0.60	0.14	0.12	0.08	0.06	

23.4.2.2 Adjustment in the Cost of Tunnelling/Underground Work due to Geological Conditions

Subject to the verification of the Re-Opener Verifier, cost variation due to geological conditions related to tunnelling and underground powerhouse work will be allowed at Commercial Operation Dates.

The cost of the tunnel and underground cavern work shall be allowed to vary depending on the category of rock encountered during construction. The increase or decrease in the cost shall be subject to the baseline conditions given in Table 23-2.

In each month of tunnel and underground powerhouse construction, the actual length of tunnelling work for each rock type shall be measured. The actual cost of tunnelling work, for each month of such construction, shall be calculated by multiplying the length of excavation of each rock type by its corresponding unit rate. The unit rates shall not vary during the construction phase.

On COD, the EPC cost shall be adjusted to reflect the actual cost of the tunnelling work. The criteria for Category A, B and C is given in Table 23-2.

Table 23-2: Tunnel – Classification of ground condition

Class	Classification Value	Length Assumed (m)	Unit Rate (PKR /meter Length)	Cost of Construction (PKR)
I				
II				
III				
IVa				
IVb				
V				

24 Conclusions and Recommendations

24.1 Conclusions

The Lower Spat Gah Feasibility Study services commenced on 09 September 2020 with the Letter for Notice of Awarding the Contract. This report along with Volumes 0 and 2 to 14 covers the Feasibility Study works.

The Lower Spat Gah Project is located in Northern Pakistan and is part of a hydropower cascade in the Spat Gah and Gabarband valley, which includes the three stages Upper Spat Gah, Middle Gabarband and Lower Spat Gah. The Project has previously been developed and optimised as part of that cascade. The status and future development of the upper two stages is unknown at the time of this study.

The Lower Spat Gah Project is located on the Spat Gah and Gabarband Rivers with the Tailrace Tunnel Outlet Structure on the Indus River about 4 km south of Dasu town. Water is partly stored and diverted at the Lower Spat Gah Headworks through the desander into the forebay and following Headrace Tunnel, Pressure Shaft and High Pressure Tunnel (11.7 km in total) into the Powerhouse. Additional water (up to 10 m^3/s) is diverted at the Lower Gabarband Intake through the desander into the Gabarband intake Tunnel which connects to the Headrace Tunnel. The water from the Power Cavern is released to the Indus River through a free-flow Tailrace Tunnel.

The Lower Spat Gah Project is a run-of-river scheme with limited peaking capabilities which uses the inflow into the reservoirs for diversion and subsequent power generation. The Lower Spat Gah Headworks and the Lower Gabarband Intake are mainly founded on river sediments and slope wash while the Power Waterway runs through rock of mainly good quality. The Project is located in a seismic highly active area.

The energy generation of the Project with a design discharge of 75 m^3/s and an Installed Capacity of 470 MW as measured at the grid connection substation is 1,925 GWh/year if operated as a stand-alone project and 1,931 GWh/year if operated as part of the cascade. The peaking design discharge of the stand-alone operation, which has to be expected up to the operation of the upstream scheme, is 65.5 m^3/s with the 90% availability criterion and generates 518 GWh/year of peaking energy.

The total costs of the Project have been estimated to 980 million USD including contingencies but without IDC, and 1,085 million USD including IDC.

With an equity IRR of 17% the equity NPV results to 256 million USD while the Project IRR and NPV are 9.6% and 112 million USD, respectively. The corresponding energy tariff is 9.88 US cent/kWh for years 1-12 and 5.31 US cent/kWh for years 13-30, with a levelized tariff of 8.6 1US cent/kWh.

The sensitivity analysis shows the impact of the varied parameters on the Project’s profitability. Special attention should be paid if the change in costs can result in a tariff adjustment or not.

24.2 Recommendations

The purpose of the Feasibility Study was to design an economically viable Project based on the given hydrological, topographical and geological conditions. The following issues need however to be addressed in the next Project phase:

- Peaking vs. standard run-of-river operation

  The Lower Spat Gah Project has been designed with a Full Supply Level and a Minimum Operating Level in the Lower Spat Gah reservoir to enable as much peaking as possible as implied by PEDO. It was briefly assessed that this results in very high costs for the Lower Spat Gah desander in the range of 25% to 35% and slightly lower generated output of 0.8% in comparison with a pure run-of river project.

  Thus, it is recommended to conduct a specific optimisation study and evaluate the costs and resulting peaking energy for a standard run-of-river project. PEDO has communicated in a meeting in April 2019 that there are no official peaking requirements. It has however also been indicated that peaking energy is beneficial for the Project regarding energy evacuation and energy tariff.

It is therefore recommended to discuss and agree the Project peaking patterns, cost and energy with PEDO before further advancing the Project in a next design stage as a more economic design is feasible for this Project. Depending on the final energy tariff / operating pattenr, it may be worth investigating the technical feasibility and the economic viability of an underground desander at the Lower Spat Gah Headworks to further optimize the Project.

- Tunnel lining

  The Headrace Tunnel and Tailrace Tunnel have been designed with reinforced lining over the entire length at this stage of the Project as the level of information about the rock mass is not sufficient and the risk to suggest the construction as unlined is perceived as high.

  The Mandraza Amphibolite and the Gabbro along the Headrace Tunnel could however provide ideal geotechnical characteristics for shotcrete lining or unlined sections in Class I and II. Shotcrete lining along the Tailrace Tunnel could also be possible depending on the rock characteristics.

  If during the excavation of the Powerhouse and Upper Erection and Gate Chamber access tunnels and various construction adits the conditions required for the unlined or shotcrete lined tunnel will be met, then the design could be re-assessed to define sections that could stay unlined or just shotcrete lined.

- Additional geological investigation

  Comprehensive complementary geological investigations have been carried out during this Feasibility Study and the geological information is based on direct information including drilling and laboratory and field tests at the Lower Spat Gah Headworks, Lower Gabarband Intake, Gabarband Crossing and Powerhouse area.

  The minimum length of steel required at the Gabarband Crossing will have to be confirmed during Project execution by means of hydro-fracturing tests performed in situ. It is also recommended to confirm the proposed location and orientation of the Powerhouse Cavern using the access tunnels as exploratory adits at the beginning of the construction phase to locate the Powerhouse in the most suitable geological unit to minimise the rock support, construction time and the geological risk.

  At the current stage of this Project the level of information about the rock mass is not sufficient and the risk to suggest the construction of the Headrace Tunnel as unlined is perceived as rather high. Therefore, the selection is made to line the entire length with reinforced concrete lining. If during the excavation of the Powerhouse and Upper Erection and Gate Chamber access tunnels and the various construction adits of the Power Waterway the conditions required for the unlined tunnel will be met, then the design could be adopted and sections that could stay unlined or just shotcrete lined could be defined accordingly. The decision must be approved during the excavation process and the final decision will have to be made after excavation.

  As usual in hydropower industry, it is recommended to conduct additional geological investigation during the Project execution to confirm the final design. The proposed investigations are listed in Chapter 6.9.

- Rainfall and discharge measurement

  The installation of the water level and rainfall gauging stations was completed in April and May 2021 near the Lower Spat Gah Headworks and Goshali Bridge, respectively. It is recommended to pursue the ongoing measurements for a minimum of one full hydrological year at both stations to check the hydrological assumptions with the conditions in the Project area.

- Sediment sampling

  A comprehensive sediment sampling and testing campaign was initiated in September 2020. It is recommended to pursue the ongoing sampling and testing to cover a minimum of one full hydrological year with particular emphasis on the 2021 high inflow season to improve the current knowledge and better assess the anticipated turbine life/amount of repair and maintenance works during operation, and eventually confirm the adequacy of the selected design grain size for desander design.

- Topography survey

  Comprehensive complementary topography surveys have been performed to confirm the accuracy of the 2010 detailed terrestrial survey where available and to collect new information i) at the Gabarband Crossing in order to advance the Headrace Tunnel crossing design, ii) along the Gabarband valley from the Spat Gah confluence to the Gabarband Crossing in order to properly design the access road, and iii) along the Spat Gah River from the Lower Spat Gah Headworks to the Indus River in order to conduct a dam break analysis as applicable.

  As usual in hydropower industry, it is recommended to re-survey the relevant project sites by the way of a detailed terrestrial survey at the very beginning of the Project implementation as basis for the final design and construction quantities.

- Residual flow release

  The Environmental and Social Impact Assessment has been submitted to the relevant Pakistani authorities. Different residual flow release scenarios have been presented in the environmental flow assessment in conjunction with their impact on fish population.

  The final decision on the environmental flow will have to be confirmed by KP EPA by considering the trade-off to power generation and the survival of the species present in the river. Based on KP EPA's decision the energy simulations might have to be updated in the next design phase.

- Location of Lower Gabarband Intake

  The selected location of the Lower Gabarband Intake is considered to be most optimal considering the maximum upsurge water levels, length of Gabarband Intake Tunnel, width of the valley, scree areas and the upstream village. The actual morphology of the area and the vegetation cover both indicate that the area is stable and does not anymore represent a risk for the structures, in contrast to the locations further upstream. It is however recommended by the Panel of Expert recommended to validate the location in the next design stage.

- Grid connection, power system and transmission network study

  The grid connection point for the purpose of this Feasibility Study has been assumed to be at the outdoor 220/765kV Connection Switchyard. A solution consisting of a 220 kV GIS located in the Transformer Cavern and a 220 kV HV cable from the transformer to the Connection Switchyard located near the Powerhouse portal area, and a 765 kV transmission line from the switchyard to the 765 kV Dasu - Manshera transmission line has been selected based on preliminary information from PPI. It is however noted that such solution is quite expensive and that cheaper solutions may be envisaged in cooperation with NTDC to optimise the cost borne by both the SPC and NTDC.

  A preliminary design of the Connection Switchyard has been prepared by PPI as part of the transmission line studies and placed near the Powerhouse portals in order to conduct the transmission line survey. At the time of the final report no feedback has been received from NTDC regarding the location and design of the Connection Switchyard. It is recommended to approach NTDC to discuss the exact energy delivery point from which onwards it will be NTDC's responsibility and to determine the design and a more proper cost for the power evacuation and grid connection works.

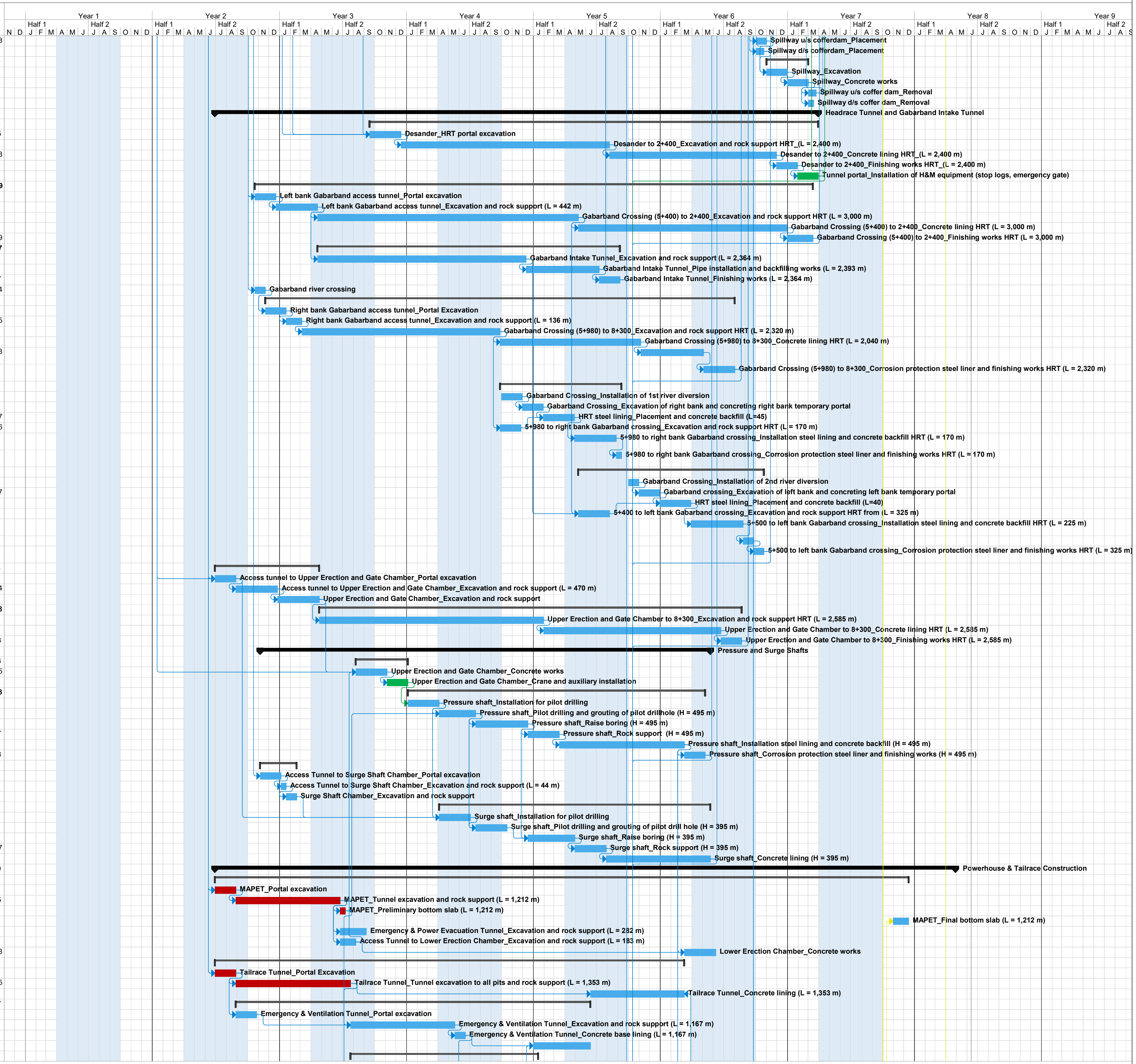
Annex 1 Construction Schedule

ID	Task Name	Duration	Start	Finish
0	**Lower Spat Gah (LSG)**	**90.67 mons**	**Sun 01/01/23**	**Wed 12/06/30**
1	**Project Milestones / Project Planning**	**19.62 mons**	**Wed 01/11/28**	**Wed 12/06/30**
2	Waterway ready for filling	0 mons	Tue 30/10/29	Tue 30/10/29
3	Lower Spat Gah reservoir ready for impounding	0 mons	Thu 21/06/29	Thu 21/06/29
4	Lower Gabarband intake ready for diversion	0 mons	Wed 01/11/28	Wed 01/11/28
5	Lower Gabarband intake ready for operation	0 mons	Fri 23/03/29	Fri 23/03/29
6	Back Energizing	0 mons	Mon 01/10/29	Mon 01/10/29
7	1st Synchronization	0 mons	Sat 15/12/29	Sat 15/12/29
8	Date of completion	0 mons	Sun 28/04/30	Sun 28/04/30
9	COD (Commercial Operation Date)	0 mons	Wed 12/06/30	Wed 12/06/30
10	**Early Works**	**36 mons**	**Sun 01/01/23**	**Mon 15/12/25**
11	Bridge across Indus river	5 mons	Sun 01/01/23	Tue 30/05/23
12	**Powerhouse/tailrace Area**	**22.5 mons**	**Sun 01/01/23**	**Tue 05/11/24**
13	Access road from main road to Powerhouse access tunnels (L = 570 m)	1 mon	Thu 02/03/23	Fri 31/03/23
14	Access road PH adit portal to Indus Bridge (L = 450 m)	1 mon	Sat 01/04/23	Sun 30/04/23
15	Access roads from Indus Bridge to Tailrace Outlet Structure (L = 120 m)	1 mon	Mon 01/05/23	Tue 30/05/23
16	Access road from junction to Upper Erection and Gate Chamber (L = 3,665 m)	12 mons	Sun 01/01/23	Tue 26/12/23
17	Construction road to top of surge shaft access tunnel (L = 3,685 m)	12 mons	Sun 12/11/23	Tue 05/11/24
18	**Spat Gah Headworks Area**	**33 mons**	**Sun 01/01/23**	**Tue 16/09/25**
19	Spat Gah access road from main road junction to Dogah (L = 9,235 m)	12 mons	Sun 01/01/23	Tue 26/12/23
20	Spat Gah access road from Dogah to Lower Spat Gah headworks (L = 8,370 m + 480 m tunnel)	18 mons	Wed 27/12/23	Wed 18/06/25
21	Temporary construction road and bridge across river at Headworks area	3 mons	Thu 19/06/25	Tue 16/09/25
22	**Gabarband Intake Area**	**6 mons**	**Wed 27/12/23**	**Sun 23/06/24**
23	Access road from Dogah to Gabarband adit (L = 2,075 m + 90 m bridge + 585 m tunnel)	6 mons	Wed 27/12/23	Sun 23/06/24
24	Owner's Engineer's camp (later Operator's Village)	6 mons	Mon 01/01/24	Fri 28/06/24
25	Reservoir clearing and grubbing	3 mons	Wed 17/09/25	Mon 15/12/25
26	**Site Installations of Civil Works Contractor**	**73.63 mons**	**Mon 01/01/24**	**Thu 17/01/30**
27	Mobilization to site	3 mons	Mon 01/01/24	Sat 30/03/24
28	**Powerhouse/Tailrace Area**	**6 mons**	**Wed 31/01/24**	**Sun 28/07/24**
29	Powerhouse/tailrace area: crushing plant, batching plant, grouting plant, steel fabrication yard	4 mons	Wed 31/01/24	Wed 29/05/24
30	Powerhouse/tailrace area: preparation of spoil and mucking area	3 mons	Sun 31/03/24	Fri 28/06/24
31	Erection of EPC Contractor's main camp 1, office, laboratory, workshop (powerhouse area)	6 mons	Wed 31/01/24	Sun 28/07/24
32	Establishment at camp 1: power supply, water supply, fuel supply, waste, wastewater, etc.	4 mons	Fri 01/03/24	Fri 28/06/24
33	**Lower Gabarband Intake Area**	**4 mons**	**Mon 24/06/24**	**Mon 21/10/24**
34	Gabarband crossing: crushing plant, batching plant, grouting plant, camp 2	4 mons	Mon 24/06/24	Mon 21/10/24
35	Gabarband crossing: preparation of spoil and mucking area	3 mons	Mon 24/06/24	Sat 21/09/24
36	**Lower Spat Gah Headworks Area**	**4 mons**	**Sun 22/09/24**	**Sun 19/01/25**
37	Spat Gah headworks: crushing plant, batching plant, grouting plant, camp 3	4 mons	Sun 22/09/24	Sun 19/01/25
38	Spat Gah headworks: preparation of spoil and mucking area	3 mons	Sun 22/09/24	Fri 20/12/24
39	Erection of hydromechanical steel workshop	5 mons	Sun 31/03/24	Tue 27/08/24
40	Demobilization and site clean-up	7 mons	Fri 22/06/29	Thu 17/01/30
41	**Lower Spat Gah Headworks**	**45.33 mons**	**Wed 01/10/25**	**Thu 21/06/29**
42	**Right Bank Works**	**44.53 mons**	**Wed 01/10/25**	**Mon 28/05/29**
43	Intermediate flushing channel pier and cut-off wall below_Construction	4 mons	Wed 01/10/25	Wed 28/01/26
44	Flushing channel u/s cofferdam incl. cut-off wall_Placement	2 mons	Thu 29/01/26	Sun 29/03/26
45	Flushing channel d/s cofferdam incl. cut-off wall_Placement	2 mons	Thu 29/01/26	Sun 29/03/26
46	**Flushing Channel (bay 2 and 3)**	**12.5 mons**	**Mon 30/03/26**	**Thu 08/04/27**
47	Flushing channel bays 2 and 3_Excavation	0.5 mons	Mon 30/03/26	Mon 13/04/26
48	Cut-off wall below flushing channel bays 2 and 3	1 mon	Tue 14/04/26	Wed 13/05/26
49	Flushing channels bays 2 and 3_Construction	5 mons	Thu 14/05/26	Sat 10/10/26
50	Flushing channels bays 2 and 3_Installation of HM equipment (crane, radial gate, stop logs)	6 mons	Sun 11/10/26	Thu 08/04/27
51	**Desander**	**44.53 mons**	**Wed 01/10/25**	**Mon 28/05/29**
52	Desander intake and cut-off wall_Excavation	2 mons	Mon 30/03/26	Thu 28/05/26
53	Desander intake_Concrete works	4 mons	Fri 29/05/26	Fri 25/09/26
54	Desander intake_Installation of HM equipment (trash rack, stop logs, gates)	5 mons	Sat 26/09/26	Mon 22/02/27
55	Desander_Excavation	15 mons	Wed 01/10/25	Thu 24/12/26
56	Desander_Concrete works	12 mons	Fri 25/12/26	Sun 19/12/27
57	(Between) flushing channel and desander_Backfilling	2 mons	Mon 20/12/27	Thu 17/02/28
58	Desander_Installation of H&M equipment (desander gates, flushing gates)	6 mons	Mon 20/12/27	Fri 16/06/28
59	Forebay_Concrete works	2 mons	Fri 30/03/29	Mon 28/05/29
60	Flushing channel u/s cofferdam_Removal	2 mons	Fri 01/10/27	Mon 29/11/27
61	Flushing channel d/s cofferdam_Removal	2 mons	Fri 01/10/27	Mon 29/11/27
62	**Left Bank Works**	**19 mons**	**Tue 30/11/27**	**Thu 21/06/29**
63	Dam body u/s cofferdam incl. cut-off wall_Placement	3 mons	Tue 30/11/27	Sun 27/02/28
64	Dam body d/s cofferdam incl. cut-off wall_Placement	3 mons	Tue 30/11/27	Sun 27/02/28
65	**Flushing Channel (bay 1)**	**9.5 mons**	**Mon 28/02/28**	**Fri 08/12/28**
66	Dam body and flushing channel bay 1_Excavation	1 mon	Mon 28/02/28	Tue 28/03/28
67	Cut-off wall below flushing channel bay 1	0.5 mons	Wed 29/03/28	Wed 12/04/28
68	Flushing channel bay 1_Construction	4 mons	Thu 13/04/28	Thu 10/08/28
69	Flushing channel bay 1_Installation of H&M equipment (stop logs, radial gate)	4 mons	Fri 11/08/28	Fri 08/12/28
70	**Dam Embankment**	**14 mons**	**Wed 29/03/28**	**Tue 22/05/29**
71	Cut-off wall and grouting gallery below dam_Construction	6 mons	Wed 29/03/28	Sun 24/09/28
72	Dam core_Placement	7 mons	Mon 25/09/28	Sun 22/04/29
73	Dam filter layers_Placement	7 mons	Tue 10/10/28	Mon 07/05/29
74	Dam rock fill_Placement	7 mons	Wed 25/10/28	Tue 22/05/29
75	Dam body u/s cofferdam_Removal	1 mon	Wed 23/05/29	Thu 21/06/29
76	Dam body d/s cofferdam_Removal	1 mon	Wed 23/05/29	Thu 21/06/29
77	**Lower Gabarband Intake**	**18 mons**	**Fri 01/10/27**	**Fri 23/03/29**
78	**Left Bank Works**	**12.25 mons**	**Fri 01/10/27**	**Mon 02/10/28**
79	**Flushing Channel of Weir**	**11 mons**	**Fri 01/10/27**	**Fri 25/08/28**
80	Dry season longitudinal cofferdam_Placement	1 mon	Fri 01/10/27	Sat 30/10/27
81	Flushing channel _Excavation	0.5 mons	Sun 31/10/27	Sun 14/11/27
82	Intermediate pier and flushing channel slab_Construction	2 mons	Mon 15/11/27	Thu 13/01/28
83	Flushing channel u/s and d/s cofferdam_Placement	1.5 mons	Fri 14/01/28	Sun 27/02/28
84	Flushing channel_Construction	3 mons	Mon 28/02/28	Sat 27/05/28
85	Flushing channel_Installation of HM equipment (radial gate, stop logs)	3 mons	Sun 28/05/28	Fri 25/08/28
86	**Desander**	**11 mons**	**Fri 01/10/27**	**Fri 25/08/28**
87	Desander_Excavation	2 mons	Fri 01/10/27	Mon 29/11/27
88	Desander intake_Excavation	0.5 mons	Mon 28/02/28	Mon 13/03/28
89	Desander intake_Concrete works	2 mons	Tue 14/03/28	Fri 12/05/28
90	Desander intake_Installation of HM equipment (trash rack, stop logs, gates)	2 mons	Sat 13/05/28	Tue 11/07/28
91	Desander_Excavation finalisation and Concrete works	4 mons	Mon 28/02/28	Mon 26/06/28
92	(Between) flushing channel and desander_Backfilling	1 mon	Tue 27/06/28	Wed 26/07/28
93	Desander and forebay_Installation of H&M equipment (flushing gates, calming racks)	2 mons	Tue 27/06/28	Fri 25/08/28
94	Forebay_Concrete works, Installation GFRP pipe to portal	2 mons	Mon 28/02/28	Thu 27/04/28
95	Forebay_Installation of HM equipment (intake gate)	0.5 mons	Fri 28/04/28	Fri 12/05/28
96	Flushing channel cofferdams_Removal	0.5 mons	Sun 17/09/28	Mon 02/10/28
97	**Right Bank Works**	**5.75 mons**	**Mon 02/10/28**	**Fri 23/03/29**

Project: Lower Spat Gah (L
Date: Thu 06/10/22

Critical Split · Electro-Mechanical · Hydro-Mechanical · Task · Split · Milestone · Summary · Project Summary · Manual Progress · Critical

