2.6 Chera-1 Project (W-02)

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A.2.6 Chera-1 (W-02)

(1) Project Summary

The Chera-1 Project is a 148.7 MW storage-type hydroelectric power project located at the Chera river in the Jajarkot District in the western region. The latest study for this project was conducted in the “Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA.” The study level for this project remains at the desk study level.

As hydrological characteristics, the annual rainfall at the Jajarkot gauging station nearest to the project site is 1,797 mm and the average river discharge at the dam site is 34.81 m^3/s. The drainage area is 809 km^2, and the specific sediment volume is estimated to be 1,000 $t/km^2/year$. This is larger than 3,960 $t/km^2/year$, which is the value adopted by the NEA as average specific sedimentation volume in the central region. No glacier lakes having a high risk of a GLOF are identified in the drainage basin.

From a geological view point, the project area lies in the Lesser Himalaya Zone and is composed mainly of meta-diamictite, quartzite and schist. The reservoir area is underlain mainly by meta-diamictite, quartzite and schist. Meta-diamictite is calcareous and should be investigated to confirm its water tightness. The dam site is underlain by meta-diamictite, which needs further investigation to confirm water tightness. The headrace tunnel route passes through meta-diamictite, schist and quartzite, which form hard and compact rock. The bedrock of the powerhouse site is mainly composed of quartzite. The project area is located in an area where a large acceleration of 250 mgal is shown on the seismic hazard map. However, it is away from a large tectonic thrust (MBT) at a long distance of 30 km and from epicenters larger than M4 at a relatively long distance of 10 km.

The impact on the Natural Environment is average and the impact on the Social Environment is low. Chera-1 is located in the Karnali river basin and the reservoir is the smallest at 4km^2. The affected forest area is 1.46 km^2, which is the smallest next to Nalsyau Gad. There are three projected areas downstream of the project area and six important species that depend on water are known. The number of resettlements is 566, which is average, but the number of resettlements per unit generation is 3.81 HH/MW, which is the highest next to Lower Badigad. There is only one affected Indigenous group (Magar (Disadvantaged)). The affected agricultural land is 1.1 $km^{2,}$ which is also the smallest next to Kokhajor-1. The number of fishermen is small at 25. There are no big development plans in the reservoir area.

From the view point of hydropower planning, a large rockfill dam with a height of 186 m and volume of 10 million m^3 is planned. Since it is recognized that the geological condition at dam site has to be confirmed in terms of water tightness, the works for dam will be on the critical path on the construction stage. The length of headrace tunnel is approximately 4 km. In the current layout, no specific risks are identified at the tunnel site in terms of geological conditions. The powerhouse is of a conventional open type, and no specific technical risks are identified at the powerhouse site.

The location, basic layout and salient features of the project are shown below.

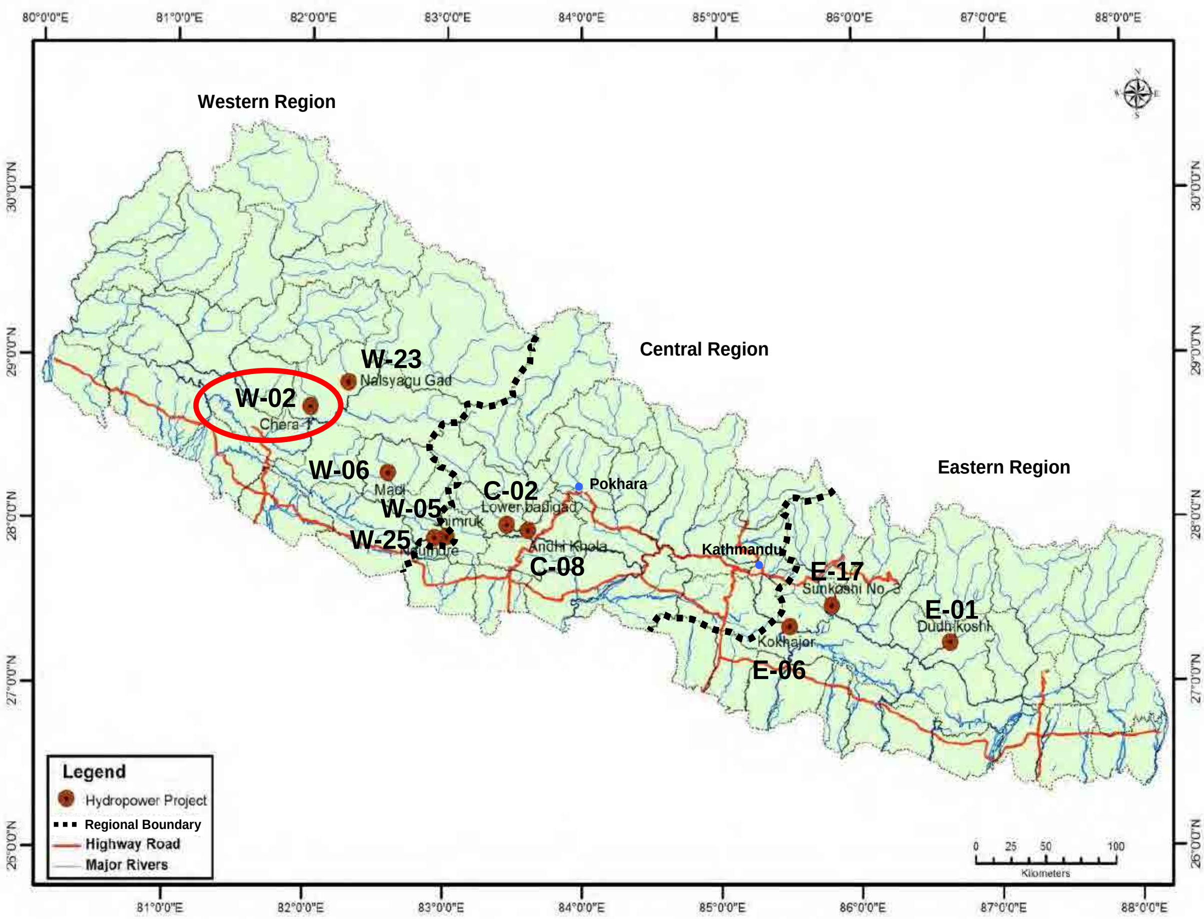


Figure A.2.6-1 Location of the Chera-1 Project (W-02)

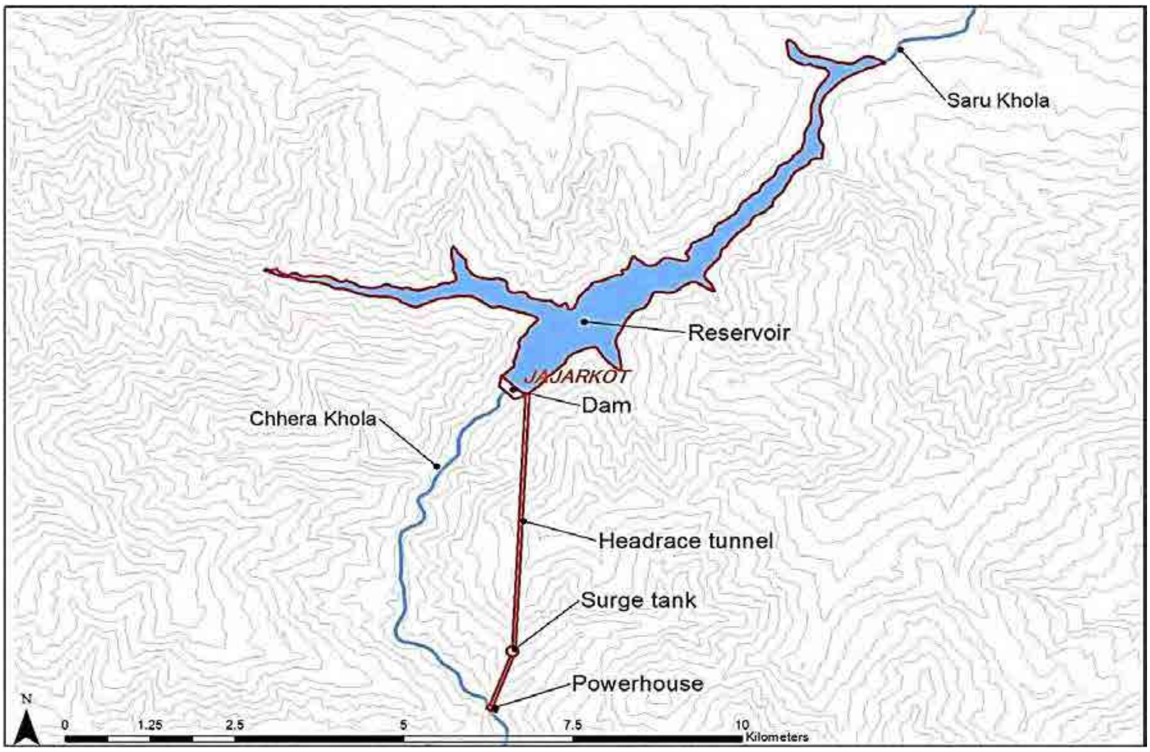


Figure A.2.6-2 General Layout of the Chera-1 Project (W-02)

Table A.2.6-1 Project Description

Item	Unit	Chera-1	Remarks
Location	(District)	Jajarkot	
Name of the River	(River)	Chera	
Installed Capacity	MW	148.7	
Catchment Area	km^2	809	
Location of Dam Site	Longitude/ Latitude	82° 1' 12.1" 28° 42' 56.4"	
Dam Height	m	186.0	
Total Storage Volume	MCM	254.9	
Effective Storage Volume	MCM	141.1	
Regulating Capability Factor	%	12.9	
Reservoir Area at FSL	km^2	4.0	
Full Supply Level	m	866.0	
Minimum Operation Level	m	814.0	
Tail Water Level	m	640.0	
Rated Gross Head	m	220.0	
Rated Net Head	m	217.6	
Rated Power Discharge	m^3/s	80.5	
Total Energy	GWh	563.2	Estimated by the Study Team.
Dry Energy (December-April)	GWh	120.6	Estimated by the Study Team.
Length of Access Road	km	5.5	
Length of Transmission Line	km	66.0	Estimated by the Study Team.
Number of Household	nos	566	Surveyed by the Study Team in 2012.
Project Cost	MUS$	576.9	Estimated by the Study Team at 2013 price level.
Unit Generation Cost	cent/kWh	10.2	Estimated by the Study Team.
EIRR (8% of Interest Rate, 12NRs/kWh)	%	12.6	Estimated by the Study Team.
FIRR (8% of Interest Rate, 12NRs/kWh)	%	17.8	Estimated by the Study Team.

Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA (except remarked items)

In addition, the summary of natural and social environmental investigation result and its evaluation are shown below. The detailed information is summarized in Appendix 3 and 5.

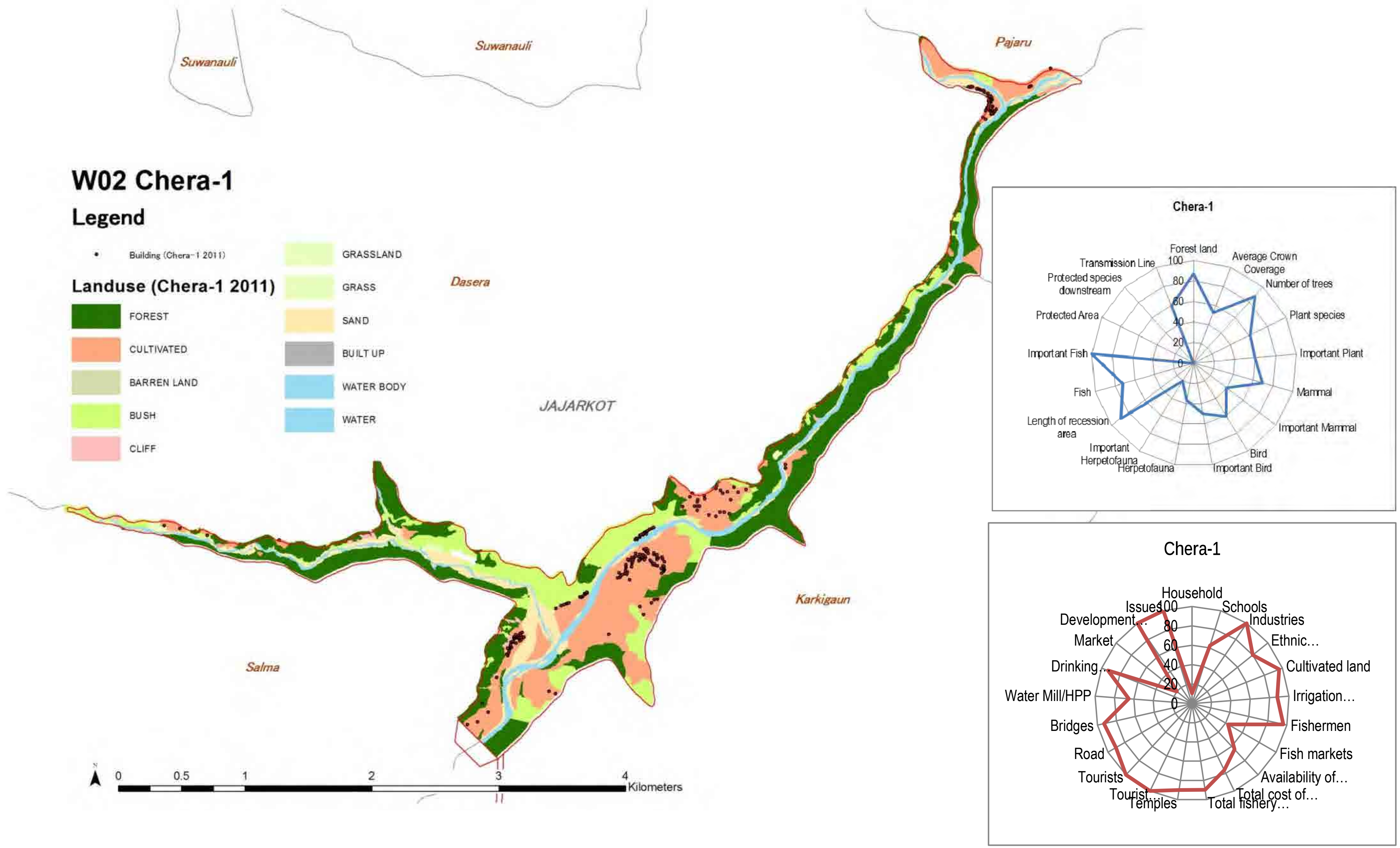


Figure A.2.6-3 Land Use and Buildings in the Reservoir Area of the Chera-1 Project

(2) Meteorology & Hydrology

With regard to the Chera-1 project, the meteorological characteristics and the criteria for hydrological evaluation, namely reliability of flow data, risk of a GLOF and sediment impact are mentioned below.

1) Meteorology

The Chera-1 project site is located at the Chera river. The district where the project site is located at is Jajarkot.

The Jajarkot precipitation station (0404) is located in the Jajarkot district. Table A.2.6-2 shows the monthly rainfall at the Jajarkot station.

Table A.2.6-2 Monthly Rainfall at the Jajarkot Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
JAJARKOT	0404	Jajarkot	PRECIPITATION	Jan, 57	28.70	82.20	1,231

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
30.3	35.4	37.2	35.0	61.9	282.0	478.8	487.0	250.8	68.7	10.4	19.0	1,796.6

2) Reliability of flow data

As there is no gauging station near the Chera-1 project site, the flow of the project is calculated by the Regional Analysis. The reliability of flow data of the Chera-1 project is relatively low.

Table A.2.6-3 shows the monthly flow data used for energy calculation.

Table A.2.6-3 Flow Data of the Chera-1 Project

(m^3/s)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
9.31	7.97	7.57	8.50	12.85	34.18	88.64	108.25	77.12	34.98	16.75	10.97	34.76

3) Risk of GLOF

There is no potentially critical glacier lake which may cause a GLOF in the upstream area of the Chera-1 project site.

4) Sediment Impact

The specific sediment yield of the Chera-1 project site was estimated to be 1,000 t/km^2/year based on the sediment data at the gauging station (240) near the project site. By using this yield, the life of the reservoir is estimated. The life of reservoir is an index to evaluate the sediment impact to reservoir and calculated dividing total storage volume by mean annual sediment yield.

Table A.2.6-4 shows the calculation result of the life of reservoir. The life of reservoir of the Chera-1 project is estimated to be 510 years.

Table A.2.6-4 Life of Reservoir

a) Specific Sediment Yield	1,000 t/km^2/yr
b) Sediment Yield (Catchment Area × Specific Sediment Yield / Sediment Density)	0.5×10^6 m^3/yr (809 km^2 × 1,000 t/km^2/y / 1.5 t/m^3)
c) Total Storage Volume	254.9×10^6 m^3
d) Life time of Storage (Total Storage Volume / Sediment Yield)	510 years (254.9×10^6 m^3 / 0.5×10^6 m^3/yr)

(3) Geology

1) Site Geology

The Chera-1 project area belongs to the Jajarkot district, west in Nepal. The dam site is located on the middle stream of the Chera river. According to the field geological survey, geology and engineering geology of the project area are as follows.

The geological map of the project area is shown in Figure A.2.6-2. The project area lies in the Lesser Himalayan Zone, and is underlain by Lower Schist, Lower Quartzite, Meta-diamictite, Upper Quartzite and Upper Schist. Lower Schist is composed of alternation of phyllite or garnet schist and quartzite. Lower Quartzite is composed of quartzite with intercalation of thin schist. Meta-diamictite is a metamorphied pelagic rock containing calcareous clasts. Upper Quartzite is composed of quartzite with intercalation of schist and phyllite. Upper Schist is composed of garnet schist and quartzite.

The reservoir and its surrounding areas are, from upstream to downstream, underlain by Lower Schist, Lower Quartzite and Meta-diamictite. Beds of these formations incline gently toward downstream. Rocks distributed in the reservoir area are impervious except meta-diamictite, some part of which may pervious as indicated by dissolved calcareous clasts by weathering. The engineering geological map of the reservoir and its surrounding area is shown in Figure A.2.6-3. Though, about half of the reservoir and its surrounding area are covered with colluvium, major landslides are limited.

The dam site is underlain by meta-diamictite, with poorly developed joints. Bedding planes incline gently toward downstream. To confirm the low permeability of meta-diamictite, further investigation is needed. The depth of river deposits is assumed to be less than 25 m.

The headrace tunnel route is located on the left bank of the Chera river, where is underlain by Meta- diamictite, Upper Quartzite and Upper Schist. Bedding planes which are oblique to the tunnel direction, incline gently toward south or southeast. The overburden of this tunnel is up to 400 m.

The powerhouse site is located on an alluvial terrace on the left bank of the Chera river. Bed rock of this site is composed of quartzite of Upper Schist. The depth of river deposits is assumed to be less than 25 m.

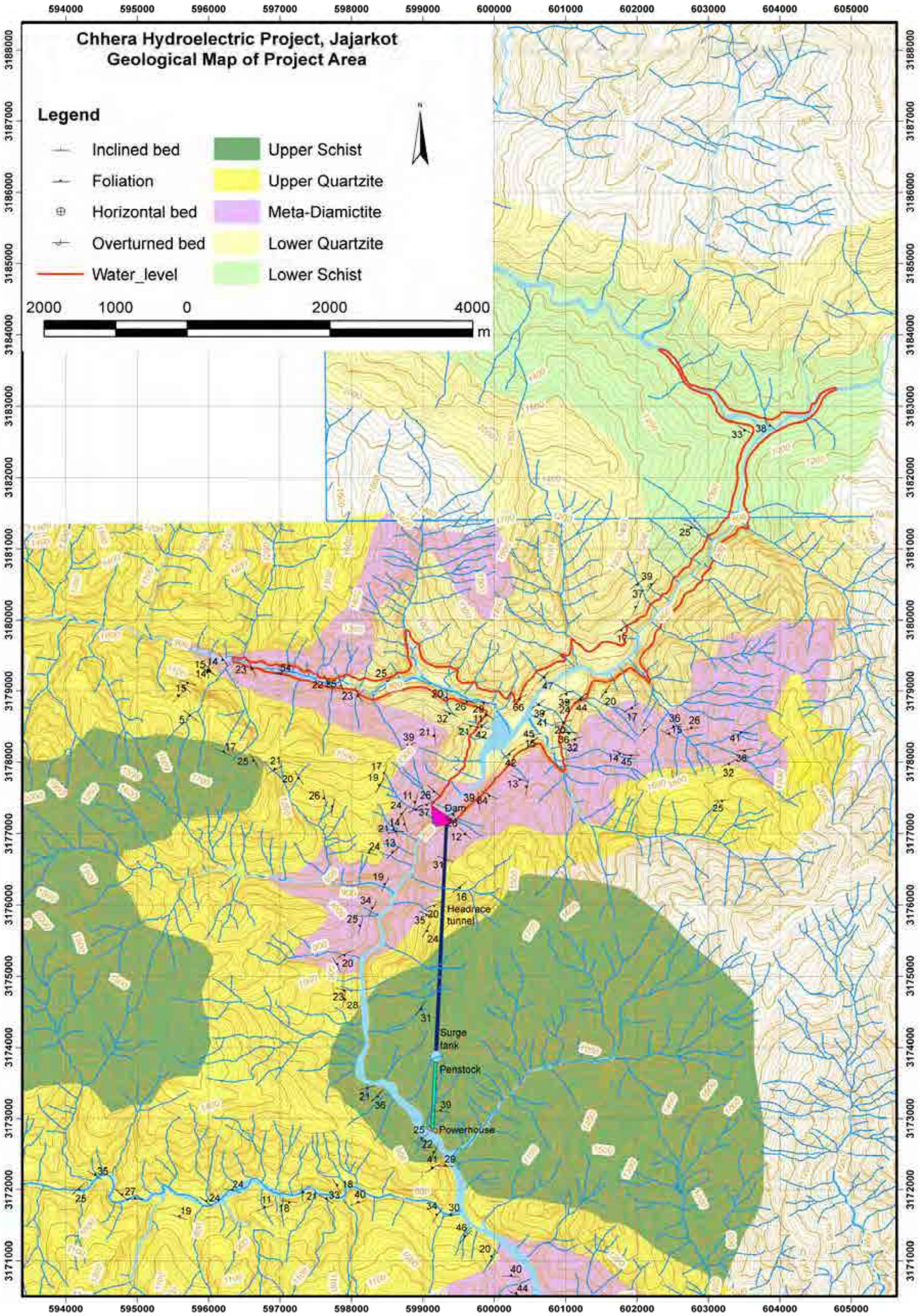
Gravels distributed near the dam site or near the confluence of the Salma river about 1 km upstream of the dam site are suitable for coarse aggregate. Fine aggregates are distributed on the river bed of the Bheri river 10 km downstream of the dam site. Colluvium and residual soil distributed in the area underlain by Upper schist or Lower schist would be investigated for borrow area of soil materials. Quartzite distributed in the reservoir area would be investigated for quarry of rock materials.