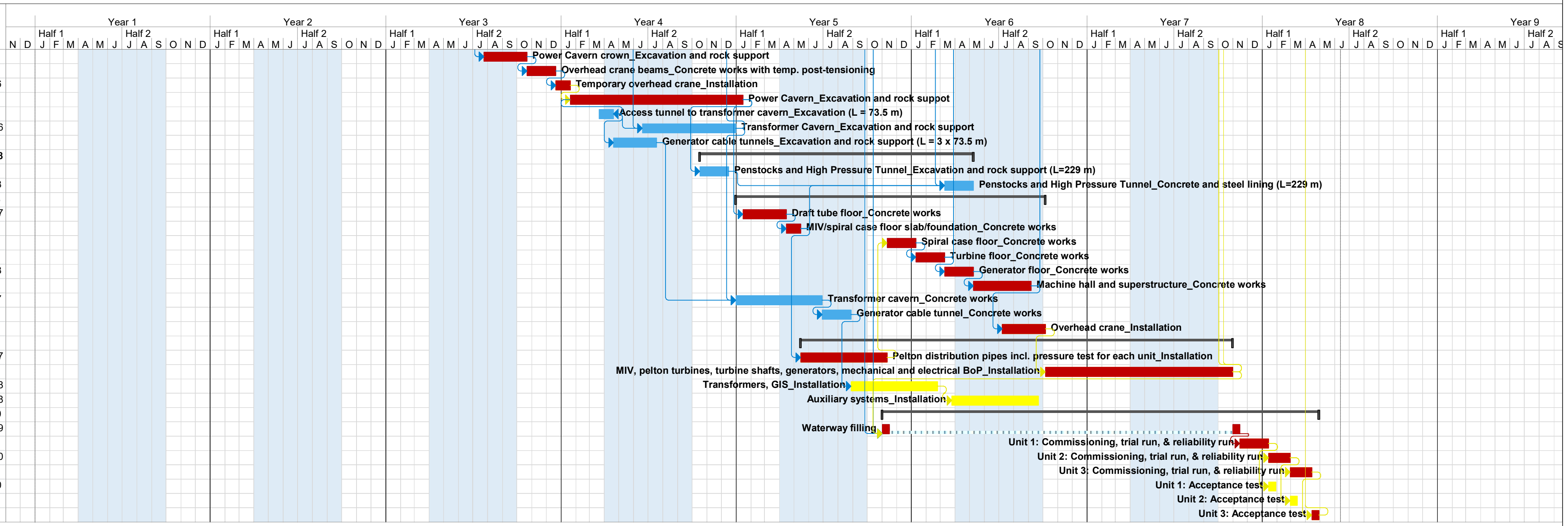
ID	Task Name	Duration	Start	Finish
98	Spillway u/s cofferdam_Placement	1 mon	Mon 02/10/28	Wed 01/11/28
99	Spillway d/s cofferdam_Placement	0.75 mons	Mon 02/10/28	Tue 24/10/28
100	**Overflow Spillway**	**4 mons**	**Wed 01/11/28**	**Thu 01/03/29**
101	Spillway_Excavation	2 mons	Wed 01/11/28	Sun 31/12/28
102	Spillway_Concrete works	2 mons	Sun 31/12/28	Thu 01/03/29
103	Spillway u/s coffer dam_Removal	0.75 mons	Thu 01/03/29	Fri 23/03/29
104	Spillway d/s coffer dam_Removal	0.5 mons	Thu 01/03/29	Fri 16/03/29
105	**Headrace Tunnel and Gabarband Intake Tunnel**	**57.83 mons**	**Sat 29/06/24**	**Thu 29/03/29**
106	**HRT (0~2+400)**	**43 mons**	**Wed 17/09/25**	**Thu 29/03/29**
107	Desander_HRT portal excavation	3 mons	Wed 17/09/25	Mon 15/12/25
108	Desander to 2+400_Excavation and rock support HRT_(L = 2,400 m)	20 mons	Tue 16/12/25	Sat 07/08/27
109	Desander to 2+400_Concrete lining HRT_(L = 2,400 m)	16 mons	Sun 08/08/27	Wed 29/11/28
110	Desander to 2+400_Finishing works HRT_(L = 2,400 m)	2 mons	Thu 30/11/28	Sun 28/01/29
111	Tunnel portal_Installation of H&M equipment (stop logs, emergency gate)	2 mons	Mon 29/01/29	Thu 29/03/29
112	**HRT (2+400~5+400)**	**53.5 mons**	**Tue 22/10/24**	**Wed 14/03/29**
113	Left bank Gabarband access tunnel_Portal excavation	2 mons	Tue 22/10/24	Fri 20/12/24
114	Left bank Gabarband access tunnel_Excavation and rock support (L = 442 m)	4 mons	Sat 21/12/24	Sat 19/04/25
115	Gabarband Crossing (5+400) to 2+400_Excavation and rock support HRT (L = 3,000 m)	25 mons	Sun 20/04/25	Sun 09/05/27
116	Gabarband Crossing (5+400) to 2+400_Concrete lining HRT (L = 3,000 m)	20 mons	Mon 10/05/27	Fri 29/12/28
117	Gabarband Crossing (5+400) to 2+400_Finishing works HRT (L = 3,000 m)	2.5 mons	Sat 30/12/28	Wed 14/03/29
118	**Gabarband Intake Tunnel**	**29 mons**	**Sun 20/04/25**	**Mon 06/09/27**
119	Gabarband Intake Tunnel_Excavation and rock support (L = 2,364 m)	20 mons	Sun 20/04/25	Thu 10/12/26
120	Gabarband Intake Tunnel_Pipe installation and backfilling works (L = 2,393 m)	7 mons	Fri 11/12/26	Thu 08/07/27
121	Gabarband Intake Tunnel_Finishing works (L = 2,364 m)	2 mons	Fri 09/07/27	Mon 06/09/27
122	Gabarband river crossing	1 mon	Tue 22/10/24	Wed 20/11/24
123	**HRT (5+980~8+300)**	**45 mons**	**Thu 21/11/24**	**Tue 01/08/28**
124	Right bank Gabarband access tunnel_Portal Excavation	2 mons	Thu 21/11/24	Sun 19/01/25
125	Right bank Gabarband access tunnel_Excavation and rock support (L = 136 m)	1.5 mons	Mon 20/01/25	Wed 05/03/25
126	Gabarband Crossing (5+980) to 8+300_Excavation and rock support HRT (L = 2,320 m)	19 mons	Thu 06/03/25	Sat 26/09/26
127	Gabarband Crossing (5+980) to 8+300_Concrete lining HRT (L = 2,040 m)	13.5 mons	Sun 27/09/26	Fri 05/11/27
128	Gabarband Crossing (5+980) to 8+300_Installation steel lining and concrete backfill HRT (L = 280 m)	6 mons	Sat 06/11/27	Wed 03/05/28
129	Gabarband Crossing (5+980) to 8+300_Corrosion protection steel liner and finishing works HRT (L = 2,320 m)	3 mons	Thu 04/05/28	Tue 01/08/28
130	**Garbarband Crossing_1st river diversion**	**11.63 mons**	**Sun 27/09/26**	**Fri 10/09/27**
131	Gabarband Crossing_Installation of 1st river diversion	2 mons	Thu 01/10/26	Sun 29/11/26
132	Gabarband Crossing_Excavation of right bank and concreting right bank temporary portal	2 mons	Mon 30/11/26	Thu 28/01/27
133	HRT steel lining_Placement and concrete backfill (L=45)	3 mons	Fri 29/01/27	Wed 28/04/27
134	5+980 to right bank Gabarband crossing_Excavation and rock support HRT (L = 170 m)	2 mons	Sun 27/09/26	Wed 25/11/26
135	5+980 to right bank Gabarband crossing_Installation steel lining and concrete backfill HRT (L = 170 m)	4 mons	Thu 29/04/27	Thu 26/08/27
136	5+980 to right bank Gabarband crossing_Corrosion protection steel liner and finishing works HRT (L = 170 m)	0.5 mons	Fri 27/08/27	Fri 10/09/27
137	**Garbarband Crossing_2nd river diversion**	**17.8 mons**	**Mon 10/05/27**	**Tue 24/10/28**
138	Gabarband Crossing_Installation of 2nd river diversion	1 mon	Fri 01/10/27	Sat 30/10/27
139	Gabarband crossing_Excavation of left bank and concreting left bank temporary portal	2 mons	Sun 31/10/27	Wed 29/12/27
140	HRT steel lining_Placement and concrete backfill (L=40)	3 mons	Thu 30/12/27	Tue 28/03/28
141	5+400 to left bank Gabarband crossing_Excavation and rock support HRT from (L = 325 m)	3 mons	Mon 10/05/27	Sat 07/08/27
142	5+500 to left bank Gabarband crossing_Installation steel lining and concrete backfill HRT (L = 225 m)	5 mons	Wed 29/03/28	Fri 25/08/28
143	5+500 to left bank Gabarband crossing_Concrete lining HRT (L = 100 m)	1 mon	Sat 26/08/28	Sun 24/09/28
144	5+500 to left bank Gabarband crossing_Corrosion protection steel liner and finishing works HRT (L = 325 m)	1 mon	Mon 25/09/28	Tue 24/10/28
145	**Upper Erection and Gate Chamber_Excavation**	**10 mons**	**Sat 29/06/24**	**Thu 24/04/25**
146	Access tunnel to Upper Erection and Gate Chamber_Portal excavation	2 mons	Sat 29/06/24	Tue 27/08/24
147	Access tunnel to Upper Erection and Gate Chamber_Excavation and rock support (L = 470 m)	4 mons	Wed 28/08/24	Wed 25/12/24
148	Upper Erection and Gate Chamber_Excavation and rock support	4 mons	Thu 26/12/24	Thu 24/04/25
149	**HRT (8+300~10+885)**	**40.5 mons**	**Fri 25/04/25**	**Mon 21/08/28**
150	Upper Erection and Gate Chamber to 8+300_Excavation and rock support HRT (L = 2,585 m)	21.5 mons	Fri 25/04/25	Fri 29/01/27
151	Upper Erection and Gate Chamber to 8+300_Concrete lining HRT (L = 2,585 m)	17 mons	Sat 30/01/27	Thu 22/06/28
152	Upper Erection and Gate Chamber to 8+300_Finishing works HRT (L = 2,585 m)	2 mons	Fri 23/06/28	Mon 21/08/28
153	**Pressure and Surge Shafts**	**43.17 mons**	**Wed 06/11/24**	**Tue 23/05/28**
154	**Upper Erection and Gate Chamber_Concrete Works**	**5 mons**	**Fri 08/08/25**	**Sun 04/01/26**
155	Upper Erection and Gate Chamber_Concrete works	3 mons	Fri 08/08/25	Wed 05/11/25
156	Upper Erection and Gate Chamber_Crane and auxiliary installation	2 mons	Thu 06/11/25	Sun 04/01/26
157	**Pressure Shaft**	**28.5 mons**	**Mon 05/01/26**	**Mon 08/05/28**
158	Pressure shaft_Installation for pilot drilling	3 mons	Mon 05/01/26	Sat 04/04/26
159	Pressure shaft_Pilot drilling and grouting of pilot drillhole (H = 495 m)	3.5 mons	Sun 05/04/26	Sat 18/07/26
160	Pressure shaft_Raise boring (H = 495 m)	5 mons	Sun 19/07/26	Tue 15/12/26
161	Pressure shaft_Rock support (H = 495 m)	3 mons	Wed 16/12/26	Mon 15/03/27
162	Pressure shaft_Installation steel lining and concrete backfill (H = 495 m)	12 mons	Tue 16/03/27	Thu 09/03/28
163	Pressure shaft_Corrosion protection steel liner and finishing works (H = 495 m)	2 mons	Fri 10/03/28	Mon 08/05/28
164	**Access Tunnel to Surge Shaft Chamber and Surge Shaft Chamber**	**3.5 mons**	**Wed 06/11/24**	**Tue 18/02/25**
165	Access Tunnel to Surge Shaft Chamber_Portal excavation	2 mons	Wed 06/11/24	Sat 04/01/25
166	Access Tunnel to Surge Shaft Chamber_Excavation and rock support (L = 44 m)	0.5 mons	Sun 05/01/25	Sun 19/01/25
167	Surge Shaft Chamber_Excavation and rock support	1 mon	Mon 20/01/25	Tue 18/02/25
168	**Surge Shaft**	**26 mons**	**Sun 05/04/26**	**Tue 23/05/28**
169	Surge shaft_Installation for pilot drilling	3 mons	Sun 05/04/26	Fri 03/07/26
170	Surge shaft_Pilot drilling and grouting of pilot drill hole (H = 395 m)	3 mons	Sun 19/07/26	Fri 16/10/26
171	Surge shaft_Raise boring (H = 395 m)	4.5 mons	Wed 16/12/26	Thu 29/04/27
172	Surge shaft_Rock support (H = 395 m)	3 mons	Fri 30/04/27	Wed 28/07/27
173	Surge shaft_Concrete lining (H = 395 m)	10 mons	Thu 29/07/27	Tue 23/05/28
174	**Powerhouse & Tailrace Construction**	**71 mons**	**Sat 29/06/24**	**Sun 28/04/30**
175	**Main Access & Power Evacuation Tunnel (MAPET)**	**66.5 mons**	**Sat 29/06/24**	**Fri 14/12/29**
176	MAPET_Portal excavation	2 mons	Sat 29/06/24	Tue 27/08/24
177	MAPET_Tunnel excavation and rock support (L = 1,212 m)	10 mons	Wed 28/08/24	Mon 23/06/25
178	MAPET_Preliminary bottom slab (L = 1,212 m)	0.5 mons	Tue 24/06/25	Tue 08/07/25
179	MAPET_Final bottom slab (L = 1,212 m)	1.5 mons	Wed 31/10/29	Fri 14/12/29
180	Emergency & Power Evacuation Tunnel_Excavation and rock support (L = 282 m)	2.5 mons	Tue 24/06/25	Sat 06/09/25
181	Access Tunnel to Lower Erection Chamber_Excavation and rock support (L = 183 m)	1.5 mons	Tue 24/06/25	Thu 07/08/25
182	Lower Erection Chamber_Concrete works	3 mons	Fri 10/03/28	Wed 07/06/28
183	**Tailrace Tunnel**	**45 mons**	**Sat 29/06/24**	**Thu 09/03/28**
184	Tailrace Tunnel_Portal Excavation	2 mons	Sat 29/06/24	Tue 27/08/24
185	Tailrace Tunnel_Tunnel excavation to all pits and rock support (L = 1,353 m)	11 mons	Wed 28/08/24	Wed 23/07/25
186	Tailrace Tunnel_Concrete lining (L = 1,353 m)	9 mons	Mon 14/06/27	Thu 09/03/28
187	**Emergency & Ventilation Tunnel**	**34 mons**	**Wed 28/08/24**	**Sun 13/06/27**
188	Emergency & Ventilation Tunnel_Portal excavation	2 mons	Wed 28/08/24	Sat 26/10/24
189	Emergency & Ventilation Tunnel_Excavation and rock support (L = 1,167 m)	10 mons	Thu 24/07/25	Tue 19/05/26
190	Emergency & Ventilation Tunnel_Concrete base lining (L = 1,167 m)	1 mon	Wed 20/05/26	Thu 18/06/26
191	Emergency & Ventilation Tunnel_Concrete lining (L = 1,167 m)	5.5 mons	Thu 31/12/26	Sun 13/06/27
192	**Powerhouse Caverns_Excavation**	**18 mons**	**Thu 24/07/25**	**Thu 14/01/27**



Project: Lower Spat Gah (L
Date: Thu 06/10/22

Critical Split | Electro-Mechanical | Hydro-Mechanical | Task | Split | Milestone | Summary | Project Summary | Manual Progress | Critical

ID	Task Name	Duration	Start	Finish
193	Power Cavern crown_Excavation and rock support	3 mons	Thu 24/07/25	Tue 21/10/25
194	Overhead crane beams_Concrete works with temp. post-tensioning	2 mons	Wed 22/10/25	Sat 20/12/25
195	Temporary overhead crane_Installation	1 mon	Sun 21/12/25	Mon 19/01/26
196	Power Cavern_Excavation and rock suppot	12 mons	Tue 20/01/26	Thu 14/01/27
197	Access tunnel to transformer cavern_Excavation (L = 73.5 m)	1 mon	Sat 21/03/26	Sun 19/04/26
198	Transformer Cavern_Excavation and rock support	6.5 mons	Fri 19/06/26	Wed 30/12/26
199	Generator cable tunnels_Excavation and rock support (L = 3 x 73.5 m)	3 mons	Mon 20/04/26	Sat 18/07/26
200	**Penstocks and High Pressure Tunnel**	**19 mons**	**Sat 17/10/26**	**Mon 08/05/28**
201	Penstocks and High Pressure Tunnel_Excavation and rock support (L=229 m)	2 mons	Sat 17/10/26	Tue 15/12/26
202	Penstocks and High Pressure Tunnel_Concrete and steel lining (L=229 m)	2 mons	Fri 10/03/28	Mon 08/05/28
203	**Powerhouse Caverns_Concrete Work**	**21.5 mons**	**Thu 31/12/26**	**Thu 05/10/28**
204	Draft tube floor_Concrete works	3 mons	Fri 15/01/27	Wed 14/04/27
205	MIV/spiral case floor slab/foundation_Concrete works	1 mon	Thu 15/04/27	Fri 14/05/27
206	Spiral case floor_Concrete works	2 mons	Thu 11/11/27	Sun 09/01/28
207	Turbine floor_Concrete works	2 mons	Mon 10/01/28	Thu 09/03/28
208	Generator floor_Concrete works	2 mons	Fri 10/03/28	Mon 08/05/28
209	Machine hall and superstructure_Concrete works	4 mons	Tue 09/05/28	Tue 05/09/28
210	Transformer cavern_Concrete works	6 mons	Thu 31/12/26	Mon 28/06/27
211	Generator cable tunnel_Concrete works	2 mons	Tue 29/06/27	Fri 27/08/27
212	Overhead crane_Installation	3 mons	Sat 08/07/28	Thu 05/10/28
213	**E&M Installation**	**30 mons**	**Sat 15/05/27**	**Tue 30/10/29**
214	Pelton distribution pipes incl. pressure test for each unit_Installation	6 mons	Sat 15/05/27	Wed 10/11/27
215	MIV, pelton turbines, turbine shafts, generators, mechanical and electrical BoP_Installation	13 mons	Fri 06/10/28	Tue 30/10/29
216	Transformers, GIS_Installation	6 mons	Sat 28/08/27	Wed 23/02/28
217	Auxiliary systems_Installation	6 mons	Sat 25/03/28	Wed 20/09/28
218	**Commissioning**	**30.33 mons**	**Mon 01/11/27**	**Sun 28/04/30**
219	Waterway filling	1 mon	Mon 01/11/27	Wed 14/11/29
220	Unit 1: Commissioning, trial run, & reliability run	2 mons	Thu 15/11/29	Sun 13/01/30
221	Unit 2: Commissioning, trial run, & reliability run	1.5 mons	Mon 14/01/30	Wed 27/02/30
222	Unit 3: Commissioning, trial run, & reliability run	1.5 mons	Thu 28/02/30	Sat 13/04/30
223	Unit 1: Acceptance test	0.5 mons	Mon 14/01/30	Mon 28/01/30
224	Unit 2: Acceptance test	0.5 mons	Thu 28/02/30	Thu 14/03/30
225	Unit 3: Acceptance test	0.5 mons	Sun 14/04/30	Sun 28/04/30



Project: Lower Spat Gah (L
Date: Thu 06/10/22

Critical Split · Electro-Mechanical · Hydro-Mechanical · Task · Split · Milestone · Summary · Project Summary · Manual Progress · Critical

Annex 2 Cost Estimate

Annex 2.1 Cost Estimate Infrastructure and Access Roads

Infrastructure & Road Works Cost Estimates of Lower Spat Gah Hydropower Project

No.	DESCRIPTION	UNIT	QUANTITY	ESTIMATE						
				LCC				FCC		TOTAL AMOUNT LCC + FCC (USD)
				UNIT PRICE (PKR)	AMOUNT (PKR)	UNIT PRICE (Eq. USD)	AMOUNT (Eq. USD)	UNIT PRICE (USD)	AMOUNT (USD)	
A	**INFRASTRUCTURE & ROAD WORKS**				**16,698,142,171**		**93,678,217**			**93,678,217**
1	**Indus Bridge**				**365,414,187**		**2,050,009**		**-**	**2,050,009**
1.1	**Unclassified excavation for foundation of structures and disposal of surplus material at designated locations and dressing of spoil material**									
1.1.1	Clearing & grubbing	m^2	202.59	44.50	9,015.35	0.25	50.58		-	50.58
1.1.2	Loose excavation	m^3	607.78	2,364.00	1,436,783.39	13.26	8,060.50		-	8,060.50
1.1.3	Ripping excavation	m^3	810.37	577.00	467,582.64	3.24	2,623.18		-	2,623.18
1.1.4	Blasting excavation	m^3	2,431.11	5,346.00	12,996,690.32	29.99	72,912.71		-	72,912.71
1.2	**Providing and placing lining concrete (16 MPa cylinder strength) using ordinary portland cement as per drawings and specifications**									
1.2.1	Lining concrete	m^3	19.77	16,225.00	320,733.07	91.02	1,799.34		-	1,799.34
1.2.2	Levelling concrete	m^3	12.58	16,225.00	204,092.85	91.02	1,144.98		-	1,144.98
1.3	**Providing and placing reinforced cement concrete (21 MPa cylinder strength) using ordinary portland cement as per drawings and specifications**									
1.3.1	*Normal concrete*									
1.3.1.1	Abutment footing	m^3	309.02	30,368.00	9,384,331.51	170.37	52,647.02		-	52,647.02
1.3.1.2	Head wall	m^3	404.29	30,368.00	12,277,563.75	170.37	68,878.34		-	68,878.34
1.3.1.3	Approach slab	m^3	37.92	30,368.00	1,151,442.93	170.37	6,459.71		-	6,459.71
1.3.1.4	Wing wall	m^3	251.37	30,368.00	7,633,604.16	170.37	42,825.27		-	42,825.27
1.3.1.5	Site concrete for bridge slabs	m^3	301.94	30,368.00	9,169,253.18	170.37	51,440.41		-	51,440.41
1.3.2	*Precast concrete*									
1.3.2.1	Slabs	m^3	145.20	37,670.00	5,469,717.90	211.33	30,685.65		-	30,685.65
1.4	**Providing and placing reinforced cement concrete (28 MPa cylinder strength) using ordinary portland cement as per drawings and specifications**									
1.4.1	Pier crosshead	m^3	33.77	37,670.00	1,272,042.37	211.33	7,136.28		-	7,136.28
1.4.2	Bearing seat	m^3	0.95	37,670.00	35,781.23	211.33	200.74		-	200.74
1.5	**Steel for bridge construction, fy > 350 N/mm² including providing, fabricating, delivery, connecting, securing and fixing in position**									
1.5.1	Total amount of steel	ton	450.00	364,005.00	163,802,250.00	2,042.10	918,946.70		-	918,946.70
1.5.2	Anti corrosion protection	m^2	1,400.00	6,450.21	9,030,294.00	36.19	50,660.84		-	50,660.84
1.6	**Setup and removal of site specific infrastructure for steel works**									
1.6.1	Setup		-		-	-	-		-	-
1.6.2	Removal		-		-	-	-		-	-
1.7	**Quality control steel and corrosion protection**									
1.7.1	Quality control		-		-	-	-		-	-
1.8	**Providing, fabricating, securing and fixing in position mild steel deformed bars**									
1.8.1	Bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening	ton	296.89	364,005.00	108,069,905.43	2,042.10	606,282.78		-	606,282.78
1.9	**Providing and placing temporary constructions**									
1.9.1	Temporary concrete foundation	m^3	80.00	30,368.00	2,429,440.00	170.37	13,629.40		-	13,629.40
1.9.2	Temporary scaffolding steel	ton	50.00	115,672.00	5,783,600.00	648.93	32,446.56		-	32,446.56
1.9.3	Temporary reinforcement	ton	16.00	182,002.50	2,912,040.00	1,021.05	16,336.83		-	16,336.83
1.10	**Furnishing and installing RC railing**									
1.10.1	Using concrete (21 MPa strength) concrete, including cost of all labour, material, reinforcement, and shuttering etc. completes as per drawings and specifications	m	235.60	3,030.03	713,875.07	17.00	4,004.91		-	4,004.91
1.11	**Providing and constructing deformation joints**									
1.11.1	Joints as per relevant drawings details and specifications	m	13.12	45,981.14	603,272.56	257.96	3,384.42		-	3,384.42
1.12	**Providing and fixing elastomeric bearing pads**									
1.12.1	Bearing pads	cm^3	1,528,590.78	4.09	6,251,936.29	0.02	35,073.98		-	35,073.98
1.13	**Providing and fixing spherical bearing pads**									
1.13.1	spherical bearing	No.	4.00		1,562,984.07	-	8768.49		-	8,768.49
1.14	**Providing and laying plant pre-mixed 80 mm thick of asphaltic material, including compaction and finishing to required camber, grade and density including**									
1.14.1	Sealing layer - 0.5 cm	m^2	549.00	658.81	361,686.69	3.70	2,029.10		-	2,029.10
1.14.2	Mastic asphalt - 3.5 cm	m^2	549.00	500.98	275,038.02	2.81	1,542.99		-	1,542.99
1.14.3	Stone mastic asphalt - 4 cm	m^2	549.00	351.46	192,951.54	1.97	1,082.48		-	1,082.48
1.15	**Providing and laying plant pre-mixed of bituminous mastic**					-	-		-	-
1.15.1	Bituminous mastic	m^3	0.40	8,516.23	3,422.40	47.78	19.20		-	19.20
1.16	**Compaction of back fill around the structures with suitable excavated material around the structure**									
1.16.1	Backfill	m^3	926.80	1,342.00	1,243,761.31	7.53	6,977.62		-	6,977.62
1.17	**Providing and fixing 150 mm diameter PVC pipe for surface drainage**									
1.17.1	PVC pipes	m	15.00	2,075.16	31,127.40	11.64	174.63		-	174.63
1.18	**Providing and installing drainage pots for surface drainage**									
1.18.1	Drainage pots	No.	6.00	15,000.00	90,000.00	84.15	504.91		-	504.91
1.19	**Providing and installing ground wire for electric devices**									
1.19.1	Ground wire	m	400.00	569.92	227,968.00	3.20	1,278.92		-	1,278.92
2	**Access Road From Indus River to Main Road**				**295,900,221**		**1,660,029**		**-**	**1,660,029**
2.1	**Unclassified excavation for structures and disposal of surplus material at designated locations and dressing of spoil material**									
2.1.1	Clearing & grubbing	m^2	11,412.32	44.50	507,848.31	0.25	2,849.08		-	2,849.08
2.1.2	Loose excavation	m^3	5,135.54	2,364.00	12,140,427.59	13.26	68,108.99		-	68,108.99
2.1.3	Ripping excavation	m^3	6,847.39	577.00	3,950,945.70	3.24	22,165.19		-	22,165.19
2.1.4	Blasting excavation	m^3	20,542.18	5,346.00	109,818,487.16	29.99	616,092.49		-	616,092.49
2.2	**Compaction of backfill around the structures with suitable material**									
2.2.1	15 cm field sod/ top soil + seeding	m^3	3,200.00	1,341.45	4,292,640.00	7.53	24,082.13		-	24,082.13
2.2.2	60 cm riprap handplaced/ river bank protection	m^3	320.00	3,756.84	1,202,188.80	21.08	6,744.40		-	6,744.40
2.2.3	Filling random material	m^3	14,085.00	1,342.00	18,902,070.00	7.53	106,042.47		-	106,042.47
2.3	**Removing trees operation**									
2.3.1	Trees 150-300 mm girth	No.	20.00	618.96	12,379.20	3.47	69.45		-	69.45
2.3.2	Trees 300-600 mm girth	No.	10.00	3,044.67	30,446.70	17.08	170.81		-	170.81
2.4	**Providing and laying cement stabilised base**									
2.4.1	Providing and laying plant 60 mm thick cement stabilised base, including compaction and finishing to required camber, grade and density	m^3	184.71	22,623.08	4,848,315.78	126.92	27,199.53		-	27,199.53
2.5	**Providing and placing base and sub-base course**									
2.5.1	15 cm thick granular base course	m^3	544.14	2,980.48	1,621,810.31	16.72	9,098.52		-	9,098.52
2.5.2	20 cm thick sub-base course	m^3	781.57	2,251.41	1,759,630.01	12.63	9,871.70		-	9,871.70
2.6	**Providing and placing lining concrete (16 MPa cylinder strength)**									
2.6.1	Using ordinary portland cement as per drawings and specifications	m^3	121.79	21,522.00	2,621,207.42	120.74	14,705.23		-	14,705.23
2.7	**Providing and placing concrete (21 MPa cylinder strength)**									
2.7.1	Using ordinary portland cement as per drawings and specifications	m^3	521.48	30,368.00	15,836,222.20	170.37	88,842.76		-	88,842.76
2.8	**Providing and Placing wire mesh**									
2.8.1	Wire mesh Ø5 mm, 100 mm x 100 mm, surface application	ton	54.51	331,200.00	18,053,082.99	1,858.06	101,279.57		-	101,279.57
2.9	**Providing and fixing 150 mm diameter PVC pipe >3% slope and maintenance opening every 200 m for drainage**									
2.9.1	Maintenance opening every 200 m for drainage	pcs	2.84	15,000.00	42,600.00	84.15	238.99		-	238.99
2.9.2	Ø150 mm PVC pipe >3% slope and maintenance opening every 200 m for drainage	m	568.00	1,556.37	884,018.16	8.73	4,959.43		-	4,959.43
2.9.3	Ø150 mm diameter PVC pipe >3% slope	m	352.00	1,556.37	547,842.24	8.73	3,073.45		-	3,073.45
2.10	**Providing and placing sand**									
2.10.1	0.73 m each layer	m^3	-		-	-	-		-	-
2.11	**Providing and placing twist hexagonal woven wire mesh**									
2.11.1	Wire mesh Ø3.70 mm	ton	-		-	-	-		-	-
2.12	**Providing and placing steel wire mesh for gabion**									
2.12.1	For Gabion	kg	5,631.78	570.75	3,214,338.44	3.20	18,032.75		-	18,032.75
2.13	**Providing and placing gabion**									
2.13.1	Gabion (1.5m x 1m x 1m)	m^3	858.00	2,602.04	2,232,550.32	14.60	12,524.83		-	12,524.83
2.13.2	Gabion (3m x 1m x 1m)	m^3	1,104.00	2,602.04	2,872,652.16	14.60	16,115.86		-	16,115.86
2.13.3	Gabion (2m x 1m x 1m)	m^3	344.00	2,602.04	895,101.76	14.60	5,021.61		-	5,021.61
2.13.4	Gabion (4m x 1m x 1m)	m^3	688.00	2,602.04	1,790,203.52	14.60	10,043.22		-	10,043.22
2.13.5	Gabion (6m x 1m x 1m)	m^3	1,548.00	2,602.04	4,027,957.92	14.60	22,597.24		-	22,597.24
2.14	**Providing and placing drainage gravel**									
2.14.1	Gravel	m^3	295.61	1,179.72	348,732.61	6.62	1,956.42		-	1,956.42
2.15	**Providing and placing stone for the cut slope**									
2.15.1	Stone	m^3	1,757.94	2,854.27	5,017,638.81	16.01	28,149.45		-	28,149.45
2.16	**Providing and placing geotextile to the wall**									
2.16.1	Geotextile	m^2	1,913.28	124.13	237,495.21	0.70	1,332.37		-	1,332.37
2.17	**Providing and placing drainage pipe for the cut slope**									
2.17.1	Perforated PVC pipe and geotextile pipe L=5.50 m	No.	242.00	14,056.69	3,401,719.22	78.86	19,083.98		-	19,083.98
2.17.2	Unperforated drainage pipe L=1.00 m	No.	242.00	2,075.16	502,188.72	11.64	2,817.33		-	2,817.33
2.17.3	Perforated PVC pipe and geotextile pipe L=3.00 m	No.	-		-	-	-		-	-
2.17.4	Unperforated drainage pipe L=0.70 m	No.	-		-	-	-		-	-
2.18	**Providing and placing rockbolting for the cut slope**									
2.18.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	-		-	-	-		-	-
2.18.2	Nut M25 + washer	No.	-		-	-	-		-	-
2.18.3	Fully grouted rockbolt Ø25 mm, L=4-8 m	No.	-		-	-	-		-	-
2.19	**Providing and placing soil nails for the cut slope**									
2.19.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	885.00	530.41	469,410.80	2.98	2,633.44		-	2,633.44
2.19.2	Nut M25 + washer	No.	885.00	152.18	134,682.84	0.85	755.58		-	755.58
2.19.3	Fully grouted rockbolt Ø25 mm, L=4-8 m	No.	729.00	5,419.52	3,950,833.00	30.40	22,164.56		-	22,164.56
2.19.4	Fully grouted rockbolt Ø25 mm, L=4-16 m	No.	156.00	9,032.54	1,409,076.24	50.67	7,905.06		-	7,905.06
2.20	**Providing and placing guard rail**									
2.20.1	Guard rail left side	m	570.00	64,657.00	36,854,492.28	362.73	206,757.32		-	206,757.32
2.20.2	Guard rail right side	m	310.00	64,657.00	20,043,671.24	362.73	112,446.96		-	112,446.96
2.21	**Rockfall barrier**									
2.21.1	Barrier	m	-		-	-	-		-	-
2.22	**Providing and placing culverts**									
2.22.1	Pipe culvert type 1	No.	-		-	-	-		-	-
2.22.2	Pipe culvert type 2	No.	2.00	20,997.95	41,995.90	117.80	235.60		-	235.60
2.23	**Providing and placing PVC cross pipes**									
2.23.1	PVC cross pipes	No.	4.00	10,375.80	41,503.20	58.21	232.84		-	232.84
2.24	**Providing and placing traffic sign**									
2.24.1	Traffic sign	No.	16.00	53,320.95	853,135.20	299.14	4,786.17		-	4,786.17
2.25	**Providing and placing posts to guide the snow clearing devices**									
2.25.1	3 m high wooden posts, placed every 10 m	No.	56.00	10,000.00	560,000.00	56.10	3,141.65		-	3,141.65
2.26	**Slope protection to prevent corrosion**	m^2	1,539.28	6,450.21	9,928,679.25	36.19	55,700.87		-	55,700.87
3	**Culverts along Access Road From Indus River to Main Road**				**4,399,070**		**24,679**		**-**	**24,679**
3.1	**Unclassified excavation for structures and disposal of surplus material at designated locations and dressing of spoil material**									
3.1.1	Clearing & grubbing	m^2	45.42	44.50	2,021.19	0.25	11.34		-	11.34
3.1.2	Loose excavation	m^3	20.44	2,364.00	48,317.80	13.26	271.07		-	271.07
3.1.3	Ripping excavation	m^3	27.25	577.00	15,724.40	3.24	88.22		-	88.22
3.1.4	Blasting excavation	m^3	81.76	5,346.00	437,067.58	29.99	2,451.99		-	2,451.99
3.2	**Providing and placing cast in-situ concrete (21 MPa cylinder strength)**									
3.2.1	Using ordinary portland cement as per drawings and specifications	m^3	57.99	30,368.00	1,761,058.66	170.37	9,879.71		-	9,879.71
3.3	**Providing and placing pre-cast unreinforced concrete pipe (28 MPa cylinder strength)**									
3.3.1	Using ordinary portland cement as per drawings and specifications	m^3	9.86	37,670.00	371,272.43	211.33	2,082.87		-	2,082.87
3.4	**Providing and placing lean concrete (16 MPa cylinder strength)**									
3.4.1	Using ordinary portland cement as per drawings and specifications	m^3	5.72	21,522.00	123,105.84	120.74	690.64		-	690.64
3.5	**Providing and placing riprap at the exit of culvert**									
3.5.1	Riprap	m^3	35.70	6,450.21	230,272.50	36.19	1,291.85		-	1,291.85
3.6	**Providing, fabricating, securing and fixing in position mild steel deformed bars**									
3.6.1	Bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening	ton	3.68	364,005.00	1,340,994.42	2,042.10	7,523.11		-	7,523.11

No.	DESCRIPTION	UNIT	QUANTITY	ESTIMATE						
				LCC				FCC		TOTAL AMOUNT LCC + FCC (USD)
				UNIT PRICE (PKR)	AMOUNT (PKR)	UNIT PRICE (Eq. USD)	AMOUNT (Eq. USD)	UNIT PRICE (USD)	AMOUNT (USD)	
3.7	**Providing and laying cement stabilised base**									
3.7.1	Providing and laying plant 60 mm thick cement stabilised base, including compaction and finishing to required camber, grade and density	m^3	1.69	22,623.08	38,278.60	126.92	214.75		-	214.75
3.8	**Providing and placing base and sub-base course**									
3.8.1	15 cm thick granular base course	m^3	4.98	2,980.48	14,847.56	16.72	83.30		-	83.30
3.8.2	20 cm thick sub-base course	m^3	7.16	2,251.41	16,109.29	12.63	90.37		-	90.37
4	**Access Road to Upper Erection and Gate Chamber**				**3,001,600,350**		**16,839,273**			**16,839,273**
4.1	**Unclassified excavation for structures and disposal of surplus material at designated locations and dressing of spoil material**									
4.1.1	Clearing & grubbing	m^2	122,379.21	18.50	2,264,015.35	0.10	12,701.35		-	12,701.35
4.1.2	Loose excavation	m^3	55,070.64	409.87	22,571,804.72	2.30	126,630.04		-	126,630.04
4.1.3	Ripping excavation	m^3	73,427.52	170.19	12,496,630.46	0.95	70,107.32		-	70,107.32
4.1.4	Blasting excavation	m^3	220,282.57	5,346.00	1,177,630,644.15	29.99	6,606,623.53		-	6,606,623.53
4.1.5	Soil disposal (hauling distance 1.8 km)	m^3	474,781.18	725.00	344,216,352.43	4.07	1,931,087.53		-	1,931,087.53
4.2	**Compaction of backfill around the structures with suitable material**									
4.2.1	15 cm field sod/ top soil + seeding	m^3	20,000.00	1,341.45	26,829,000.00	7.53	150,513.32		-	150,513.32
4.2.2	60 cm riprap handplaced/ river bank protection	m^3	2,000.00	6,450.21	12,900,420.00	36.19	72,372.62		-	72,372.62
4.2.3	Filling random material	m^3	2,497.74	1,342.00	3,351,961.71	7.53	18,804.83		-	18,804.83
4.3	**Removing trees operation**									
4.3.1	Trees 150-300 mm girth	No.	150.00	618.96	92,844.00	3.47	520.86		-	520.86
4.3.2	Trees 300-600 mm girth	No.	50.00	3,044.67	152,233.50	17.08	854.04		-	854.04
4.4	**Providing and laying cement stabilised base**									
4.4.1	Providing and laying plant 60 mm thick cement stabilised base, including compaction and finishing to required camber, grade and density	m^3	1,185.03	22,623.08	26,809,001.34	126.92	150,401.13		-	150,401.13
4.5	**Providing and placing base and sub-base course**									
4.5.1	15 cm thick granular base course	m^3	3,490.95	2,980.48	10,404,712.62	16.72	58,371.46		-	58,371.46
4.5.2	20 cm thick sub-base course	m^3	5,014.14	2,251.41	11,288,893.94	12.63	63,331.80		-	63,331.80
4.6	**Providing and placing lining concrete (16 MPa cylinder strength)**									
4.6.1	Using ordinary portland cement as per drawings and specifications	m^3	43.25	21,522.00	930,826.50	120.74	5,222.03		-	5,222.03
4.7	**Providing and placing shotcrete (21 MPa cylinder strength)**									
4.7.1	Using ordinary portland cement as per drawings and specifications	m^3	7,253.53	98,956.00	717,780,507.29	555.15	4,026,819.12		-	4,026,819.12
4.8	**Providing and placing wire mesh**									
4.8.1	Wire mesh Ø5 mm, 100 mm x 100 mm, surface application	ton	627.09	331,200.00	207,693,711.52	1,858.06	1,165,182.11		-	1,165,182.11
4.9	**Providing and fixing 150 mm diameter PVC pipe >3% slope and maintenance opening every 200 m for drainage**									
4.9.1	Maintenance opening every 200 m for drainage	pcs	18.22	15,000.00	273,300.00	84.15	1,533.24		-	1,533.24
4.9.2	Ø150 mm PVC pipe >3% slope and maintenance opening every 200 m for drainage	m	3,644.00	2,075.16	7,561,883.04	11.64	42,422.91		-	42,422.91
4.9.3	Ø150 mm diameter PVC pipe >3% slope	m	125.00	2,075.16	259,395.00	11.64	1,455.23		-	1,455.23
4.10	**Providing and placing sand**									
4.10.1	0.73 m each layer	m^3	-		-	-	-		-	-
4.11	**Providing and placing twist hexagonal woven wire mesh**									
4.11.1	Wire mesh Ø3.70 mm	ton	-		-	-	-		-	-
4.12	**Providing and placing steel wire mesh for gabion**									
4.12.1	For Gabion	kg	4,931.12	310.00	1,528,647.20	1.74	8,575.86		-	8,575.86
4.13	**Providing and placing gabion**									
4.13.1	Gabion (1.5m x 1m x 1m)	m^3	2,176.50	2,602.04	5,663,340.06	14.60	31,771.89		-	31,771.89
4.13.2	Gabion (3m x 1m x 1m)	m^3	1,500.00	2,602.04	3,903,060.00	14.60	21,896.55		-	21,896.55
4.13.3	Gabion (2m x 1m x 1m)	m^3	-		-	-	-		-	-
4.13.4	Gabion (4m x 1m x 1m)	m^3	-		-	-	-		-	-
4.13.5	Gabion (6m x 1m x 1m)	m^3	-		-	-	-		-	-
4.14	**Providing and placing drainage gravel**									
4.14.1	Gravel	m^3	197.15	1,179.72	232,584.86	6.62	1,304.82		-	1,304.82
4.15	**Providing and placing stone for the cut slope**									
4.15.1	Stone	m^3	1,147.53	3,558.45	4,083,430.19	19.96	22,908.44		-	22,908.44
4.16	**Providing and placing geotextile to the wall**									
4.16.1	Geotextile	m^2	2,721.66	124.13	337,839.14	0.70	1,895.31		-	1,895.31
4.17	**Providing and placing drainage pipe for the cut slope**									
4.17.1	Perforated PVC pipe and geotextile pipe L=4.50 m	No.	1,794.00	7,667.29	13,755,111.08	43.01	77,167.52		-	77,167.52
4.17.2	Unperforated drainage pipe L=1.00 m	No.	1,794.00	1,452.61	2,605,985.93	8.15	14,619.84		-	14,619.84
4.17.3	Perforated PVC pipe and geotextile pipe L=3.00 m	No.	375.53	7,667.29	2,879,295.91	43.01	16,153.13		-	16,153.13
4.17.4	Unperforated drainage pipe L=0.70 m	No.	375.53	1,452.61	545,499.38	8.15	3,060.31		-	3,060.31
4.18	**Providing and placing rockbolting for the cut slope**									
4.18.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	2,217.23	530.41	1,176,033.17	2.98	6,597.66		-	6,597.66
4.18.2	Nut M25 + washer	No.	2,217.23	152.18	337,426.17	0.85	1,892.99		-	1,892.99
4.18.3	Fully grouted rockbolt Ø25 mm, L=4-8 m	No.	2,217.23	7,226.03	16,021,738.80	40.54	89,883.53		-	89,883.53
4.19	**Providing and placing soil nails for the cut slope**									
4.19.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	7,296.00	530.41	3,869,854.43	2.98	21,710.26		-	21,710.26
4.19.2	Nut M25 + washer	No.	7,296.00	152.18	1,110,334.46	0.85	6,229.09		-	6,229.09
4.19.3	Fully grouted rockbolt Ø25 mm, L=4-8 m	No.	3,024.00	27,097.62	81,943,202.88	152.02	459,709.41		-	459,709.41
4.19.4	Fully grouted rockbolt Ø25 mm, L=4-16 m	No.	4,272.00	45,162.70	192,935,054.40	253.37	1,082,384.60		-	1,082,384.60
4.20	**Providing and placing guard rail**									
4.20.1	Guard rail left side	m	220.00	2,602.04	572,448.80	14.60	3,211.49		-	3,211.49
4.20.2	Guard rail right side	m	360.00	2,602.04	936,734.40	14.60	5,255.17		-	5,255.17
4.21	**Rockfall barrier**									
4.21.1	Barrier	m	1,175.00	9,604.73	11,285,557.75	53.88	63,313.09		-	63,313.09
4.22	**Providing and placing culverts**									
4.22.1	Pipe culvert type 1	No.	10.00	52,142.50	521,425.00	292.52	2,925.25		-	2,925.25
4.22.2	Pipe culvert type 2	No.	4.00	20,997.95	83,991.80	117.80	471.20		-	471.20
4.23	**Providing and placing PVC cross pipes**									
4.23.1	PVC cross pipes	No.	18.00	10,375.80	186,764.40	58.21	1,047.77		-	1,047.77
4.24	**Providing and placing traffic sign**									
4.24.1	Traffic sign	No.	42.00	53,320.95	2,239,479.90	299.14	12,563.70		-	12,563.70
4.25	**Providing and placing posts to guide the snow clearing devices**									
4.25.1	3 m high wooden posts, placed every 10 m	No.	364.00	10,000.00	3,640,000.00	56.10	20,420.76		-	20,420.76
4.26	**Slope protection to prevent corrosion**	m^2	9,875.24	6,450.21	63,697,371.80	36.19	357,348.51		-	357,348.51
5	**Culverts along Access Road to Upper Erection and Gate Chamber**				**20,571,416**		**115,408**		-	**115,408**
5.1	**Unclassified excavation for structures and disposal of surplus material at designated locations and dressing of spoil material**									
5.1.1	Clearing & grubbing	m^2	184.41	44.50	8,206.10	0.25	46.04		-	46.04
5.1.2	Loose excavation	m^3	82.98	2,364.00	196,171.81	13.26	1,100.54		-	1,100.54
5.1.3	Ripping excavation	m^3	110.64	577.00	63,841.59	3.24	358.16		-	358.16
5.1.4	Blasting excavation	m^3	331.93	5,346.00	1,774,508.47	29.99	9,955.17		-	9,955.17
5.2	**Providing and placing cast in-situ concrete (21 MPa cylinder strength)**									
5.2.1	using ordinary portland cement as per drawings and specifications	m^3	259.36	30,368.00	7,876,290.27	170.37	44,186.76		-	44,186.76
5.3	**Providing and placing Pre-cast unreinforced concrete pipe (28 MPa cylinder strength)**									
5.3.1	Using ordinary portland cement as per drawings and specifications	m^3	45.53	37,669.00	1,715,000.11	211.33	9,621.32		-	9,621.32
5.4	**Providing and placing lean concrete (16 MPa cylinder strength)**									
5.4.1	Using ordinary portland cement as per drawings and specifications	m^3	29.75	16,225.00	482,693.75	91.02	2,707.96		-	2,707.96
5.5	**Providing and placing riprap at the exit of culvert**									
5.5.1	Riprap	m^3	214.90	6,450.21	1,386,150.13	36.19	7,776.44		-	7,776.44
5.6	**Providing, fabricating, securing and fixing in position mild steel deformed bars**									
5.6.1	Bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening	ton	18.37	364,005.00	6,686,043.84	2,042.10	37,509.36		-	37,509.36
5.7	**Providing and laying cement stabilised base**									
5.7.1	Providing and laying plant 60 mm thick cement stabilised base, including compaction and finishing to required camber, grade and density	m^3	8.59	22,623.08	225,344.25	126.92	1,264.20		-	1,264.20
5.8	**Providing and placing base and sub-base course**									
5.8.1	15 cm thick granular base course	m^3	25.29	2,980.48	75,379.92	16.72	422.89		-	422.89
5.8.2	20 cm thick sub base course	m^3	36.33	2,251.41	81,785.62	12.63	458.83		-	458.83
6	**Construction Road to the Surge Shaft Chamber Access Tunnel**				**2,454,343,854**		**13,769,110**		-	**13,769,110**
6.1	**Unclassified excavation for structures and disposal of surplus material at designated locations and dressing of spoil material**									
6.1.1	Clearing & grubbing	m^2	119,098.43	44.50	5,299,880.27	0.25	29,732.85		-	29,732.85
6.1.2	Loose excavation	m^3	53,594.29	2,364.00	126,696,913.03	13.26	710,782.12		-	710,782.12
6.1.3	Ripping excavation	m^3	71,459.06	577.00	41,231,877.51	3.24	231,314.88		-	231,314.88
6.1.4	Blasting excavation	m^3	214,377.18	5,346.00	1,146,060,401.09	29.99	6,429,511.37		-	6,429,511.37
6.1.5	Soil disposal (hauling distance 0.48 km)	m^3	456,885.62	656.83	300,095,269.13	3.68	1,683,563.92		-	1,683,563.92
6.2	**Compaction of back fill around the structures with suitable material**									
6.2.1	15 cm field sod/ top soil + seeding	m^3	20,000.00	1,341.45	26,829,000.00	7.53	150,513.32		-	150,513.32
6.2.2	60 cm riprap handplaced/ river bank protection	m^3	2,000.00	3,558.45	7,116,900.00	19.96	39,926.51		-	39,926.51
6.2.3	Filling random material	m^3	7,598.27	1,342.00	10,196,874.31	7.53	57,205.47		-	57,205.47
6.3	**Removing trees operation**									
6.3.1	Trees 150-300 mm girth	No.	150.00	618.96	92,844.00	3.47	520.86		-	520.86
6.3.2	Trees 300-600 mm girth	No.	50.00	30,446.70	1,522,335.00	170.81	8,540.45		-	8,540.45
6.4	**Providing and laying cement stabilised base**									
6.4.1	Providing and laying plant 60 mm thick cement stabilised base, including compaction and finishing to required camber, grade and density	m^3	1,198.69	22,623.08	31,462,837.96	126.92	176,509.61		-	176,509.61
6.5	**Providing and placing base and sub-base course**									
6.5.1	15 cm thick granular base course	m^3	3,531.19	2,980.48	10,524,635.21	16.72	59,044.24		-	59,044.24
6.5.2	20 cm thick sub-base course	m^3	5,071.94	2,251.41	11,419,007.43	12.63	64,061.75		-	64,061.75
6.6	**Providing and placing lining concrete (16 MPa cylinder strength)**									
6.6.1	Using ordinary portland cement as per drawings and specifications	m^3	-		-	-	-		-	-
6.7	**Providing and placing shotcrete (21 MPa cylinder strength)**					-	-		-	-
6.7.1	Using ordinary portland cement as per drawings and specifications	m^3	2,870.53	98,956.00	284,055,888.03	555.15	1,593,581.42		-	1,593,581.42
6.8	**Providing and placing wire mesh**									
6.8.1	Wire mesh Ø5 mm, 100 mm x 100 mm, surface application	ton	318.34	331,200.00	105,433,718.63	1,858.06	591,493.51		-	591,493.51
6.9	**Providing and fixing 150 mm diameter PVC pipe >3% slope and maintenance opening every 200 m for drainage**									
6.9.1	Maintenance opening every 200 m for drainage	pcs	18.43	15,000.00	276,450.00	84.15	1,550.91		-	1,550.91
6.9.2	Ø150 mm PVC pipe >3% slope and maintenance opening every 200 m for drainage	m	3,686.00	2,075.16	7,649,039.76	11.64	42,911.86		-	42,911.86
6.9.3	Ø150 mm diameter PVC pipe >3% slope	m	-		-	-	-		-	-
6.10	**Providing and placing sand**									
6.10.1	0.73 m each layer	m^3	-		-	-	-		-	-
6.11	**Providing and placing twist hexagonal woven wire mesh**									
6.11.1	Wire mesh Ø3.70 mm	ton	-		-	-	-		-	-
6.12	**Providing and placing steel wire mesh for gabion**									
6.12.1	For gabion	kg	5,618.00	570.75	3,206,473.50	3.20	17,988.63		-	17,988.63
6.13	**Providing and placing gabion**									
6.13.1	Gabion (1.5m x 1m x 1m)	m^3	1,462.50	2,602.04	3,805,483.50	14.60	21,349.14		-	21,349.14
6.13.2	Gabion (3m x 1m x 1m)	m^3	450.00	2,602.04	1,170,918.00	14.60	6,568.96		-	6,568.96
6.13.3	Gabion (2m x 1m x 1m)	m^3	-		-	-	-		-	-
6.13.4	Gabion (4m x 1m x 1m)	m^3	1,500.00	2,602.04	3,903,060.00	14.60	21,896.55		-	21,896.55
6.13.5	Gabion (6m x 1m x 1m)	m^3	1,050.00	2,602.04	2,732,142.00	14.60	15,327.58		-	15,327.58
6.14	**Providing and placing drainage gravel**									
6.14.1	Gravel	m^3	-		-	-	-		-	-
6.15	**Providing and placing stone for the cut slope**									
6.15.1	Stone	m^3	-		-	-	-		-	-
6.16	**Providing and placing geotextile to the wall**									
6.16.1	Geotextile	m^2	3,352.36	124.13	416,128.25	0.70	2,334.52		-	2,334.52
6.17	**Providing and placing drainage pipe for the cut slope**									
6.17.1	Perforated PVC pipe and geotextile pipe L=4.50 m	No.	-		-	-	-		-	-
6.17.2	Unperforated drainage pipe L=1.00 m	No.	-		-	-	-		-	-
6.17.3	Perforated PVC pipe and geotextile pipe L=3.00 m	No.	874.20	7,667.29	6,702,741.42	43.01	37,603.04		-	37,603.04
6.17.4	Unperforated drainage pipe L=0.70 m	No.	874.20	1,452.61	1,269,873.41	8.15	7,124.11		-	7,124.11
6.18	**Providing and placing rockbolting for the cut slope**									
6.18.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	4,624.80	530.41	2,453,029.44	2.98	13,761.74		-	13,761.74
6.18.2	Nut M25 + washer	No.	4,624.80	152.18	703,820.56	0.85	3,948.50		-	3,948.50
6.18.3	Fully grouted rockbolt Ø25 mm, L=4-8 m	No.	4,624.80	7,226.03	33,418,952.79	40.54	187,483.61		-	187,483.61