2) Thrust and Fault

Among large tectonic thrust, MBT is located to the southwest of the dam site at a distance of 30 km. Major fault has not been found at a distance less than 1 km from the dam site.

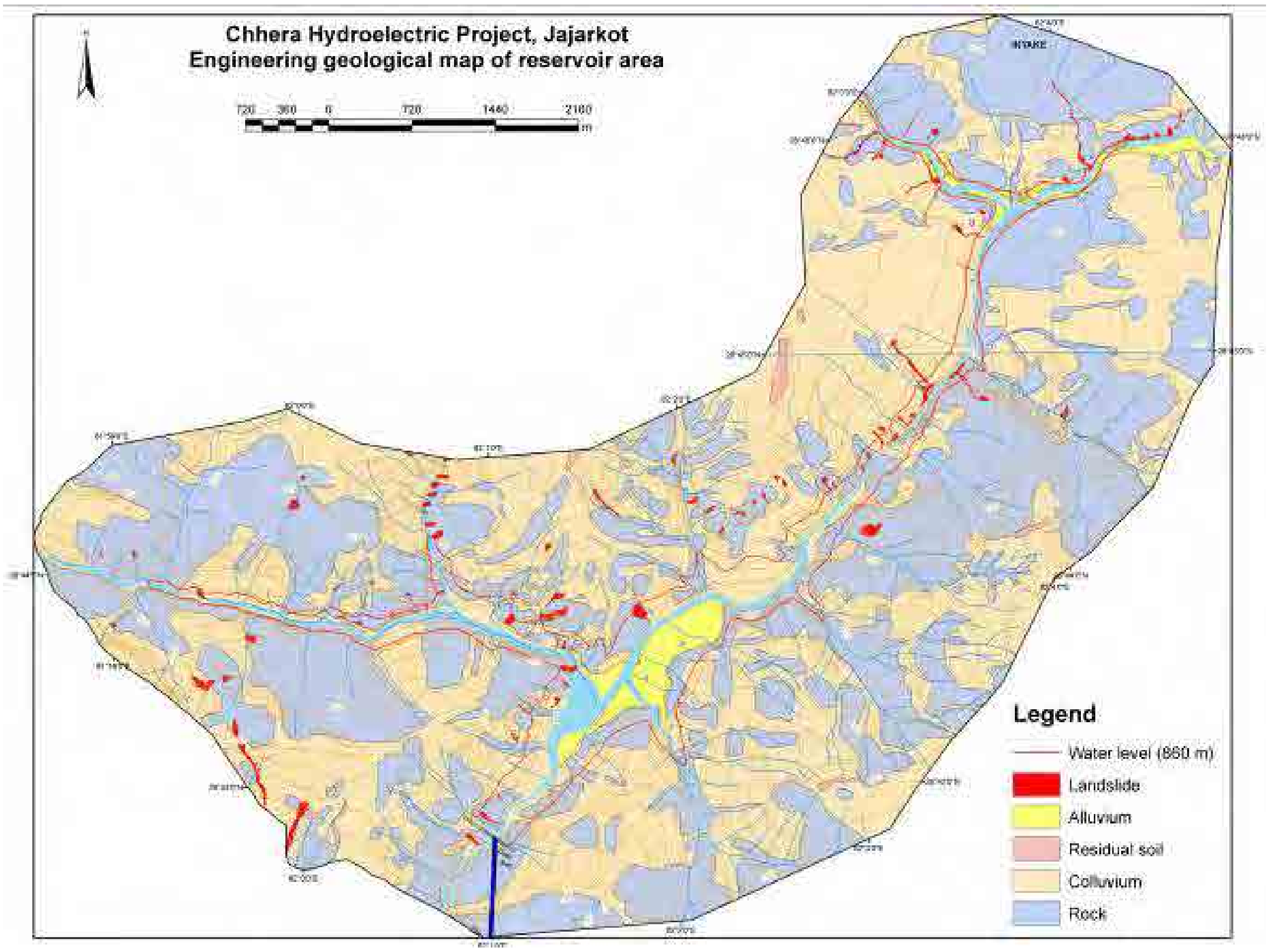
3) Seismicity

The Project area is located in the Lesser Himalaya. The horizontal ground acceleration of this area is 250 mgal according to the Seismic Hazard Map of Nepal. The nearest epicenter of $M \geqq 4$ to the dam site is located to the northwest at a distance of about 10 km.



Source: NESS Field Survey, 2012

Figure A.2.6-4 Geological map of the project area



Source: NESS Field Survey, 2012

Figure A.2.6-5 Engineering geological map of the reservoir and its surrounding region

(4) Development Plan

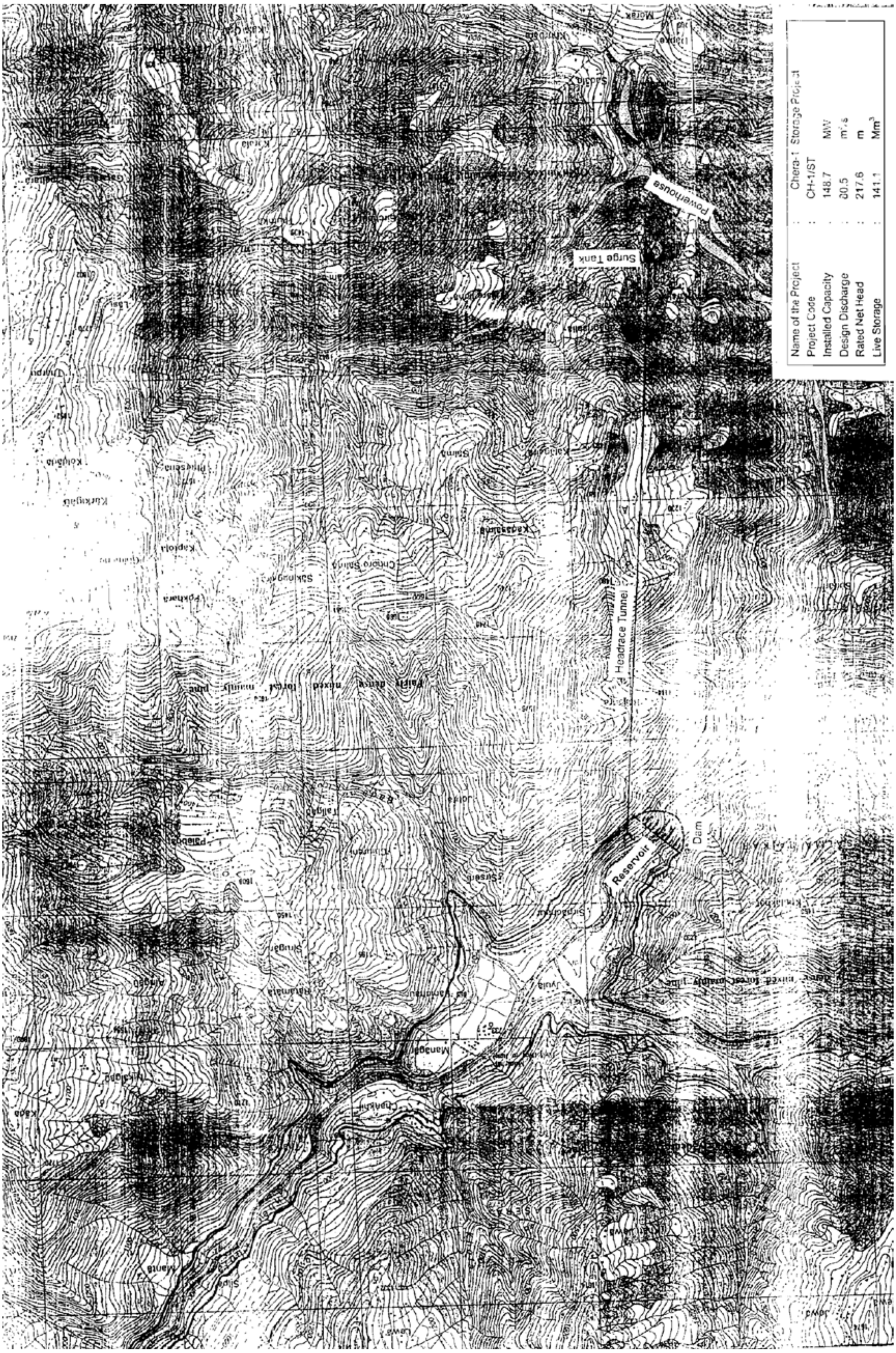
The Chera-1 Project is a dam and waterway-type hydropower project. Since the study level stays at desk study level, the basic design drawings are not available.

The salient features of principal layout and basic layout drawing of the project are as follows:

Table A.2.6-5 Salient Features

Item	Unit	Chera-1	Remarks
Reservoir			
Reservoir Area at FSL	km^2	4.0	
Total Storage Capacity	MCM	254.9	
Effective Storage Capacity	MCM	141.1	
Full Supply Level (FSL)	m	866.0	
Minimum Operating Level (MOL)	m	814.0	
Dam			
Type of Dam	-	Rockfill	
Dam Volume	MCM	9.8	
Total Dam Height	m	186	
River Bed Level at Dam Axis	m	700	
Spillway Type	-	Gated Spillway	
Waterway & Powerhouse			
Intake Type	-	Normal Pressure Intake	
Concrete Lined Headrace Tunnel Length	m	4,250	
Circular Tunnel Diameter	m	5.90	
Penstock Length	m	250	
Type of Powerhouse	-	Surface	
Turbine Type	-	Vertical Francis	
Installed Capacity	MW	148.7	
Design Discharge	m^3/s	80.5	
Rated Net Head	m	217.6	
Tail Water Level	m	640	
Tailrace Length	m	0	

Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA



Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA

Figure A.2.6-6 General Layout

(5) Electrical/Mechanical Equipment and Transmission Line

1) General

Rated effective head, power discharge and installed capacity of Chera-1 Project are as follows;

Rated Effective Head	: 217.60 m
Rated Power Discharge	: 80.50 m^3/s
Installed Capacity	: 148.7 MW

The HD Wiz (developed by J-POWER, based on existing hydropower plant data around world) has been used for reviewing design of electrical/mechanical equipment taking above information into consideration. Turbine efficiency and generator efficiency have been improved in recent years and installed capacity exceeded above-mentioned 148.7 MW consequently.

2) Unit Capacity and Number of Unit

Generally, for the turbine-generator, a large unit capacity is said to be more economical merits of scale. However, optimum unit capacity of the turbine-generator is determined in consideration of influence to the power system, development timing and transportation restriction.

In this project, all electrical and mechanical equipment will be transporting from foreign countries via Indian national road and un-maintained Nepalese national road to the project site. Therefore maximum unit capacity shall be set as around 100 MW and number of 2 units plan has been adopted for the project taking accident, maintenance and operation into consideration.

3) Turbine

a) Turbine Output

Rated turbine output at rated effective head of 217.60 m and rated power discharge of 40.25 m^3/s per unit can be calculated as follow;

$$\begin{aligned} Pt &= 9.8 \times Hn \times Qt \times \eta t \\ &= 9.8 \times 217.60 \times 40.25 \times 0.92 \\ &\approx 78{,}900 \text{ kW} \end{aligned}$$

where

Pt	: Rated turbine output per unit (kW)
Hn	: Rated effective head (m)
Qt	: Rated power discharge per unit (m^3/s)
ηt	: Turbine efficiency

b) Type of Turbine

Generally, type of turbine can be determined by close relation between effective head and turbine output. Vertical shaft Francis type turbine can be selected taking rated effective head and turbine output into consideration.

c) Runner Material

Stainless steel anti-corrosion type such as 13 chrome high nickels stainless steel is recommended to be applied for the runner material. Surface of runner and wear ring shall be coated (hard or soft) in case of water quality. Detailed coating method shall be specified in the detailed design stage.

d) Installed Capacity

Installed capacity can be calculated from aforementioned turbine output per unit as follow;

$$78{,}900 \text{ kW} \times 2 = 157{,}800 \text{ kW}$$

Review of energy calculation is conducted by using above installed capacity.

4) Generator

A three phase alternating current synchronous generator with vertical shaft rated capacity of 85,600 kVA and power factor of 90% lag are selected.

a) Generator Capacity

Rated generator capacity can be calculated from rated turbine output, power factor and generator efficiency as follows;

$$\begin{aligned} Pg &= Pt \times \eta g \,/\, p.f \text{ (kVA)} \\ &= 78{,}900 \times 0.977 \,/\, 0.90 \\ &\approx 85{,}600 \text{ kVA} \end{aligned}$$

where

Pg	: Rated generator capacity (kVA)
Pt	: Rated turbine output (kW)
ηg	: Generator efficiency
p.f	: Power factor, lag

As the results of above calculation, rated generator capacity is 85,600 kVA.

5) Transmission Line

Regarding designing of the transmission line, transmission line shall be connected to the closest substation based on 400 kV Transmission Line Power Development Plan by the NEA. And also thermal capacity and maximum surface potential gradient have been taken into consideration for designing of the transmission line and following specifications have been adopted. As for the transmission line length, the direct length from project area to closest substation was measured from map. Therefore, some allowance has been taken into consideration.

Connected Substation	: Chaujhari Substation
Transmission Line Voltage	: 220 kV
Length of Transmission Line	: 66 km
Conductor Type	: Bison × 1, 2 circuits

2.7 Lower Jhimruk Project (W-05)

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A.2.7 Lower Jhimruk (W-05)

(1) Project Summary

The Lower Jhimruk Project is a 142.5 MW storage-type hydroelectric power project located at the Jhimruk river in the Arghakhachi District and the Pyuthan District in the western region. The latest study for this project was conducted in the "Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA." The study level for this project remains at the desk study level.

As hydrological characteristics, the annual rainfall at the Khanchikot gauging station nearest to the project site is 1,772 mm and the average river discharge at the dam site is 33.9 m^3/s. The drainage area is 995 km^2, and the specific sediment volume is estimated to be 5,750 $t/km^2/year$. This is larger than 3,960 $t/km^2/year$, which is the value adopted by the NEA as average specific sedimentation volume in the western region. No glacier lakes having a high risk of a GLOF are identified in the drainage basin.

From a geological view point, the project area lies in the Lesser Himalaya Zone and is composed mainly of shale, sandstone and dolomite. The reservoir area is underlain mainly by shale, sandstone and dolomite. Dolomite should be investigated to confirm its water tightness. The dam site is underlain by shale and sandstone, which form sound and impervious bedrock. The headrace tunnel route passes through shale and sandstone, which would form hard and compact rock. It also passes through one major fault. The bedrock of the powerhouse site is composed of sheared slate, which would decrease the stability of slopes behind the powerhouse site. The project area is located in an area where a relatively small acceleration of 150 mgal is shown on the seismic hazard map. It is away from epicenters larger than M4 at a long distance of 34 km. However, it is close to a large tectonic thrust (MBT) at a short distance of 2 km.

The impact on the Natural Environment is average and the impact on the Social Environment is low. Lower Jhimruk is located in the Rapti river basin and the reservoir area is 6 km^2. The affected forest area is not large at 1.87 km^2. The recorded number of plants is relatively high at 55. The recorded number of fauna is relatively high with numbers such as 23 mammals, 49 birds, and 17 Herpetofauna. The number of resettlements is 229. There are 3 affected irrigation systems. The number of fishermen is 254, which is relatively high next to Sun Koshi No.3. The Indigenous groups in the reservoir area are the Newar (Advanced), Magar (Disadvantaged), Gurung (Disadvantaged) and Kumal (Marginalised).

From the view point of hydropower planning, a rockfill dam with a height of 167 m and a volume of 7 million m^3 as well as a headrace tunnel of 6 km are planned. In the current layout, the dam and powerhouse of the Lower Jhimruk project are located in the reservoir of the Naumure project located downstream of the Lower Jhimruk. Therefore, it is impossible to construct both projects with the current layouts. It is at least necessary to change the layout of either project to implement both projects.

The location, basic layout and salient features of the project are shown below.

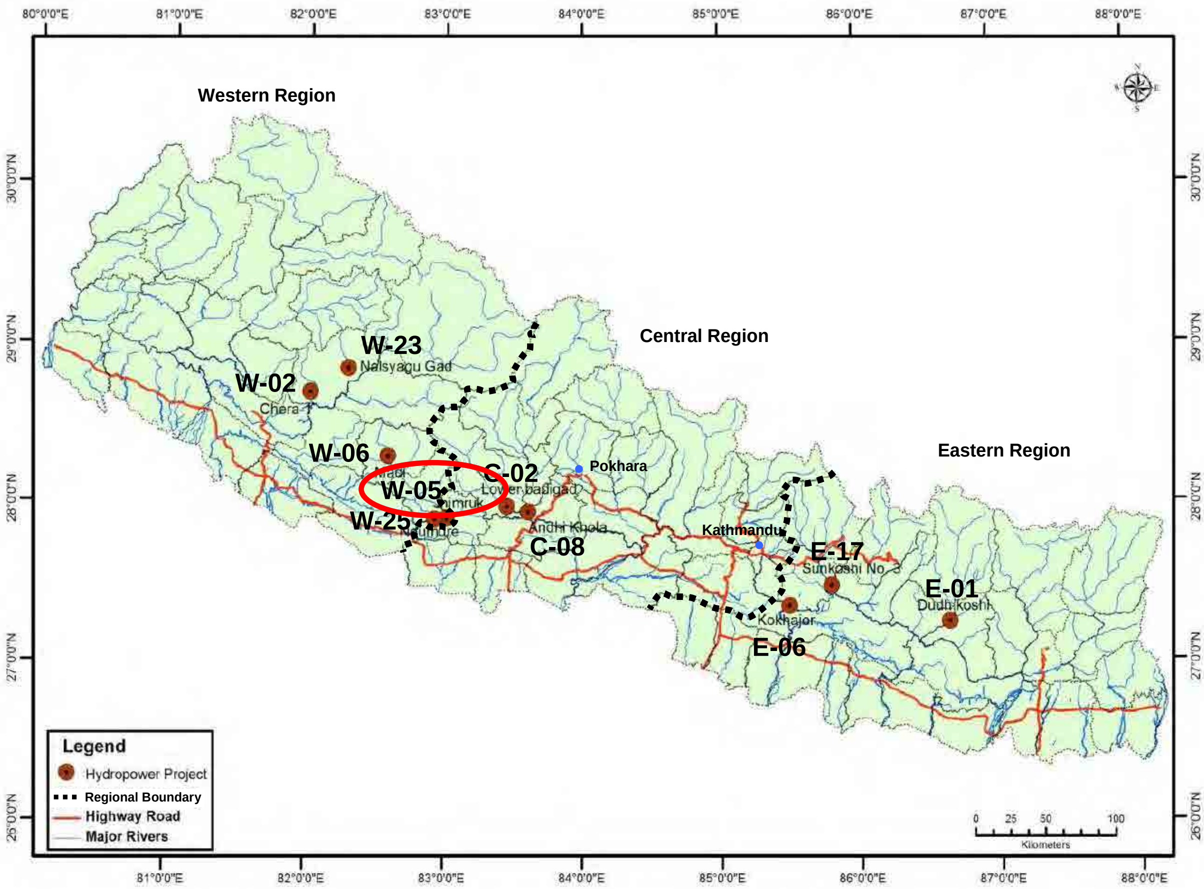


Figure A.2.7-1 Location of the Lower Jhimruk Project (W-05)