No.	DESCRIPTION	UNIT	QUANTITY	ESTIMATE						
				LCC				FCC		TOTAL AMOUNT LCC + FCC (USD)
				UNIT PRICE (PKR)	AMOUNT (PKR)	UNIT PRICE (Eq. USD)	AMOUNT (Eq. USD)	UNIT PRICE (USD)	AMOUNT (USD)	
6.19	**Providing and placing soil nails for the cut slope**									
6.19.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	-		-	-	-		-	-
6.19.2	Nut M25 + washer	No.	-		-	-	-		-	-
6.19.3	Fully grouted rockbolt Ø25 mm, L=4-8 m	No.	-		-	-	-		-	-
6.19.4	Fully grouted rockbolt Ø25 mm, L=4-16 m	No.	-		-	-	-		-	-
6.20	**Providing and placing guard rail**									
6.20.1	Guard rail left side	m	1,390.00	64,657.00	89,873,235.56	362.73	504,197.67		-	504,197.67
6.20.2	Guard rail right side	m	1,775.00	64,657.00	114,766,182.10	362.73	643,849.55		-	643,849.55
6.21	**Rockfall barrier**									
6.21.1	Barrier	m	365.00	9,604.73	3,505,726.45	53.88	19,667.47		-	19,667.47
6.22	**Providing and placing culverts**									
6.22.1	Pipe culvert type 1	No.	6.00	52,142.50	312,855.00	292.52	1,755.15		-	1,755.15
6.22.2	Pipe culvert type 2	No.	3.00	20,997.95	62,993.85	117.80	353.40		-	353.40
6.23	**Providing and placing PVC cross pipes**									
6.23.1	PVC cross pipes	No.	17.00	2,075.16	35,277.72	11.64	197.91		-	197.91
6.24	**Providing and placing traffic sign**									
6.24.1	Traffic sign	No.	36.00	53,320.95	1,919,554.20	299.14	10,768.89		-	10,768.89
6.25	**Providing and placing posts to guide the snow clearing devices**									
6.25.1	3 m high wooden posts, placed every 10 m	No.	369.00	10,000.00	3,690,000.00	56.10	20,701.26		-	20,701.26
6.26	**Slope protection to prevent corrosion**	m^2	9,989.06	6,450.21	64,431,534.70	36.19	361,467.24		-	361,467.24
7	**Culverts along Construction Road to the Surge Shaft Chamber Access Tunnel**				**13,355,117**		**74,924**		**-**	**74,924**
7.1	**Unclassified excavation for structures and disposal of surplus material at**									
7.1.1	Clearing & grubbing	m^2	124.27	44.50	5,530.02	0.25	31.02		-	31.02
7.1.2	Loose excavation	m^3	55.92	2,364.00	132,198.43	13.26	741.65		-	741.65
7.1.3	Ripping excavation	m^3	74.56	577.00	43,022.27	3.24	241.36		-	241.36
7.1.4	Blasting excavation	m^3	223.69	5,346.00	1,195,825.36	29.99	6,708.70		-	6,708.70
7.2	**Providing and placing cast in-situ concrete (21 MPa cylinder strength)**									
7.2.1	Using ordinary portland cement as per drawings and specifications	m^3	173.01	30,368.00	5,254,091.76	170.37	29,475.97		-	29,475.97
7.3	**Providing and placing Pre-cast unreinforced concrete pipe (28 MPa cylinder strength)**									
7.3.1	Using ordinary portland cement as per drawings and specifications	m^3	30.27	37,669.00	1,140,378.84	211.33	6,397.64		-	6,397.64
7.4	**Providing and placing lean concrete (16 MPa cylinder strength)**									
7.4.1	Using ordinary portland cement as per drawings and specifications	m^3	19.57	21,522.00	421,099.45	120.74	2,362.41		-	2,362.41
7.5	**Providing and placing riprap at the exit of culvert**									
7.5.1	Riprap	m^3	139.65	3,558.45	496,937.54	19.96	2,787.87		-	2,787.87
7.6	**Providing, fabricating, securing and fixing in position mild steel deformed bars**									
7.6.1	Bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening	ton	12.13	364,005.00	4,413,924.63	2,042.10	24,762.55		-	24,762.55
7.7	**Providing and laying cement stabilised base**									
7.7.1	Providing and laying plant 60 mm thick cement stabilised base, including compaction and finishing to required camber, grade and density	m^3	5.66	22,623.08	148,522.35	126.92	833.22		-	833.22
7.8	**Providing and placing base and sub-base course**									
7.8.1	15 cm thick granular base course	m^3	16.67	2,980.48	49,682.22	16.72	278.72		-	278.72
7.8.2	20 cm thick sub base course	m^3	23.94	2,251.41	53,904.16	12.63	302.41		-	302.41
8	**Access Road from Jalkot to Lower Spat Gah Headworks**				**4,085,092,273**		**22,917,769**		**-**	**22,917,769**
8.1	**Unclassified excavation for structures and disposal of surplus material at designated locations and dressing of spoil material**									
8.1.1	Clearing & grubbing	m^2	182,602.85	44.50	8,125,826.63	0.25	45,586.69		-	45,586.69
8.1.2	Loose excavation	m^3	82,171.28	2,364.00	194,252,907.13	13.26	1,089,777.88		-	1,089,777.88
8.1.3	Ripping excavation	m^3	109,561.71	577.00	63,217,105.14	3.24	354,654.17		-	354,654.17
8.1.4	Blasting excavation	m^3	328,685.12	5,346.00	1,757,150,662.48	29.99	9,857,787.73		-	9,857,787.73
8.1.5	Soil disposal (hauling distance 9.04 km)	m^3	640,353.69	334.00	213,878,131.72	1.87	1,199,877.32		-	1,199,877.32
8.2	**Compaction of back fill around the structures with suitable material**									
8.2.1	15 cm field sod/ top soil + seeding	m^3	100,000.00	1,341.45	134,145,000.00	7.53	752,566.62		-	752,566.62
8.2.2	60 cm riprap handplaced/ river bank protection	m^3	10,000.00	6,450.21	64,502,100.00	36.19	361,863.11		-	361,863.11
8.2.3	Filling random material	m^3	71,797.41	1,342.00	96,352,124.22	7.53	540,544.88		-	540,544.88
8.3	**Removing trees operation**					-	-		-	-
8.3.1	Trees 150-300 mm girth	No.	700.00	618.96	433,272.00	3.47	2,430.70		-	2,430.70
8.3.2	Trees 300-600 mm girth	No.	300.00	3,044.67	913,401.00	17.08	5,124.27		-	5,124.27
8.4	**Providing and laying cement stabilised base**									
8.4.1	Providing and laying plant 60 mm thick cement stabilised base, including compaction and finishing to required camber, grade and density	m^3	5,876.36	22,623.08	154,241,313.59	126.92	865,308.91		-	865,308.91
8.5	**Providing and placing base and sub-base course**									
8.5.1	15 cm thick granular base course	m^3	17,311.06	2,980.48	51,595,268.11	16.72	289,454.52		-	289,454.52
8.5.2	20 cm thick sub-base course	m^3	24,864.32	2,251.41	55,979,778.69	12.63	314,052.05		-	314,052.05
8.6	**Providing and placing lining concrete (16 MPa cylinder strength)**									
8.6.1	Using ordinary portland cement as per drawings and specifications	m^3	818.29	7,176.10	5,872,130.87	40.26	32,943.23		-	32,943.23
8.7	**Providing and placing concrete (21 MPa cylinder strength)**									
8.7.1	Using ordinary portland cement as per drawings and specifications	m^3	6,522.99	30,368.00	198,090,039.36	170.37	1,111,304.57		-	1,111,304.57
8.8	**Providing and placing wire mesh**									
8.8.1	Wire mesh Ø5 mm, 100 mm x 100 mm, surface application	ton	703.16	331,200.00	232,887,291.11	1,858.06	1,306,520.57		-	1,306,520.57
8.9	**Providing and fixing 150 mm diameter PVC pipe >3% slope and maintenance opening every 200 m for drainage**									
8.9.1	Maintenance opening every 200 m for drainage	pcs	90.35	15,000.00	1,355,250.00	84.15	7,603.09		-	7,603.09
8.9.2	Ø150 mm PVC pipe >3% slope and maintenance opening every 200 m for drainage	m	18,070.00	2,075.16	37,498,141.20	11.64	210,368.25		-	210,368.25
8.9.3	Ø150 mm diameter PVC pipe >3% slope	m	2,365.00	2,075.16	4,907,753.40	11.64	27,532.98		-	27,532.98
8.10	**Providing and placing sand**									
8.10.1	0.73 m each layer	m^3	1,906.76	1,328.38	2,532,901.85	7.45	14,209.83		-	14,209.83
8.11	**Providing and placing twist hexagonal woven wire mesh**									
8.11.1	Wire mesh Ø3.70 mm	ton	41.29	570.75	23,565.21	3.20	132.20		-	132.20
8.12	**Providing and placing steel wire mesh for gabion**									
8.12.1	For gabion	kg	22,790.00	2,602.04	59,300,491.60	14.60	332,681.58		-	332,681.58
8.13	**Providing and placing gabion**									
8.13.1	Gabion (1.5m x 1m x 1m)	m^3	7,875.00	2,602.04	20,491,065.00	14.60	114,956.89		-	114,956.89
8.13.2	Gabion (3m x 1m x 1m)	m^3	3,300.00	2,602.04	8,586,732.00	14.60	48,172.41		-	48,172.41
8.13.3	Gabion (2m x 1m x 1m)	m^3	2,900.00	2,602.04	7,545,916.00	14.60	42,333.33		-	42,333.33
8.13.4	Gabion (4m x 1m x 1m)	m^3	2,700.00	2,602.04	7,025,508.00	14.60	39,413.79		-	39,413.79
8.13.5	Gabion (6m x 1m x 1m)	m^3	450.00	2,602.04	1,170,918.00	14.60	6,568.96		-	6,568.96
8.14	**Providing and placing drainage gravel**									
8.14.1	Gravel	m^3	1,591.84	1,179.72	1,877,923.62	6.62	10,535.34		-	10,535.34
8.15	**Providing and placing stone for the cut slope**									
8.15.1	Stone	m^3	9,573.08	6,450.21	61,748,364.58	36.19	346,414.39		-	346,414.39
8.16	**Providing and placing geotextile to the wall**									
8.16.1	Geotextile	m^2	13,171.41	124.13	1,634,966.63	0.70	9,172.32		-	9,172.32
8.17	**Providing and placing drainage pipe for the cut slope**									
8.17.1	Perforated PVC pipe and geotextile pipe L=4.50 m	No.	1,436.00	11,500.93	16,515,334.04	64.52	92,652.65		-	92,652.65
8.17.2	Unperforated drainage pipe L=1.00 m	No.	1,436.00	2,075.16	2,979,929.76	11.64	16,717.70		-	16,717.70
8.17.3	Perforated PVC pipe and geotextile pipe L=3.00 m	No.	969.14	7,667.29	7,430,673.55	43.01	41,686.81		-	41,686.81
8.17.4	Unperforated drainage pipe L=0.70 m	No.	969.14	1,452.61	1,407,784.39	8.15	7,897.81		-	7,897.81
8.18	**Providing and placing rockbolting for the cut slope**									
8.18.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	5,149.32	530.41	2,731,238.87	2.98	15,322.52		-	15,322.52
8.18.2	Nut M25 + washer	No.	5,149.32	152.18	783,644.11	0.85	4,396.32		-	4,396.32
8.18.3	Fully grouted rockbolt Ø25 mm, L=4-8 m	No.	5,149.32	8,671.24	44,650,981.32	48.65	250,496.39		-	250,496.39
8.19	**Providing and placing soil nails for the cut slope**									
8.19.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	5,330.00	530.41	2,827,072.93	2.98	15,860.16		-	15,860.16
8.19.2	Nut M25 + washer	No.	5,330.00	152.18	811,140.72	0.85	4,550.58		-	4,550.58
8.19.3	Fully grouted rockbolt Ø25 mm, L=4-8 m	No.	4,538.00	8,671.24	39,350,079.86	48.65	220,757.81		-	220,757.81
8.19.4	Fully grouted rockbolt Ø25 mm, L=4-16 m	No.	792.00	14,452.06	11,446,034.69	81.08	64,213.38		-	64,213.38
8.20	**Providing and placing guard rail**									
8.20.1	Guard rail left side	m	1,960.00	64,657.00	126,727,727.84	362.73	710,954.99		-	710,954.99
8.20.2	Guard rail right side	m	265.00	64,657.00	17,134,106.06	362.73	96,124.02		-	96,124.02
8.21	**Rockfall barrier**									
8.21.1	Barrier	m	2,125.00	9,604.73	20,410,051.25	53.88	114,502.39		-	114,502.39
8.22	**Providing and placing culverts**									
8.22.1	Pipe culvert type 1	No.	36.00	52,142.50	1,877,130.00	292.52	10,530.88		-	10,530.88
8.22.2	Pipe culvert type 2	No.	16.00	20,997.95	335,967.20	117.80	1,884.81		-	1,884.81
8.23	**Providing and placing PVC cross pipes**									
8.23.1	PVC cross pipes	No.	84.00	2,075.16	174,313.44	11.64	977.92		-	977.92
8.24	**Providing and placing traffic sign**									
8.24.1	Traffic sign	No.	132.00	53,320.95	7,038,365.40	299.14	39,485.92		-	39,485.92
8.25	**Providing and placing posts to guide the snow clearing devices**									
8.25.1	3 m high wooden posts, placed every 10 m	No.	1,726.00	10,000.00	17,260,000.00	56.10	96,830.29		-	96,830.29
8.26	**Slope protection to prevent corrosion**	m^2	48,969.70	6,450.21	315,864,848.64	36.19	1,772,032.81		-	1,772,032.81
9	**Culverts along Access Road from Jalkot to Lower Spat Gah Headworks**				**79,159,257**		**444,091**		**-**	**444,091**
9.1	**Unclassified excavation for structures and disposal of surplus material at designated locations and dressing of spoil material**									
9.1.1	Clearing & grubbing	m^2	713.55	44.50	31,753.12	0.25	178.14		-	178.14
9.1.2	Loose excavation	m^3	321.10	2,364.00	759,078.04	13.26	4,258.50		-	4,258.50
9.1.3	Ripping excavation	m^3	428.13	577.00	247,032.16	3.24	1,385.87		-	1,385.87
9.1.4	Blasting excavation	m^3	1,284.40	5,346.00	6,866,381.02	29.99	38,521.07		-	38,521.07
9.2	**Providing and placing cast in-situ concrete (21 MPa cylinder strength)**									
9.2.1	Using ordinary portland cement as per drawings and specifications	m^3	994.75	30,368.00	30,208,603.96	170.37	169,473.23		-	169,473.23
9.3	**Providing and placing pre-cast unreinforced concrete pipe (28 MPa cylinder strength)**									
9.3.1	Using ordinary portland cement as per drawings and specifications	m^3	174.13	37,669.00	6,559,394.24	211.33	36,798.85		-	36,798.85
9.4	**Providing and placing lean concrete (16 MPa cylinder strength)**									
9.4.1	Using ordinary portland cement as per drawings and specifications	m^3	112.71	21,522.00	2,425,637.01	120.74	13,608.06		-	13,608.06
9.5	**Providing and placing riprap at the exit of culvert**									
9.5.1	Riprap	m^3	805.70	6,450.21	5,196,934.20	36.19	29,155.31		-	29,155.31
9.6	**Providing, fabricating, securing and fixing in position mild steel deformed bars**									
9.6.1	Bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening	ton	69.81	364,005.00	25,412,645.07	2,042.10	142,567.43		-	142,567.43
9.7	**Providing and laying cement stabilised base**									
9.7.1	Providing and laying plant 60 mm thick cement stabilised base, including compaction and finishing to required camber, grade and density	m^3	32.59	22,623.08	855,283.88	126.92	4,798.23		-	4,798.23
9.8	**Providing and placing base and sub-base course**									
9.8.1	15 cm thick granular base course	m^3	95.99	2,980.48	286,101.04	16.72	1,605.05		-	1,605.05
9.8.2	20 cm thick sub base course	m^3	137.88	2,251.41	310,413.60	12.63	1,741.45		-	1,741.45
10	**Avalanche Galleries along Access Road from Jalkot to Lower Spat Gah Headworks**				**683,223,995**		**3,832,954**		**-**	**3,832,954**
10.1	**Unclassified excavation for structures and disposal of surplus material at designated locations and dressing of spoil material**									
10.1.1	Clearing & grubbing	m^2	6,930.50	44.50	308,407.25	0.25	1,730.19		-	1,730.19
10.1.2	Loose excavation	m^3	3,118.73	2,364.00	7,372,665.90	13.26	41,361.38		-	41,361.38
10.1.3	Ripping excavation	m^3	4,158.30	577.00	2,399,339.10	3.24	13,460.53		-	13,460.53
10.1.4	Blasting excavation	m^3	12,474.90	5,346.00	66,690,815.40	29.99	374,142.02		-	374,142.02
10.2	**Providing and laying ganular fill material**									
10.2.1	Comprise of gravel and sand, mixed in ratio 2:3, in layers not exceeding 150 mm thick including compaction of layers with approved mechanical plate compactor to achieve 95% of the maximum dry density	m^3	15,931.50	1,509.59	24,050,033.09	8.47	134,923.05		-	134,923.05
10.3	**Providing and placing lean concrete (16 MPa cylinder strength)**									
10.3.1	Using ordinary portland cement as per drawings and specifications	m^3	260.00	21,522.00	5,595,720.00	120.74	31,392.54		-	31,392.54
10.4	**Providing and placing reinforce concrete (21 MPa cylinder strength)**									
10.4.1	Using ordinary portland cement as per drawings and specifications	m^3	5,463.25	30,368.00	165,907,976.00	170.37	930,760.03		-	930,760.03
10.5	**Providing, fabricating, securing and fixing in position mild steel deformed bars**									
10.5.1	Bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening	ton	1,092.65	364,005.00	397,730,063.25	2,042.10	2,231,304.70		-	2,231,304.70
10.6	**Providing and placing geotextile**									
10.6.1	Geotextile	m^2	890.50	124.13	110,537.77	0.70	620.13		-	620.13
10.7	**Providing and placing filter gravel**									
10.7.1	Gravel Ø20 mm - 40 mm	m^3	1,059.50	1,179.72	1,249,913.34	6.62	7,012.14		-	7,012.14

No.	DESCRIPTION	UNIT	QUANTITY	ESTIMATE						
				LCC				FCC		TOTAL AMOUNT LCC + FCC (USD)
				UNIT PRICE (PKR)	AMOUNT (PKR)	UNIT PRICE (Eq. USD)	AMOUNT (Eq. USD)	UNIT PRICE (USD)	AMOUNT (USD)	
10.8	Providing and placing water stops									
10.8.1	Water stops type AC 300	m	1,300.00	561.81	730,353.00	3.15	4,097.35		-	4,097.35
10.9	Providing and laying plant pre-mixed of bituminous mastic									
10.9.1	Bituminous mastic	m^3	1.30	8,516.23	11,071.09	47.78	62.11		-	62.11
10.10	Providing and fixing 200mm diameter PVC pipe for surface drainage									
10.10.1	Dewatering pipe PVC Ø200 mm	m	325.00	2,075.16	674,427.00	11.64	3,783.60		-	3,783.60
10.10.2	Slotted pipe Ø200 mm	m	650.00	2,075.16	1,348,854.00	11.64	7,567.20		-	7,567.20
10.11	Providing and installing ground wire for electric devices									
10.11.1	Fiber Optic	m	650.00	1,230.18	799,617.00	6.90	4,485.93		-	4,485.93
10.11.2	8" 11kV	m	650.00	5,495.00	3,571,750.00	30.83	20,037.87		-	20,037.87
10.11.3	6" 400V	m	325.00	3,474.00	1,129,050.00	19.49	6,334.08		-	6,334.08
10.11.4	6" spare	m	325.00	3,474.00	1,129,050.00	19.49	6,334.08		-	6,334.08
10.11.5	2" spare	m	325.00	44.16	14,352.00	0.25	80.52		-	80.52
10.12	Providing and placing lighting									
10.12.1	Lighting	No	160.00	15,000.00	2,400,000.00	84.15	13,464.24		-	13,464.24
11	**Tunnel along Access Road from Jalkot to Lower Spat Gah Headworks**				**770,104,954**		**4,320,364**		**-**	**4,320,364**
11.1	Unclassified excavation for structures and disposal of surplus material at designated locations and dressing of spoil material									
11.1.1	Clearing & grubbing	m^3	7,466.03	44.50	332,238.22	0.25	1,863.89		-	1,863.89
11.1.2	Loose excavation	m^3	14,932.05	2,364.00	35,299,377.78	13.26	198,032.97		-	198,032.97
11.1.3	Ripping excavation	m^3	22,398.08	577.00	12,923,693.52	3.24	72,503.19		-	72,503.19
11.1.4	Blasting excavation	m^3	104,524.38	5,346.00	558,787,358.47	29.99	3,134,851.94		-	3,134,851.94
11.2	Providing and placing reinforce concrete (21 MPa cylinder strength)									
11.2.1	Using ordinary portland cement as per drawings and specifications	m^3	1,015.43	30,368.00	30,836,432.47	170.37	172,995.41		-	172,995.41
11.3	Providing and placing shotcrete (21 MPa cylinder strength)									
11.3.1	Using ordinary portland cement as per drawings and specifications	m^3	992.69	30,368.00	30,146,064.58	170.37	169,122.38		-	169,122.38
11.4	Providing, fabricating, securing and fixing in position mild steel deformed bars									
11.4.1	Bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening	ton	203.09	364,005.00	73,923,969.99	2,042.10	414,720.73		-	414,720.73
11.4.2	Wire mesh Ø5 mm	ton	21.09	331,200.00	6,984,016.85	1,858.06	39,181.02		-	39,181.02
11.5	Providing and fixing 200 mm diameter PVC pipe for surface drainage									
11.5.1	PVC pipes	m	378.89	2,075.16	786,257.37	11.64	4,410.98		-	4,410.98
11.6	Providing and installing ground wire for electric devices									
11.6.1	Fiber Optic	m	757.78	1,230.18	932,205.80	6.90	5,229.77		-	5,229.77
11.6.2	8" 11kV	m	757.78	5,495.00	4,164,001.10	30.83	23,360.45		-	23,360.45
11.6.3	6" 400V	m	378.89	3,474.00	1,316,263.86	19.49	7,384.37		-	7,384.37
11.6.4	6" spare	m	378.89	3,474.00	1,316,263.86	19.49	7,384.37		-	7,384.37
11.6.5	2" spare	m	378.89	44.16	16,731.78	0.25	93.87		-	93.87
11.7	Providing and placing lighting									
11.7.1	Lighting	No	180.00	15,000.00	2,700,000.00	84.15	15,147.27		-	15,147.27
11.8	Providing and placing rockbolting for the tunnel									
11.8.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	2,772.00	530.41	1,470,290.09	2.98	8,248.47		-	8,248.47
11.8.2	Nut M25 + washer	No.	2,772.00	152.18	421,854.05	0.85	2,366.64		-	2,366.64
11.8.3	Fully grouted rockbolt Ø25 mm, L=3 m	No.	2,772.00	2,795.07	7,747,934.04	15.68	43,466.67		-	43,466.67
12	**Goshali Bridge along Access Road from Jalkot to Lower Spat Gah Headworks**				**118,794,601**		**666,449**		**-**	**666,449**
12.1	Unclassified excavation for foundation of structures and disposal of surplus material at designated locations and dressing of spoil material									
12.1.1	clearing & grubbing	m^3	59.14	44.50	2,631.92	0.25	14.77		-	14.77
12.1.2	Loose excavation	m^3	177.43	2,364.00	419,451.23	13.26	2,353.16		-	2,353.16
12.1.3	Ripping excavation	m^3	236.58	577.00	136,505.00	3.24	765.81		-	765.81
12.1.4	Blasting excavation	m^3	709.73	5,346.00	3,794,223.85	29.99	21,285.97		-	21,285.97
12.2	Providing and placing lining concrete (21 MPa cylinder strength) using ordinary portland cement as per drawings and specifications									
12.2.1	Lining concrete	m^3	19.77	21,522.00	425,443.28	120.74	2,386.78		-	2,386.78
12.2.2	Leveling concrete	m^3	12.58	21,522.00	270,723.34	120.74	1,518.78		-	1,518.78
12.3	Providing and placing reinforced cement concrete (21MPa cylinder strength) using ordinary portland cement as per drawings and specifications									
12.3.1	*Normal concrete*	m^3	765.22	30,368.00	23,238,244.24	170.37	130,368.83		-	130,368.83
12.3.1.1	Abutment footing	m^3	252.28	30,368.00	7,661,178.30	170.37	42,979.96		-	42,979.96
12.3.1.2	Head wall	m^3	123.85	30,368.00	3,761,161.83	170.37	21,100.49		-	21,100.49
12.3.1.3	Cross beam	m^3	18.39	30,368.00	558,406.78	170.37	3,132.72		-	3,132.72
12.3.1.4	Approach slab	m^3	37.92	30,368.00	1,151,442.93	170.37	6,459.71		-	6,459.71
12.3.1.5	Wing wall	m^3	251.37	30,368.00	7,633,604.16	170.37	42,825.27		-	42,825.27
12.3.1.6	Site concrete	m^3	27.13	30,368.00	823,871.09	170.37	4,622.00		-	4,622.00
12.3.1.7	Pile foundation	m^3	54.29	30,368.00	1,648,579.14	170.37	9,248.69		-	9,248.69
12.3.2	*Precast concrete*	m^3	14.02	30,368.00	425,647.00	170.37	2,387.92		-	2,387.92
12.3.2.1	Slabs	m^3	14.02	37,670.00	527,994.02	211.33	2,962.10		-	2,962.10
12.4	Providing and placing reinforced cement concrete (30MPa cylinder strength) using ordinary portland cement as per drawings and specifications									
12.4.1	Pier crosshead	m^3	33.77	37,670.00	1,272,042.37	211.33	7,136.28		-	7,136.28
12.4.2	Bearing seat	m^3	0.18	37,670.00	6,893.61	211.33	38.67		-	38.67
12.5	Providing, casting and launching in position prestressed concrete girders (35MPa cylinder strength) complete in all respects including post-tensioning, as per drawings, specifications and as directed by the Engineer Girder - 19m Long	m^3	53.41	60,027.00	3,205,982.04	336.76	17,985.87		-	17,985.87
12.6	Providing, fabricating, securing and fixing in position mild steel deformed bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening	ton	162.46	364,005.00	59,137,056.90	2,042.10	331,764.70		-	331,764.70
12.7	Furnishing and installing RC railing using concrete (21 MPa strength) concrete, including cost of all labour, material, reinforcement, and shuttering etc. completes as per drawings and specifications	Rm	54.00	3,030.03	163,621.62	17.00	917.93		-	917.93
12.8	Providing and constructing deformation joints as per relevant drawings details and specifications	Rm	13.12	45,981.14	603,272.56	257.96	3,384.42		-	3,384.42
12.9	Providing and fixing elastomeric bearing pads (320mm x 360mm x 100mm), including galvanized stell plate, cement mortar as shown on the drawing and as per specifications or as directed by the Engineer	No.	8.00	4.09	32.72	0.02	0.18		-	0.18
12.10	Providing and laying plant pre-mixed 80mm thick of asphaltic material, including compaction and finishing to required camber, grade and density including bituminous priming coat									
12.10.1	Sealing layer - 0.5cm	m^2	95.00	658.81	62,586.95	3.70	351.12		-	351.12
12.10.2	Mastic asphalt - 3.5cm	m^2	95.00	500.98	47,593.10	2.81	267.00		-	267.00
12.10.3	Stone mastic asphalt - 4cm	m^2	95.00	351.46	33,388.70	1.97	187.31		-	187.31
12.11	Providing and laying plant pre-mixed of bituminous mastic	m^3	0.07	1,473.66	102.48	8.27	0.57		-	0.57
12.12	Compaction of back fill around the structures with suitable excavated material around the structure									
12.12.1	Backfill	m^3	926.80	1,342.00	1,243,761.31	7.53	6,977.62		-	6,977.62
12.12.2	Backfill	m^3	314.16	1,342.00	421,602.72	7.53	2,365.23		-	2,365.23
12.13	Providing and fixing 150mm diameter PVC pipe for surface drainage	Rm	7.50	2,075.16	15,563.70	11.64	87.31		-	87.31
12.14	Providing and installing drainage pots for surface drainage	No.	3.00	15,000.00	45,000.00	84.15	252.45		-	252.45
12.15	Providing and installing ground wire for electric devices	Rm	100.00	569.92	56,992.00	3.20	319.73		-	319.73
13	**Bridge d-s confluence along Access Road from Jalkot to Lower Spat Gah Headworks**				**124,439,270**		**698,117**		**-**	**698,117**
13.1	Unclassified excavation for foundation of structures and disposal of surplus material at designated locations and dressing of spoil material									
13.1.1	clearing & grubbing	m^3	59.14	44.50	2,631.92	0.25	14.77		-	14.77
13.1.2	Loose excavation	m^3	177.43	2,364.00	419,451.23	13.26	2,353.16		-	2,353.16
13.1.3	Ripping excavation	m^3	236.58	577.00	136,505.00	3.24	765.81		-	765.81
13.1.4	Blasting excavation	m^3	709.73	5,346.00	3,794,223.85	29.99	21,285.97		-	21,285.97
13.2	Providing and placing lining concrete (21 MPa cylinder strength) using ordinary portland cement as per drawings and specifications									
13.2.1	Lining concrete	m^3	19.77	3,030.03	59,897.12	17.00	336.03		-	336.03
13.2.2	Leveling concrete	m^3	12.58	16,225.00	204,092.85	91.02	1,144.98		-	1,144.98
13.3	Providing and placing reinforced cement concrete (21MPa cylinder strength) using ordinary portland cement as per drawings and specifications									
13.3.1	*Normal concrete*	m^3	776.20	30,368.00	23,571,607.13	170.37	132,239.03		-	132,239.03
13.3.1.1	Abutment footing	m^3	252.28	30,368.00	7,661,178.30	170.37	42,979.96		-	42,979.96
13.3.1.2	Head wall	m^3	123.85	30,368.00	3,761,161.83	170.37	21,100.49		-	21,100.49
13.3.1.3	Cross beam	m^3	18.39	30,368.00	558,406.78	170.37	3,132.72		-	3,132.72
13.3.1.4	Approach slab	m^3	37.92	30,368.00	1,151,442.93	170.37	6,459.71		-	6,459.71
13.3.1.5	Wing wall	m^3	251.37	30,368.00	7,633,604.16	170.37	42,825.27		-	42,825.27
13.3.1.6	Site concrete	m^3	38.11	30,368.00	1,157,233.98	170.37	6,492.20		-	6,492.20
13.3.1.7	Pile foundation	m^3	54.29	30,368.00	1,648,579.14	170.37	9,248.69		-	9,248.69
13.3.2	*Precast concrete*	m^3	19.92	30,368.00	604,866.79	170.37	3,393.36		-	3,393.36
13.3.2.1	Slabs	m^3	19.92	37,670.00	750,307.29	211.33	4,209.30		-	4,209.30
13.4	Providing and placing reinforced cement concrete (30MPa cylinder strength) using ordinary portland cement as per drawings and specifications									
13.4.1	Pier crosshead	m^3	33.77	37,670.00	1,272,042.37	211.33	7,136.28		-	7,136.28
13.4.2	Bearing seat	m^3	0.18	37,670.00	6,893.61	211.33	38.67		-	38.67
13.5	Providing, casting and launching in position prestressed concrete girders (35MPa cylinder strength) complete in all respects including post-tensioning, as per drawings, specifications and as directed by the Engineer Girder - 19m Long	m^3	75.90	60,027.00	4,555,869.22	336.76	25,558.87		-	25,558.87
13.6	Providing, fabricating, securing and fixing in position mild steel deformed bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening	ton	170.34	364,005.00	62,003,016.78	2,042.10	347,843.01		-	347,843.01
13.7	Furnishing and installing RC railing using concrete (21 MPa strength) concrete, including cost of all labour, material, reinforcement, and shuttering etc. completes as per drawings and specifications	Rm	70.00	3,030.03	212,102.10	17.00	1,189.91		-	1,189.91
13.8	Providing and constructing deformation joints as per relevant drawings details and specifications	Rm	13.12	45,981.14	603,272.56	257.96	3,384.42		-	3,384.42
13.9	Providing and fixing elastomeric bearing pads (320mm x 360mm x 100mm), including galvanized stell plate, cement mortar as shown on the drawing and as per specifications or as directed by the Engineer	No.	8.00	4.09	32.72	0.02	0.18		-	0.18
13.10	Providing and laying plant pre-mixed 80mm thick of asphaltic material, including compaction and finishing to required camber, grade and density including bituminous priming coat									
13.10.1	Sealing layer - 0.5cm	m^2	135.00	658.81	88,939.35	3.70	498.96		-	498.96
13.10.2	Mastic asphalt - 3.5cm	m^2	135.00	500.98	67,632.30	2.81	379.42		-	379.42
13.10.3	Stone mastic asphalt - 4cm	m^2	135.00	351.46	47,447.10	1.97	266.18		-	266.18
13.11	Providing and laying plant pre-mixed of bituminous mastic	m^3	0.10	1,473.66	145.63	8.27	0.82		-	0.82
13.12	Compaction of back fill around the structures with suitable excavated material around the structure									
13.12.1	Backfill	m^3	926.80	1,342.00	1,243,761.31	7.53	6,977.62		-	6,977.62
13.12.2	Stones with edge length >1m under water	m^3	387.36	2,691.58	1,042,610.43	15.10	5,849.15		-	5,849.15
13.13	Providing and fixing 150mm diameter PVC pipe for surface drainage	Rm	7.50	1,375.00	10,312.50	7.71	57.85		-	57.85
13.14	Providing and installing drainage pots for surface drainage	No.	3.00	37,670.00	113,010.00	211.33	634.00		-	634.00
13.15	Providing and installing ground wire for electric devices	Rm	100.00	569.92	56,992.00	3.20	319.73		-	319.73
14	**Bridge u-s confluence along Access Road from Jalkot to Lower Spat Gah Headworks**				**123,834,239**		**694,722**		**-**	**694,722**
14.1	Unclassified excavation for foundation of structures and disposal of surplus material at designated locations and dressing of spoil material									
14.1.1	clearing & grubbing	m^3	59.14	44.50	2,631.92	0.25	14.77		-	14.77
14.1.2	Loose excavation	m^3	177.43	2,364.00	419,451.23	13.26	2,353.16		-	2,353.16
14.1.3	Ripping excavation	m^3	236.58	577.00	136,505.00	3.24	765.81		-	765.81
14.1.4	Blasting excavation	m^3	709.73	5,346.00	3,794,223.85	29.99	21,285.97		-	21,285.97
14.2	Providing and placing lining concrete (21 MPa cylinder strength) using ordinary portland cement as per drawings and specifications									
14.2.1	Lining concrete	m^3	19.77	21,522.00	425,443.28	120.74	2,386.78		-	2,386.78
14.2.2	Leveling concrete	m^3	12.58	21,522.00	270,723.34	120.74	1,518.78		-	1,518.78

No.	DESCRIPTION	UNIT	QUANTITY	ESTIMATE: LCC UNIT PRICE (PKR)	LCC AMOUNT (PKR)	LCC UNIT PRICE (Eq. USD)	LCC AMOUNT (Eq. USD)	FCC UNIT PRICE (USD)	FCC AMOUNT (USD)	TOTAL AMOUNT LCC + FCC (USD)
14.3	**Providing and placing reinforced cement concrete (21MPa cylinder strength) using ordinary portland cement as per drawings and specifications**									
14.3.1	*Normal concrete*	m^3	721.91	30,368.00	21,923,027.99	170.37	122,990.34		-	122,990.34
14.3.1.1	Abutment footing	m^3	252.28	30,368.00	7,661,178.30	170.37	42,979.96		-	42,979.96
14.3.1.2	Head wall	m^3	123.85	30,368.00	3,761,161.83	170.37	21,100.49		-	21,100.49
14.3.1.3	Cross beam	m^3	18.39	30,368.00	558,406.78	170.37	3,132.72		-	3,132.72
14.3.1.4	Approach slab	m^3	37.92	30,368.00	1,151,442.93	170.37	6,459.71		-	6,459.71
14.3.1.5	Wing wall	m^3	251.37	30,368.00	7,633,604.16	170.37	42,825.27		-	42,825.27
14.3.1.6	Site concrete	m^3	38.11	30,368.00	1,157,233.98	170.37	6,492.20		-	6,492.20
14.3.1.7	Pile foundation	m^3	54.29	30,368.00	1,648,579.14	170.37	9,248.69		-	9,248.69
14.3.2	*Precast concrete*					-	-		-	-
14.3.2.1	Slabs	m^3	19.92	37,670.00	750,307.29	211.33	4,209.30		-	4,209.30
14.4	**Providing and placing reinforced cement concrete (30MPa cylinder strength) using ordinary portland cement as per drawings and specifications**	m^3	33.95	37,670.00	1,278,935.98	211.33	7,174.96		-	7,174.96
14.4.1	Pier crosshead	m^3	33.77	37,670.00	1,272,042.37	211.33	7,136.28		-	7,136.28
14.4.2	Bearing seat	m^3	0.18	37,670.00	6,893.61	211.33	38.67		-	38.67
14.5	**Providing, casting and launching in position prestressed concrete girders (35MPa cylinder strength) complete in all respects including post-tensioning, as per drawings, specifications and as directed by the Engineer Girder - 19m Long**	m^3	75.90	60,027.00	4,555,869.22	336.76	25,558.87		-	25,558.87
14.6	**Providing, fabricating, securing and fixing in position mild steel deformed bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening**	ton	170.34	364,005.00	62,003,016.78	2,042.10	347,843.01		-	347,843.01
14.7	**Furnishing and installing RC railing using concrete (21 MPa strength) concrete, including cost of all labour, material, reinforcement, and shuttering etc. completes as per drawings and specifications**	Rm	70.00	3,030.03	212,102.10	17.00	1,189.91		-	1,189.91
14.8	**Providing and constructing deformation joints as per relevant drawings details and specifications**	Rm	13.12	45,981.14	603,272.56	257.96	3,384.42		-	3,384.42
14.9	**Providing and fixing elastomeric bearing pads (320mm x 360mm x 100mm), including galvanized stell plate, cement mortar as shown on the drawing and as per specifications or as directed by the Engineer**	No.	8.00	4.09	32.72	0.02	0.18		-	0.18
14.10	**Providing and laying plant pre-mixed 80mm thick of asphaltic material, including compaction and finishing to required camber, grade and density including bituminous priming coat**									
14.10.1	Sealing layer - 0.5cm	m^2	135.00	658.81	88,939.35	3.70	498.96		-	498.96
14.10.2	Mastic asphalt - 3.5cm	m^2	135.00	500.98	67,632.30	2.81	379.42		-	379.42
14.10.3	Stone mastic asphalt - 4cm	m^2	135.00	351.46	47,447.10	1.97	266.18		-	266.18
14.11	**Providing and laying plant pre-mixed of bituminous mastic**	m^3	0.10	2,094.15	206.94	11.75	1.16		-	1.16
14.12	**Compaction of back fill around the structures with suitable excavated material around the structure**									
14.12.1	Backfill	m^3	926.80	1,342.00	1,243,761.31	7.53	6,977.62		-	6,977.62
14.12.2	Stones with edge length >1m under water	m^3	387.36	2,691.58	1,042,610.43	15.10	5,849.15		-	5,849.15
14.13	**Providing and fixing 150mm diameter PVC pipe for surface drainage**	Rm	7.50	2,075.16	15,563.70	11.64	87.31		-	87.31
14.14	**Providing and installing drainage pots for surface drainage**	No.	3.00	15,000.00	45,000.00	84.15	252.45		-	252.45
14.15	**Providing and installing ground wire for electric devices**	Rm	100.00	569.92	56,992.00	3.20	319.73		-	319.73
15	**Khudli Bridge along Access Road from Jalkot to Lower Spat Gah Headworks**				**123,159,963**		**690,939**		**-**	**690,939**
15.1	**Unclassified excavation for foundation of structures and disposal of surplus material at designated locations and dressing of spoil material**									
15.1.1	clearing & grubbing	m^3	59.14	44.50	2,631.92	0.25	14.77		-	14.77
15.1.2	Loose excavation	m^3	177.43	2,364.00	419,451.23	13.26	2,353.16		-	2,353.16
15.1.3	Ripping excavation	m^3	236.58	577.00	136,505.00	3.24	765.81		-	765.81
15.1.4	Blasting excavation	m^3	709.73	5,346.00	3,794,223.85	29.99	21,285.97		-	21,285.97
15.2	**Compaction of back fill around the structures with suitable excavated material around the structure**									
15.2.1	Backfill	m^3	926.80	1,342.00	1,243,761.31	7.53	6,977.62		-	6,977.62
15.2.2	Stones with edge length >1m under water	m^3	387.36	2,691.58	1,042,610.43	15.10	5,849.15		-	5,849.15
15.3	**Providing and placing lining concrete (21 MPa cylinder strength) using ordinary portland cement as per drawings and specifications**									
15.3.1	Lining concrete	m^3	19.77	21,522.00	425,443.28	120.74	2,386.78		-	2,386.78
15.3.2	Leveling concrete	m^3	12.58	21,522.00	270,723.34	120.74	1,518.78		-	1,518.78
15.4	**Providing and placing reinforced cement concrete (21MPa cylinder strength) using ordinary portland cement as per drawings and specifications**									
15.4.1	*Normal concrete*	m^3	721.91	30,368.00	21,923,027.99	170.37	122,990.34		-	122,990.34
15.4.1.1	Abutment footing	m^3	252.28	30,368.00	7,661,178.30	170.37	42,979.96		-	42,979.96
15.4.1.2	Head wall	m^3	123.85	30,368.00	3,761,161.83	170.37	21,100.49		-	21,100.49
15.4.1.3	Cross beam	m^3	18.39	30,368.00	558,406.78	170.37	3,132.72		-	3,132.72
15.4.1.4	Approach slab	m^3	37.92	30,368.00	1,151,442.93	170.37	6,459.71		-	6,459.71
15.4.1.5	Wing wall	m^3	251.37	30,368.00	7,633,604.16	170.37	42,825.27		-	42,825.27
15.4.1.6	Site concrete	m^3	38.11	30,368.00	1,157,233.98	170.37	6,492.20		-	6,492.20
15.4.1.7	Pile foundation	m^3	54.29	30,368.00	1,648,579.14	170.37	9,248.69		-	9,248.69
15.4.2	*Precast concrete*	m^3	19.92	30,368.00	604,866.79	170.37	3,393.36		-	3,393.36
15.4.2.1	Slabs	m^3	19.92	37,670.00	750,307.29	211.33	4,209.30		-	4,209.30
15.5	**Providing and placing reinforced cement concrete (30MPa cylinder strength) using ordinary portland cement as per drawings and specifications**									
15.5.1	Pier crosshead	m^3	33.77	37,670.00	1,272,042.37	211.33	7,136.28		-	7,136.28
15.5.2	Bearing seat	m^3	0.18	37,670.00	6,893.61	211.33	38.67		-	38.67
15.6	**Providing, casting and launching in position prestressed concrete girders (35MPa cylinder strength) complete in all respects including post-tensioning, as per drawings, specifications and as directed by the Engineer Girder - 19m Long**	m^3	75.90	60,027.00	4,555,869.22	336.76	25,558.87		-	25,558.87
15.7	**Providing, fabricating, securing and fixing in position mild steel deformed bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening**	ton	170.34	364,005.00	62,003,016.78	2,042.10	347,843.01		-	347,843.01
15.8	**Furnishing and installing RC railing using concrete (21 MPa strength) concrete, including cost of all labour, material, reinforcement, and shuttering etc. completes as per drawings and specifications**	Rm	70.00	3,030.03	212,102.10	17.00	1,189.91		-	1,189.91
15.9	**Providing and constructing deformation joints as per relevant drawings details and specifications**	Rm	13.12	45,981.14	603,272.56	257.96	3,384.42		-	3,384.42
15.10	**Providing and fixing elastomeric bearing pads (320mm x 360mm x 100mm), including galvanized stell plate, cement mortar as shown on the drawing and as per specifications or as directed by the Engineer**	No.	8.00	4.09	32.72	0.02	0.18		-	0.18
15.11	**Providing and laying plant pre-mixed 80mm thick of asphaltic material, including compaction and finishing to required camber, grade and density including bituminous priming coat**									
15.11.1	Sealing layer - 0.5cm	m^2	135.00	658.81	88,939.35	3.70	498.96		-	498.96
15.11.2	Mastic asphalt - 3.5cm	m^2	135.00	500.98	67,632.30	2.81	379.42		-	379.42
15.11.3	Stone mastic asphalt - 4cm	m^2	135.00	351.46	47,447.10	1.97	266.18		-	266.18
15.12	**Providing and laying plant pre-mixed of bituminous mastic**	m^3	0.10	1.31	0.13	0.01	0.00		-	0.00
15.13	**Providing and fixing 150mm diameter PVC pipe for surface drainage**	Rm	7.50	2,075.16	15,563.70	11.64	87.31		-	87.31
15.14	**Providing and installing drainage pots for surface drainage**	No.	3.00	15,000.00	45,000.00	84.15	252.45		-	252.45
15.15	**Providing and installing ground wire for electric devices**	Rm	100.00	569.92	56,992.00	3.20	319.73		-	319.73
16	**Khel Bhek Bridge along Access Road from Jalkot to Lower Spat Gah Headworks**				**114,795,223**		**644,012**		**-**	**644,012**
16.1	**Unclassified excavation for foundation of structures and disposal of surplus material at designated locations and dressing of spoil material**									
16.1.1	clearing & grubbing	m^3	59.14	44.50	2,631.92	0.25	14.77		-	14.77
16.1.2	Loose excavation	m^3	177.43	2,364.00	419,451.23	13.26	2,353.16		-	2,353.16
16.1.3	Ripping excavation	m^3	236.58	577.00	136,505.00	3.24	765.81		-	765.81
16.1.4	Blasting excavation	m^3	709.73	5,346.00	3,794,223.85	29.99	21,285.97		-	21,285.97
16.2	**Providing and placing lining concrete (21 MPa cylinder strength) using ordinary portland cement as per drawings and specifications**									
16.2.1	Lining concrete	m^3	19.77	21,522.00	425,443.28	120.74	2,386.78		-	2,386.78
16.2.2	Leveling concrete	m^3	12.58	21,522.00	270,723.34	120.74	1,518.78		-	1,518.78
16.3	**Providing and placing reinforced cement concrete (21MPa cylinder strength) using ordinary portland cement as per drawings and specifications**									
16.3.1	*Normal concrete*	m^3	705.45	30,368.00	21,422,983.64	170.37	120,185.04		-	120,185.04
16.3.1.1	Abutment footing	m^3	252.28	30,368.00	7,661,178.30	170.37	42,979.96		-	42,979.96
16.3.1.2	Head wall	m^3	123.85	30,368.00	3,761,161.83	170.37	21,100.49		-	21,100.49
16.3.1.3	Cross beam	m^3	18.39	30,368.00	558,406.78	170.37	3,132.72		-	3,132.72
16.3.1.4	Approach slab	m^3	37.92	30,368.00	1,151,442.93	170.37	6,459.71		-	6,459.71
16.3.1.5	Wing wall	m^3	251.37	30,368.00	7,633,604.16	170.37	42,825.27		-	42,825.27
16.3.1.6	Site concrete	m^3	21.64	30,368.00	657,189.64	170.37	3,686.90		-	3,686.90
16.3.1.7	Pile foundation	m^3	54.29	30,368.00	1,648,579.14	170.37	9,248.69		-	9,248.69
16.3.2	*Precast concrete*									
16.3.2.1	Slabs	m^3	11.07	37,670.00	416,837.39	211.33	2,338.50		-	2,338.50
16.4	**Providing and placing reinforced cement concrete (30MPa cylinder strength) using ordinary portland cement as per drawings and specifications**									
16.4.1	Pier crosshead	m^3	33.77	37,670.00	1,272,042.37	211.33	7,136.28		-	7,136.28
16.4.2	Bearing seat	m^3	0.18	37,670.00	6,893.61	211.33	38.67		-	38.67
16.5	**Providing, casting and launching in position prestressed concrete girders (35MPa cylinder strength) complete in all respects including post-tensioning, as per drawings, specifications and as directed by the Engineer Girder - 19m Long**	m^3	42.17	60,027.00	2,531,038.46	336.76	14,199.37		-	14,199.37
16.6	**Providing, fabricating, securing and fixing in position mild steel deformed bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening**	ton	158.53	364,005.00	57,704,076.96	2,042.10	323,725.54		-	323,725.54
16.7	**Furnishing and installing RC railing using concrete (21 MPa strength) concrete, including cost of all labour, material, reinforcement, and shuttering etc. completes as per drawings and specifications**	Rm	46.00	3,030.03	139,381.38	17.00	781.94		-	781.94
16.8	**Providing and constructing deformation joints as per relevant drawings details and specifications**	Rm	13.12	45,981.14	603,272.56	257.96	3,384.42		-	3,384.42
16.9	**Providing and fixing elastomeric bearing pads (320mm x 360mm x 100mm), including galvanized stell plate, cement mortar as shown on the drawing and as per specifications or as directed by the Engineer**	No.	8.00	47,116.80	376,934.40	264.33	2,114.64		-	2,114.64
16.10	**Providing and laying plant pre-mixed 80mm thick of asphaltic material, including compaction and finishing to required camber, grade and density including bituminous priming coat**									
16.10.1	Sealing layer - 0.5cm	m^2	75.00	658.81	49,410.75	3.70	277.20		-	277.20
16.10.2	Mastic asphalt - 3.5cm	m^2	75.00	500.98	37,573.50	2.81	210.79		-	210.79
16.10.3	Stone mastic asphalt - 4cm	m^2	75.00	351.46	26,359.50	1.97	147.88		-	147.88
16.11	**Providing and laying plant pre-mixed of bituminous mastic**	m^3	0.05	1,162.06	63.80	6.52	0.36		-	0.36
16.12	**Comaction of back fill around the structures with suitable excavated material around the structure in 150mm layers and density of soil must be 90% of maximum modified Proctor dry density**									
16.12.1	Backfill	m^3	926.80	1,342.00	1,243,761.31	7.53	6,977.62		-	6,977.62
16.12.2	Stones with edge length >1m under water	m^3	271.36	2,691.58	730,387.15	15.10	4,097.54		-	4,097.54
16.13	**Providing and fixing 150mm diameter PVC pipe for surface drainage**	Rm	7.50	1,556.37	11,672.78	8.73	65.49		-	65.49
16.14	**Providing and installing drainage pots for surface drainage**	No.	3.00	15,000.00	45,000.00	84.15	252.45		-	252.45
16.15	**Providing and installing ground wire for electric devices**	Rm	100.00	569.92	56,992.00	3.20	319.73		-	319.73
17	**Construction Road to Spat Gah Headworks Right Bank**				**1,132,396,046**		**6,352,853**		**-**	**6,352,853**
17.1	**Unclassified excavation for structures and disposal of surplus material at designated locations and dressing of spoil material**									
17.1.1	Clearing & grubbing	m^3	34,427.32	44.50	1,532,015.66	0.25	8,594.76		-	8,594.76
17.1.2	Loose excavation	m^3	15,492.29	2,364.00	36,623,781.01	13.26	205,463.01		-	205,463.01
17.1.3	Ripping excavation	m^3	20,656.39	577.00	11,918,737.53	3.24	66,865.29		-	66,865.29
17.1.4	Blasting excavation	m^3	61,969.17	5,346.00	331,287,196.78	29.99	1,858,553.70		-	1,858,553.70
17.1.5	Soil disposal (hauling distance 0.48 km)	m^3	133,867.54	342.00	45,782,698.90	1.92	256,845.44		-	256,845.44
17.2	**Compaction of back fill around the structures with suitable material**									
17.2.1	15 cm field sod/ top soil + seeding	m^3	2,700.00	1,341.45	3,621,915.00	7.53	20,319.30		-	20,319.30
17.2.2	60 cm riprap handplaced/ river bank protection	m^3	270.00	3,558.45	960,781.50	19.96	5,390.08		-	5,390.08
17.2.3	Filling random material	m^3	399.00	1,342.00	535,458.00	7.53	3,003.97		-	3,003.97

No.		DESCRIPTION	UNIT	QUANTITY	ESTIMATE						
					LCC				FCC		TOTAL AMOUNT LCC + FCC (USD)
					UNIT PRICE (PKR)	AMOUNT (PKR)	UNIT PRICE (Eq. USD)	AMOUNT (Eq. USD)	UNIT PRICE (USD)	AMOUNT (USD)	
17.3		**Removing trees operation**									
	17.3.1	Trees 150-300 mm girth	No.	20.00	618.96	12,379.20	3.47	69.45		-	69.45
	17.3.2	Trees 300-600 mm girth	No.	10.00	3,044.67	30,446.70	17.08	170.81		-	170.81
17.4		**Providing and laying cement stabilised base**									
	17.4.1	Providing and laying plant 60 mm thick cement stabilised base, including compaction and finishing to required camber, grade and density	m^3	155.77	22,623.08	4,088,632.50	126.92	22,937.63		-	22,937.63
17.5		**Providing and placing base and sub-base course**									
	17.5.1	15 cm thick granular base course	m^3	458.88	2,980.48	1,367,688.62	16.72	7,672.87		-	7,672.87
	17.5.2	20 cm thick sub-base course	m^3	659.10	2,251.41	1,483,913.34	12.63	8,324.90		-	8,324.90
17.6		**Providing and placing lining concrete (16 MPa cylinder strength)**									
	17.6.1	Using ordinary portland cement as per drawings and specifications	m^3	-		-	-	-		-	-
17.7		**Providing and placing shotcrete (21 MPa cylinder strength)**									
	17.7.1	Using ordinary portland cement as per drawings and specifications	m^3	492.93	98,956.00	48,777,908.13	555.15	273,648.85		-	273,648.85
17.8		**Providing and placing wire mesh**									
	17.8.1	Wire mesh Ø5 mm, 100 mm x 100 mm, surface application	ton	55.80	331,200.00	18,481,119.84	1,858.06	103,680.90		-	103,680.90
17.9		**Providing and fixing 150 mm diameter PVC pipe >3% slope and maintenance opening every 200 m for drainage**									
	17.9.1	Maintenance opening every 200 m for drainage	pcs	2.40	15,000.00	35,925.00	84.15	201.54		-	201.54
	17.9.2	Ø150 mm PVC pipe >3% slope and maintenance opening every 200 m for drainage	m	479.00	2,075.16	994,001.64	11.64	5,576.45		-	5,576.45
	17.9.3	Ø150 mm diameter PVC pipe >3% slope	m				-	-		-	-
17.10		**Providing and placing sand**									
	17.10.1	0.73 m each layer	m^3	-	1,328.38	-	7.45	-		-	-
17.11		**Providing and placing twist hexagonal woven wire mesh**									
	17.11.1	Wire mesh Ø3.70 mm	ton	-		-	-	-		-	-
17.12		**Providing and placing steel wire mesh for gabion**									
	17.12.1	For gabion	kg	1,815.25	331,200.00	601,210,800.00	1,858.06	3,372,851.61		-	3,372,851.61
17.13		**Providing and placing gabion**									
	17.13.1	Gabion (1.5m x 1m x 1m)	m^3	262.50	2,602.04	683,035.50	14.60	3,831.90		-	3,831.90
	17.13.2	Gabion (3m x 1m x 1m)	m^3	150.00	2,602.04	390,306.00	14.60	2,189.65		-	2,189.65
	17.13.3	Gabion (2m x 1m x 1m)	m^3	200.00	2,602.04	520,408.00	14.60	2,919.54		-	2,919.54
	17.13.4	Gabion (4m x 1m x 1m)	m^3	400.00	2,602.04	1,040,816.00	14.60	5,839.08		-	5,839.08
	17.13.5	Gabion (6m x 1m x 1m)	m^3	450.00	2,602.04	1,170,918.00	14.60	6,568.96		-	6,568.96
17.14		**Providing and placing drainage gravel**									
	17.14.1	Gravel	m^3	-		-	-	-		-	-
17.15		**Providing and placing stone for the cut slope**									
	17.15.1	Stone	m^3	-		-	-	-		-	-
17.16		**Providing and placing geotextile to the wall**									
	17.16.1	Geotextile	m^2	699.06	124.13	86,774.18	0.70	486.81		-	486.81
17.17		**Providing and placing drainage pipe for the cut slope**									
	17.17.1	Perforated PVC pipe and geotextile pipe L=4.50 m	No.	-		-	-	-		-	-
	17.17.2	Unperforated drainage pipe L=1.00 m	No.	-		-	-	-		-	-
	17.17.3	Perforated PVC pipe and geotextile pipe L=3.00 m	No.	124.08	7,667.29	951,356.85	43.01	5,337.21		-	5,337.21
	17.17.4	Unperforated drainage pipe L=0.70 m	No.	124.08	1,452.61	180,240.10	8.15	1,011.16		-	1,011.16
17.18		**Providing and placing rockbolting for the cut slope**									
	17.18.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	781.14	530.41	414,322.66	2.98	2,324.39		-	2,324.39
	17.18.2	Nut M25 + washer	No.	781.14	152.18	118,877.01	0.85	666.91		-	666.91
	17.18.3	Fully grouted rockbolt Ø25 mm, L=4-8 m	No.	781.14	7,226.03	5,644,542.64	40.54	31,666.44		-	31,666.44
17.19		**Providing and placing soil nails for the cut slope**									
	17.19.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	-		-	-	-		-	-
	17.19.2	Nut M25 + washer	No.	-		-	-	-		-	-
	17.19.3	Fully grouted rockbolt Ø25 mm, L=4-8 m	No.	-		-	-	-		-	-
	17.19.4	Fully grouted rockbolt Ø25 mm, L=4-16 m	No.	-		-	-	-		-	-
17.20		**Providing and placing guard rail**									
	17.20.1	Guard rail left side	m	20.00	64,657.00	1,293,140.08	362.73	7,254.64		-	7,254.64
	17.20.2	Guard rail right side	m	30.00	64,657.00	1,939,710.12	362.73	10,881.96		-	10,881.96
17.21		**Rockfall barrier**									
	17.21.1	Barrier	m	-		-	-	-		-	-
17.22		**Providing and placing culverts**									
	17.22.1	Pipe culvert type 1	No.	-		-	-	-		-	-
	17.22.2	Pipe culvert type 2	No.	-		-	-	-		-	-
17.23		**Providing and placing PVC cross pipes**									
	17.23.1	PVC cross pipes	No.	-		-	-	-		-	-
17.24		**Providing and placing traffic sign**									
	17.24.1	Traffic sign	No.	7.00	53,320.95	373,246.65	299.14	2,093.95		-	2,093.95
17.25		**Providing and placing posts to guide the snow clearing devices**									
	17.25.1	3 m high wooden posts, placed every 10 m	No.	47.00	10,000.00	470,000.00	56.10	2,636.75		-	2,636.75
17.26		**Slope protection to prevent corrosion**	m^2	1,298.09	6,450.21	8,372,953.10	36.19	46,973.09		-	46,973.09
18		**Access Road to Gabarband Crossing**				**1,047,819,287**		**5,878,369**		**-**	**5,878,369**
18.1		**Unclassified excavation for structures and disposal of surplus material at designated locations and dressing of spoil material**									
	18.1.1	Clearing & grubbing	m^2	54,871.66	44.50	2,441,788.87	0.25	13,698.68		-	13,698.68
	18.1.2	Loose excavation	m^3	24,692.25	2,364.00	58,372,471.89	13.26	327,475.30		-	327,475.30
	18.1.3	Ripping excavation	m^3	32,923.00	577.00	18,996,568.69	3.24	106,572.62		-	106,572.62
	18.1.4	Blasting excavation	m^3	98,768.99	5,346.00	528,019,009.72	29.99	2,962,238.48		-	2,962,238.48
	18.1.5	Soil disposal (hauling distance 2.75 km)	m^3	212,475.06	465.41	98,888,019.51	2.61	554,771.50		-	554,771.50
18.2		**Compaction of back fill around the structures with suitable material**									
	18.2.1	15 cm field sod/ top soil + seeding	m^3	15,125.00	1,341.45	20,289,431.25	7.53	113,825.70		-	113,825.70
	18.2.2	60 cm riprap handplaced/ river bank protection	m^3	10,000.00	3,558.45	35,584,500.00	19.96	199,632.54		-	199,632.54
	18.2.3	Filling random material	m^3	1,524.41	1,342.00	2,045,758.22	7.53	11,476.90		-	11,476.90
18.3		**Removing trees operation**									
	18.3.1	Trees 150-300 mm girth	No.	105.88	618.96	65,535.54	3.47	367.66		-	367.66
	18.3.2	Trees 300-600 mm girth	No.	45.38	30,446.70	1,381,585.33	170.81	7,750.83		-	7,750.83
18.4		**Providing and laying cement stabilised base**									
	18.4.1	Providing and laying plant 60 mm thick cement stabilised base, including compaction and finishing to required camber, grade and density	m^3	894.34	22,623.08	23,474,486.57	126.92	131,694.17		-	131,694.17
18.5		**Providing and placing base and sub-base course**									
	18.5.1	15 cm thick granular base course	m^3	2,634.63	2,980.48	7,852,451.46	16.72	44,053.02		-	44,053.02
	18.5.2	20 cm thick sub-base course	m^3	3,784.18	2,251.41	8,519,744.37	12.63	47,796.60		-	47,796.60
18.6		**Providing and placing lining concrete (16 MPa cylinder strength)**									
	18.6.1	Using ordinary portland cement as per drawings and specifications	m^3	-		-	-	-		-	-
18.7		**Providing and placing shotcrete (21 MPa cylinder strength)**					-	-		-	-
	18.7.1	Using ordinary portland cement as per drawings and specifications	m^3	2,600.49	12,801.51	33,290,200.32	71.82	186,761.29		-	186,761.29
18.8		**Providing and placing wire mesh**									
	18.8.1	Wire mesh Ø5 mm, 100 mm x 100 mm, surface application	ton	298.76	331,200.00	98,950,777.13	1,858.06	555,123.57		-	555,123.57
18.9		**Providing and fixing 150 mm diameter PVC pipe >3% slope and maintenance opening every 200 m for drainage**									
	18.9.1	Maintenance opening every 200 m for drainage	pcs	13.75	15,000.00	206,259.90	84.15	1,157.14		-	1,157.14
	18.9.2	Ø150 mm PVC pipe >3% slope and maintenance opening every 200 m for drainage	m	2,750.13	2,075.16	5,706,963.92	11.64	32,016.63		-	32,016.63
	18.9.3	Ø150 mm diameter PVC pipe >3% slope	m	-		-	-	-		-	-
18.10		**Providing and placing sand**									
	18.10.1	0.73 m each layer	m^3	-		-	-	-		-	-
18.11		**Providing and placing twist hexagonal woven wire mesh**									
	18.11.1	Wire mesh Ø3.70 mm	ton	-		-	-	-		-	-
18.12		**Providing and placing steel wire mesh for gabion**									
	18.12.1	For gabion	kg	1,788.75	570.75	1,020,929.06	3.20	5,727.51		-	5,727.51
18.13		**Providing and placing gabion**									
	18.13.1	Gabion (1.5m x 1m x 1m)	m^3	675.00	2,602.04	1,756,377.00	14.60	9,853.45		-	9,853.45
	18.13.2	Gabion (3m x 1m x 1m)	m^3	675.00	2,602.04	1,756,377.00	14.60	9,853.45		-	9,853.45
	18.13.3	Gabion (2m x 1m x 1m)	m^3	-		-	-	-		-	-
	18.13.4	Gabion (4m x 1m x 1m)	m^3	-		-	-	-		-	-
	18.13.5	Gabion (6m x 1m x 1m)	m^3	-		-	-	-		-	-
18.14		**Providing and placing drainage gravel**									
	18.14.1	Gravel	m^3	-		-	-	-		-	-
18.15		**Providing and placing stone for the cut slope**									
	18.15.1	Stone	m^3	-		-	-	-		-	-
18.16		**Providing and placing geotextile to the wall**									
	18.16.1	Geotextile	m^2	842.65	124.13	104,597.76	0.70	586.80		-	586.80
18.17		**Providing and placing drainage pipe for the cut slope**									
	18.17.1	Perforated PVC pipe and geotextile pipe L=4.50 m	No.	476.00	11,500.93	5,474,442.20	64.52	30,712.16		-	30,712.16
	18.17.2	Unperforated drainage pipe L=1.00 m	No.	476.00	2,075.16	987,776.16	11.64	5,541.52		-	5,541.52
	18.17.3	Perforated PVC pipe and geotextile pipe L=3.00 m	No.	393.39	7,667.29	3,016,233.64	43.01	16,921.37		-	16,921.37
	18.17.4	Unperforated drainage pipe L=0.70 m	No.	393.39	2,075.16	816,347.19	11.64	4,579.79		-	4,579.79
18.18		**Providing and placing rockbolting for the cut slope**									
	18.18.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	1,663.80	530.41	882,492.30	2.98	4,950.87		-	4,950.87
	18.18.2	Nut M25 + washer	No.	1,663.80	152.18	253,203.74	0.85	1,420.50		-	1,420.50
	18.18.3	Fully grouted rockbolt Ø25 mm, L=4-8 m	No.	1,663.80	5,419.52	9,017,004.03	30.40	50,586.28		-	50,586.28
18.19		**Providing and placing soil nails for the cut slope**									
	18.19.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	1,996.00	530.41	1,058,693.73	2.98	5,939.38		-	5,939.38
	18.19.2	Nut M25 + washer	No.	1,996.00	152.18	303,759.26	0.85	1,704.12		-	1,704.12
	18.19.3	Fully grouted rockbolt Ø25 mm, L=4-8 m	No.	1,240.00	5,419.52	6,720,209.76	30.40	37,701.04		-	37,701.04
	18.19.4	Fully grouted rockbolt Ø25 mm, L=4-16 m	No.	756.00	9,032.54	6,828,600.24	50.67	38,309.12		-	38,309.12
18.20		**Providing and placing guard rail**									
	18.20.1	Guard rail left side	m	410.00	64,657.00	26,509,371.64	362.73	148,720.18		-	148,720.18
	18.20.2	Guard rail right side	m	25.00	64,657.00	1,616,425.10	362.73	9,068.30		-	9,068.30
18.21		**Rockfall barrier**									
	18.21.1	Barrier	m	650.00	9,604.73	6,243,074.50	53.88	35,024.26		-	35,024.26
18.22		**Providing and placing culverts**									
	18.22.1	Pipe culvert type 1	No.	1.00	52,142.50	52,142.50	292.52	292.52		-	292.52
	18.22.2	Pipe culvert type 2	No.	-		-	-	-		-	-
18.23		**Providing and placing PVC cross pipes**									
	18.23.1	PVC cross pipes	No.	10.00	2,075.16	20,751.60	11.64	116.42		-	116.42
18.24		**Providing and placing traffic sign**									
	18.24.1	Traffic sign	No.	13.00	53,320.95	693,172.35	299.14	3,888.76		-	3,888.76
18.25		**Providing and placing posts to guide the snow clearing devices**									
	18.25.1	3 m high wooden posts, placed every 10 m	No.	208.11	10,000.00	2,081,132.00	56.10	11,675.35		-	11,675.35
18.26		**Slope protection to prevent corrosion**	m^2	7,452.86	3,558.45	26,520,621.55	19.96	148,783.29		-	148,783.29
19		**Culverts along of Access Road to Gabarband Crossing**				**1,150,370**		**6,454**		**-**	**6,454**
19.1		**Unclassified excavation for structures and disposal of surplus material at designated locations and dressing of spoil material**									
	19.1.1	Clearing & grubbing	m^2	9.36	44.50	416.37	0.25	2.34		-	2.34
	19.1.2	Loose excavation	m^3	4.21	2,364.00	9,953.62	13.26	55.84		-	55.84
	19.1.3	Ripping excavation	m^3	5.61	577.00	3,239.28	3.24	18.17		-	18.17
	19.1.4	Blasting excavation	m^3	16.84	5,346.00	90,037.33	29.99	505.12		-	505.12
19.2		**Providing and placing cast in-situ concrete (21 MPa cylinder strength)**									
	19.2.1	Using ordinary portland cement as per drawings and specifications	m^3	14.34	30,368.00	435,417.30	170.37	2,442.73		-	2,442.73
19.3		**Providing and placing Pre-cast unreinforced concrete pipe (28 MPa cylinder strength)**									
	19.3.1	Using ordinary portland cement as per drawings and specifications	m^3	2.58	37,669.00	97,247.50	211.33	545.57		-	545.57
19.4		**Providing and placing lean concrete (16 MPa cylinder strength)**									
	19.4.1	Using ordinary portland cement as per drawings and specifications	m^3	1.83	21,522.00	39,406.78	120.74	221.08		-	221.08
19.5		**Providing and placing riprap at the exit of culvert**									
	19.5.1	Riprap	m^3	14.35	3,558.45	51,063.76	19.96	286.47		-	286.47
19.6		**Providing, fabricating, securing and fixing in position mild steel deformed bars**									
	19.6.1	Bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening	ton	1.10	364,005.00	400,405.50	2,042.10	2,246.31		-	2,246.31
19.7		**Providing and laying cement stabilised base**									
	19.7.1	Providing and laying plant 60 mm thick cement stabilised base, including compaction and finishing to required camber, grade and density	m^3	0.52	22,623.08	13,657.23	126.92	76.62		-	76.62