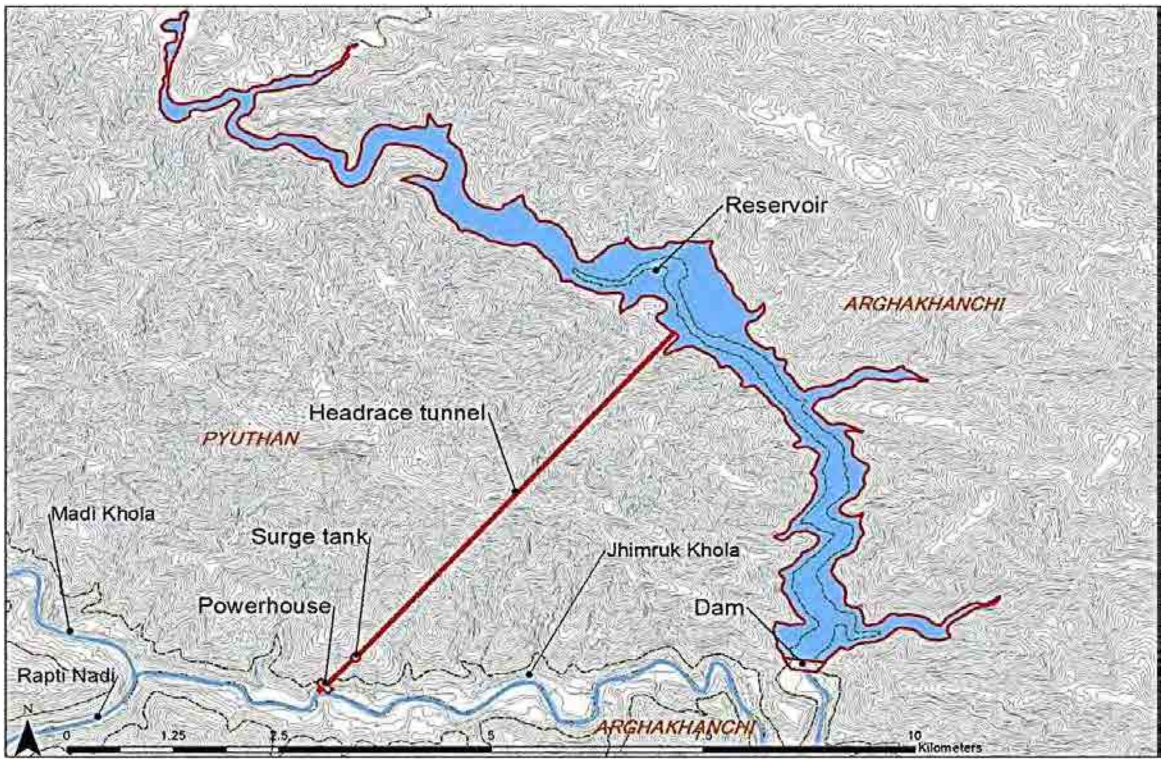


Figure A.2.7-2 General Layout of the Lower Jhimruk Project (W-05)

Table A.2.7-1 Project Description

Item	Unit	Lower Jhimruk	Remarks
Location	(District)	Arghakhachi Pyuthan	
Name of the River	(River)	Jhimruk	
Installed Capacity	MW	199.8	
Catchment Area	km^2	995.0	
Location of Dam Site	Longitude/ Latitude	83° 1' 1" 27° 55' 30.8"	
Dam Height	m	167.0	
Total Storage Volume	MCM	386.0	
Effective Storage Volume	MCM	211.6	
Regulating Capability Factor	%	19.8	
Reservoir Area at FSL	km^2	5.7	
Full Supply Level	m	597.0	
Minimum Operation Level	m	557.0	
Tail Water Level	m	390.0	
Rated Gross Head	m	194.6	
Rated Net Head	m	190.4	
Rated Power Discharge	m^3/s	88.1	
Total Energy	GWh	454.7	Estimated by the Study Team.
Dry Energy (December-April)	GWh	94.4	Estimated by the Study Team.
Length of Access Road	km	18.0	
Length of Transmission Line	km	75.0	Estimated by the Study Team.
Number of Household	nos	229	Surveyed by the Study Team in 2012.
Project Cost	MUS$	520.9	Estimated by the Study Team at 2013 price level.
Unit Generation Cost	cent/kWh	11.5	Estimated by the Study Team.
EIRR (8% of Interest Rate, 12NRs/kWh)	%	10.9	Estimated by the Study Team.
FIRR (8% of Interest Rate, 12NRs/kWh)	%	11.5	Estimated by the Study Team.

Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA (except remarked items)

In addition, the summary of natural and social environmental investigation result and its evaluation are shown below. The detailed information is summarized in Appendix 3 and 5.

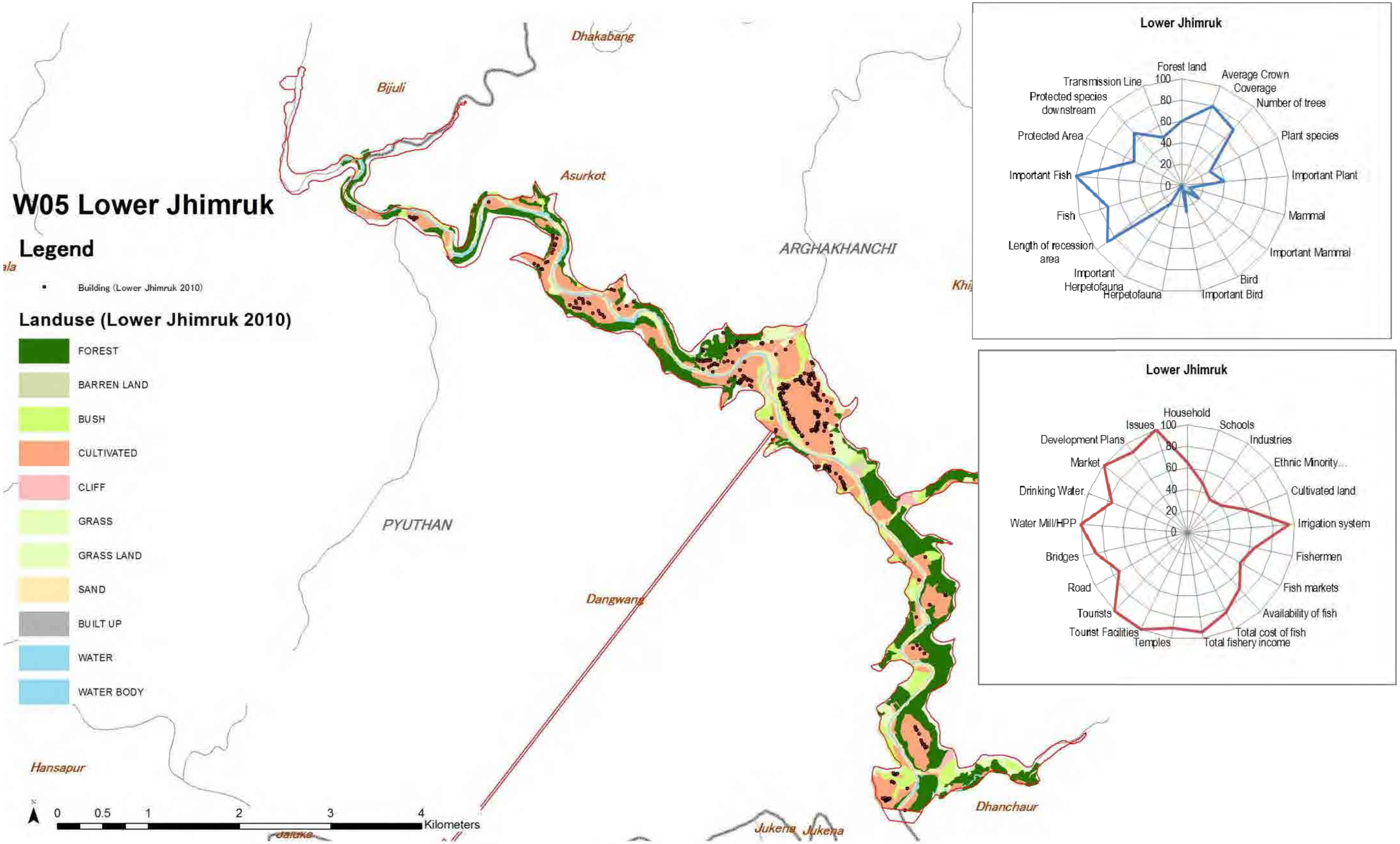


Figure A.2.7-3 Land Use and Buildings in the Reservoir Area of the Lower Jhimruk Project

(2) Meteorology & Hydrology

With regarding to the Lower Jhimruk project, the meteorological characteristics and the criteria for hydrological evaluation, namely reliability of flow data, risk of a GLOF and sediment impact are mentioned below.

1) Meteorology

The Lower Jhimruk project site is located at the Jhimruk river. The districts where the project site is located at are Arghakhanchi and Pyuthan.

The Khanchikot climatology station (0715) is located in the Arghakhanchi district. Table A.2.7-2 shows the monthly rainfall at the Khanchikot station.

The Bijuwartar precipitation station (0505) is located in the Pyuthan district. Table A.2.7-3 shows the monthly rainfall at the Bijuwartar station.

Table A.2.7-2 Monthly Rainfall at the Khanchikot Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
KHANCHIKOT	0715	Arghakhanchi	CLIMATOLOGY	Jan, 71	27.93	83.15	1,760

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
26.9	35.4	30.2	36.6	105.7	280.0	495.1	390.0	269.2	67.2	12.5	23.6	1,772.3

Source: Department of Hydrology and Meteorology: DHM

Table A.2.7-3 Monthly Rainfall at the Bijuwartar Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
BIJUWAR TAR	0505	Pyuthan	PRECIPITATION	Jan, 73	28.10	82.87	823

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
23.4	27.2	25.5	35.7	78.2	234.5	314.4	265.6	156.0	42.5	6.6	11.0	1,220.4

Source: Department of Hydrology and Meteorology: DHM

2) Reliability of flow data

As the gauging station (330) is located at 27 km upstream of the dam axis, multiplying the flow data of the gauging station by the rate of catchment area of the project site to that of gauging station gives the flow data of the Lower Jhimruk project. The reliability of flow data of the Lower Jhimruk project is relatively high.

Table A.2.7-4 shows the monthly flow data used for energy calculation.

Table A.2.7-4 Flow Data of the Lower Jhimruk Project

(m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
1997	17.10	13.66	10.73	13.45	8.83	20.74	129.38	80.09	77.53	28.29	14.63	12.94	35.61
1998	7.96	6.26	6.11	5.60	5.39	10.27	81.63	150.94	124.76	57.50	27.83	18.43	41.89
1999	13.86	10.63	8.63	7.29	8.42	50.52	102.68	180.21	209.47	84.20	18.48	8.42	58.57
2000	5.80	4.92	3.72	7.39	8.21	49.90	88.31	243.36	195.10	54.42	19.05	10.83	57.58
2001	8.32	6.83	6.01	5.54	6.57	25.41	88.82	137.08	103.71	41.12	18.07	11.35	38.24
2002	10.37	10.83	8.68	6.57	7.75	11.96	24.90	91.90	36.20	18.74	9.81	6.42	20.34
2003	5.60	4.88	3.34	2.78	2.70	9.86	53.40	121.17	105.76	45.33	17.10	10.88	31.90
2004	9.34	7.39	5.90	6.93	7.70	9.24	43.74	47.70	28.96	23.98	11.91	8.11	17.58
2005	8.06	7.24	6.21	5.39	4.91	5.80	38.66	61.10	52.88	24.08	13.40	10.01	19.81
2006	7.86	6.78	6.78	6.26	8.57	11.35	37.07	43.43	39.74	18.69	10.32	7.60	17.04
Ave.	9.43	7.94	6.61	6.72	6.91	20.51	68.86	115.70	97.41	39.64	16.06	10.50	33.86

3) Risk of GLOF

There is no potentially critical glacier lake which may cause a GLOF in the upstream area of the Lower Jhimruk project site.

4) Sedimentation

The specific sediment yield of the Jhimruk Hydroelectric Project which is located near the Lower Jhimruk project site is adopted as the specific sediment yield of the Lower Jhimruk Project. According to the FS report, the specific sediment yield of the Jhimruk Hydroelectric Project is from 5,000 t/km^2/year to 6,500 t/km^2/year. The average value, 5,750 t/km^2/year, was adopted for calculation of the life of reservoir. The life of reservoir is an index to evaluate the sediment impact to reservoir and calculated dividing total storage volume by mean annual sediment yield. It indicates how many years it will take to fulfill a reservoir by sedimentation.

Table A.2.7-5 shows the calculation result of the life of reservoir. The life of reservoir of the Lower Jhimruk project is estimated to be 102 years.

Table A.2.7-5 Life of Reservoir

a) Specific Sediment Yield	5,750 t/km^2/yr
b) Sediment Yield (Catchment Area × Specific Sediment Yield / Sediment Density)	3.8×10^6 m^3/yr (995 km^2 × 5,750 t/km^2/yr / 1.5 t/m^3)
c) Total Storage Volume	386×10^6 m^3
d) Life time of Storage (Total Storage Volume / Sediment Yield)	102 years (386×10^6 m^3 / 3.8×10^6 m^3/yr)

(3) Geology

1) Site Geology

The Lower Jhimruk project area belongs to the Arghakahchi district and the Pyuthan district, west in Nepal. The project area is located on the Jhimruk river which is the border between abovementioned districts. According to the field geological survey, geology and engineering geology of the project area are as follows.

The geological map of the project area is shown in Figure A.2.7-2.The project area lies in the Lesser Himalayan Zone. MBT is located to the south of the dam site at a distance of about 3km. From south to north,, the project area is under lain by the Ranagaun Formation composed of shale with sandstone, the Khamari Formation composed of sandstone and shale, Eocene Beds composed of sandstone, the Khamari Formation and the Dhorbang Formation composed of dolomite. Beds of these rocks incline toward north. Northern limit of Eocene Beds is a fault.

The reservoir and its surrounding area are mainly underlain by sandstone and shale of the Khamari Formation, sandstone of Eocene Beds and dolomite of the Dhorbang Formation. The fault at the northern limit of Eocene Beds crosses the reservoir area. Further investigation of dolomite in terms of permeability is necessary in order to evaluate the watertightness of the reservoir area. The engineering geological map of the reservoir and its surrounding area is shown in Figure A.2.7-3. In these areas, small scale land slides are observed.

The dam site is underlain by shale and sandstone of the Khamari Formation which form sound and impervious bed rock.

The headrace tunnel route is located on the right bank of the Jhimruk river. It starts from the intake about 3 km upstream of the dam site. This route penetrates, from intake to surge tank, sandstone and shale of the Khamari Formation, fault, shale, sandstone of Eocene Beds, sandstone and shale of the Khamari Formation and shale of the Ranagaun Formation. Overburden of this tunnel is up to 700 m.

Powerhouse site is located on an alluvial terrace on the right bank of the Jhimruk river. This site is composed of shale and sandstone of the Ranagaun Formation, which bedding planes incline toward mountain, but the bedrocks are supposed to be sheared by MBT. River deposits are assumed to be relatively thick.

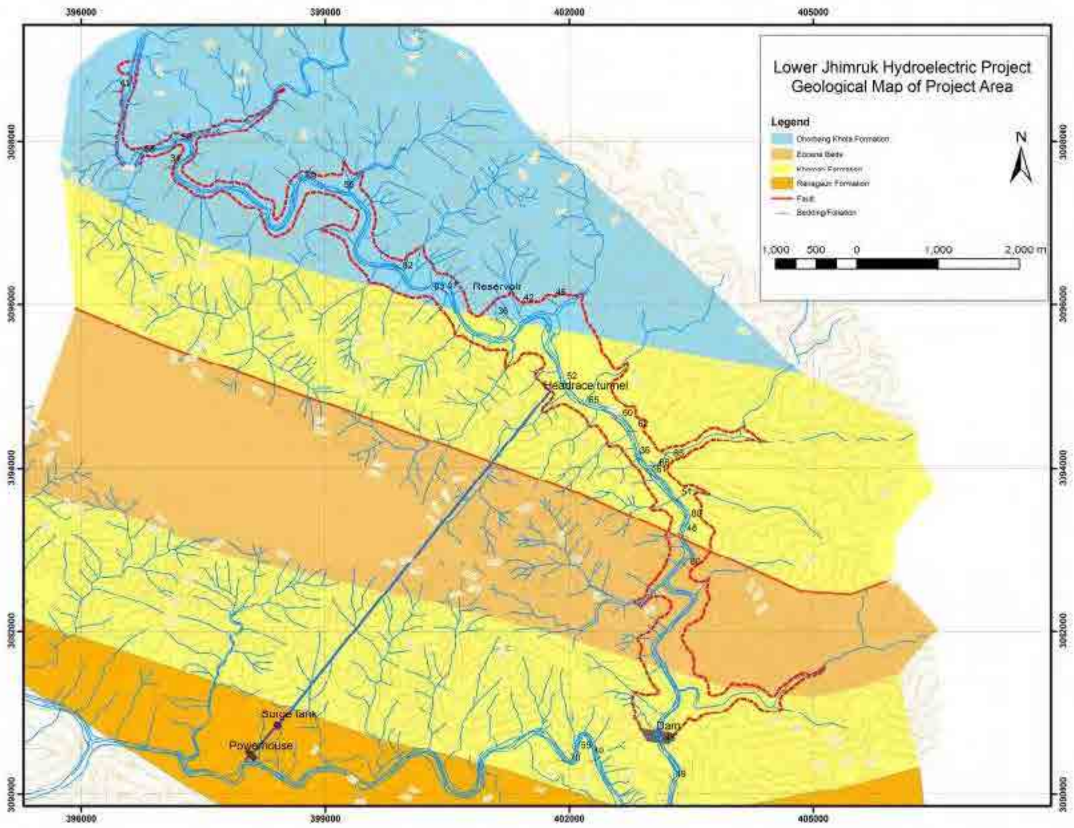
Gravels distributed near the dam site are suitable for coarse aggregate. Fine aggregates are obtained from alluvial terrace deposits near Chedda 500 m upstream of the dam site. Colluvium and residual soil distributed in the area underlain by slate or shale would be investigated for borrow area of soil materials. Dolomite distributed in the reservoir area would be investigated for quarry of rock materials.

2) Thrust and Fault

Among large tectonic thrust, MBT is located to the south of the dam site at a distance of about 3 km. A local major fault has not been found at a distance less than 1 km from the dam site.

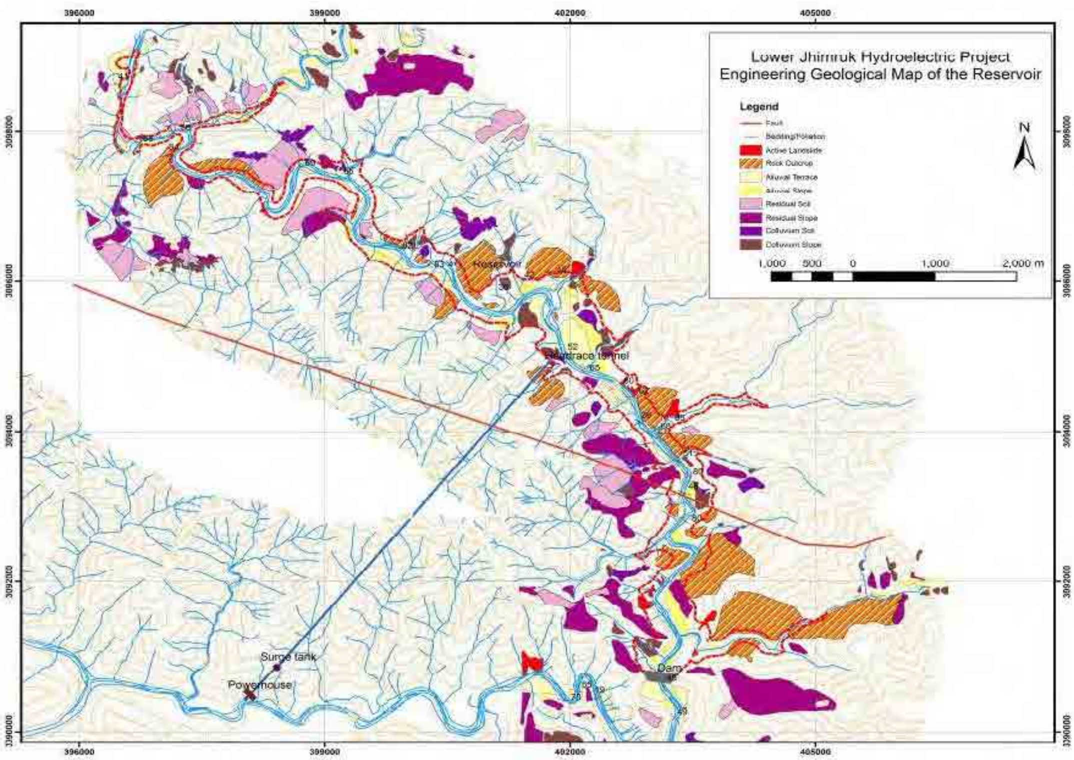
3) Seismicity

The Project area is located in the Lesser Himalaya. The horizontal ground acceleration of this area is 150 mgal according to the Seismic Hazard Map of Nepal. The nearest epicenter of $M \geqq 4$ to the dam site is located to the northeast at a distance of about 34 km



Source: NESS Field Survey, 2012

Figure A.2.7-4 Geological map of the project area



Source: NESS Field Survey, 2012

Figure A.2.7-5 Engineering geological map of the reservoir and its surrounding region

(4) Development Plan

The Lower Jhimruk Project is a dam and waterway-type hydropower project. Since the study level stays at desk study level, the basic design drawings are not available.

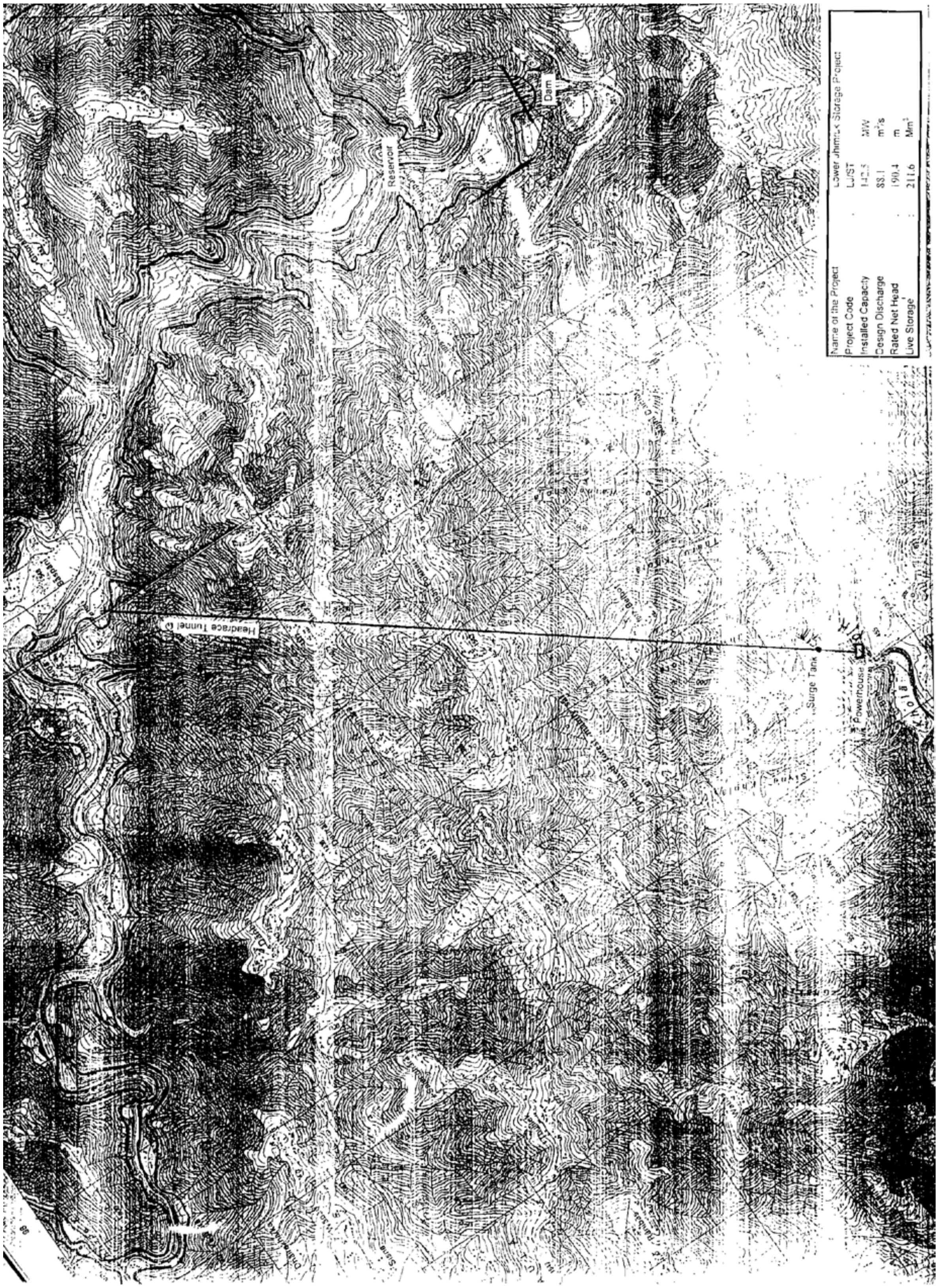
The salient features of principal layout and basic layout drawing of the project are as follows:

Table A.2.7-6 Salient Features

Item	Unit	Lower Jhimruk	Remarks
Reservoir			
Reservoir Area at FSL	km^2	5.7	
Total Storage Capacity	MCM	386.0	
Effective Storage Capacity	MCM	211.6	
Full Suply Level (FSL)	m	597.0	
Minimum Operating Level (MOL)	m	557.0	
Dam			
Type of Dam	-	Rockfill	
Dam Volume	MCM	6.8	
Total Dam Height	m	167	
River Bed Level at Dam Axis	m	450	
Spillway Type	-	Gated Spillway	
Waterway & Powerhouse			
Intake Type	-	Normal Pressure Intake	
Concrete Lined Headrace Tunnel Length	m	5,800	
Circular Tunnel Diameter	m	6.28	
Penstock Length	m	260	
Type of Powerhouse	-	Surface	
Turbine Type	-	Vertical Francis	
Installed Capacity	MW	142.5	
Design Discharge	m^3/s	88.1	
Rated Net Head	m	190.4	
Tail Water Level	m	390	
Tailrace Length	m	50	

Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA

Where, it should be noted that the powerhouse of the Lower Jhimruk Project is located in the reservoir of the Naumure project, therefore, both projects cannot be developed together with the current layout.



Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA

Figure A.2.7-6 General Layout

(5) Electrical/Mechanical Equipment and Transmission Line

1) General

Rated effective head, power discharge and installed capacity of the Lower Jhimruk Project are as follows;

Rated Effective Head	: 190.40 m
Rated Power Discharge	: 88.10 m^3/s
Installed Capacity	: 142.5 MW

The HD Wiz (developed by J-POWER, based on existing hydropower plant data around world) has been used for reviewing design of electrical/mechanical equipment taking above information into consideration. Turbine efficiency and generator efficiency have been improved in recent years and installed capacity exceeded above-mentioned 142.5 MW consequently.

2) Unit Capacity and Number of Unit

Generally, for the turbine-generator, a large unit capacity is said to be more economical merits of scale. However, optimum unit capacity of the turbine-generator is determined in consideration of influence to the power system, development timing and transportation restriction.

In this project, all electrical and mechanical equipment will be transporting from foreign countries via Indian national road and un-maintained Nepalese national road to the project site. Therefore maximum unit capacity shall be set as around 100 MW and number of 2 units plan has been adopted for the project taking accident, maintenance and operation into consideration.

3) Turbine

a) Turbine Output

Rated turbine output at rated effective head of 190.40m and rated power discharge of 44.05 m^3/s per unit can be calculated as follow;

$$\begin{aligned} Pt &= 9.8 \times Hn \times Qt \times \eta t \\ &= 9.8 \times 190.40 \times 44.05 \times 0.927 \\ &\approx 76{,}100 \text{ kW} \end{aligned}$$

where

Pt	: Rated turbine output per unit (kW)
Hn	: Rated effective head (m)
Qt	: Rated power discharge per unit (m^3/s)
ηt	: Turbine efficiency

b) Type of Turbine

Generally, type of turbine can be determined by close relation between effective head and turbine output. Vertical shaft Francis type turbine can be selected taking rated effective head and turbine output into consideration.

c) Runner Material

Stainless steel anti-corrosion type such as 13 chrome high nickels stainless steel is recommended to be applied for the runner material. Surface of runner and wear ring shall be coated (hard or soft) in case of water quality. Detailed coating method shall be specified in the detailed design stage.

d) Installed Capacity

Installed capacity can be calculated from aforementioned turbine output per unit as follow;

$$76{,}100 \text{ kW} \times 2 = 152{,}200 \text{ kW}$$

Review of energy calculation is conducted by using above installed capacity.

4) Generator

A three phase alternating current synchronous generator with vertical shaft rated capacity of 82,600 kVA and power factor of 90% lag are selected.

a) Generator Capacity

Rated generator capacity can be calculated from rated turbine output, power factor and generator efficiency as follows;

$$\begin{aligned} Pg &= Pt \times \eta g \,/\, p.f \text{ (kVA)} \\ &= 76{,}100 \times 0.978 / 0.90 \\ &\approx 82{,}600 \text{ kVA} \end{aligned}$$

where

Pg	: Rated generator capacity (kVA)
Pt	: Rated turbine output (kW)
ηg	: Generator efficiency
p.f	: Power factor, lag

As the results of above calculation, rated generator capacity is 82,600 kVA.

5) Transmission Line

Regarding designing of the transmission line, transmission line shall be connected to the closest substation based on 400 kV Transmission Line Power Development Plan by the NEA. And also thermal capacity and maximum surface potential gradient have been taken into consideration for designing of the transmission line and following specifications have been adopted. As for the transmission line length, the direct length from project area to closest substation was measured from map. Therefore, some allowance has been taken into consideration.

Connected Substation	: Butwal Substation
Transmission Line Voltage	: 220 kV
Length of Transmission Line	: 75 km
Conductor Type	: Bison × 1, 2 circuits

2.8 Madi Project (W-06)

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A.2.8 Madi (W-06)

(1) Project Summary

The Madi Project is a 199.8 MW storage-type hydroelectric power project located at the Madi river in the Rolpa District in the western region. The latest study for this project was conducted in the “Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA.” The study level for this project remains at the desk study level.

As hydrological characteristics, the annual rainfall at the Libang Gaun gauging station nearest to the project site is 1,708 mm and the average river discharge at the dam site is 30.6 m^3/s. The drainage area is 674 km^2, and the specific sediment volume is estimated to be 5,750 t/km^2/year. This is larger than 3,960 t/km^2/year, which is the value adopted by NEA as average specific sedimentation volume in the western region. No glacier lakes having a high risk of a GLOF is identified in the drainage basin.

From a geological view point, the project area lies in the Lesser Himalaya Zone and is composed mainly of limestone, shale, slate and sandstone. The reservoir area is underlain mainly by limestone, shale and sandstone. The limestone should be investigated to confirm its water tightness. Large landslides are distributed in the reservoir surrounding area, which is widely covered by colluvium. The dam site is underlain by limestone and slate, which form sound bedrock. The limestone seems watertight because it is siliceous and without any solution features on its surface. The headrace tunnel route passes through slate and limestone, which would form hard and compact rock. The bedrock of the powerhouse site is composed of slate and limestone. The project area is located in an area where a relatively small acceleration of 160 mgal is shown on the seismic hazard map. It is away from a large tectonic thrust (MBT) at a long distance of 25 km and from epicenters the larger than M4 at a long distance of 35 km.

The impact on the Natural Environment is average and the impact on the Social Environment is relatively lower. Madi is located in the Rapti river basin and the reservoir area is 7.7 km^2. The affected forest area is small at 1.64 km^2. The number of recorded plant species is the largest at 74. The number of recorded fauna is relatively low, with numbers such as 18 mammals, 21 birds, and 9 Herpetofauna. The number of resettlement is 336. 11.2 km of drivable roads, 6 suspension bridges, and 22 water supply schemes will be affected. The Indigenous group in the reservoir area is the Magar (Disadvantaged).

From the view point of hydropower planning, a rockfill dam with a height of 190 m and volume of 9 million m^3 as well as a headrace tunnel of 6 km are planned. In the current layout, no specific risks are identified at the dam site and tunnel site in terms of geological conditions. The powerhouse is of a conventional open type, and no specific technical risks are identified at the powerhouse site.

The location, basic layout and salient features of the project are shown below.

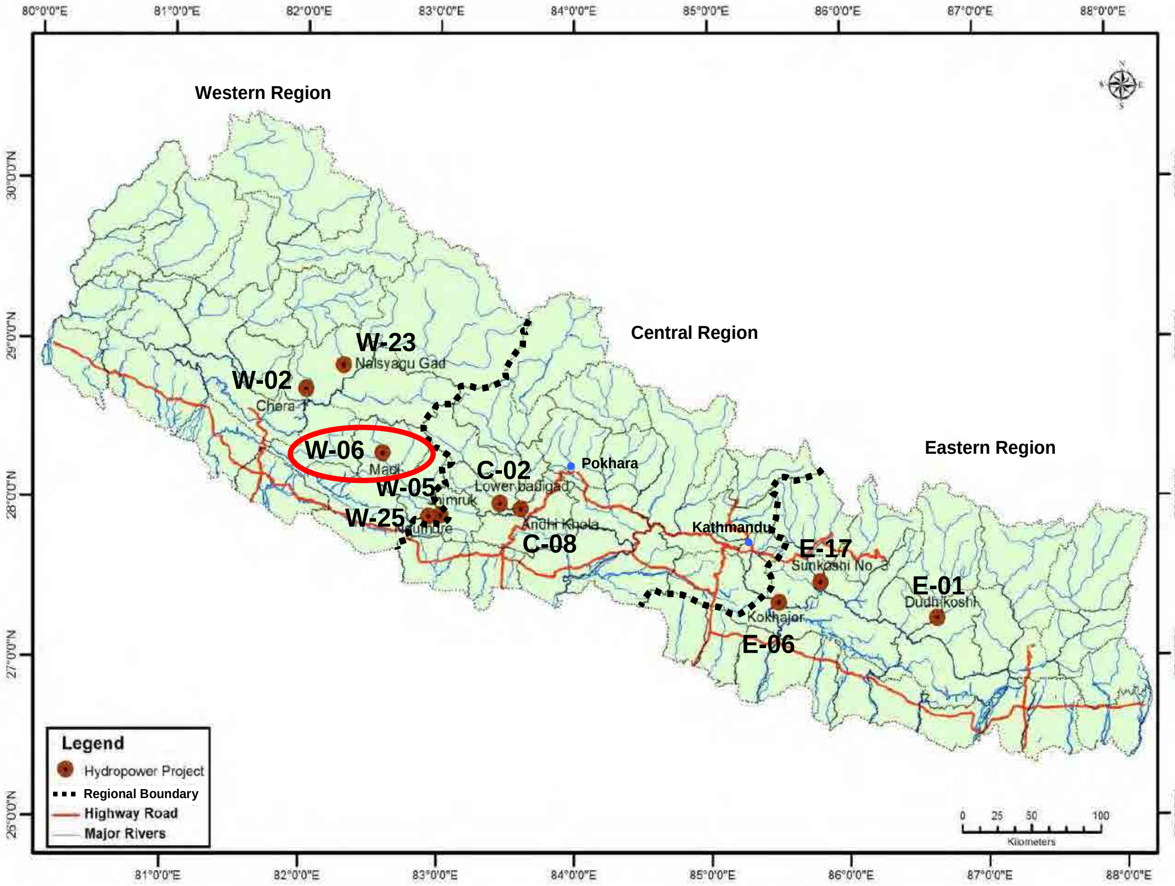


Figure A.2.8-1 Location of the Madi Project (W-06)

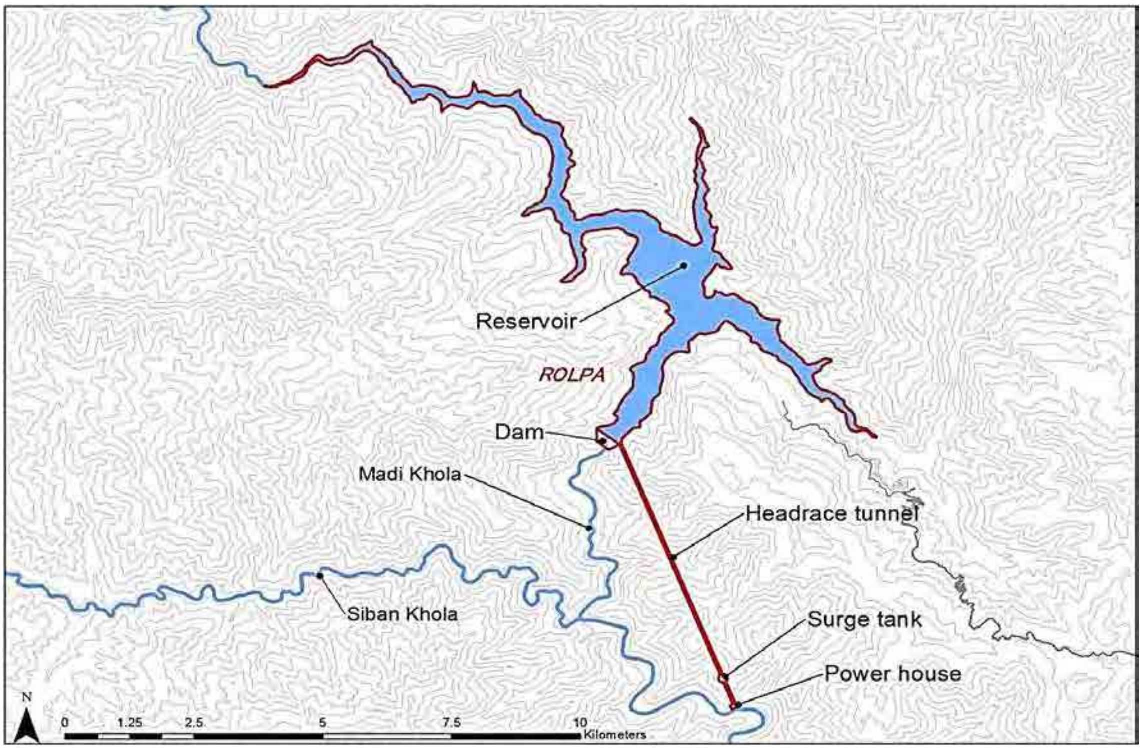


Figure A.2.8-2 General Layout of the Madi Project (W-06)

Table A.2.8-1 Project Description

Item	Unit	Madi Project	Remarks
Location	(District)	Rolpa	
Name of the River	(River)	Madi	
Installed Capacity	MW	199.8	
Catchment Area	km^2	674.0	
Location of Dam Site	Longitude/ Latitude	82° 35' 15.5" 28° 18' 48.5"	
Dam Height	m	190.0	
Total Storage Volume	MCM	359.5	
Effective Storage Volume	MCM	235.1	
Regulating Capability Factor	%	24.3	
Reservoir Area at FSL	km^2	7.7	
Full Supply Level	m	1,090.0	
Minimum Operation Level	m	1,030.0	
Tail Water Level	m	800.0	
Rated Gross Head	m	280.8	
Rated Net Head	m	277.0	
Rated Power Discharge	m^3/s	84.9	
Total Energy	GWh	621.1	Estimated by the Study Team.
Dry Energy (December-April)	GWh	170.7	Estimated by the Study Team.
Length of Access Road	km	15.0	
Length of Transmission Line	km	62.0	Estimated by the Study Team.
Number of Household	nos	336	Surveyed by the Study Team in 2012.
Project Cost	MUS$	637.3	Estimated by the Study Team at 2013 price level.
Unit Generation Cost	cent/kWh	10.3	Estimated by the Study Team.
EIRR (8% of Interest Rate, 12NRs/kWh)	%	12.3	Estimated by the Study Team.
FIRR (8% of Interest Rate, 12NRs/kWh)	%	16.8	Estimated by the Study Team.

Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA (except remarked items)

In addition, the summary of natural and social environmental investigation result and its evaluation are shown below. The detailed information is summarized in Appendix 3 and 5.

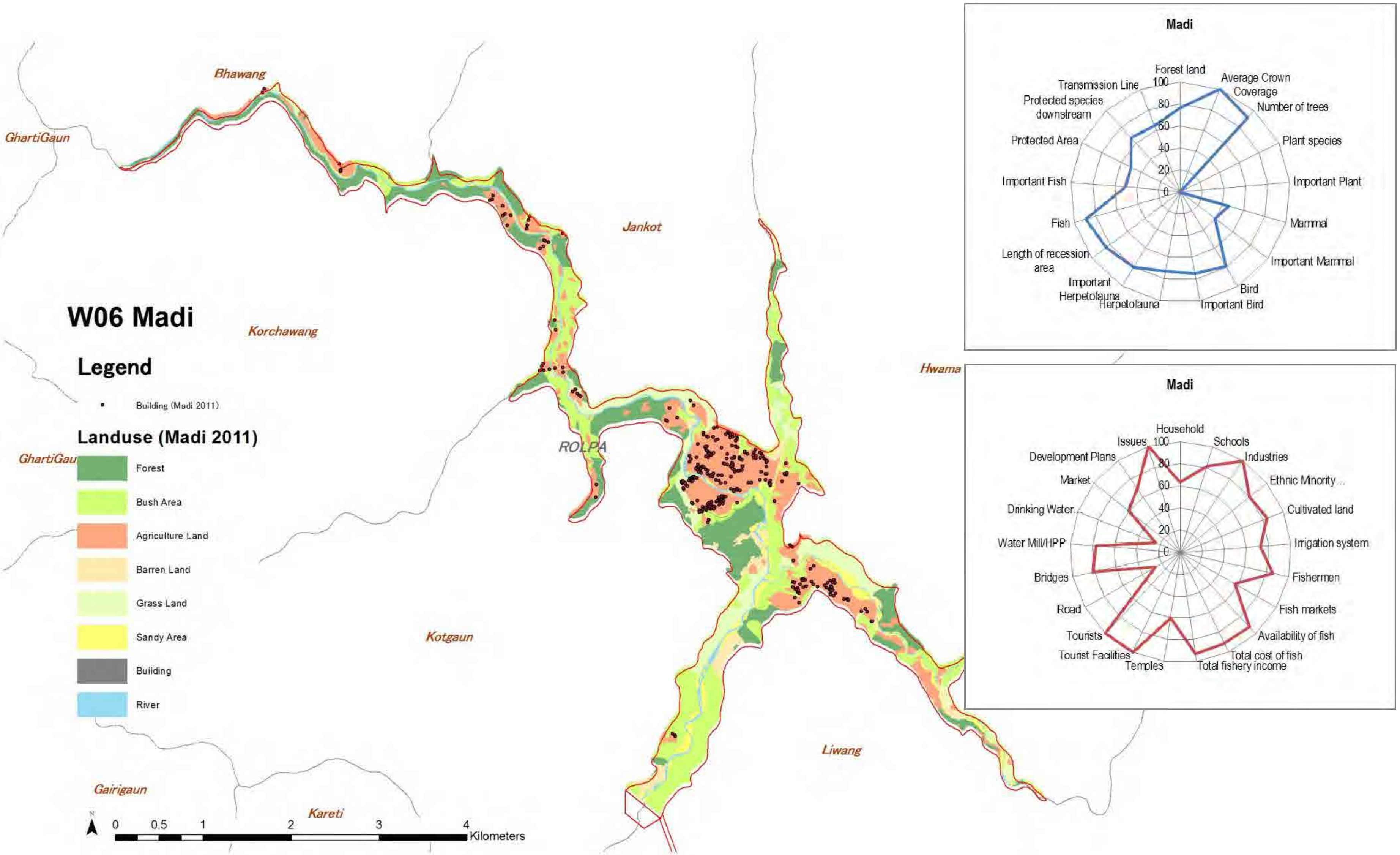


Figure A.2.8-3 Land Use and Buildings in the Reservoir Area of the Madi Project

(2) Meteorology & Hydrology

With regard to the Madi project, the meteorological characteristics and the criteria for hydrological evaluation, namely reliability of flow data, risk of a GLOF and sediment impact are mentioned below.