No.	DESCRIPTION	UNIT	QUANTITY	ESTIMATE						
				LCC				FCC		TOTAL AMOUNT LCC + FCC (USD)
				UNIT PRICE (PKR)	AMOUNT (PKR)	UNIT PRICE (Eq. USD)	AMOUNT (Eq. USD)	UNIT PRICE (USD)	AMOUNT (USD)	
19.8	**Providing and placing base and sub-base course**									
19.8.1	15 cm thick granular base course	m^3	1.53	2,980.48	4,568.48	16.72	25.63		-	25.63
19.8.2	20 cm thick sub base course	m^3	2.20	2,251.41	4,956.70	12.63	27.81		-	27.81
20	**Tunnels along Access Road to Gabarband Crossing**				**1,208,254,644**		**6,778,427**		**-**	**6,778,427**
20.1	**Unclassified excavation for structures and disposal of surplus material at designated locations and dressing of spoil material**									
20.1.1	Clearing & grubbing	m^3	11,527.43	44.50	512,970.41	0.25	2,877.81		-	2,877.81
20.1.2	Loose excavation	m^3	23,054.85	2,364.00	54,501,665.40	13.26	305,759.69		-	305,759.69
20.1.3	Ripping excavation	m^3	34,582.28	577.00	19,953,972.68	3.24	111,943.75		-	111,943.75
20.1.4	Blasting excavation	m^3	161,383.95	5,346.00	862,758,596.70	29.99	4,840,160.43		-	4,840,160.43
20.2	**Providing and placing reinforce concrete (21 MPa cylinder strength)**									
20.2.1	Using ordinary portland cement as per drawings and specifications	m^3	1,567.80	30,368.00	47,610,950.40	170.37	267,102.11		-	267,102.11
20.3	**Providing and placing shotcrete (21 MPa cylinder strength)**					-	-		-	-
20.3.1	Using ordinary portland cement as per drawings and specifications	m^3	1,532.70	30,368.00	46,545,033.60	170.37	261,122.21		-	261,122.21
20.4	**Providing, fabricating, securing and fixing in position mild steel deformed bars**									
20.4.1	Bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening	ton	313.56	364,005.00	114,137,407.80	2,042.10	640,322.06		-	640,322.06
20.4.2	Wire mesh Ø5 mm	ton	32.56	331,200.00	10,783,208.47	1,858.06	60,494.86		-	60,494.86
20.5	**Providing and fixing 200 mm diameter PVC pipe for surface drainage**									
20.5.1	PVC pipes	m	585.00	2,075.16	1,213,968.60	11.64	6,810.48		-	6,810.48
20.6	**Providing and installing ground wire for electric devices**									
20.6.1	Fiber Optic	m	1,170.00	1,230.18	1,439,310.60	6.90	8,074.67		-	8,074.67
20.6.2	8" 11kV	m	1,170.00	5,495.00	6,429,150.00	30.83	36,068.16		-	36,068.16
20.6.3	6" 400V	m	585.00	3,474.00	2,032,290.00	19.49	11,401.35		-	11,401.35
20.6.4	6" spare	m	585.00	3,474.00	2,032,290.00	19.49	11,401.35		-	11,401.35
20.6.5	2" spare	m	585.00	44.16	25,833.60	0.25	144.93		-	144.93
20.7	**Providing and placing lighting**									
20.7.1	Lighting	No	290.00	15,000.00	4,350,000.00	84.15	24,403.93		-	24,403.93
20.8	**Providing and placing rockbolting for the tunnel**									
20.8.1	Steel plate, anchor plate (150 mm x 150 mm x 10 mm)	No.	4,290.00	530.41	2,275,448.95	2.98	12,765.49		-	12,765.49
20.8.2	Nut M25 + washer	No.	4,290.00	152.18	652,869.36	0.85	3,662.66		-	3,662.66
20.8.3	Fully grouted rockbolt Ø25 mm, L=3 m	No.	4,290.00	7,226.03	30,999,677.28	40.54	173,911.23		-	173,911.23
21	**Bridge along Access Road to Gabarband Crossing**				**135,184,206**		**758,397**		**-**	**758,397**
21.1	**Unclassified excavation for foundation of structures and disposal of surplus material at designated locations and dressing of spoil material**									
21.1.1	Clearing & grubbing	m^2	394.30	44.50	17,546.14	0.25	98.44		-	98.44
21.1.2	Loose excavation	m^3	177.43	2,364.00	419,451.23	13.26	2,353.16		-	2,353.16
21.1.3	Ripping excavation	m^3	236.58	577.00	136,505.00	3.24	765.81		-	765.81
21.1.4	Blasting excavation	m^3	709.73	5,346.00	3,794,223.85	29.99	21,285.97		-	21,285.97
21.2	**Providing and placing lining concrete (16 MPa cylinder strength) using ordinary portland cement as per drawings and specifications**									
21.2.1	Lining concrete	m^3	19.77	16,225.00	320,733.07	91.02	1,799.34		-	1,799.34
21.2.2	Levelling concrete	m^3	12.58	16,225.00	204,092.85	91.02	1,144.98		-	1,144.98
21.3	**Providing and placing reinforced cement concrete (21MPa cylinder strength) using ordinary portland cement as per drawings and specifications**									
21.3.1	*Normal concrete*									
21.3.1.1	Abutment footing	m^3	252.28	30,368.00	7,661,178.30	170.37	42,979.96		-	42,979.96
21.3.1.2	Head wall	m^3	123.85	30,368.00	3,761,161.83	170.37	21,100.49		-	21,100.49
21.3.1.3	Cross beam	m^3	18.39	30,368.00	558,406.78	170.37	3,132.72		-	3,132.72
21.3.1.4	Approach slab	m^3	37.92	30,368.00	1,151,442.93	170.37	6,459.71		-	6,459.71
21.3.1.5	Wing wall	m^3	251.37	30,368.00	7,633,604.16	170.37	42,825.27		-	42,825.27
21.3.1.6	Site concrete	m^3	113.85	30,368.00	3,457,437.98	170.37	19,396.57		-	19,396.57
21.3.1.7	Pile foundation	m^3	54.29	30,368.00	1,648,579.14	170.37	9,248.69		-	9,248.69
21.3.2	*Precast concrete*									
21.3.2.1	Slabs	m^3	60.64	37,670.00	2,284,268.87	211.33	12,814.97		-	12,814.97
21.4	**Providing and placing reinforced cement concrete (28 MPa cylinder strength) using ordinary portland cement as per drawings and specifications**									
21.4.1	Pier crosshead	m^3	33.77	37,670.00	1,272,042.37	211.33	7,136.28		-	7,136.28
21.4.2	Bearing seat	m^3	0.18	37,670.00	6,893.61	211.33	38.67		-	38.67
21.5	**Providing, casting and launching in position prestressed concrete girders (35 MPa cylinder strength) complete in all respects including post-tensioning, as per drawings, specifications and as directed by the Engineer**									
21.5.1	Girder 27m long	m^3	180.40	60,027.00	10,828,870.80	336.76	60,751.03		-	60,751.03
21.6	**Providing, fabricating, securing and fixing in position mild steel deformed bars**									
21.6.1	Bars of 420 MPa yield strength for reinforced cement concrete including cutting, bending, binding, laying and securing in position, making joints and fastening	ton	224.66	364,005.00	81,778,139.94	2,042.10	458,783.39		-	458,783.39
21.7	**Furnishing and installing standart detail barrier**									
21.7.1	Using concrete (21 MPa strength) concrete, including cost of all labour, material, reinforcement, and shuttering etc. completes as per drawings and specifications	m	180.40	30,368.00	5,478,387.20	170.37	30,734.29		-	30,734.29
21.8	**Providing and constructing deformation joints**									
21.8.1	Joints as per relevant drawings details and specifications	m	13.12	45,981.14	603,272.56	257.96	3,384.42		-	3,384.42
21.9	**Providing and fixing elastomeric bearing pads**									
21.9.1	Bearing pads (320 mm x 360 mm x 100 mm), including galvanised stell plate, cement mortar as shown on the drawing and as per specifications or as directed by the Engineer	cm^3	92,160.00	4.09	376,934.40	0.02	2,114.64		-	2,114.64
21.10	**Providing and laying plant pre-mixed 80 mm thick of asphaltic material, including compaction and finishing to required camber, grade and density including bituminous priming coat**									
21.10.1	Sealing layer - 0.5 cm	m^2	411.00	658.81	270,770.91	3.70	1,519.05		-	1,519.05
21.10.2	Mastic asphalt - 3.5 cm	m^2	411.00	500.98	205,902.78	2.81	1,155.13		-	1,155.13
21.10.3	Stone mastic asphalt - 4 cm	m^2	411.00	351.46	144,450.06	1.97	810.38		-	810.38
21.11	**Providing and laying plant pre-mixed of bituminous mastic**									
21.11.1	Bituminous mastic	m^3	0.30	6,357.48	1,912.66	35.67	10.73		-	10.73
21.12	**Compaction of back fill around the structures with suitable excavated material around the structure**									
21.12.1	Backfill	m^3	926.80	226.70	210,104.83	1.27	1,178.71		-	1,178.71
21.12.2	Stones with edge length >1 m under water	m^3	314.16	2,691.58	845,586.77	15.10	4,743.82		-	4,743.82
21.13	**Providing and fixing 150 mm diameter PVC pipe for surface drainage**									
21.13.1	PVC pipes	m	7.50	1,375.00	10,312.50	7.71	57.85		-	57.85
21.14	**Providing and installing drainage pots for surface drainage**					-	-		-	-
21.14.1	Drainage pots	No.	3.00	15,000.00	45,000.00	84.15	252.45		-	252.45
21.15	**Providing and installing ground wire for electric devices**									
21.15.1	Ground wire	m	100.00	569.92	56,992.00	3.20	319.73		-	319.73
22	**Contingencies**				**795,149,627**		**4,460,867**		**-**	**4,460,867**
22.1.1.	Contingency	%	5%		795,149,627.21		4,460,867.47			

Annex 2.2 Cost Estimate Civil Works

Civil Works Cost Estimate of Lower Spat Gah Hydropower Project

No.	DESCRIPTION	UNIT	QUANTITY	ESTIMATE						
				LCC				FCC		TOTAL AMOUNT LCC + FCC (USD)
				UNIT PRICE (PKR)	AMOUNT (PKR)	UNIT PRICE (Eq. USD)	AMOUNT (Eq. USD)	UNIT PRICE (USD)	AMOUNT (USD)	
B	**CIVIL WORKS**				**65,335,460,022**		**366,538,345**		**38,423,402**	**404,961,747**
11	**Lower Spat Gah Headworks**				**24,919,702,667**		**139,801,978**		**1,693,267**	**141,495,245**
11.1	**General Construction**				**299,358,441**		**1,679,430**		**0**	**1,679,430**
11.1.1	*Cofferdams*									
11.1.1.1	Rockfill cofferdams	m^3	17,273.00	4,230.00	73,064,790	23.7	409,901		-	409,901
11.1.1.2	Clay blanketing cofferdams	m^3	4,297.00	2,188.84	9,405,435	12.3	52,765		-	52,765
11.1.1.3	Removal of cofferdams	m^3	21,570.00	1,106.95	23,876,804	6.2	133,951		-	133,951
11.1.1.4	Cut-off wall	m^3	2,865.50	49,880.00	142,931,140	279.8	801,858		-	801,858
11.1.2	*Instrumentation*									
11.1.2.1	Control & Instrumentation	LS	1		-	-	0		-	0
11.1.3	*Buildings*									
11.1.3.1	Control / Diesel Generator Building	LS	1		5,000,000	-	28,050		-	28,050
11.1.4	*Provisions*									
11.1.4.1	Provison cut-off wall cofferdams, consolidation grouting, and unbilled items	%	20%		45,080,273	-	252,905		-	252,905
11.2	**Dam**				**1,183,529,242**		**6,639,715**		**18,067**	**6,657,782**
11.2.1	*Surface Excavation*									
11.2.1.1	Clearing & grubbing	m^2	11,193.00	57.00	638,001	0.3	3,579		-	3,579
11.2.1.2	Loose excavation	m^3	33,915.00	2,364.00	80,175,060	13.3	449,790		-	449,790
11.2.1.3	Ripping excavation	m^3	2,119.70	577.00	1,223,067	3.2	6,862		-	6,862
11.2.1.4	Blasting excavation	m^3	6,359.10	6,682.00	42,491,506	37.5	238,382		-	238,382
11.2.2	*Rock Stabilisation & Support*									
11.2.2.1	Shotcrete C20, surface application	m^3	80.51	98,956.00	7,967,032	555.2	44,696		-	44,696
11.2.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, surface application	m	805.11		-	-	-	22.4	18,067.0	18,067
11.2.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, surface application	t	2.48	468,000.00	1,160,640	2,625.5	6,511		-	6,511
11.2.2.4	Surface Drainage	m	201.28	5,594.28	1,126,017	31.4	6,317		-	6,317
11.2.3	*Drilling & Grouting*									
11.2.3.1	Consolidation grouting — drilling	m	3,500.00	3,000.00	10,500,000	16.8	58,906		-	58,906
11.2.3.2	Consolidation grouting	m^3	140.00	154,205.00	21,588,700	865.1	121,115		-	121,115
11.2.3.3	Cut-off wall	m^2	1,175.00	49,880.00	58,609,000	279.8	328,802		-	328,802
11.2.3.4	Grout curtain - drilling	m	896.00	3,000.00	2,688,000	16.8	15,080		-	15,080
11.2.3.5	Grout curtain	m^3	35.84	154,205.00	5,526,707	865.1	31,005		-	31,005
11.2.4	*Rockfill Dam*									
11.2.4.1	Clay	m^3	40,561.00	2,188.84	88,781,438	12.3	498,073		-	498,073
11.2.4.2	Filter/Transition	m^3	31,910.00	6,626.58	211,454,168	37.2	1,186,279		-	1,186,279
11.2.4.3	Rockfill	m^3	100,353.00	4,230.00	424,493,190	23.7	2,381,448		-	2,381,448
11.2.4.4	Rip Rap	m^3	11,902.00	5,020.06	59,748,784	28.2	335,197		-	335,197
11.2.4.5	Asphalt Road	m	151.00	25,549.00	3,857,899	143.3	21,643		-	21,643
11.2.5	*Concrete & Reinforcement*									
11.2.5.1	Mass concrete C15	m^3	63.00	29,736.00	1,873,368	166.8	10,510		-	10,510
11.2.5.2	Structural concrete C25	m^3	2,390.00	37,669.00	90,028,910	211.3	505,071		-	505,071
11.2.5.3	Reinforcement	t	191.20	364,005.00	69,597,756	2,042.1	390,450		-	390,450
11.3	**Weir**				**5,064,737,695**		**28,413,676**		**0**	**28,413,676**
11.3.1	*Surface Excavation*									
11.3.1.1	Clearing & grubbing	m^2	9,616.00	57.00	548,112	0.3	3,075		-	3,075
11.3.1.2	Loose excavation	m^3	37,646.00	2,364.00	88,995,144	13.3	499,271		-	499,271
11.3.1.3	Ripping excavation	m^3	-			-	-		-	0
11.3.1.4	Blasting excavation	m^3	-			-	-		-	0
11.3.2	*Rock Stabilisation & Support*									
11.3.2.1	Shotcrete C20, surface application	m^3	-			-	-		-	0
11.3.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, surface application	m	-			-	-		-	0
11.3.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, surface application	t	-			-	-		-	0
11.3.2.4	Surface Drainage	m	-			-	-		-	0
11.3.3	*Drilling & Grouting*					-	-		-	
11.3.3.1	Consolidation grouting — drilling	m	7,500.00	3,000.00	22,500,000	16.8	126,227		-	126,227
11.3.3.2	Consolidation grouting	m^3	300.00	154,205.00	46,261,500	865.1	259,532		-	259,532
11.3.3.3	Cut-off wall	m^2	3,961.80	49,880.00	197,614,584	279.8	1,108,637		-	1,108,637
11.3.4	*Concrete & Reinforcement*									
11.3.4.1	Mass concrete, C15	m^3	429.00	29,736.00	12,756,744	166.8	71,567		-	71,567
11.3.4.2	Structural concrete C25	m^3	61,396.00	37,669.00	2,312,725,924	211.3	12,974,619		-	12,974,619
11.3.4.3	Reinforcement	t	6,525.58	364,005.00	2,375,343,748	2,042.1	13,325,912		-	13,325,912
11.3.4.4	Rip Rap	m^3	1,592.00	5,020.06	7,991,940	28.2	44,836		-	44,836
11.4	**Intake and Desander**				**17,185,424,780**		**96,411,920**		**1,594,568**	**98,006,488**
11.4.1	*Surface Excavation*									
11.4.1.1	Clearing & grubbing	m^2	52,245.00	57.00	2,977,965	0.3	16,707		-	16,707
11.4.1.2	Loose excavation	m^3	572,525.25	2,364.00	1,353,449,691	13.3	7,592,986		-	7,592,986
11.4.1.3	Ripping excavation	m^3	104,095.50	577.00	60,063,104	3.2	336,960		-	336,960
11.4.1.4	Blasting excavation	m^3	364,334.25	6,682.00	2,434,481,459	37.5	13,657,680		-	13,657,680
11.4.2	*Rock Stabilisation & Support*									
11.4.2.1	Shotcrete C20, surface application	m^3	6,020.27	98,956.00	595,741,482	555.2	3,342,168		-	3,342,168
11.4.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, surface application	m	56,740.34	-	-	-	-	22.4	1,273,275.5	1,273,275
11.4.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, surface application	t	250.32	468,000.00	117,148,948	2,625.5	657,217		-	657,217
11.4.2.4	Pre-stressed thread bar anchors, surface application	m	13,016.00	-	-	-	-	25	321,292.6	321,293
11.4.2.5	Surface Drainage	m	8,572.17	5,594.28	47,955,097	31.4	269,033		-	269,033
11.4.3	*Drilling & Grouting*									
11.4.3.1	Consolidation grouting — drilling	m	7,837.50	3,000.00	23,512,500	16.8	131,907		-	131,907
11.4.3.2	Consolidation grouting	m^3	391.88	154,205.00	60,429,084	865.1	339,013		-	339,013
11.4.3.3	Cut-off wall	m^2	5,188.00	49,880.00	258,777,440	279.8	1,451,767		-	1,451,767
11.4.4	*Concrete & Reinforcement*									
11.4.4.1	Mass concrete, C15	m^3	2,074.00	29,736.00	61,672,464	166.8	345,989		-	345,989
11.4.4.2	Structural concrete C25	m^3	142,307.00	37,669.00	5,360,562,383	211.3	30,073,281		-	30,073,281
11.4.4.3	Reinforcement	t	17,431.36	364,005.00	6,345,102,197	2,042.1	35,596,646		-	35,596,646
11.4.4.4	Free-Draining Backfill	m^3	113,203.00	4,084.00	462,321,052	22.9	2,593,666		-	2,593,666
11.4.4.5	Rip Rap	m^3	245.00	5,020.06	1,229,915	28.2	6,900		-	6,900
11.5	**Contingencies**				**1,186,652,508**		**6,657,237**		**80,632**	**6,737,869**
11.5.1.1	Contingencies	%	5%		1,186,652,508	-	6,657,237		80,632	6,737,869
12	**Lower Gabarband Intake**				**1,667,802,081**		**9,356,533**		**168,506**	**9,525,039**
12.1	**General**				**44,265,103**		**248,332**		**0**	**248,332**
12.1.1	*Cofferdams*									
12.1.1.1	Rockfill cofferdams	m^3	4,607.90	4,230.00	19,491,417	23.7	109,349		-	109,349
12.1.1.2	Filter cofferdams	m^3	569.10	6,626.58	3,771,187	37.2	21,157		-	21,157
12.1.1.3	Rip rap cofferdams	m^3	568.00	5,020.06	2,851,396	28.2	15,997		-	15,997
12.1.1.4	Clay	m^3	622.80	2,188.84	1,363,208	12.3	7,648		-	7,648
12.1.1.5	Geomembrane	m^2	1,726.00	248.26	428,497	1.4	2,404		-	2,404
12.1.1.6	Removal of cofferdams	m^3	5,745.00	1,106.95	6,359,399	6.2	35,677		-	35,677
12.1.2	*Instrumentation*									
12.1.2.1	Control & Instrumentation	LS	1.00		5,000,000	-	28,050		-	28,050
12.1.3	*Buildings*									
12.1.3.1	Control / Diesel Generator Building	LS	1.00		5,000,000	-	28,050		-	28,050
12.2	**Weir**				**750,075,959**		**4,208,000**		**33,046**	**4,241,045**
12.2.1	*Surface Excavation*									
12.2.1.1	Clearing & grubbing	m^2	4,003.00	57.00	228,171	0.3	1,280		-	1,280
12.2.1.2	Loose excavation	m^3	10,006.50	2,364.00	23,655,366	13.3	132,709		-	132,709
12.2.1.3	Ripping excavation	m^3	714.75	577.00	412,411	3.2	2,314		-	2,314
12.2.1.4	Blasting excavation	m^3	3,573.75	6,682.00	23,879,798	37.5	133,968		-	133,968
12.2.2	*Rock Stabilisation & Support*									
12.2.2.1	Shotcrete C20, surface application	m^3	147.26	98,956.00	14,572,229	555.2	81,752		-	81,752
12.2.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, surface application	m	1,472.60	-	-	-	-	22.4	33,045.7	33,046
12.2.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, surface application	t	9.13	468,000.00	4,272,887	2,625.5	23,971		-	23,971
12.2.2.4	Surface Drainage	m	368.15	5,594.28	2,059,530	31.4	11,554		-	11,554
12.2.3	*Drilling & Grouting*									
12.2.3.1	Consolidation grouting — drilling	m	-			-	-		-	0
12.2.3.2	Consolidation grouting	m^3	-			-	-		-	0
12.2.4	*Concrete & Reinforcement*					-	-		-	
12.2.4.1	Mass concrete, C15	m^3	1,516.00	29,736.00	45,079,776	166.8	252,902		-	252,902
12.2.4.2	Structural concrete C25	m^3	8,635.00	37,669.00	325,271,815	211.3	1,824,807		-	1,824,807
12.2.4.3	Reinforcement	t	811.22	364,005.00	295,288,136	2,042.1	1,656,595		-	1,656,595
12.2.4.4	Free-Draining Backfill	m^3	3,036.00	4,084.00	12,399,024	22.9	69,560		-	69,560
12.2.4.5	Rip Rap	m^3	589.00	5,020.06	2,956,817	28.2	16,588		-	16,588

No.		DESCRIPTION	UNIT	QUANTITY	ESTIMATE						
					LCC				FCC		TOTAL AMOUNT LCC + FCC (USD)
					UNIT PRICE (PKR)	AMOUNT (PKR)	UNIT PRICE (Eq. USD)	AMOUNT (Eq. USD)	UNIT PRICE (USD)	AMOUNT (USD)	
12.3		**Intake and Desander**				**794,041,872**		**4,454,653**		**127,436**	**4,582,089**
12.3.1		*Surface Excavation*									
	12.3.1.1	Clearing & grubbing	m^2	5,465.00	57.00	311,505	0.3	1,748		-	1,748
	12.3.1.2	Loose excavation	m^3	16,543.80	2,364.00	39,109,543	13.3	219,408		-	219,408
	12.3.1.3	Ripping excavation	m^3	2,757.30	577.00	1,590,962	3.2	8,925		-	8,925
	12.3.1.4	Blasting excavation	m^3	8,271.90	6,682.00	55,272,836	37.5	310,086		-	310,086
12.3.2		*Rock Stabilisation & Support*									
	12.3.2.1	Shotcrete C20, surface application	m^3	436.45	98,956.00	43,188,913	555.2	242,294		-	242,294
	12.3.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, surface application	m	5,678.86	-	-	-	-	22.4	127,435.9	127,436
	12.3.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, surface application	t	19.56	468,000.00	9,155,450	2,625.5	51,363		-	51,363
	12.3.2.4	Surface Drainage	m	873.01	5,594.28	4,883,885	31.4	27,399		-	27,399
12.3.3		*Drilling & Grouting*									
	12.3.3.1	Consolidation grouting — drilling	m	196.88	3,000.00	590,625	16.8	3,313		-	3,313
	12.3.3.2	Consolidation grouting	m^3	9.84	154,205.00	1,517,955	865.1	8,516		-	8,516
12.3.4		*Concrete & Reinforcement*									
	12.3.4.1	Mass concrete, C15	m^3	311.00	29,736.00	9,247,896	166.8	51,882		-	51,882
	12.3.4.2	Structural concrete C25	m^3	6,678.00	37,669.00	251,553,582	211.3	1,411,240		-	1,411,240
	12.3.4.3	Reinforcement	t	953.43	364,005.00	347,053,287	2,042.1	1,947,003		-	1,947,003
	12.3.4.4	Free-Draining Backfill	m^3	7,392.00	4,084.00	30,188,928	22.9	169,363		-	169,363
	12.3.4.5	Rip Rap	m^3	75.00	5,020.06	376,505	28.2	2,112		-	2,112
12.4		**Contingencies**				**79,419,147**		**445,549**		**8,024**	**453,573**
	12.4.1.1	Contingencies	%	5.00		79,419,147	-	445,549		8,024	453,573
13		**Power Waterway**				**27,143,803,283**		**152,279,401**		**11,332,568**	**163,611,969**
13.1		**Headrace Tunnel**				**17,477,290,343**		**98,049,315**		**6,577,234**	**104,626,548**
13.1.1		*Underground Excavation*									
	13.1.1.1	D&B Excavation	m^3	398,232.81	10,068.00	4,009,407,933	56.5	22,493,172		-	22,493,172
	13.1.1.2	Care of water & ventilation	%	4%		160,376,317	-	899,727		-	899,727
13.1.2		*Rock Stabilisation & Support*									
	13.1.2.1	Shotcrete C20, underground application	m^3	14,560.09	98,956.00	1,440,808,468	555.2	8,083,077		-	8,083,077
	13.1.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	174,328.78		-	-	-	27.5	4,797,097.8	4,797,098
	13.1.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	658.30	468,000.00	308,083,748	2,625.5	1,728,380		-	1,728,380
	13.1.2.4	Spiling Ø25 mm, 420 N/mm2	m	34,973.39	-	-	-	-	30	1,058,619.5	1,058,619
	13.1.2.5	Steel ribs TH36	t	254.22		-	-	-	2,838	721,516.4	721,516
	13.1.2.6	PVC foil	m^2	13,392.51	375.00	5,022,193	2.1	28,175		-	28,175
13.1.3		*Concrete & Reinforcement*									
	13.1.3.1	Invert Concrete	m^3	8,600.80	43,319.35	372,580,855	243.0	2,090,215		-	2,090,215
	13.1.3.2	Final concrete lining C25	m^3	128,552.51	43,319.35	5,568,811,304	243.0	31,241,578		-	31,241,578
	13.1.3.3	Reinforcement	t	13,895.52	364,005.00	5,058,038,216	2,042.1	28,376,091		-	28,376,091
	13.1.3.4	Consolidation and Contact Grouting of Concrete Lining	m^3	631.14	3,000.00	1,893,430	16.8	10,622		-	10,622
	13.1.3.5	Steel lining backfill concrete C20	m^3	15,002.16	36,350.00	545,328,653	203.9	3,059,347		-	3,059,347
	13.1.3.6	Contact Grouting of Steel Liner	m^3	45.00	154,205.00	6,939,225	865.1	38,930		-	38,930
13.2		**Surge Shaft**				**642,683,130**		**3,605,515**		**423,526**	**4,029,041**
13.2.1		*Underground Excavation*									
	13.2.1.1	D&B Excavation	m^3	18,406.66	10,068.00	185,318,205	56.5	1,039,653		-	1,039,653
	13.2.1.2	Care of water & ventilation	%	4%		7,412,728	-	41,586		-	41,586
13.2.2		*Rock Stabilisation & Support*									
	13.2.2.1	Shotcrete C20, underground application	m^3	916.15	98,956.00	90,658,519	555.2	508,603		-	508,603
	13.2.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	14,176.07	-	-	-	-	28	390,090.3	390,090
	13.2.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	31.95	468,000.00	14,954,195	2,625.5	83,895		-	83,895
	13.2.2.4	Steel ribs HEB200	t	11.78	0.00	0	-	0	2,838	33,435.6	33,436
13.2.3		*Concrete & Reinforcement*									
	13.2.3.1	Final concrete lining C25	m^3	4,397.01	37,669.00	165,631,116	211.3	929,207		-	929,207
	13.2.3.2	Reinforcement	t	483.67	364,005.00	176,058,854	2,042.1	987,707		-	987,707
	13.2.3.3	Consolidation and Contact Grouting of Concrete Lining	m^3	17.18	154,205.00	2,649,512	865.1	14,864		-	14,864
13.3		**Pressure Shaft**				**355,843,606**		**1,996,318**		**174,655**	**2,170,972**
13.3.1		*Underground Excavation*									
	13.3.1.1	D&B Excavation	m^3	10,239.46	12,585.00	128,863,658	70.6	722,938		-	722,938
	13.3.1.2	Care of water & ventilation	%	4%		5,154,546	-	28,918		-	28,918
13.3.2		*Rock Stabilisation & Support*									
	13.3.2.1	Shotcrete C20, underground application	m^3	696.94	98,956.00	68,966,010	555.2	386,906		-	386,906
	13.3.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	5,380.65	0.00	0	-	0	28	148,062.3	148,062
	13.3.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	26.36	468,000.00	12,337,182	2,625.5	69,213		-	69,213
	13.3.2.4	Steel ribs HEB200	t	9.37	0.00	0	-	0	2,838	26,592.2	26,592
13.3.3		*Concrete & Reinforcement*									
	13.3.3.1	Steel lining backfill concrete C20	m^3	3,717.33	36,350.00	135,125,035	203.9	758,065		-	758,065
	13.3.3.2	Contact Grouting of Steel Liner	m^3	35.00	154,205.00	5,397,175	865.1	30,279		-	30,279
13.4		**High Pressure Tunnel**				**102,661,823**		**575,943**		**54,611**	**630,554**
13.4.1		*Underground Excavation*									
	13.4.1.1	D&B Excavation	m^3	2,497.62	12,585.00	31,432,534	70.6	176,340		-	176,340
	13.4.1.2	Care of water & ventilation	%	4%		1,257,301	-	7,054		-	7,054
13.4.2		*Rock Stabilisation & Support*									
	13.4.2.1	Shotcrete C20, underground application	m^3	109.28	98,956.00	10,814,102	555.2	60,668		-	60,668
	13.4.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	1,333.00	0.00	-	-	0	28	36,680.9	36,681
	13.4.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	4.77	468,000.00	2,234,447	2,625.5	12,535		-	12,535
	13.4.2.4	Spiling Ø25 mm, 420 N/mm2	m	352.26	0.00	-	-	0	30	10,662.5	10,663
	13.4.2.5	Steel ribs TH36	t	2.56	0.00	-	-	0	2,838	7,267.2	7,267
13.4.3		*Concrete & Reinforcement*									
	13.4.3.1	Invert Concrete	m^3	55.30	43,319.35	2,395,622	243.0	13,440		-	13,440
	13.4.3.2	Steel lining backfill concrete C20	m^3	1,468.26	36,350.00	53,371,280	203.9	299,418		-	299,418
	13.4.3.2	Contact Grouting of Steel Liner	m^3	7.50	154,205.00	1,156,538	865.1	6,488		-	6,488
13.5		**Penstock**				**96,683,515**		**542,404**		**58,854**	**601,258**
13.5.1		*Underground Excavation*									
	13.5.1.1	D&B Excavation	m^3	2,058.99	10,068.00	20,729,895	56.5	116,297		-	116,297
	13.5.1.2	Care of water & ventilation	%	0.04		829,196	-	4,652		-	4,652
13.5.2		*Rock Stabilisation & Support*									
	13.5.2.1	Shotcrete C20, underground application	m^3	115.69	98,956.00	11,448,635	555.2	64,228		-	64,228
	13.5.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	2,138.79	0.00	0	-	0	28	58,854.2	58,854
	13.5.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	5.38	468,000.00	2,515,822	2,625.5	14,114		-	14,114
13.5.3		*Concrete & Reinforcement*									
	13.5.3.1	Invert Concrete	m^3	69.98	43,319.35	3,031,401	243.0	17,006		-	17,006
	13.5.3.2	Final concrete lining C25	m^3	365.75	43,319.35	15,843,836	243.0	88,885		-	88,885
	13.5.3.3	Reinforcement	t	40.23	364,005.00	14,644,631	2,042.1	82,158		-	82,158
	13.5.3.4	Steel lining backfill concrete C20	m^3	732.81	36,350.00	26,637,767	203.9	149,440		-	149,440
	13.5.3.5	Contact Grouting of Steel Liner	m^3	6.50	154,205.00	1,002,333	865.1	5,623		-	5,623
13.6		**Tailrace Tunnel**				**2,550,143,874**		**14,306,558**		**1,216,411**	**15,522,969**
13.6.1		*Underground Excavation*									
	13.6.1.1	D&B Excavation	m^3	71,583.97	10,068.00	720,707,420	56.5	4,043,239		-	4,043,239
	13.6.1.2	Care of water & ventilation	%	0.04		28,828,297	-	161,730		-	161,730
13.6.2		*Rock Stabilisation & Support*									
	13.6.2.1	Shotcrete C20, underground application	m^3	2,081.05	98,956.00	205,932,718	555.2	1,155,303		-	1,155,303
	13.6.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	30,189.92	0.00	-	-	0	28	830,752.1	830,752
	13.6.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	99.77	468,000.00	46,691,449	2,625.5	261,944		-	261,944
	13.6.2.4	Spiling Ø25 mm, 420 N/mm2	m	7,552.17	0.00	-	-	0	30	228,598.7	228,599
	13.6.2.5	Steel ribs TH36	t	55.34	0.00	-	-	0	2,838	157,060.4	157,060
13.6.3		*Concrete & Reinforcement*									
	13.6.3.1	Invert Concrete	m^3	1,305.91	43,319.35	56,571,249	243.0	317,370		-	317,370
	13.6.3.2	Final concrete lining C25	m^3	18,202.71	43,319.35	788,529,705	243.0	4,423,729		-	4,423,729
	13.6.3.3	Reinforcement	t	1,902.16	364,005.00	692,395,735	2,042.1	3,884,408		-	3,884,408
	13.6.3.4	Consolidation Grouting	m^3	68.01	154,205.00	10,487,302	865.1	58,835		-	58,835
13.7		**Gabarband Intake Tunnel**				**2,973,079,831**		**16,679,270**		**1,447,972**	**18,127,241**
13.7.1		*Underground Excavation*									
	13.7.1.1	D&B Excavation	m^3	102,084.55	10,068.00	1,027,787,281	56.5	5,765,988		-	5,765,988
	13.7.1.2	Care of water & ventilation	%	0.04		41,111,491	-	230,640		-	230,640
13.7.2		*Rock Stabilisation & Support*									
	13.7.2.1	Shotcrete C20, underground application	m^3	3,396.17	98,956.00	336,071,072	555.2	1,885,392		-	1,885,392
	13.7.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	44,710.05	0.00	-	-	0	28	1,230,310.1	1,230,310
	13.7.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	155.34	468,000.00	72,696,846	2,625.5	407,836		-	407,836
	13.7.2.4	Spiling Ø25 mm, 420 N/mm2	m	4,539.57	0.00	0	-	0	30	137,409.6	137,410
	13.7.2.5	Steel ribs TH36	t	28.28	0.00	-	-	0	2,838	80,251.9	80,252
13.7.3		*Concrete & Reinforcement*									
	13.7.3.1	Invert Concrete + Fill concrete	m^3	2,694.90	43,319.35	116,741,209	243.0	654,930		-	654,930
	13.7.3.2	Final concrete lining C25	m^3	3,333.75	43,319.35	144,415,779	243.0	810,187		-	810,187
	13.7.3.3	Reinforcement	t	98.68	364,005.00	35,919,624	2,042.1	201,513		-	201,513
	13.7.3.4	Backfill concrete C20	m^3	1,569.94	36,350.00	57,067,139	203.9	320,152		-	320,152
13.7.4		*GRP Pipe*									
	13.7.4.1	GRP Pipe	m	2,393.10	476,900.00	1,141,269,390	2,675.5	6,402,633		-	6,402,633

No.	DESCRIPTION	UNIT	QUANTITY	ESTIMATE LCC UNIT PRICE (PKR)	AMOUNT (PKR)	UNIT PRICE (Eq. USD)	AMOUNT (Eq. USD)	FCC UNIT PRICE (USD)	AMOUNT (USD)	TOTAL AMOUNT LCC + FCC (USD)
13.8	**Gabarband Crossing - Adit Tunnel Left Bank /Access Tunnel Gabarband Intake**				**341,034,129**		**1,913,235**		**230,894**	**2,144,128**
13.8.1	*Underground Excavation*									
13.8.1.1	D&B Excavation	m³	13,323.68	10,068.00	134,142,764	56.5	752,554		-	752,554
13.8.1.2	Care of water & ventilation	%	4.00		5,365,711	-	30,102		-	30,102
13.8.2	*Rock Stabilisation & Support*									
13.8.2.1	Shotcrete C20, underground application	m³	989.23	98,956.00	97,890,125	555.2	549,173		-	549,173
13.8.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	8,390.78	0.00	-	-	0	28	230,893.6	230,894
13.8.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	40.60	468,000.00	19,001,990	2,625.5	106,603		-	106,603
13.8.3	*Concrete & Reinforcement*									
13.8.3.1	Invert Concrete	m³	251.72	43,319.35	10,904,494	243.0	61,175		-	61,175
13.8.3.2	Final concrete lining C25	m³	613.85	43,319.35	26,591,661	243.0	149,182		-	149,182
13.8.3.3	Reinforcement	t	19.61	364,005.00	7,137,384	2,042.1	40,041		-	40,041
13.8.4	*Portal Works*									
13.8.4.1	Portal & Allied Works	LS	1	40,000,000	40,000,000	224,403.9	224,404		-	224,404
13.9	**Gabarband Crossing - Adit Tunnel Right Bank**				**105,712,511**		**593,058**		**56,198**	**649,255**
13.9.1	*Underground Excavation*									
13.9.1.1	D&B Excavation	m³	2,522.86	10,068.00	25,400,149	56.5	142,497		-	142,497
13.9.1.2	Care of water & ventilation	%	4.00		1,016,006	-	5,700		-	5,700
13.9.2	*Rock Stabilisation & Support*									
13.9.2.1	Shotcrete C20, underground application	m³	157.93	98,956.00	15,628,517	555.2	87,678		-	87,678
13.9.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	2,042.25	0.00	-	-	0	28	56,197.7	56,198
13.9.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	4.87	468,000.00	2,278,563	2,625.5	12,783		-	12,783
13.9.3	*Concrete & Reinforcement*									
13.9.3.1	Invert Concrete	m³	58.54	43,319.35	2,536,110	243.0	14,228		-	14,228
13.9.3.2	Final concrete lining C25	m³	401.48	43,319.35	17,391,766	243.0	97,570		-	97,570
13.9.3.3	Reinforcement	t	4.01	364,005.00	1,461,400	2,042.1	8,199		-	8,199
13.9.4	*Portal Works*									
13.9.4.1	Portal & Allied Works	LS	1	40,000,000	40,000,000	224,403.9	224,404		-	224,404
13.10	**Access Tunnel to Surge Shaft Chamber**				**54,788,487**		**307,369**		**20,443**	**327,812**
13.10.1	*Underground Excavation*									
13.10.1.1	D&B Excavation	m³	1,318.43	10,068.00	13,273,943	56.5	74,468		-	74,468
13.10.1.2	Care of water & ventilation	%	4.00		530,958	-	2,979		-	2,979
13.10.2	*Rock Stabilisation & Support*									
13.10.2.1	Shotcrete C20, underground application	m³	97.89	98,956.00	9,686,605	555.2	54,343		-	54,343
13.10.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	742.90	0.00	-	-	0	28	20,442.8	20,443
13.10.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	4.02	468,000.00	1,880,320	2,625.5	10,549		-	10,549
13.10.3	*Concrete & Reinforcement*									
13.10.3.1	Invert Concrete	m³	24.91	43,319.35	1,079,042	243.0	6,054		-	6,054
13.10.3.2	Final concrete lining C25	m³	60.74	43,319.35	2,631,347	243.0	14,762		-	14,762
13.10.3.3	Reinforcement	t	1.94	364,005.00	706,272	2,042.1	3,962		-	3,962
13.10.4	*Portal Works*									
13.10.4.1	Portal & Allied Works	LS	1	25,000,000	25,000,000	140,252.5	140,252		-	140,252
13.11	**Surge Shaft Chamber**				**18,336,468**		**102,869**		**16,125**	**118,995**
13.11.1	*Underground Excavation*									
13.11.1.1	D&B Excavation	m³	964.00	10,068.00	9,705,552	56.5	54,449		-	54,449
13.11.1.2	Care of water & ventilation	%	4.00		388,222	-	2,178		-	2,178
13.11.2	*Rock Stabilisation & Support*									
13.11.2.1	Shotcrete C20, underground application	m³	70.32	98,956.00	6,958,586	555.2	39,038		-	39,038
13.11.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	586.00	0.00	-	-	0	28	16,125.3	16,125
13.11.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	1.44	468,000.00	672,720	2,625.5	3,774		-	3,774
13.11.3	*Concrete & Reinforcement*									
13.11.3.1	Invert Concrete	m³	14.11	43,319.35	611,388	243.0	3,430		-	3,430
13.12	**Access Tunnel to Upper Erection & Gate Chamber**				**380,400,053**		**2,134,082**		**219,879**	**2,353,961**
13.12.1	*Underground Excavation*									
13.12.1.1	D&B Excavation	m³	14,180.81	10,068.00	142,772,346	56.5	800,967		-	800,967
13.12.1.2	Care of water & ventilation	%	4.00		5,710,894	-	32,039		-	32,039
13.12.2	*Rock Stabilisation & Support*									
13.12.2.1	Shotcrete C20, underground application	m³	1,052.87	98,956.00	104,187,527	555.2	584,502		-	584,502
13.12.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	7,990.51	0.00	-	-	0	28	219,879.1	219,879
13.12.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	43.21	468,000.00	20,224,413	2,625.5	113,461		-	113,461
13.12.3	*Concrete & Reinforcement*									
13.12.3.1	Invert Concrete	m³	267.92	43,319.35	11,605,995	243.0	65,111		-	65,111
13.12.3.2	Final concrete lining C25	m³	653.34	43,319.35	28,302,338	243.0	158,779		-	158,779
13.12.3.3	Reinforcement	t	20.87	364,005.00	7,596,541	2,042.1	42,617		-	42,617
13.12.4	*Portal Works*									
13.12.4.1	Portal & Allied Works	LS	1	60,000,000.00	60,000,000	336,605.9	336,606		-	336,606
13.13	**Upper Erection & Gate Chamber and Mucking Tunnel**				**330,521,611**		**1,854,259**		**117,940**	**1,972,199**
13.13.1	*Underground Excavation*									
13.3.1.1	D&B Excavation	m³	11,941.00	10,068.00	120,221,988	56.5	674,457		-	674,457
13.3.1.2	Care of water & ventilation	%	4.00		4,808,880	-	26,978		-	26,978
13.3.2	*Rock Stabilisation & Support*									
13.3.2.1	Shotcrete C20, underground application	m³	513.94	98,956.00	50,857,447	555.2	285,315		-	285,315
13.3.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	4,286.00	0.00	-	-	0	28	117,940.1	117,940
13.3.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	17.98	468,000.00	8,413,807	2,625.5	47,202		-	47,202
13.3.3	*Concrete & Reinforcement*									
13.3.3.1	Invert Concrete	m³	163.00	43,319.35	7,061,054	243.0	39,613		-	39,613
13.3.3.2	Steel Lining backfill concrete C20	m³	1,965.03	36,350.00	71,428,747	203.9	400,722		-	400,722
13.3.3.3	Reinforcement	t	186.07	364,005.00	67,729,688	2,042.1	379,970		-	379,970
13.14	**Adit Tunnel to Lower Erection Chamber**				**105,874,673**		**593,967**		**102,572**	**696,539**
13.14.1	*Underground Excavation*									
13.14.1.1	D&B Excavation	m³	6,343.85	10,068.00	63,869,882	56.5	358,316		-	358,316
13.14.1.2	Care of water & ventilation	%	4.00	0.00	2,554,795	-	14,333		-	14,333
13.14.2	*Rock Stabilisation & Support*									
13.14.2.1	Shotcrete C20, underground application	m³	299.98	98,956.00	29,684,326	555.2	166,532		-	166,532
13.14.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	3,727.50	0.00	0	-	0	28	102,572	102,572
13.14.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	9.20	468,000.00	4,306,349	2,625.5	24,159		-	24,159
13.14.3	*Concrete & Reinforcement*									
13.14.3.1	Invert Concrete	m³	126.03	43,319.35	5,459,321	243.0	30,627		-	30,627
13.15	**Lower Erection Chamber (space for tunnel excluded)**				**316,187,169**		**1,773,841**		**75,610**	**1,849,451**
13.15.1	*Underground Excavation*									
13.15.1.1	D&B Excavation	m³	7,118.00	10,068.00	71,664,024	56.5	402,042		-	402,042
13.15.1.2	Care of water & ventilation	%	4.00		2,866,561	-	16,082		-	16,082
13.15.2	*Rock Stabilisation & Support*									
13.15.2.1	Shotcrete C20, underground application	m³	183.18	98,956.00	18,126,760	555.2	101,693		-	101,693
13.15.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	2,747.70	0.00	-	-	0	28	75,609.9	75,610
13.15.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	2.75	468,000.00	1,285,924	2,625.5	7,214		-	7,214
13.5.3	*Concrete & Reinforcement*									
13.5.3.1	Backfill concrete C20	m³	6,114.00	36,350.00	222,243,900	203.9	1,246,810		-	1,246,810
13.16	**Contingencies**				**1,292,562,061**		**7,251,400**		**539,646**	**7,791,046**
13.16.1.1	Contingencies	%	5%		1,292,562,061	-	7,251,400		539,646	7,791,046
14	**Gabarband Crossing**				**603,950,230**		**3,388,220**		**54,804**	**3,443,024**
14.1	**Gabarband Crossing**				**575,190,696**		**3,226,876**		**52,195**	**3,279,071**
14.1.1	*Surface Excavation*									
14.1.1.1	Clearing & grubbing	m²	3,000.00	57.00	171,000	0.3	959		-	959
14.1.1.2	Loose excavation	m³	46,616.40	2,364.00	110,201,170	13.3	618,239		-	618,239
14.1.1.3	Ripping excavation	m³	2,589.80	577.00	1,494,315	3.2	8,383		-	8,383
14.1.1.4	Blasting excavation	m³	2,589.80	6,682.00	17,305,044	37.5	97,083		-	97,083
14.1.2	*Rock Stabilisation & Support*									
14.1.2.1	Shotcrete C20, surface application	m³	143.26	98,956.00	14,176,445	555.2	79,531		-	79,531
14.1.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, surface application	m	1,896.78	0.00	-	-	0	28	52,194.6	52,195
14.1.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, surface application	t	7.22	468,000.00	3,379,924	2,625.5	18,962		-	18,962
14.1.2.4	Surface Drainage	m	265.27	5,594.28	1,483,968	31.4	8,325		-	8,325
14.1.3	*Drilling & Grouting*									
14.1.3.1	Cut-off wall	m²	1,665.00	49,880.00	83,050,200	279.8	465,920		-	465,920
14.1.4	*Concrete & Reinforcement*									
14.1.4.1	Mass concrete, C15	m³	350.00	29,736.00	10,407,600	166.8	58,388		-	58,388
14.1.4.2	Structural concrete C25	m³	2,073.00	43,319.35	89,801,013	243.0	503,792		-	503,792
14.1.4.3	Reinforcement	t	145.11	364,005.00	52,820,766	2,042.1	296,330		-	296,330
14.1.4.4	Free-Draining Backfill	m³	44,672.00	4,084.00	182,440,448	22.9	1,023,509		-	1,023,509
14.1.4.5	Rip Rap	m³	1,685.00	5,020.06	8,458,805	28.2	47,455		-	47,455
14.2	**Contingencies**				**28,759,535**		**161,344**		**2,610**	**163,954**
14.2.1.1	Contingencies	%	5%		28,759,535	-	161,344		2,610	163,954
15	**Tailrace Outlet Structrure**				**312,814,808**		**1,754,922**		**112,327**	**1,867,249**
15.1	**Tailrace Outlet Structure**				**297,918,865**		**1,671,354**		**106,978**	**1,778,332**
15.1.1	*Surface Excavation*									
15.1.1.1	Clearing & grubbing	m²	500.00	57.00	28,500	0.3	160		-	160
15.1.1.2	Loose excavation	m³	7,419.00	2,364.00	17,538,516	13.3	98,393		-	98,393
15.1.1.3	Ripping excavation	m³	3,709.50	577.00	2,140,382	3.2	12,008		-	12,008
15.1.1.4	Blasting excavation	m³	25,966.50	6,682.00	173,508,153	37.5	973,398		-	973,398
15.1.2	*Rock Stabilisation & Support*									
15.1.2.1	Shotcrete C20, surface application	m³	487.00	98,956.00	48,191,572	555.2	270,359		-	270,359
15.1.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, surface application	m	3,887.63	0.00	0	-	0	28	106,977.8	106,978
15.1.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, surface application	t	18.75	468,000.00	8,774,766	2,625.5	49,227		-	49,227
15.1.2.4	Surface Drainage	m	740.50	5,594.28	4,142,564	31.4	23,240		-	23,240
15.1.3	*Concrete & Reinforcement*									
15.1.3.1	Mass concrete, C15	m³	24.00	29,736.00	713,664	166.8	4,004		-	4,004
15.1.3.2	Structural concrete C25	m³	613.00	43,319.35	26,554,762	243.0	148,975		-	148,975
15.1.3.3	Reinforcement	t	42.91	364,005.00	15,619,455	2,042.1	87,627		-	87,627
15.1.3.4	Free-Draining Backfill	m³	173.00	4,084.00	706,532	22.9	3,964		-	3,964