1) Meteorology

The Madi project site is located at the Madi river. The district where the project site is located at is Rolpa.

The Libang precipitation station (0504) is located in the Rolpa district. Table A.2.8-2 shows the monthly rainfall at the Libang station.

Table A.2.8-2 Monthly Rainfall at the Libang Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
LIBANG GAUN	0504	Rolpa	PRECIPITATION	Jan, 73	28.30	82.63	1,270

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
28.1	48.0	39.5	46.9	106.6	293.5	417.3	382.7	264.0	53.6	10.3	17.0	1,707.5

Source: Department of Hydrology and Meteorology: DHM

2) Reliability of flow data

As there is no gauging station near the Madi project site, the flow of the project is calculated by the Regional Analysis. The reliability of flow data of the Madi project is relatively low.

Table A.2.8-3 shows the monthly flow data used for energy calculation.

Table A.2.8-3 Flow Data of the Madi Project

(m^3/s)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
7.92	6.77	6.42	7.17	10.75	30.01	78.87	95.77	68.36	31.00	14.81	9.66	30.63

3) Risk of GLOF

There is no potentially critical glacier lake which may cause a GLOF in the upstream area of Madi project site.

4) Sedimentation

The specific sediment yield of the Jhimruk Hydroelectric Project which is located near the Madi project site is adopted as the specific sediment yield of the Madi project. According to the FS report, the specific sediment yield of the Jhimruk Hydroelectric Project is from 5,000 to

6,500 t/km^2/year. The average value, 5,750 t/km^2/year, was adopted for calculation of the life of reservoir. The life of reservoir is an index to evaluate the sediment impact to reservoir and calculated dividing total storage volume by mean annual sediment yield.

Table A.2.8-4 shows the calculation result of the life of reservoir. The life of reservoir of the Madi project is estimated to be 138 years.

Table A.2.8-4 Life of Reservoir

a) Specific Sediment Yield	5,750 t/km^2/yr
b) Sediment Yield (Catchment Area × Specific Sediment Yield / Sediment Density)	2.6×10^6 m^3/yr (674 km^2 × 5,750 t/km^2/yr / 1.5 t/m^3)
c) Total Storage Volume	359.5×10^6 m^3
d) Life time of Storage (Total Storage Volume / Sediment Yield)	138 years (359.5×10^6 m / 2.6×10^6 m^3/yr)

(3) Geology

1) Site Geology

The Madi project area belongs to the Rolpa district, west in Nepal. The project area is located in the valley of the Madi river. According to the field geological survey, geology and engineering geology of the project area are as follows.

The geological map of the project area is shown in Figure A.2.8-2. The project area lies in the Lesser Himalayan Zone, and is underlain by 4 formations, from upstream to downstream, the Garnet Schist Unit, the Srichaur Formation composed of thin bedded limestone and shale, the Sattim Formation composed of sandstone and shale and the Ranibas Formation composed of thick bedded limestone and slate.

Reservoir and its surrounding areas are underlain by 4 units. There is a fault between the Srichaur Formation and the Sattim Formation. This fault crosses the reservoir area in NE-SW direction at a distance of 2.5 km from the dam site. There is another fault about 2 km northeast and semi-parallel to this fault along the boundary of the Garnet Schist Unit and the Srichaur Formation. Bedding planes, which strikes are NE-SW, incline toward upstream at angles more than 30 degrees. Many limestone beds are distributed in the reservoir area and further investigation is needed in order to evaluate the watertightness of the reservoir. The engineering geological map of the reservoir and its surrounding area is shown in Figure A.2.8-3. The reservoir and its surrounding area are widely covered with colluvium. There are major landslides on the left bank along abovementioned fault.

The dam site is underlain by thick bedded limestone and slate of the Ranibas Formation. Bedding planes incline toward upstream at angles of about 60 degrees. Limestone beds at the dam site are siliceous and show no solution features on their surface.

The headrace tunnel route on the right bank of the Madi river, where is supposed to be underlain by thick bedded limestone and slate of the Ranibas Formation. The overburden of this tunnel is up to 400 m.

The powerhouse site is located on the left bank of the Madi river. Bed rock of this site is supposed to be composed of thick bedded limestone and slate unit. River deposits are assumed to be thick.

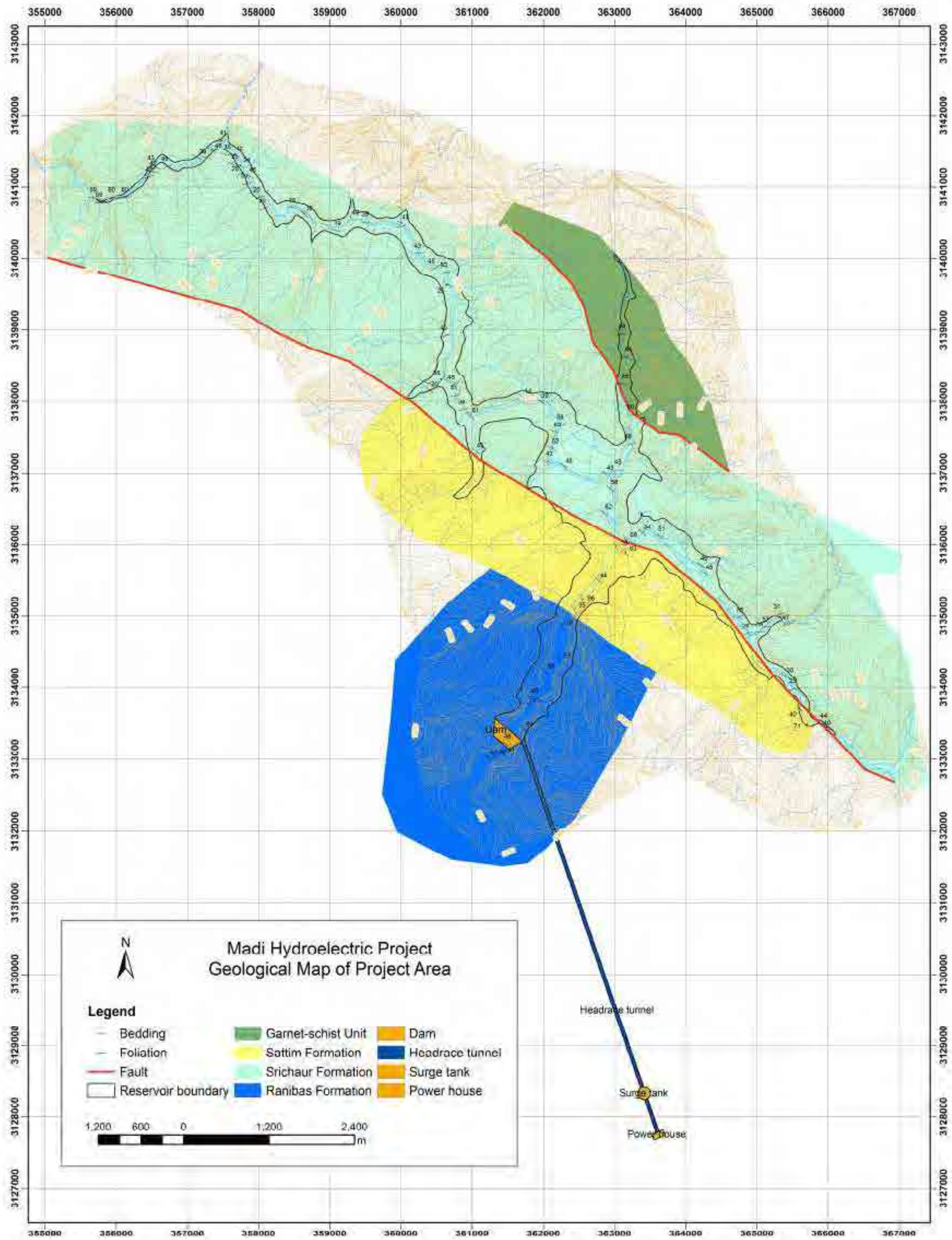
Enough volume of sand and gravel for aggregates are distributed on the river bed at the dam site and at the confluence of the Dhansi river about 2.5 km upstream of the dam site. Thick bedded limestone distributed in the vicinity of the dam site would be investigated for quarry of rock materials. Colluvium and residual soil distributed in the area underlain by thin bedded limestone and shale unit and sandstone and shale unit would be investigated for borrow area of soil materials. Dolomite distributed in the reservoir area would be investigated for quarry of rock materials.

2) Thrust and Fault

Among large tectonic thrust, MBT is located to the south of the dam site at a distance of 25 km. A local major fault has not been found in the vicinity of the dam site. A fault between thin bedded limestone and shale unit and sandstone and shale unit is at a distance of 2.5 km from the dam site.

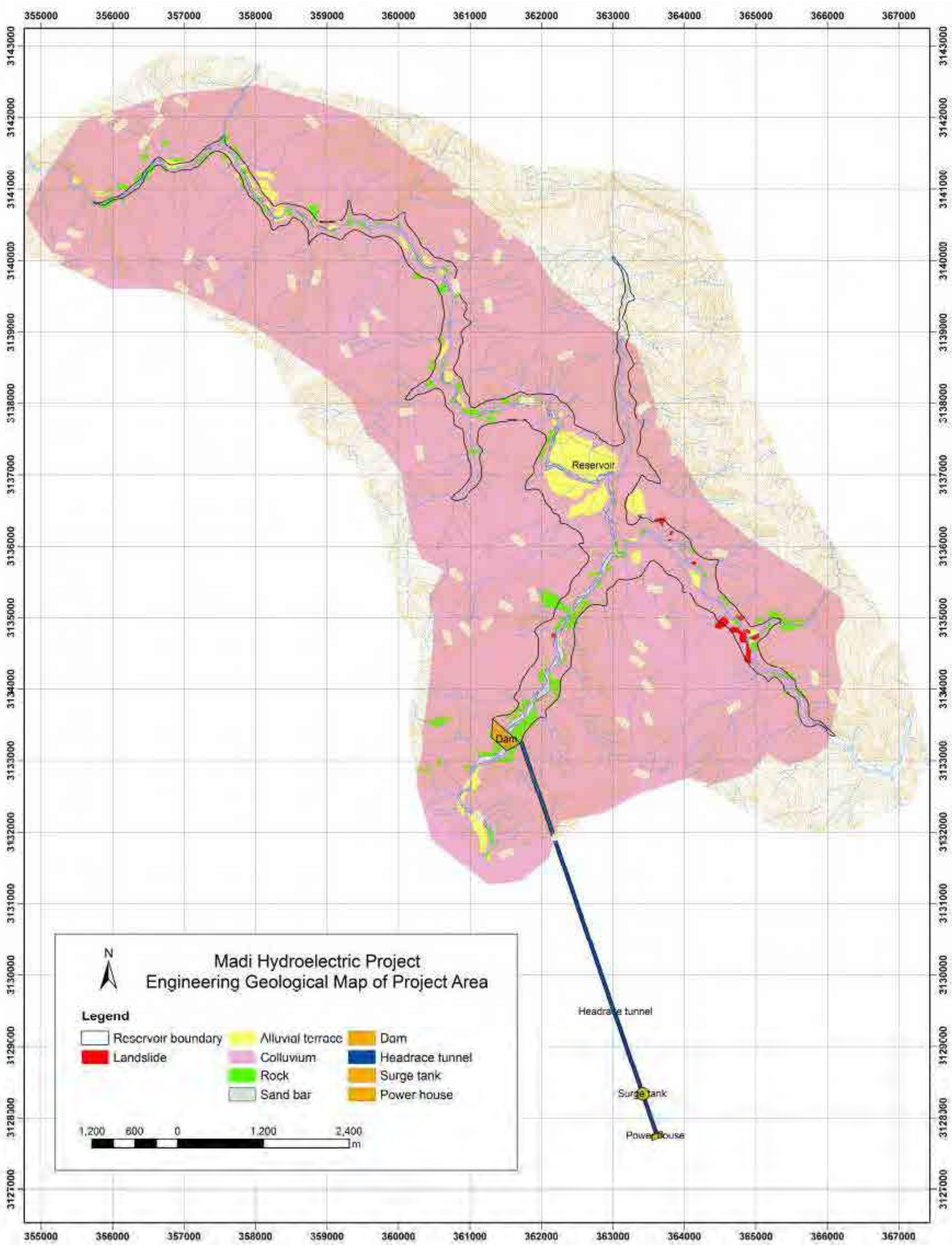
3) Seismicity

The Project area is located in the Lesser Himalaya. The horizontal ground acceleration of this area is 160 mgal according to the Seismic Hazard Map of Nepal. The nearest epicenter of M≧4 to the dam site is located to the northeast at a distance of about 35 km.



Source: NESS Field Survey, 2012

Figure A.2.8-4 Geological map of the project area



Source: NESS Field Survey, 2012

Figure A.2.8-5 Engineering geological map of the reservoir and its surrounding region

(4) Development Plan

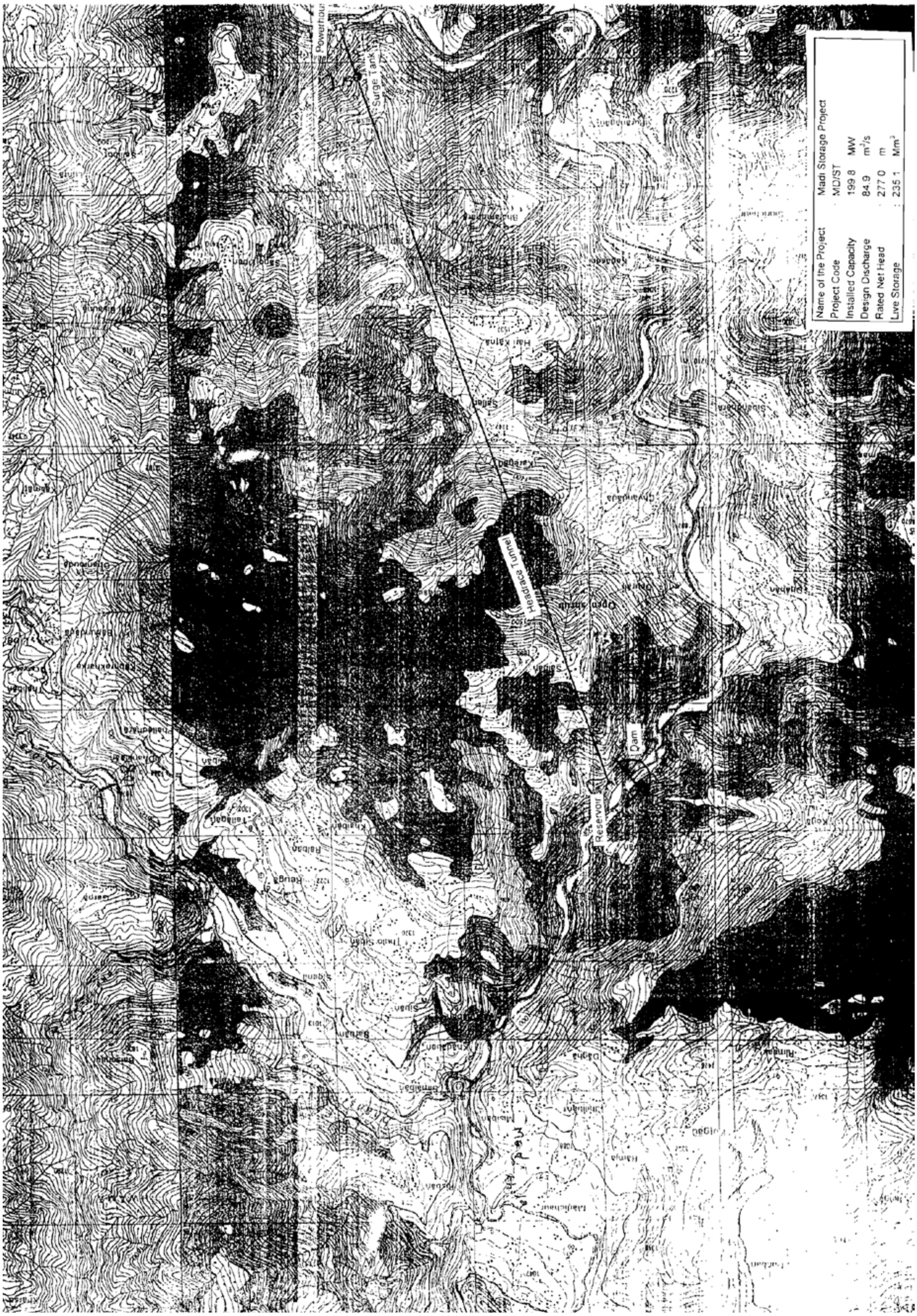
Madi Project is a dam and waterway-type hydropower project. Since the study level stays at desk study level, the basic design drawings are not available.

The salient features of principal layout and basic layout drawing of the project are as follows:

Table A.2.8-5 Salient Features

Item	Unit	Madi Project	Remarks
Reservoir			
Reservoir Area at FSL	km^2	7.7	
Total Storage Capacity	MCM	359.5	
Effective Storage Capacity	MCM	235.1	
Full Suply Level (FSL)	m	1,090.0	
Minimum Operating Level (MOL)	m	1,030.0	
Dam			
Type of Dam	-	Rockfill	
Dam Volume	MCM	9.2	
Total Dam Height	m	190	
River Bed Level at Dam Axis	m	920	
Spillway Type	-	Gated Spillway	
Waterway & Powerhouse			
Intake Type	-	Normal Pressure Intake	
Concrete Lined Headrace Tunnel Length	m	5,700	
Circular Tunnel Diameter	m	6.08	
Penstock Length	m	460	
Type of Powerhouse	-	Surface	
Turbine Type	-	Vertical Francis	
Installed Capacity	MW	199.8	
Design Discharge	m^3/s	84.9	
Rated Net Head	m	277.0	
Tail Water Level	m	800	
Tailrace Length	m	0	

Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA



Source: Update and Review of Identification and Feasibility Study of Storage Project, 2002, NEA

Figure A.2.8-6 General Layout

(5) Electrical/Mechanical Equipment and Transmission Line

1) General

Rated effective head, power discharge and installed capacity of the Madi Project are as follows;

Rated Effective Head	: 277.00 m
Rated Power Discharge	: 84.90 m^3/s
Installed Capacity	: 199.8 MW

The HD Wiz (developed by J-POWER, based on existing hydropower plant data around world) has been used for reviewing design of electrical/mechanical equipment taking above information into consideration. Turbine efficiency and generator efficiency have been improved in recent years and installed capacity exceeded above-mentioned 199.8 MW consequently.

2) Capacity and Number of Unit

Generally, for the turbine-generator, a large unit capacity is said to be more economical merits of scale. However, optimum unit capacity of the turbine-generator is determined in consideration of influence to the power system, development timing and transportation restriction.

In this project, all electrical and mechanical equipment will be transporting from foreign countries via Indian national road and un-maintained Nepalese national road to the project site. Therefore maximum unit capacity shall be set as around 100 MW and number of 2 units plan has been adopted for the project taking accident, maintenance and operation into consideration.

3) Turbine

a) Turbine Output

Rated turbine output at rated effective head of 277.00 m and rated power discharge of 42.45 m^3/s per unit can be calculated as follow;

$$\begin{aligned} Pt &= 9.8 \times Hn \times Qt \times \eta t \\ &= 9.8 \times 277.00 \times 42.45 \times 0.92 \\ &\approx 106{,}000 \text{ kW} \end{aligned}$$

where

Pt	: Rated turbine output per unit (kW)
Hn	: Rated effective head (m)
Qt	: Rated power discharge per unit (m^3/s)
ηt	: Turbine efficiency

b) Type of Turbine

Generally, type of turbine can be determined by close relation between effective head and turbine output. Vertical shaft Francis type turbine can be selected taking rated effective head and turbine output into consideration.

c) Runner Material

Stainless steel anti-corrosion type such as 13 chrome high nickels stainless steel is recommended to be applied for the runner material. Surface of runner and wear ring shall be coated (hard or soft) in case of water quality. Detailed coating method shall be specified in the detailed design stage.

d) Installed Capacity

Installed capacity can be calculated from aforementioned turbine output per unit as follow;

$$106{,}000 \text{ kW} \times 2 = 212{,}000 \text{ kW}$$

Review of energy calculation is conducted by using above installed capacity.

4) Generator

A three phase alternating current synchronous generator with vertical shaft rated capacity of 115,500 kVA and power factor of 90% lag are selected.

a) Generator Capacity

Rated generator capacity can be calculated from rated turbine output, power factor and generator efficiency as follows;

$$\begin{aligned} Pg &= Pt \times \eta g \,/\, p.f \text{ (kVA)} \\ &= 106{,}000 \times 0.981 \,/\, 0.90 \\ &\approx 115{,}500 \text{ kVA} \end{aligned}$$

where

- Pg : Rated generator capacity (kVA)
- Pt : Rated turbine output (kW)
- ηg : Generator efficiency
- p.f : Power factor, lag

As the results of above calculation, rated generator capacity is 115,500kVA.