No.		DESCRIPTION	UNIT	QUANTITY	ESTIMATE						
					LCC				FCC		TOTAL AMOUNT LCC + FCC (USD)
					UNIT PRICE (PKR)	AMOUNT (PKR)	UNIT PRICE (Eq. USD)	AMOUNT (Eq. USD)	UNIT PRICE (USD)	AMOUNT (USD)	
15.2		**Contingencies**				**14,895,943**		**83,568**		**5,349**	**88,917**
	15.2.1.1	Contingencies	%	5%		14,895,943	-	83,568		5,349	88,917
16		**Powerhouse and Transformer Caverns incl. Access Tunnels**				**7,748,969,823**		**43,472,481**		**2,879,569**	**46,352,050**
16.1		**Powerhouse and Transformer Caverns**				**4,989,447,613**		**27,991,291**		**1,031,290**	**29,022,581**
16.1.1		*Underground Excavation*									
	16.1.1.1	D&B Excavation - normal	m^3	52,050.44	10,068.00	524,043,850	56.5	2,939,937		-	2,939,937
	16.1.1.2	D&B Excavation - smooth	m^3	87,823.63	6,050.00	531,332,962	33.9	2,980,830		-	2,980,830
	16.1.1.3	Care of water & ventilation	%	4.00		42,215,072	-	236,831		-	236,831
16.1.2		*Rock Stabilisation & Support*									
	16.1.2.1	Shotcrete C20, underground application	m^3	5,422.00	98,956.00	536,539,036	555.2	3,010,037		-	3,010,037
	16.1.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	37,477.58	0.00	-	-	0	28	1,031,290.4	1,031,290
	16.1.2.3	Pre-stressed tendons	m	4,200.00	385.00	1,617,000	2.2	9,072		-	9,072
	16.1.2.4	Pre-stressed thread bar anchors	m	9,746.06	2,580.00	25,144,841	14.5	141,065		-	141,065
	16.1.2.5	Wire mesh 100 mm x 100 mm, underground application	t	448.40	468,000.00	209,851,317	2,625.5	1,177,286		-	1,177,286
16.1.3		*Concrete & Reinforcement*									
	16.1.3.1	Invert Concrete	m^3	45.41	43,319.35	1,967,045	243.0	11,035		-	11,035
	16.1.3.2	Final concrete lining C25	m^3	643.10	44,618.93	28,694,613	250.3	160,980		-	160,980
	16.1.3.3	First Stage Concrete C25	m^3	28,004.30	45,957.50	1,287,007,573	257.8	7,220,239		-	7,220,239
	16.1.3.4	Second Stage Concrete C25	m^3	2,114.00	47,336.22	100,068,776	265.6	561,396		-	561,396
	16.1.3.5	Reinforcement	t	4,672.21	364,005.00	1,700,709,053	2,042.1	9,541,145		-	9,541,145
	16.1.3.6	Consolidation Grouting	m^3	1.66	154,205.00	256,474	865.1	1,439		-	1,439
16.2		**Main Access & Power Evacuation Tunnel**				**1,370,539,795**		**7,688,863**		**1,124,556**	**8,813,419**
16.2.1		*Underground Excavation*									
	16.2.1.1	D&B Excavation	m^3	65,444.20	10,068.00	658,892,191	56.5	3,696,450		-	3,696,450
	16.2.1.2	Care of water & ventilation	%	4.00		26,355,688	-	147,858		-	147,858
16.2.2		*Rock Stabilisation & Support*									
	16.2.2.1	Shotcrete C20, underground application	m^3	1,870.41	98,956.00	185,088,210	555.2	1,038,363		-	1,038,363
	16.2.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	27,375.29	0.00	-	-	0	28	753,300.4	753,300
	16.2.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	97.63	468,000.00	45,690,398	2,625.5	256,328		-	256,328
	16.2.2.4	Spiling Ø25 mm, 420 N/mm2	m	7,758.02	0.00	-	-	0	30	234,829.6	234,830
	16.2.2.5	Steel ribs TH36	t	48.07	0.00	0	-	0	2,838	136,426.0	136,426
16.2.3		*Concrete & Reinforcement*									
	16.2.3.1	Invert Concrete	m^3	1,500.93	43,319.35	65,019,470	243.0	364,766		-	364,766
	16.2.3.2	Backfill concrete C20	m^3	417.48	36,350.00	15,175,334	203.9	85,135		-	85,135
	16.2.3.3	Final concrete lining C25	m^3	4,878.55	47,336.22	230,931,915	265.6	1,295,551		-	1,295,551
	16.2.3.4	Reinforcement	t	119.19	364,005.00	43,386,589	2,042.1	243,403		-	243,403
16.2.4		*Portal Works*									
	16.2.4.1	Portal & Allied Works	LS	1	100,000,000	100,000,000	561,009.8	561,010		-	561,010
16.3		**Emergency & Ventilation Tunnel**				**547,835,326**		**3,073,410**		**491,699**	**3,565,109**
16.3.1		*Underground Excavation*									
	16.3.1.1	D&B Excavation	m^3	22,948.08	10,068.00	231,041,285	56.5	1,296,164		-	1,296,164
	16.3.1.2	Care of water & ventilation	%	4.00		9,241,651	-	51,847		-	51,847
16.3.2		*Rock Stabilisation & Support*									
	16.3.2.1	Shotcrete C20, underground application	m^3	1,124.69	98,956.00	111,294,718	555.2	624,374		-	624,374
	16.3.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	11,165.22	0.00	-	-	0	28	307,239.3	307,239
	16.3.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	56.56	468,000.00	26,470,385	2,625.5	148,501		-	148,501
	16.3.2.4	Spiling Ø25 mm, 420 N/mm2	m	3,360.07	0.00	-	-	0	30	101,706.8	101,707
	16.3.2.5	Steel ribs TH36	t	29.16	0.00	0	-	0	2,838	82,752.7	82,753
16.3.3		*Concrete & Reinforcement*									
	16.3.3.1	Invert Concrete	m^3	908.27	43,319.35	39,345,573	243.0	220,733		-	220,733
	16.3.3.2	Backfill concrete C20	m^3	294.71	36,350.00	10,712,559	203.9	60,099		-	60,099
	16.3.3.3	Final concrete lining C25	m^3	1,248.36	44,618.93	55,700,412	250.3	312,485		-	312,485
	16.3.3.4	Reinforcement	t	38.54	364,005.00	14,028,742	2,042.1	78,703		-	78,703
16.3.4		*Portal Works*									
	16.3.4.1	Portal & Allied Works	LS	1	50,000,000	50,000,000	280,504.9	280,505		-	280,505
16.4		**Emergency & Power Evacuation Tunnel**				**95,251,228**		**534,369**		**89,501**	**623,870**
16.4.1		*Underground Excavation*									
	16.4.1.1	D&B Excavation	m^3	4,878.75	10,068.00	49,119,255	56.5	275,564		-	275,564
	16.4.1.2	Care of water & ventilation	%	4%		1,964,770	-	11,023		-	11,023
16.4.2		*Rock Stabilisation & Support*									
	16.4.2.1	Shotcrete C20, underground application	m^3	304.43	36,350.00	11,066,176	203.9	62,082		-	62,082
	16.4.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	3,252.50	0.00	-	-	0	28	89,500.8	89,501
	16.4.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	12.84	468,000.00	6,008,309	2,625.5	33,707		-	33,707
16.4.3		*Concrete & Reinforcement*									
	16.4.3.1	Invert Concrete	m^3	169.13	43,319.35	7,326,602	243.0	41,103		-	41,103
	16.4.3.2	Final concrete lining C25	m^3	353.87	44,618.93	15,789,390	250.3	88,580		-	88,580
	16.4.3.3	Reinforcement	t	10.92	364,005.00	3,976,726	2,042.1	22,310		-	22,310
16.5		**Emergency Tunnel**				**6,897,297**		**38,695**		**5,400**	**44,095**
16.5.1		*Underground Excavation*									
	16.5.1.1	D&B Excavation	m^3	294.38	10,068.00	2,963,768	56.5	16,627		-	16,627
	16.5.1.2	Care of water & ventilation	%	4%		118,551	-	665		-	665
16.5.2		*Rock Stabilisation & Support*									
	16.5.2.1	Shotcrete C20, underground application	m^3	18.37	98,956.00	1,817,723	555.2	10,198		-	10,198
	16.5.2.2	Grouted Rockbolts Ø25 mm, 420 N/mm2, underground application	m	196.25	0.00	-	-	0	28	5,400.3	5,400
	16.5.2.3	Wire mesh Ø5 mm, 100 mm x 100 mm, underground application	t	0.77	468,000.00	362,531	2,625.5	2,034		-	2,034
16.5.3		*Concrete & Reinforcement*									
	16.5.3.1	Invert Concrete	m^3	10.21	43,319.35	442,074	243.0	2,480		-	2,480
	16.5.3.2	Final concrete lining C25	m^3	21.35	44,618.93	952,703	250.3	5,345		-	5,345
	16.5.3.3	Reinforcement	t	0.66	364,005.00	239,948	2,042.1	1,346		-	1,346
16.6		**Architectural finishing**				**350,000,000**		**1,963,534**		**0**	**1,963,534**
	16.6.1.1	Architectural finishing	LS	1	350,000,000	350,000,000	1,963,534.4	1,963,534		-	1,963,534
16.7		**Fire Fighting System**				**20,000,000**		**112,202**		**0**	**112,202**
	16.7.1.1	Water tank	LS	1	20,000,000	20,000,000	112,202.0	112,202		-	112,202
16.8		**Contingencies**				**368,998,563**		**2,070,118**		**137,122**	**2,207,240**
	16.8.1.1	Contingencies	%	5%		368,998,563	-	2,070,118		137,122	2,207,240
17		**Connection Switchyard**				**105,000,000**		**589,060**		**0**	**589,060**
	17.1.1.1	Civil Works	LS	1	100,000,000	100,000,000	561,009.8	561,010		-	561,010
	17.1.1.2	Contingencies	%	5%		5,000,000	-	28,050		-	28,050
18		**O&M Staff Colony**				**713,000,000**		**4,000,000**			**4,000,000**
18.1.1.		O&M Staff Colony	LS			713,000,000		4,000,000			4,000,000
19		**EPC Contractor Preliminary Works and Camp Establishment Cost**				**2,120,417,129**		**11,895,748**		**22,182,362**	**34,078,110**
19.1		**Buildings Furniture and Fixtures**				**801,000,000**		**4,493,689**		**-**	**4,493,689**
1.1.1		Offices	ft^2	25,000	3,500	87,500,000	20	490,884		-	490,884
1.1.2		Labour Accomodation	ft^2	150,000	2,500	375,000,000	14	2,103,787		-	2,103,787
1.1.3		Korean Accomodation	ft^2	20,000	3,500	70,000,000	20	392,707		-	392,707
1.1.4		Workshop	ft^2	12,000	2,000	24,000,000	11	134,642		-	134,642
1.1.5		Mosque	ft^2	2,000	3,500	7,000,000	20	39,271		-	39,271
1.1.6		Common Facilities	ft^2	15,000	3,500	52,500,000	20	294,530		-	294,530
1.1.7		Resturants	ft^2	10,000	3,500	35,000,000	20	196,353		-	196,353
1.1.8		Furniture & Fixtures and Office Supplies	LS			150,000,000		841,515		-	841,515

No.	DESCRIPTION	UNIT	QUANTITY	ESTIMATE						
				LCC				FCC		TOTAL AMOUNT LCC + FCC (USD)
				UNIT PRICE (PKR)	AMOUNT (PKR)	UNIT PRICE (Eq. USD)	AMOUNT (Eq. USD)	UNIT PRICE (USD)	AMOUNT (USD)	
19.2	**Establishment**				**1,011,935,879**		**5,677,060**		**22,182,362**	**27,859,421**
1.2.1	*Batching Plant*									
1.2.1.1	Batching Plant (2.5 Cubic Meter)	No.	1		-		-	429,730	429,730	429,730
1.2.1.2	Batching Plant (1.5 Cubic Meter)	No.	2		-		-	298,134	596,268	596,268
1.2.2	Concrete Transit Mixers	No.	8		-		-	72,931	583,448	583,448
1.2.3	*Concrete Pumps*									
1.2.3.1	Mobile Pump	No.	1		-		-	235,139	235,139	235,139
1.2.3.2	Stationary Pump	No.	2		-		-	163,951	327,902	327,902
1.2.4	Loader	No.	2		-		-	140,957	281,914	281,914
1.2.5	Towner Crane (16 Tons)	No.	1		-		-	425,245	425,245	425,245
1.2.6	Mobile Crane	No.	2		-		-	420,757	841,514	841,514
1.2.7	Raise Boring Machine (Rent)	No.	1		-		-	71,248	71,248	71,248
1.2.8	Shortcrete Machine	No.	2		-		-	180,926	361,852	361,852
1.2.9	Jumbo Drill	No.	3		-		-	142,853	428,559	428,559
1.2.10	Dozers	No.	3		-		-	85,331	255,993	255,993
1.2.11	Ice Plant	No.	1		-		-	321,344	321,344	321,344
1.2.12	Chiller Plant	No.	2		-		-	83,205	166,410	166,410
1.2.13	QAQC Lab Equipments	LS			-		-		152,904	152,904
1.2.14	Workshop equipment	LS			-		-		114,766	114,766
1.2.15	Weighing Bridge	No.	1		-		-	172,149	172,149	172,149
1.2.16	Light Construction Equipment	LS			-		-		573,829	573,829
1.2.17	Backup Generators	MW	4		-		-	252,945	1,011,780	1,011,780
1.2.18	Excavators	No.	6		-		-	91,813	550,878	550,878
1.2.19	Dump Trucks	No.	8		-		-	57,383	459,064	459,064
1.2.20	Insurances									
1.2.20.1	Expat Insurance (required to work overseas)	LS			-		-		292,426	292,426
1.2.20.2	Construction Plant & Equipment	LS			-		-		228,000	228,000
1.2.20.3	Marine Cargo Insurance	LS			-		-		150,000	150,000
1.2.20.4	Group Health and Life Insurance	LS			-		-		150,000	150,000
1.2.21	Legal & Professional Charges	LS			-		-		250,000	250,000
1.2.22	Communication (Wireless, Telephone and Internet)	LS			32,085,000		180,000		-	180,000
1.2.23	Rental Equipment	LS			84,668,750		475,000		-	475,000
1.2.24	Fleet Management Cost	LS			26,737,500		150,000		-	150,000
1.2.25	Light Vehicles	No	8	8,000,000	64,000,000		359,046		-	359,046
1.2.26	*Meal and Entertainment and Supplies*									
1.2.26.1	Local	LS			360,000,000		2,019,635		-	2,019,635
1.2.26.2	Foreigners	LS			117,707,129		660,349		-	660,349
1.2.27	Health Safety & Environment	LS			300,000,000		1,683,029		-	1,683,029
1.2.28	International Travelling, Boarding & Lodging	LS			-		-		600,000	600,000
1.2.29	Construction Measurement Monitoring System	LS			-		-		500,000	500,000
1.2.30	Water Filtration Plant	LS			-		-		100,000	100,000
1.2.31	Expat Staff Salaries & Oversees Expenses	LS			-		-		11,050,000	11,050,000
1.2.32	Site Drainage System & landscaping	LS			26,737,500		150,000		-	150,000
1.2.33	Demobilization and Site Cleaning	LS			-		-		500,000	500,000
19.3	**Electricity (Installation and Operation)**				**307,481,250**		**1,725,000**			**1,725,000**
1.3.1	Temporary Electricity Facility	LS			89,125,000		500,000		-	500,000
1.3.2	Electrical Expenses	LS			129,231,250		725,000		-	725,000
1.3.3	Diesel for Generator / Construction	LS			89,125,000		500,000		-	500,000

Annex 2.3 Cost Estimate Hydromechanical and Electro-Mechanical Works

HM & E&M Cost Estimate of Lower Spat Gah Hydropower Project

No.	DESCRIPTION	UNIT	QUANTITY	ESTIMATE LCC UNIT PRICE (PKR)	LCC AMOUNT (PKR)	LCC UNIT PRICE (Eq. USD)	LCC AMOUNT (Eq. USD)	FCC UNIT PRICE (USD)	FCC AMOUNT (USD)	TOTAL AMOUNT LCC + FCC (USD)
C	**HYDROMECHANICAL EQUIPMENT**						**-**		**56,764,521**	**56,764,521**
21	**Lower Spat Gah Headworks**				**-**		**-**		**22,555,605**	**22,555,605**
21.1	Radial Gates & Ancillaries total size 23.71 m x 9.5 m, incl. embedded parts, lifting beam and hoisting system	Set	3		-	-	-	2,744,757	8,234,270	8,234,270
21.2	Stoplog Panels 22.98 m x 9.5 m incl. embedded parts and lifting beam	Lot	1		-	-	-	1,935,514	1,935,514	1,935,514
21.3	Stoplog Panels 3 m x 9.5 m incl. embedded parts and lifting beam	Lot	1		-	-	-	110,553	110,553	110,553
21.4	Environmental flow release including intake, piping system and valves DN = 0.8 m	Lot	1		-	-	-	117,016	117,016	117,016
21.5	Gantry crane with capacity of 35 t	No.	1		-	-	-	613,000	613,000	613,000
21.6	Trashrack Panels 6.6 m x 14.1 m incl. embedded parts	Set	3		-	-	-	262,500	787,500	787,500
21.7	Trashrack Cleaning Machine	No.	1		-	-	-	949,000	949,000	949,000
21.8	Sliding gates 6.6 m x 7.0 m incl. embedded parts and hoisting system	Set	3		-	-	-	1,037,939	3,113,817	3,113,817
21.9	Stoplog Panels 6.6 m x 7.0 m incl. embedded parts	Set	1		-	-	-	504,575	504,575	504,575
21.10	Calming racks	Set	6		-	-	-	186,667	1,120,000	1,120,000
21.11	Sliding gates 1.0 m x 1.3 m incl. embedded parts and hoisting system	Set	12		-	-	-	36,128	433,541	433,541
21.12	End sill roller gates 6.15 m x 5.1 m incl. embedded parts and hoisting system	Set	6		-	-	-	681,114	4,086,683	4,086,683
21.13	Contingencies	%	2.5%		-	-	-		550,137	550,137
22	**Lower Gabarband Intake**						**-**		**1,399,032**	**1,399,032**
22.1	Radial Gate 7.08 m x 4.0 m incl. embedded earts and hoisting system	Set	1		-	-	-	154,328	154,328	154,328
22.2	Stoplog Panels 6.1 m x 4.0 m incl. embedded parts and lifting beam	Lot	1		-	-	-	88,865	88,865	88,865
22.3	Environmental flow release including intake, piping system and valves DN = 0.3 m	Lot	1		-	-	-	9,794	9,794	9,794
22.4	Trashrack Panels 2.5 m x 4.2 m incl. embedded parts	Set	2		-	-	-	52,500	105,000	105,000
22.5	Trashrack Cleaning Machine	No.	1		-	-	-	858,000	858,000	858,000
22.6	Fixed-wheel gates 2.0 m x 1.4 m incl. embedded parts and hoisting system	Set	2		-	-	-	34,662	69,324	69,324
22.7	Stoplog Panels 2.0 m 1.4 m incl. embedded parts	Lot	1		-	-	-	5,905	5,905	5,905
22.8	Calming racks	Set	6		-	-	-	9,333	56,000	56,000
22.9	Sliding gates 1.0 m x 1.0 m incl. embedded parts and hoisting system	Set	2		-	-	-	4,423	8,847	8,847
22.10	Tunnel intake fixed-wheel gate 2.1 m x 2.1 m incl. Embedded parts and hoisting system	Set	1		-	-	-	8,847	8,847	8,847
22.11	Contingencies	%	2.5%		-	-	-		34,123	34,123
23	**Power Waterway**						**-**		**32,809,884**	**32,809,884**
23.1	Fixed wheel gate 5.3 m x 5.3 m incl. embedded parts and hoisting system	Set	1		-	-	-	982,835	982,835	982,835
23.2	Stoplog Panels 5.3 m x 5.3 m incl. embedded parts	Set	1		-	-	-	370,920	370,920	370,920
23.3	Headrace tunnel steel liner Gabarband crossing, D= 4.0 m, Length=762 m	t	1,365		-	-	-	6,823	9,312,713	9,312,713
23.4	Surge shaft to pressure shaft steel liner, D=4.0 m	t	159		-	-	-	6,823	1,084,778	1,084,778
23.5	Headrace Tunnel Butterfly valve DN = 4.0 m	No.	1		-	-	-	2,798,781	2,798,781	2,798,781
23.6	Valve chamber bridge crane, lifting capacity 60 t	No.	1		-	-	-	135,086	135,086	135,086
23.7	Pressure shaft steel liner, D= 4.0 m, Length=497 m	t	1,673		-	-	-	6,823	11,414,043	11,414,043
23.8	High pressure tunnel steel liner, D= 4.0 m, Length=95 m	t	401		-	-	-	6,823	2,735,823	2,735,823
23.9	Penstock	t	422		-	-	-	6,823	2,879,095	2,879,095
23.10	Gabarband Intake Tunnel steel pipe	t	10		-	-	-	6,823	68,225	68,225
23.11	Gabarband Intake Tunnel Butterfly valve DN = 1.5 m	No.	1		-	-	-	209,345	209,345	209,345
23.12	Gabarband Junction Chamber hand chain hoist, lifting capacity 15 t	No.	1		-	-	-	18,000	18,000	18,000
23.13	Contingencies	%	2.5%		-	-	-		800,241	800,241
D	**ELECTRO-MECHANICAL EQUIPMENT**						**-**		**223,111,105**	**223,111,105**
31	**Mechanical Equipment Powerhouse**						**-**		**83,674,535**	**83,674,535**
31.1	Pelton Turbines, Governors & MIV (3 x 159.4 MW)	No.	3		-	-	-	23,507,400	70,522,200	70,522,200
31.2	Auxiliary Equipment	LS	1		-	-	-	3,647,700	3,647,700	3,647,700
31.3	Powerhouse Overhead Crane	LS	1		-	-	-	3,726,116	3,726,116	3,726,116
31.4	Fire Fighting System	LS	1		-	-	-	342,073	342,073	342,073
31.5	Air Conditioning & Ventilation System	LS	1		-	-	-	3,395,603	3,395,603	3,395,603
31.6	Contigencies	%	2.5%		-	-	-		2,040,842	2,040,842
32	**Electrical Equipment Powerhouse**						**-**		**114,209,664**	**114,209,664**
32.1	Generators (3 x 190 MVA)	No.	3		-	-	-	21,949,697	65,849,091	65,849,091
32.2	Main Unit Transformers	No.	3		-	-	-	6,746,894	20,240,682	20,240,682
32.3	Switchgears and Cables	LS	1		-	-	-	10,733,357	10,733,357	10,733,357
32.4	Control & Protection System	LS	1		-	-	-	3,343,725	3,343,725	3,343,725
32.5	Auxiliary Equipment	LS	1		-	-	-	11,257,208	11,257,208	11,257,208
32.6	Contingencies	%	2.5%		-	-	-		2,785,602	2,785,602
33	**Switchyard/GIS**						**-**		**18,688,313**	**18,688,313**
33.1	220 kV Gas isolated switchgear (GIS) in transformer cavern	LS	1		-	-	-	10,132,500	10,132,500	10,132,500
33.2	220 kV HV Cable in Tunnel and to Connection Switchyard	m	2,050		-	-	-	3,000	6,150,000	6,150,000
33.2	220 kV Connection Switchyard Equipment	LS	1		-	-	-		1,950,000	1,950,000
33.3	Contingencies	%	2.5%		-	-	-		455,813	455,813
34	**Auxiliary Supply Equipment Portal/Access Area**						**-**		**3,156,289**	**3,156,289**
34.1	11 kV Cable in Power Evacuation Tunnel	m	1,170		-	-	-	143	167,890	167,890
34.2	11 kV Cable in Main Access tunnel	m	1,520		-	-	-	143	218,113	218,113
34.3	MV Switchgear with 7 circuit breakers and complete with accessories	No.	1		-	-	-	110,381	110,381	110,381
34.4	1,000 KVA rating 11/0.4kV dry type transformer	No.	1		-	-	-	2,207,626	2,207,626	2,207,626
34.5	1,000 KVA rating 11/0.4kV Emergency Diesel Generator Set	No.	1		-	-	-	331,144	331,144	331,144
34.6	Bus tie Bus LV switchgear with 8 circuit breakers	No.	1		-	-	-	44,153	44,153	44,153
34.7	Contingencies	%	2.5%		-	-	-		76,983	76,983
35	**Auxiliary Supply Equipment Upper Erection Chamber/Surge Tank**						**-**		**161,238**	**161,238**
35.1	11kV Overhead Line from Portal/Acces Area to Upper Erection Chamber	m	1,560		-	-	-	37	57,962	57,962
35.2	25 KVA rating 11/0.4kV dry type transformer	No.	1		-	-	-	55,191	55,191	55,191
35.3	LV switchgear with 4 circuit breakers	No.	1		-	-	-	44,153	44,153	44,153
35.4	Contingencies	%	2.5%		-	-	-		3,933	3,933
36	**Auxiliary Supply Equipment Lower Spat Gah Headworks**						**-**		**1,088,294**	**1,088,294**
36.1	11kV Overhead Line from Portal/Acces Area to Lower Spat Gah Headworks Area	m	16,990		-	-	-	37	631,263	631,263
36.2	160 KVA rating 11/0.4kV dry type transformer	No.	1		-	-	-	353,220	353,220	353,220
36.3	Bus tie Bus LV switchgear with 8 circuit breakers	No.	1		-	-	-	44,153	44,153	44,153
36.4	100 KVA rating 11/0.4kV Emergency Diesel Generator Set	No.	1		-	-	-	33,114	33,114	33,114
36.5	Contingencies	%	2.5%		-	-	-		26,544	26,544
37	**Auxiliary Supply Equipment Lower Gabarband Intake**						**-**		**2,132,772**	**2,132,772**
37.1	11kV Overhead Line from Gabarband Confluence to Gabarband Crossing	m	2,830		-	-	-	37	105,149	105,149
37.2	MV Switchgear with 5 circuit breakers and complete with accessories	No.	1		-	-	-	110,381	110,381	110,381
37.3	100 KVA rating 11/0.4kV dry type transformer	No.	1		-	-	-	220,763	220,763	220,763
37.4	LV switchgear with 4 circuit breakers	No.	1		-	-	-	44,153	44,153	44,153
37.5	11 kV Cables from Gabarband Crossing to Gabarband Intake area	m	2,730		-	-	-	287	783,486	783,486
37.6	MV Switchgear with 3 circuit breakers and complete with accessories	No.	1		-	-	-	110,381	110,381	110,381
37.7	25 KVA rating 11/0.4kV dry type transformer	No.	1		-	-	-	55,191	55,191	55,191
37.8	LV switchgear with 4 circuit breakers	No.	1		-	-	-	44,153	44,153	44,153
37.9	160 KVA rating 11/0.4kV dry type transformer	No.	1		-	-	-	353,220	353,220	353,220
37.10	11 kV Circuit Breakers provided at HV side of 160 KVA rating 11/0.4kV dry type transformer	No.	2		-	-	-	22,076	44,153	44,153
37.11	Bus tie Bus LV switchgear with 8 circuit breakers	No.	1		-	-	-	44,153	44,153	44,153
37.12	500 KVA rating 11/0.4kV Emergency Diesel Generator Set	No.	1		-	-	-	165,572	165,572	165,572
37.13	Contingencies	%	2.5%		-	-	-		52,019	52,019
	INSURANCE FREIGHT									
	Delivery Cost Insurance Freight of HM & E&M Works								**19,591,294**	**19,591,294**
	Delivery Cost Insurance Freight of EMH Works including contigency	%	7%						19,591,294	19,591,294

Annex 3 Financial Analysis

LSG HYDROPOWER PROJECT
FINANCIAL PROJECTIONS
MODEL ASSUMPTIONS

Project capital cost (Amounts in USD)		
1. EPC Cost		
Onshore Works		515,266,178
E&M - Offshore		299,466,920
Sub Total		814,733,097
2. Lenders Fees		18,040,791
3. Agency & Advisory Costs		7,755,328
4. Engineering Supervision		34,998,402
5. Land Acquisition & Resettlement		7,824,235
6. Insurance During Construction		24,500,000
7. O&M Mobilization		4,626,524
8. Customs Duties and Taxes		16,575,494
9. Project Development Cost		38,971,603
10. Environment & Ecology		9,616,490
11. Legal Cost		2,679,520
Total General & Non EPC Costs	20.3%	165,588,387
Base Project Cost		980,321,484
Negative cost overruns		-
Add: Interest During Construction		104,832,000
Total Cost for EPC Stage Tariff		1,085,153,484

Financing structure (Amounts in USD)		
Debt	75%	813,865,113
Equity	25%	271,288,371
		1,085,153,484

Foreign financing terms	
Foreign Debt (percentage)	100%
LIBOR	0.3%
Spread per annum	4.6%
Total Interest Rate (p.a.)	4.9%
WHT rate on interest payments	0.0%
Grossed up rate for WHT	4.9%
Debt - Door to Door Tenure - Years	17
Debt Availability Period - Years	5
Debt Repayment Tenure - Years	12

Operating costs		US$/annum	US Cent/KWh
Water Use Charge		4,590,954	0.2384
Variable O&M		1,937,053	0.1006
Fixed O&M - Foreign	60%	8,933,368	0.4640
Fixed O&M - Local	40%	5,955,579	0.3093
Insurance during Operations		8,147,331	0.4231

Plant out-up & general assumptions	
Net Generation per annum (Gwh)	1,925.5
Minimum E-Flows (cusecs)	1.3
Gross Capacity at Generator Terminal (MW)	470
Net Capacity at Metering System (MW)	451
Exchange rate (1 US$ = Rupees)	178.25
Water Use charge (Rupees/KWh)	0.425
Equity IRR	17.0%
Discount Rate	10.0%
Total Project Life (years)	30
Operations Insurance p.a. (% of EPC Cost)	1.00%
Variable Cost (US cents per kWh)	0.1006
O&M Cost per MW (US$ p.a.)	35,800

Equity & Loan Drawdown Pattern

Months	Equity	Debt
Pre-FC 30 months period	1.00%	0.00%
	3.00%	0.00%
	20.00%	0.00%
6	0.00%	14.00%
12	0.00%	10.00%
18	6.50%	6.50%
24	9.50%	9.50%
30	10.00%	10.00%
36	10.00%	10.00%
42	10.00%	10.00%
48	10.00%	10.00%
54	10.00%	10.00%
60	10.00%	10.00%
	100.00%	100.00%

Key project indicators	
Taxation	0%
Levelized Tariff (US cents/KWh)	8.6094
Levelized Tariff (Rupees/KWh)	15.3462
EPC Cost per MW (US$ m)	1.73
Project Cost per MW (US$ m)	2.31
Project IRR	9.56%
Project NPV @ WACC - (US$ m)	111.51
Project Payback - Years	6.76
Equity IRR	17.00%
Equity NPV @ WACC - (US$ m)	256.06
Equity Payback - Years	3.38
Minimum DSCR	1.77x
Minimum LLCR	1.87x

Sensitivity scenarios - with tariff adjustment	
Project Capacity	Project Capacity - Base Case
Project Capital Costs	Project Capital Cost - Base Case
Project OPEX	Project OPEX - Base Case

Sensitivity scenarios - without tariff adjustment	
Project Capacity	Project Capacity - Base Case
Project Capital Costs	Project Capital Cost - Base Case
Project OPEX	Project OPEX - Base Case

Working capital & other assumptions	
Receivables Period - Days	-
Payables Period - Days	-
Depreciation rate - annual	3.30%
Cash reserve requirement - USD M	-