5) Transmission Line

Regarding designing of the transmission line, transmission line shall be connected to the closest substation based on 400 kV Transmission Line Power Development Plan by the NEA. And also thermal capacity and maximum surface potential gradient have been taken into consideration for designing of the transmission line and following specifications have been adopted. As for the transmission line length, the direct length from project area to closest substation was measured from map. Therefore, some allowance has been taken into consideration.

Connected Substation	: Chaujhari Substation
Transmission Line Voltage	: 22 0 kV
Length of Transmission Line	: 62 km
Conductor Type	: Bison × 1, 2 circuits

2.9 Nalsyau Gad Project (W-23)

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A.2.9 Nalsyau Gad (W-23)

(1) Project Summary

The Nalsyau Gad Project is a 410 MW storage-type hydroelectric power project located at the Nalsyagu Gad river in the Jajarkot District in the western region. For existing studies, a pre feasibility study was conducted in 2004 by the NEA. After that, a feasibility study commenced in 2010 and had been completed in 2012.

As hydrological characteristics, the annual rainfall at the Jajarkot gauging station nearest to the project site is 1,797 mm and the average river discharge at the dam site is 26.4 m^3/s. The drainage area is 570 km^2, and the specific sediment volume is estimated to be 3,960 $t/km^2/year$. This is the same value adopted by the NEA as average specific sedimentation volume in the western region. No glacier lakes having a high risk of a GLOF are identified in the drainage basin.

From a geological view point, the project area lies in the Lesser Himalaya Zone and is composed mainly of dolomite, slate and quartzite. The reservoir area is underlain by dolomite and slate. The dolomite should be investigated to confirm its water tightness. The dam site is underlain by dolomite, which forms sound bedrock, but this needs further investigation to confirm water tightness. The headrace tunnel route passes through dolomite, slate, quartzite and two major sheared zones. The bedrock of power house site is mainly composed of phyllite and quartzite. The project area is located in an area where a medium acceleration of 200 mgal is shown on the seismic hazard map. It is away from a large tectonic thrust (MBT) at a long distance of 60 km and from epicenters larger than M4 at a relatively long distance of 7 km.

Both the impact on the Natural Environment and the Social Environment are relatively low. Nalsyau Gad is located in the Karnali river basin and the reservoir area is 6.3 km^2. The affected forest area is the lowest out of the ten promising projects at 0.76 km^2. Although the number of recorded plant species is relatively high at 59, the number of recorded fauna is relatively low, with numbers such as 11 mammals, 13 birds, and 8 Herpetofauna. There are three protected species downstream of the project area and 6 important species that depend on water are known. The length of the Transmission line is the longest, which is 112 km. The number of resettlements is as average at 263, but the number of resettlements per unit generation is lower, which is 0.64 HH/MW. There are no affected Indigenous groups, no affected irrigation systems, and no affected drivable roads.

From the view point of hydropower planning, a large rockfill dam with a height of 200 m and volume of 18 million m^3 are planned in the current layout. Since it is recognized that the geological condition at the dam site has to be confirmed in terms of water tightness, the work for the dam will be on the critical path in the construction stage. It should be noted that the headrace tunnel of 8 km passes through two large fracture zones. Since the powerhouse is of an underground type, the construction risk will be relatively higher. Therefore, geological investigations should be carried out as detail as possible in the detailed design stage. Furthermore, the effective head of this project is 635 m, which is extremely large. The turbine is planned to be of a Pelton type. It should be noted that the penstock has to be designed carefully since the water pressure in the penstock near the powerhouse is to be extremely high.

The location, basic layout and salient features of the project are shown below.

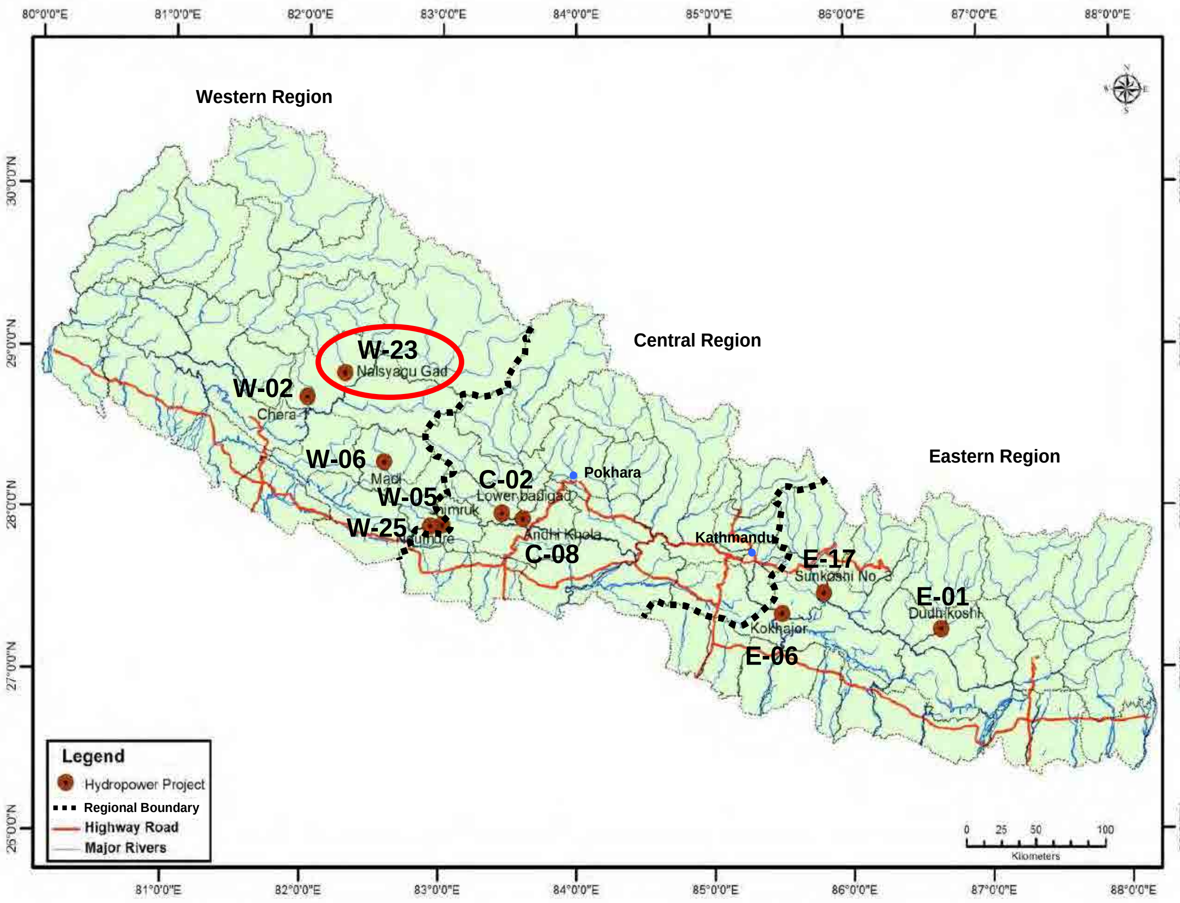


Figure A.2.9-1 Location of the Nalsyau Gad Project (W-23)

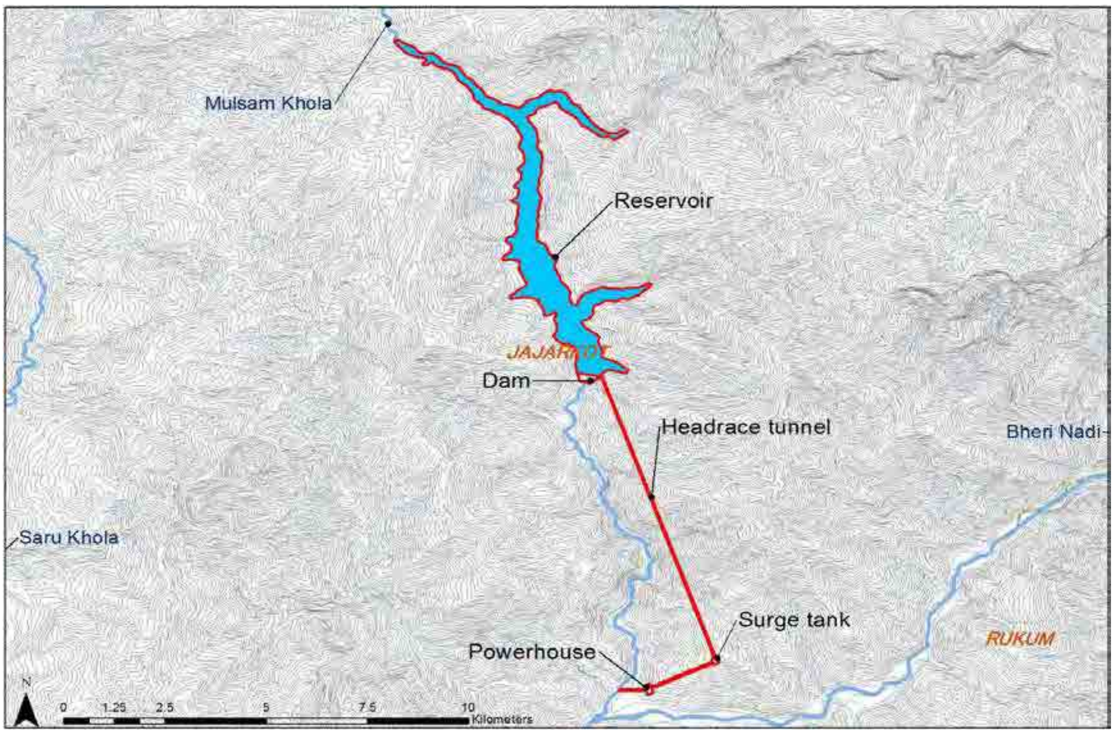


Figure A.2.9-2 General Layout of the Nalsyau Gad Project (W-23)

Table A.2.9-1 Project Description

Item	Unit	Nalsyau Gad	Remarks
Location	(District)	Jajarkot	
Name of the River	(River)	Nalsyau Gad	
Installed Capacity	MW	410	
Catchment Area	km^2	570	
Location of Dam Site	Longitude/ Latitude	82° 17' 42.8" 28° 52' 4.7"	
Dam Height	m	200.0	
Total Storage Volume	MCM	419.6	
Effective Storage Volume	MCM	296.3	
Regulating Capability Factor	%	58.36	
Reservoir Area at FSL	km^2	6.3	
Full Supply Level	m	1,570	
Minimum Operation Level	m	1,498	
Tail Water Level	m	872	
Rated Gross Head	m	649.3	
Rated Net Head	m	635.5	
Rated Power Discharge	m^3/s	75	
Total Energy	GWh	1,406.1	
Dry Energy (December-April)	GWh	581.8	
Length of Access Road	km	25.0	
Length of Transmission Line	km	112.0	
Number of Household	nos	124	Surveyed by the Study Team in 2012.
Project Cost	MUS$	966.9	Incl. Price .Contingency & IDC (Interest during construction)
Unit Generation Cost	cent/kWh	6.9	Estimated by the Study Team.
EIRR (8% of Interest Rate, 12NRs/kWh)	%	15.6	Estimated by the Study Team.
FIRR (8% of Interest Rate, 12NRs/kWh)	%	25.8	Estimated by the Study Team

Source: Nalsyau Gad Hydropower Project Feasibility Study Executive Summary, 2012, NEA (except remarked items)

In addition, the summary of natural and social environmental investigation result and its evaluation are shown below. The detailed information is summarized in Appendix 3 and 5.

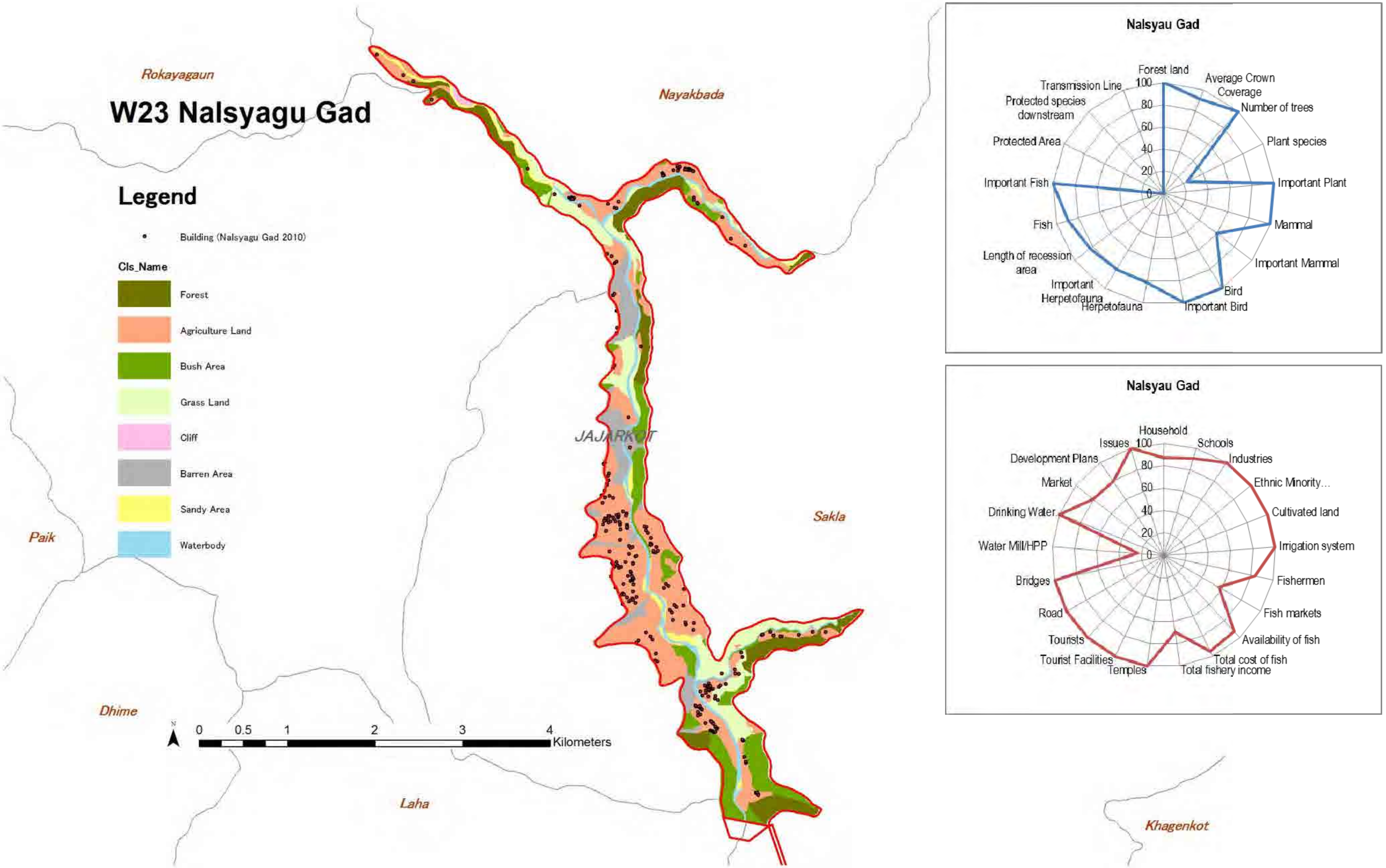


Figure A.2.9-3 Land Use and Buildings in the Reservoir Area of the Nalsyau Gad Project

(2) Meteorology & Hydrology

With regard to the Nalsyau Gad project, the meteorological characteristics and the criteria for hydrological evaluation, namely reliability of flow data, risk of a GLOF and sediment impact are mentioned below.

1) Meteorology

The Nalsyau Gad project site is located at the Nalsyau Gad river. The district where the project site is located at is Jajarkot.

The Jajarkot precipitation station (0404) is located in Jajarkot district. Table A.2.9-2 shows the monthly rainfall at the Jajarkot station.

Table A.2.9-2 Monthly Rainfall at the Jajarkot Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
JAJARKOT	0404	Jajarkot	PRECIPITATION	Jan, 57	28.70	82.20	1,231

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
30.3	35.4	37.2	35.0	61.9	282.0	478.8	487.0	250.8	68.7	10.4	19.0	1,796.6

Source: Department of Hydrology and Meteorology: DHM

2) Reliability of flow data

As there is no gauging station near the Nalsyau Gad project site, the flow of the project is calculated by the Regional Analysis. The reliability of flow data of the Nalsyau Gad project is relatively low.

Table A.2.9-3 shows the monthly flow data for energy calculation.

Table A.2.9-3 Flow data of the Nalsyau Gad Project

(m^3/s)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
6.83	5.84	5.52	6.14	9.14	25.73	67.96	82.57	59.06	26.85	12.80	8.34	26.40

3) Risk of GLOF

There is no potentially critical glacier lake which may cause a GLOF in the upstream area of the Nalsyau Gad project site.

4) Sedimentation

According to FS report, the specific sediment yield is estimated to be 3,960 t/km^2/year. By using this yield, the life of the reservoir is estimated. The life of reservoir is an index to evaluate the sediment impact to reservoir and calculated dividing total storage volume by mean annual sediment yield.

Table A.2.9-4 shows the calculation result of the life of reservoir. The life of reservoir of the Nalsyau Gad project is estimated to be 280 years.

Table A.2.9-4 Life of Reservoir

a) Specific Sediment Yield	3,960 t/km^2/yr
b) Sediment Yield (Catchment Area × Specific Sediment Yield / Sediment Density)	1.5×10^6 m^3/yr (570.5 km^2 × 3,960 t/km^2/yr / 1.5 t/m^3)
c) Total Storage Volume	419.6×10^6 m^3
d) Life time of Storage (Total Storage Volume / Sediment Yield)	280 years (419.6×10^6 m^3 / 1.5×10^6 m^3/yr)

(3) Geology

1) Site Geology

The Nalsyau Gad project area belongs to the Jajarkot district, west in Nepal. The dam site is located in the valley of the Nalsyau Gad river. The powerhouse site is located on the left bank of the Nalsyau Gad river about 8 km downstream of the dam site. According to the FS report (2012) and Pre-FS report (2004), geology and engineering geology of the project area are summarized as follows.

The geological map of the project area is shown in Figure A.2.9-2. The project area lies in the Lesser Himalayan Zone, and is mainly underlain by dolomite and slate.

The reservoir and its surrounding area are underlain by slate except the potion close to the dam site, where is underlain by dolomite. While permeability of slate is impervious, that of dolomite should be confirmed by further investigation. A fault which passes upslope of the right bank of the dam site and crosses the upstream portion of the reservoir area is shown in the Pre-FS report (Figure A.2.9-3).

The geological map and section of the dam site is shown in Figure A.2.9-2 and Figure A.2.9-4. The dam site is underlain by dolomite, which bedding planes incline toward upstream and right bank at mean angles of about 50 degrees. Permeability of dolomite should be confirmed by further investigation. 10m deep river deposit was confirmed on the left bank close to river bed.

The headrace tunnel route passes on the left bank of the Nalsyau Gad river, where is underlain by dolomite. Bedding planes, which strikes are almost perpendicular to tunnel direction, incline toward intake at angles of 30 to 70 degrees. This route encounters 2 sheared zones, which are parallel to bedding planes. Overburden of this tunnel is up to 500 m.

The powerhouse site is located on the alluvial terrace on the left bank of the Nalsyau Gad river. Bed rock of this site is composed of phyllite, quartzite and shale, which bedding planes, incline toward northwest at angles of about 60 degrees. The depth of river deposits is assumed to be 15 m.

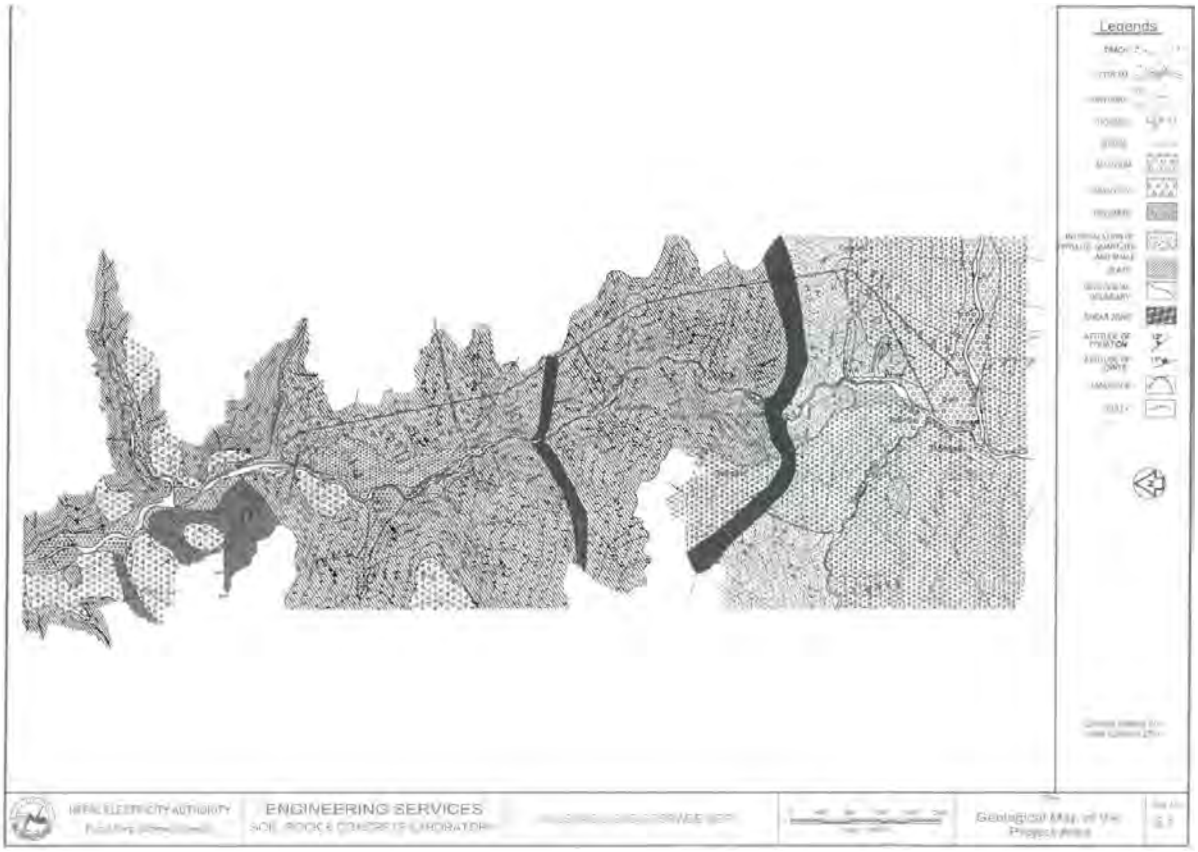
Sand and gravel distributed in the vicinity of the dam site was studied for aggregates. Dolomite distributed in the vicinity of the dam site was studied for aggregate and rock materials. Colluvium and residual soil distributed on the slopes in the reservoir was studied for soil materials.

2) Thrust and Fault

Among large tectonic thrust, MBT is located to the south of the dam site at a distance of 60 km. Nalsyau Gad Fault is located at a distance of 500 m from the dam site.

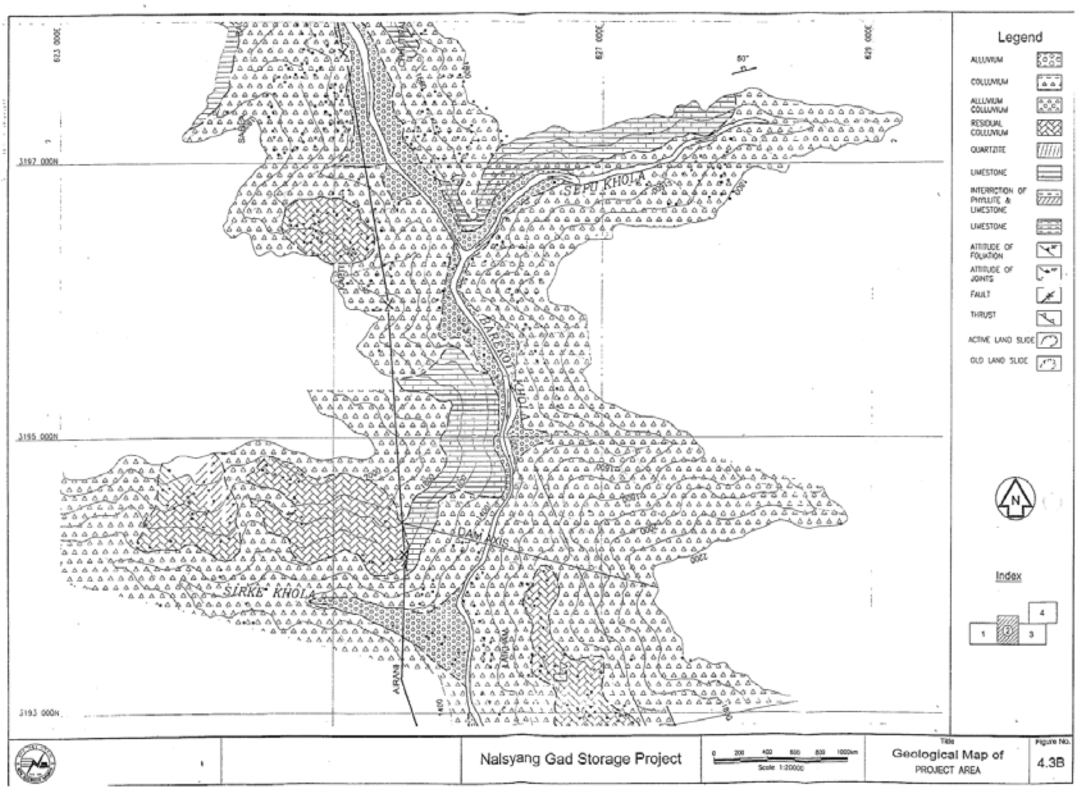
3) Seismicity

The Project area is located in the Lesser Himalaya. The horizontal ground acceleration of this area is 200 mgal according to the Seismic Hazard Map of Nepal. The nearest epicenter of M≧4 to the dam site is located to the northwest at a distance of about 7 km.



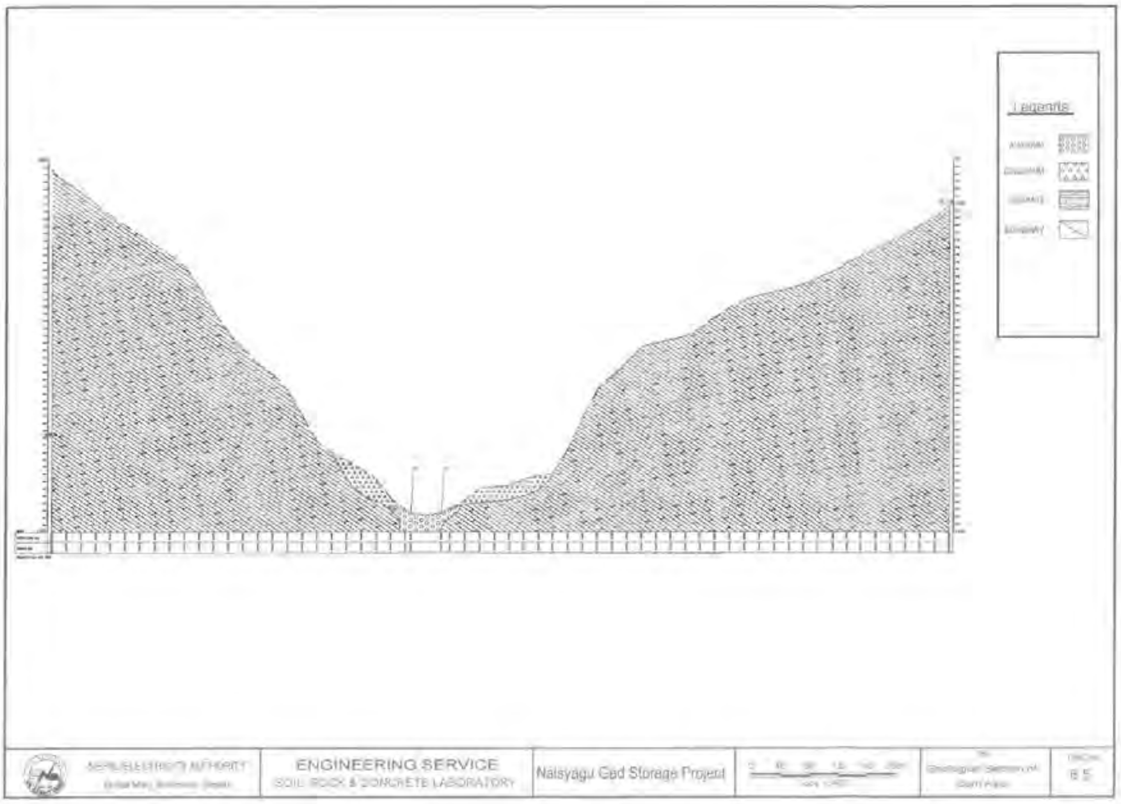
Source: Nalsyau Gad Hydropower Project Feasibility Study Report, 2012, NEA

Figure A.2.9-4 Geological map of the project area



Source: Nalsyau Gad Hydropower Project Pre-feasibility Study Report, 2004, NEA

Figure A.2.9-5 Geological map of the dam site



Source: Nalsyau Gad Hydropower Project Feasibility Study Report, 2012, NEA

Figure A.2.9-6 Geological map of the dam site

(4) Development Plan

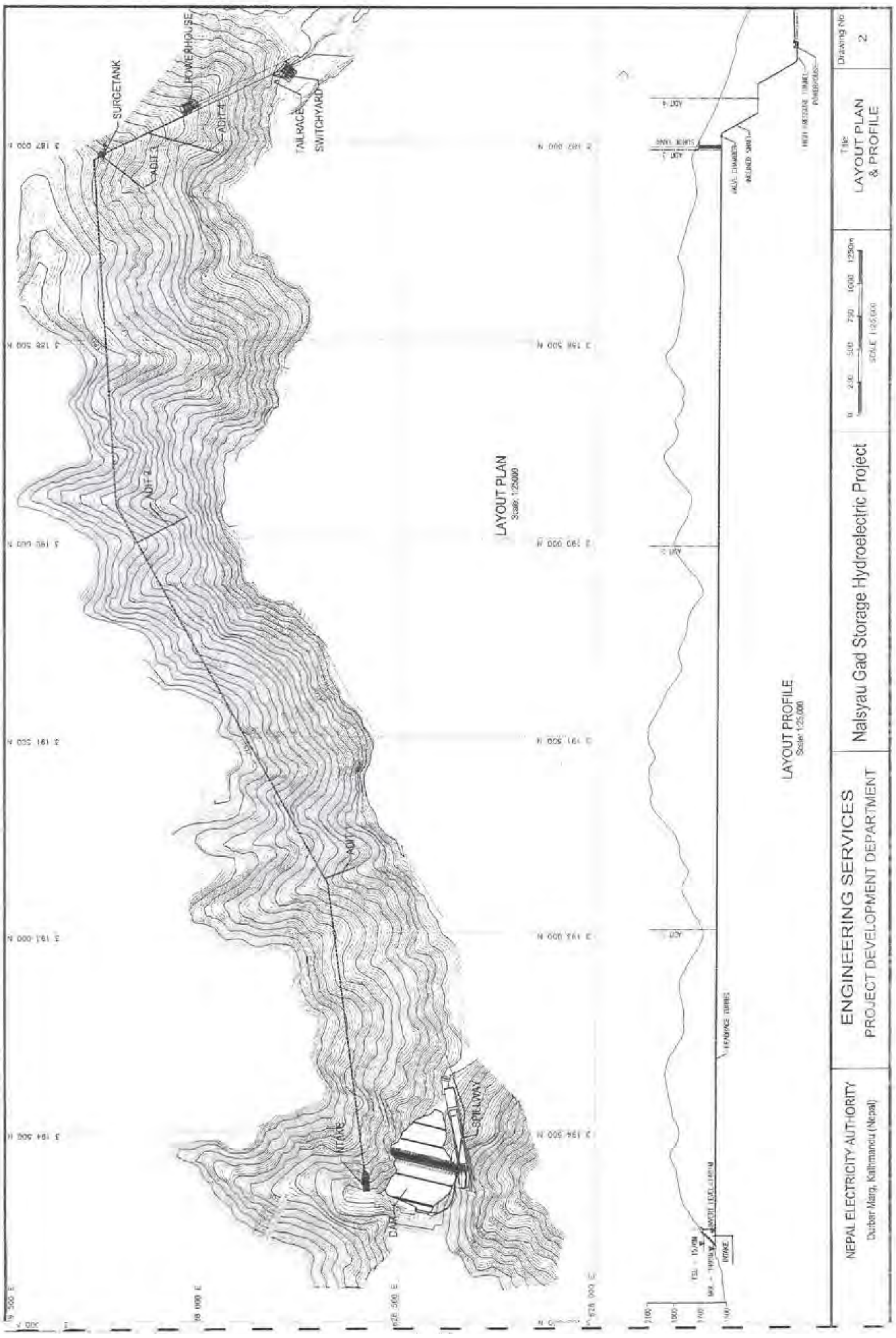
Nalsyau Gad Project is a dam and waterway-type hydropower project. As the study level stays at feasibility study level, some design drawings are available. The salient features of principal layout and basic layout drawing of the project are as follows:

Table A.2.9-5 Salient Features

Item	Unit	Nalsyau Gad	Remarks
Reservoir			
Reservoir Area at FSL	km^2	6.3	
Total Storage Capacity	MCM	419.6	
Effective Storage Capacity	MCM	296.3	
Full Suply Level (FSL)	m	1,570	
Minimum Operating Level (MOL)	m	1,498	
Dam			
Type of Dam	-	Rockfill	
Dam Volume	MCM	17.9	
Total Dam Height	m	200	
River Bed Level at Dam Axis	m	-	
Spillway Type	-	Gated Spillway	
Waterway & Powerhouse			
Intake Type	-	Sloping Intake	
Concrete Lined Headrace Tunnel Length	m	8,215	
Tunnel Diameter	m	5.7	Modified Horse Shoe
Penstock Length	m	990	D = 4.2m – 3.9m
Type of Powerhouse	-	Underground	106m × 13m × 31m
Turbine Type	-	Vertical Pelton	(4 x 102.5MW)
Installed Capacity	MW	410	
Design Discharge	m^3/s	75	
Rated Net Head	m	635.5	
Tail Water Level	m	863.3	Turbine Center = EL.872m
Tailrace Length	m	1,280	Inverted D Shaped W4.5m x H3.5m

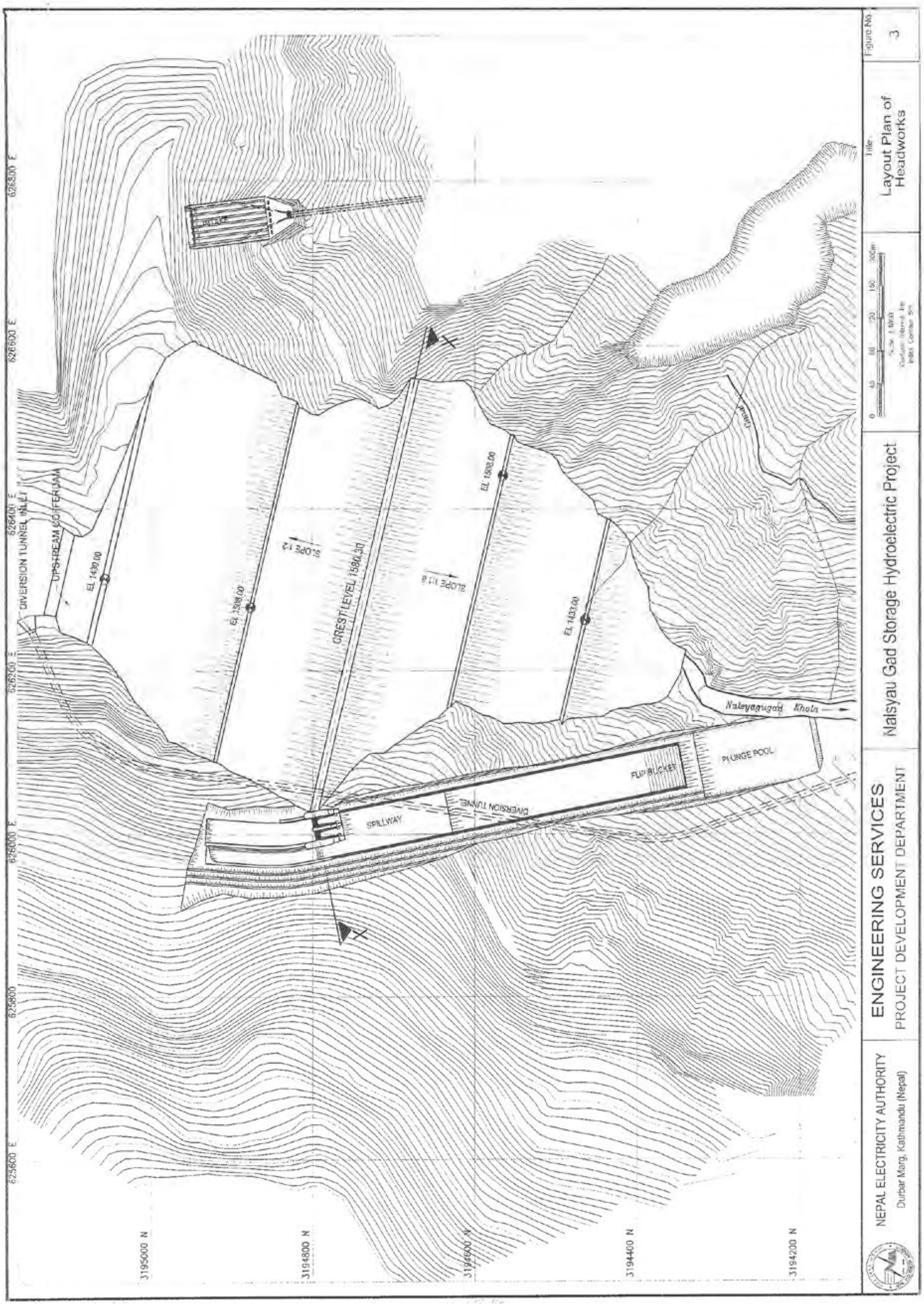
Source: Nalsyau Gad Hydropower Project Feasibility Study Executive Summary, 2012, NEA

Where, as for the Nalsyau Gad Project, there is information that a Chinese company offered to develop the project to the NEA though it has yet to reply.



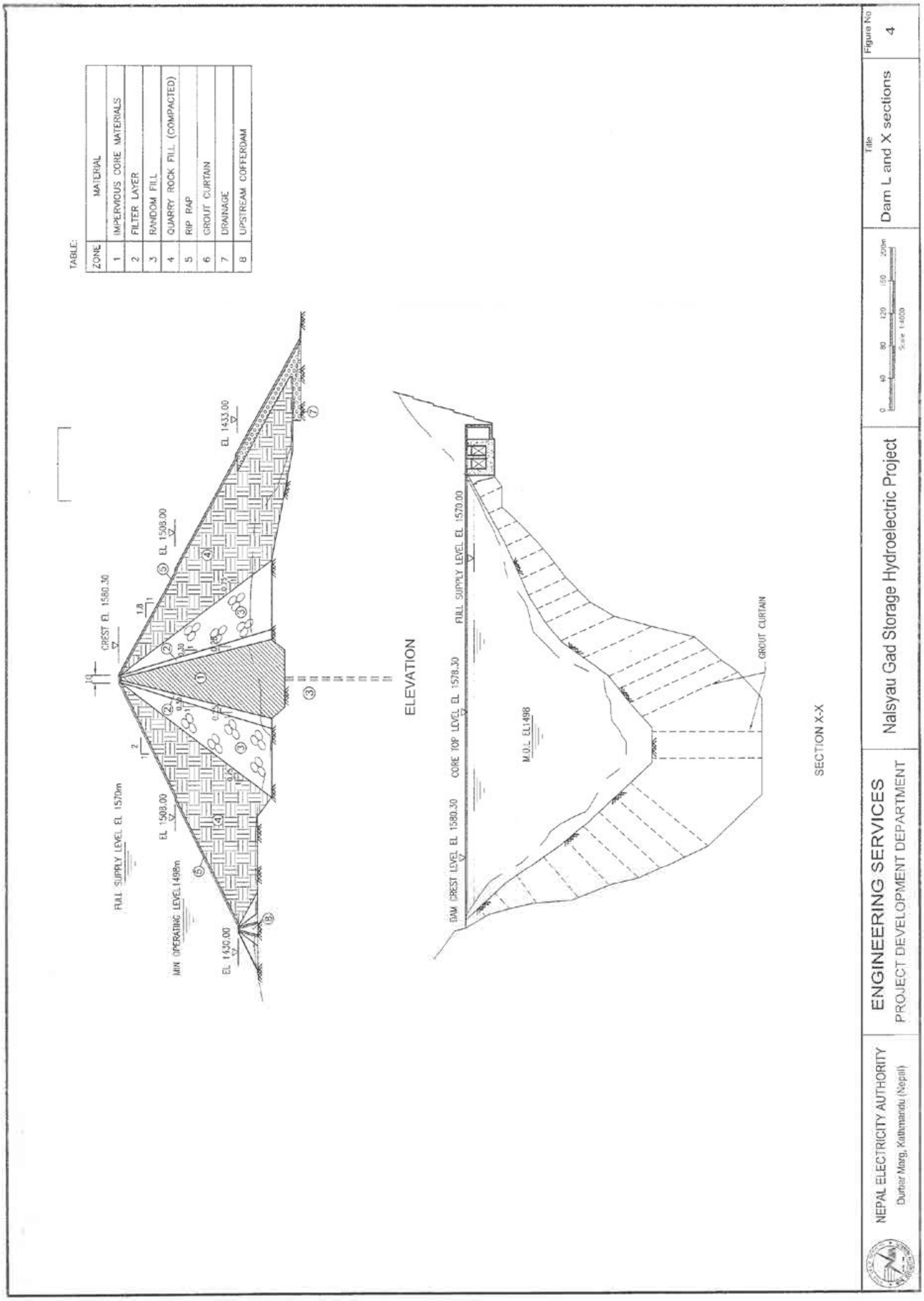
Source: Nalsyau Gad Hydropower Project Feasibility Study Executive Summary, 2012, NEA

Figure A.2.9-7 General Layout



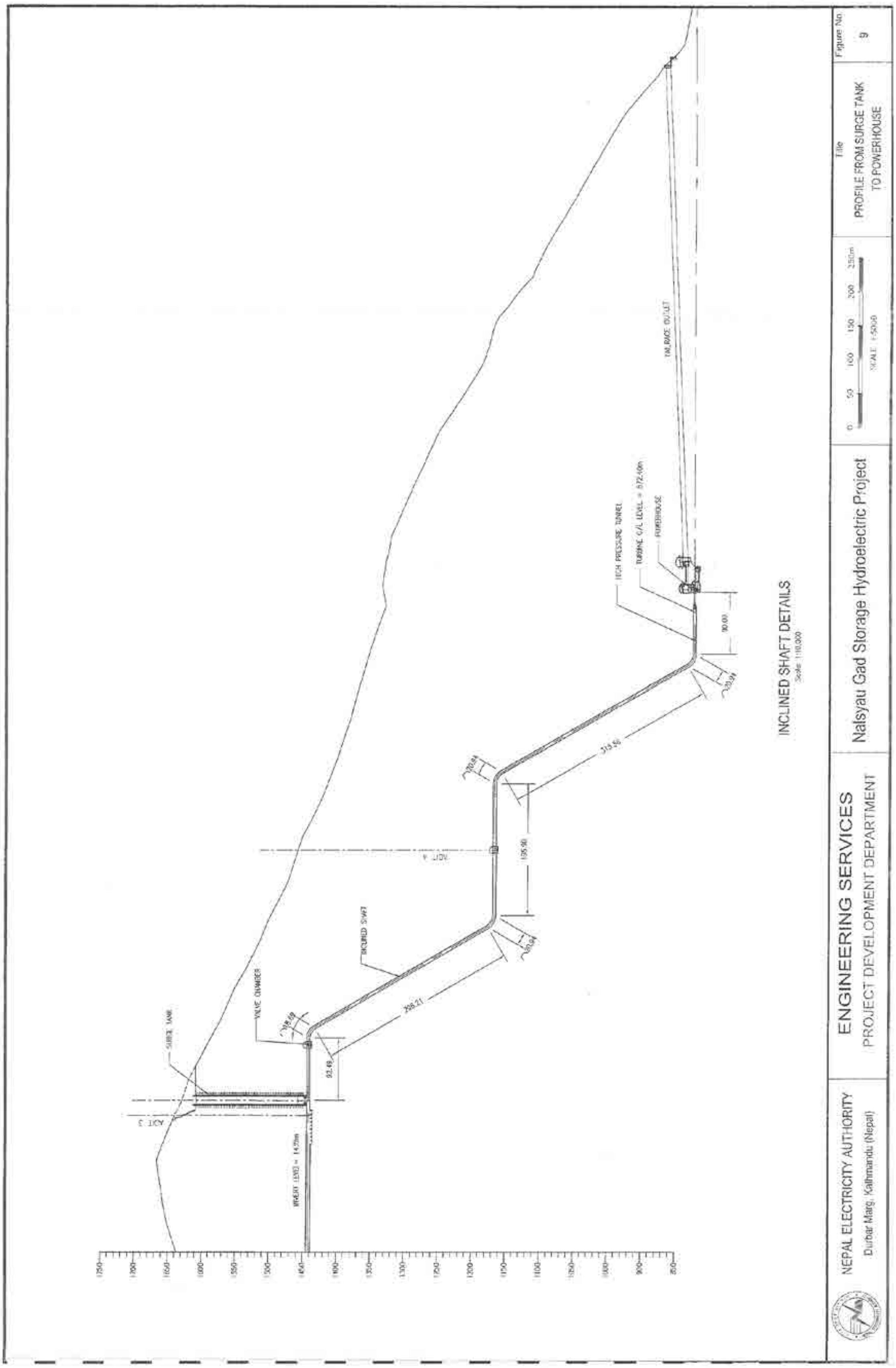
Source: Nalsyau Gad Hydropower Project Feasibility Study Executive Summary, 2012, NEA

Figure A.2.9-8 Dam Plan



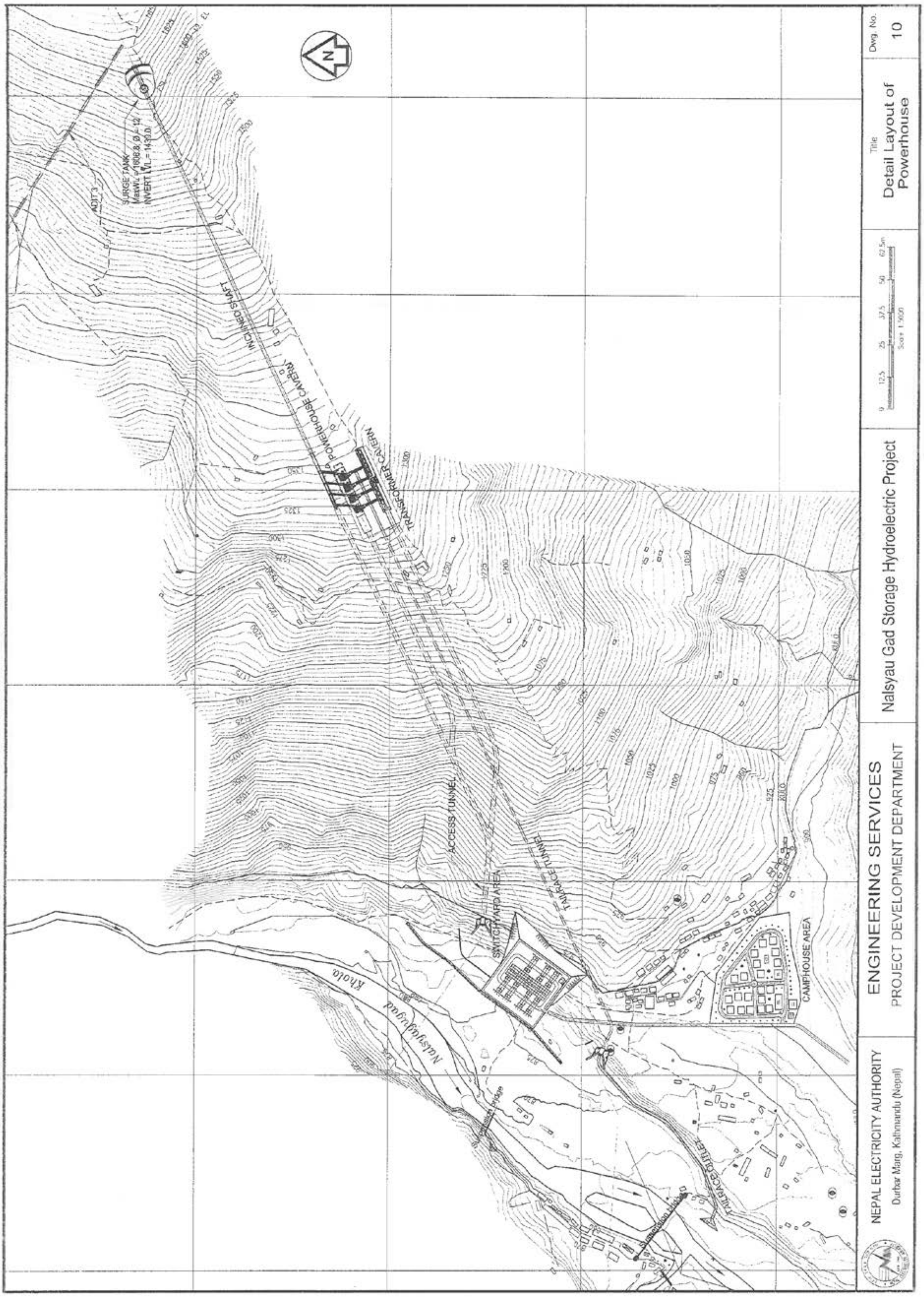
Source: Nalsyau Gad Hydropower Project Feasibility Study Executive Summary, 2012, NEA

Figure A.2.9-9 Dam Section



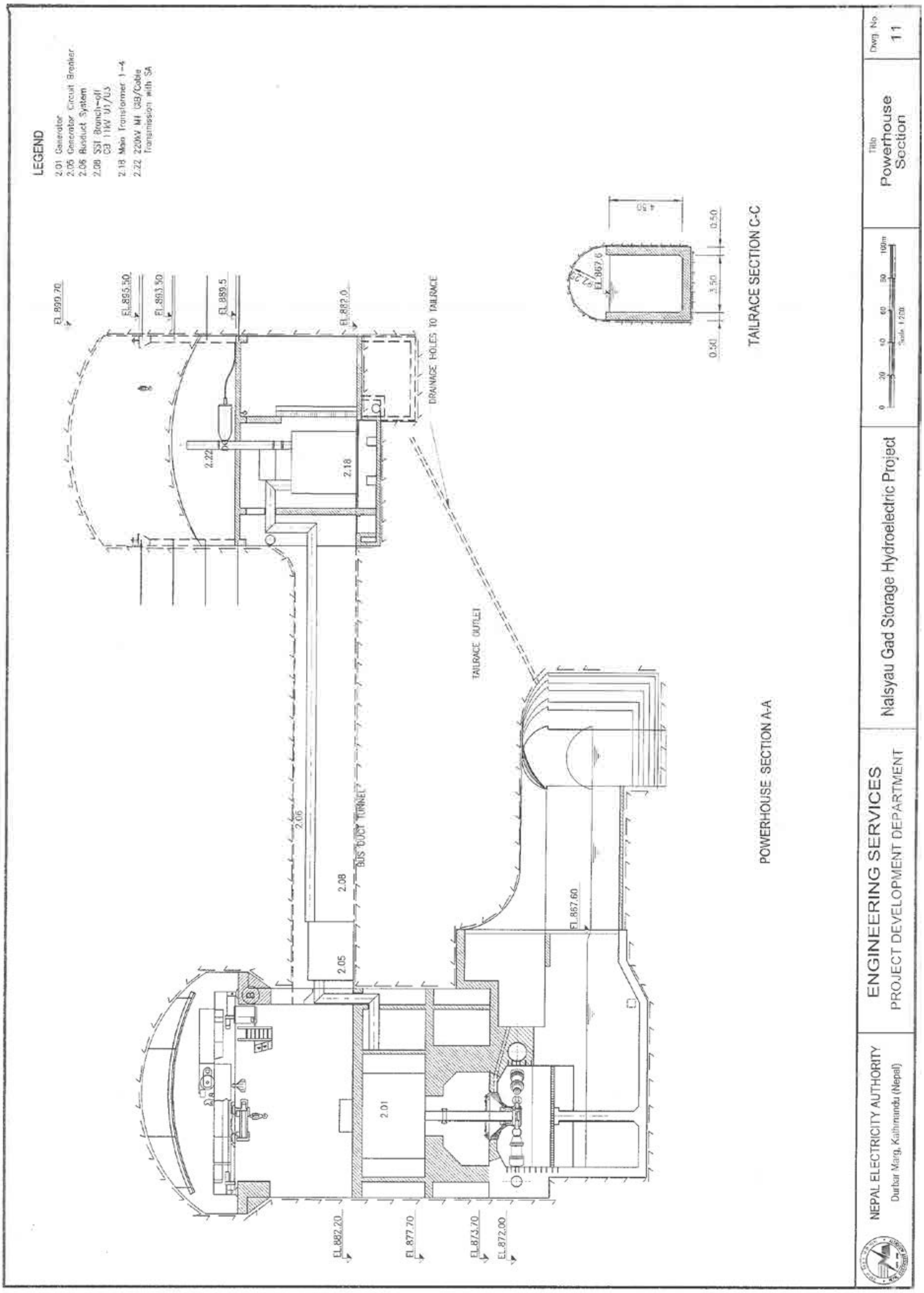
Source: Nalsyau Gad Hydropower Project Feasibility Study Executive Summary, 2012, NEA

Figure A.2.9-10 Waterway Section



Source: Nalsyau Gad Hydropower Project Feasibility Study Executive Summary, 2012, NEA

Figure A.2.9-11 Powerhouse Plan



Source: Nalsyau Gad Hydropower Project Feasibility Study Executive Summary, 2012, NEA

Figure A.2.9-12 Powerhouse Section

(5) Electrical/Mechanical Equipment and Transmission Line

1) General

Rated effective head, power discharge and installed capacity of the Nalsyau Gad Project are as follows;

Rated Effective Head	: 630.50 m
Rated Power Discharge	: 75.00 m^3/s
Installed Capacity	: 410 MW

The HD Wiz (developed by J-POWER, based on existing hydropower plant data around world) has been used for reviewing design of electrical/mechanical equipment taking above information into consideration. Turbine efficiency and generator efficiency have been improved in recent years and installed capacity exceeded above-mentioned 410 MW consequently.

2) Unit Capacity and Number of Unit

Generally, for the turbine-generator, a large unit capacity is said to be more economical merits of scale. However, optimum unit capacity of the turbine-generator is determined in consideration of influence to the power system, development timing and transportation restriction.

In this project, all electrical and mechanical equipment will be transporting from foreign countries via Indian national road and un-maintained Nepalese national road to the project site. Therefore maximum unit capacity shall be set as around 100 MW and number of 4 units plan has been adopted for the project.

3) Turbine

a) Turbine Output

Rated turbine output at rated effective head of 630.50 m and rated power discharge of 18.75 m^3/s per unit can be calculated as follow;

$$
\begin{aligned}
Pt &= 9.8 \times Hn \times Qt \times \eta t \\
&= 9.8 \times 630.50 \times 18.75 \times 0.90 \\
&\approx 104{,}200 \text{ kW}
\end{aligned}
$$

where

- Pt : Rated turbine output per unit (kW)
- Hn : Rated effective head (m)
- Qt : Rated power discharge per unit (m^3/s)
- ηt : Turbine efficiency

b) Type of Turbine

Generally, type of turbine can be determined by close relation between effective head and turbine output. Vertical shaft Pelton type turbine can be selected taking rated effective head and turbine output into consideration.

c) Runner Material

Stainless steel anti-corrosion type such as 13 chrome high nickels stainless steel is recommended to be applied for the runner material. Surface of runner, bucket and wear ring shall be coated (hard or soft) in case of water quality. Detailed coating method shall be specified in the detailed design stage.

d) Installed Capacity

Installed capacity can be calculated from aforementioned turbine output per unit as follow;

$$104{,}200 \text{ kW} \times 4 = 416{,}800 \text{ kW}$$

Review of energy calculation is conducted by using above installed capacity.

4) Generator

A three phase alternating current synchronous generator with vertical shaft rated capacity of 113,500 kVA and power factor of 90% lag are selected.

a) Generator Capacity

Rated generator capacity can be calculated from rated turbine output, power factor and generator efficiency as follows;

$$\begin{aligned} Pg &= Pt \times \eta g / p.f \text{ (kVA)} \\ &= 104{,}200 \times 0.981 / 0.90 \\ &\approx 113{,}500 \text{ VA} \end{aligned}$$

where

Pg : Rated generator capacity (kVA)
Pt : Rated turbine output (kW)
ηg : Generator efficiency (%)
p.f : Power factor, lag

As the results of above calculation, rated generator capacity is 113,500 kVA.

5) Transmission Line

Regarding designing of the transmission line, transmission line shall be connected to the closest substation based on 400 kV Transmission Line Power Development Plan by the NEA. And also thermal capacity and maximum surface potential gradient have been taken into consideration for designing of the transmission line and following specifications have been adopted. As for the transmission line length, the direct length from project area to closest substation was measured from map. Therefore, some allowance has been taken into consideration.

Connected Substation	: Chaujhari Substation
Transmission Line Voltage	: 220 kV
Length of Transmission Line	: 33 km
Conductor Type	: Bison × 2, 2 circuits

2.10 Naumure (W.Rapti) Project (W-25)

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A.2.10 Naumure (W.Rapti) (W-25)

(1) Project Summary

The Naumure Project is a 245 MW storage-type hydroelectric power project located at the West Rapti river in the Argakhanchi District and the Pyuthan District in the western region. The latest study was conducted in the "Naumure (W.Rapti) Hydroelectric Project Pre-Feasibility Study, 1990, NEA." The study level for this project attains the pre-feasibility study level.

As hydrological characteristics, the annual rainfall at Khanchikot gauging station nearest to the project site is 1,772 mm and the average river discharge at the dam site is 138.7 m^3/s. The drainage area is 3,430 km^2, and the specific sediment volume is estimated to be 5,750 t/km^2/year. This is larger than 3,960 t/km^2/year, which is the value adopted by the NEA as average specific sedimentation volume in the western region. No glacier lakes having a high risk of a GLOF are identified in the drainage basin.

From a geological view point, the project area lies both in the Lesser Himalaya Zone and in the Sub Himalaya Zone. These zones are divided by MBT. The Lesser Himalaya Zone is composed mainly of shale, quartzite and limestone. The Sub Himalaya Zone is composed mainly of sandstone and siltstone. The upstream portion of the reservoir area is in the Lesser Himalaya Zone and the downstream portion of reservoir area is in the Sub Himalaya Zone, which increases reservoir water tightness. Rocks close to MBT are sheared and would provide unstable slopes. The dam site, headrace tunnel route and powerhouse site are located in the Sub Himalaya Zone. The dam site is underlain by sandstone and siltstone, which form medium-hard and relatively permeable bedrock. The headrace tunnel route passes through sound sandstone. The bedrock of the powerhouse site is mainly composed of sandstone and siltstone, which would not be suitable for an underground power house. The project area is located in the area where a relatively small acceleration of 130 mgal is shown on the seismic hazard map. It is away from epicenters larger than M4 at a relatively long distance of 40 km. However, it is close to a large tectonic thrust (MBT) at a short distance of 3 km.

The impact on the Natural Environment is relatively high and the impact on the Social Environment is average. Naumure (W. Rapti) is located in the Rapti river basin and the reservoir area is 19.8 km^2, which is the biggest next to Sun Koshi No.3. The affected forest area is 7.85 km^2, which is the largest next to Sun Koshi No.3. The number of recorded plant species is relatively high at 55. The number of recorded fauna is also high, with numbers such as 24 mammals, 49 birds, and 17 Herpetofauna. The dewatering area is the shortest at 0.5 km. The number of resettlements is 456. The affected agricultural land is 6.1 km^2, which is the largest next to Sun Koshi No.3. The number of fishermen is relatively small at 43. The Indigenous groups in the reservoir area are the Magar (Disadvantaged) and the Gurung (Disadvantaged).

From the view point of hydropower planning, a large rockfill dam with a height of 190 m and a volume of 13.2 million m^3 are planned in the current layout. It is recognized that the work for dam will be on the critical path in the construction stage.

In the current layout, the dam and powerhouse upstream of the Lower Jhimruk project located upstream of the Naumure project, are located in the reservoir of the Naumure project. Therefore, it is impossible to construct both projects with the current layouts. It is at least necessary to change the layout of either project to implement both projects. In addition, it should be noted that the Naumure project would be developed as a multipurpose project since implementation of irrigation project is planned.

The location, basic layout and salient features of the project are shown below.

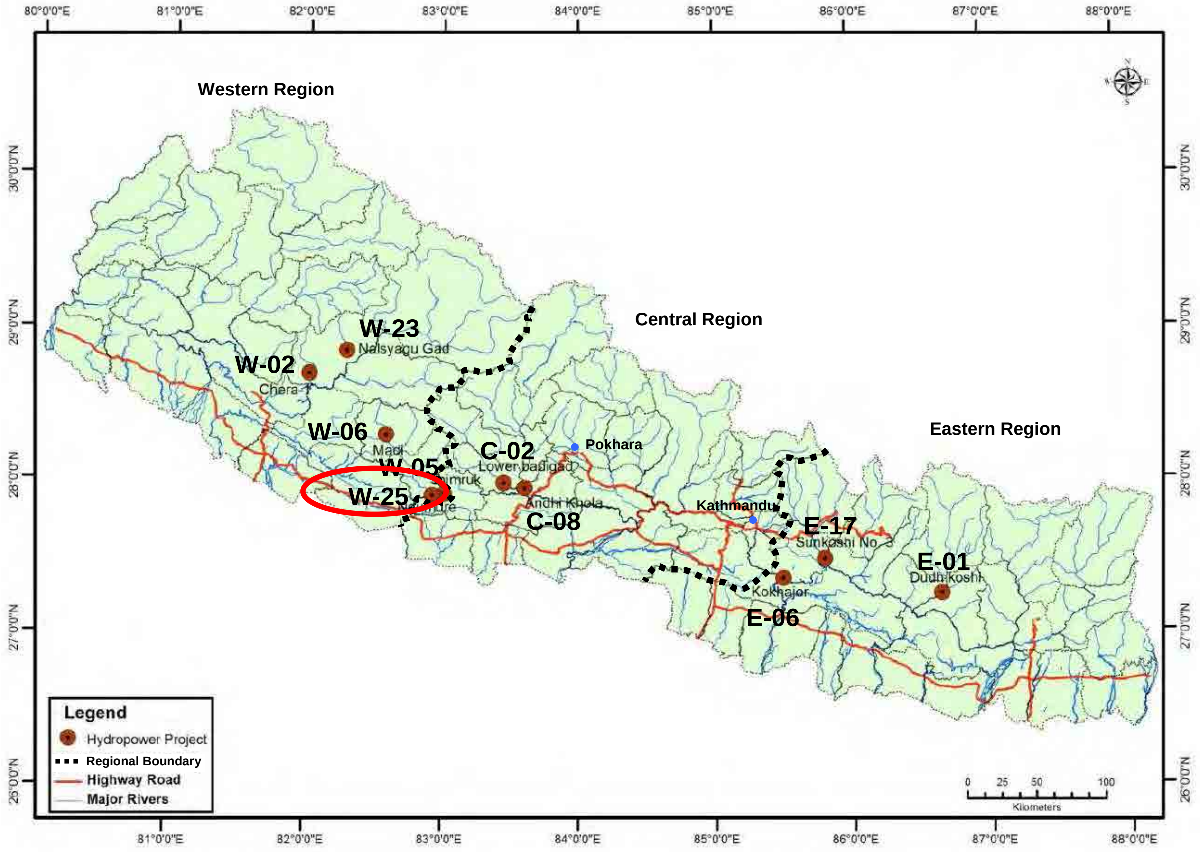


Figure A.2.10-1 General Layout of the Naumure (W. Rapti) Project (W-25)

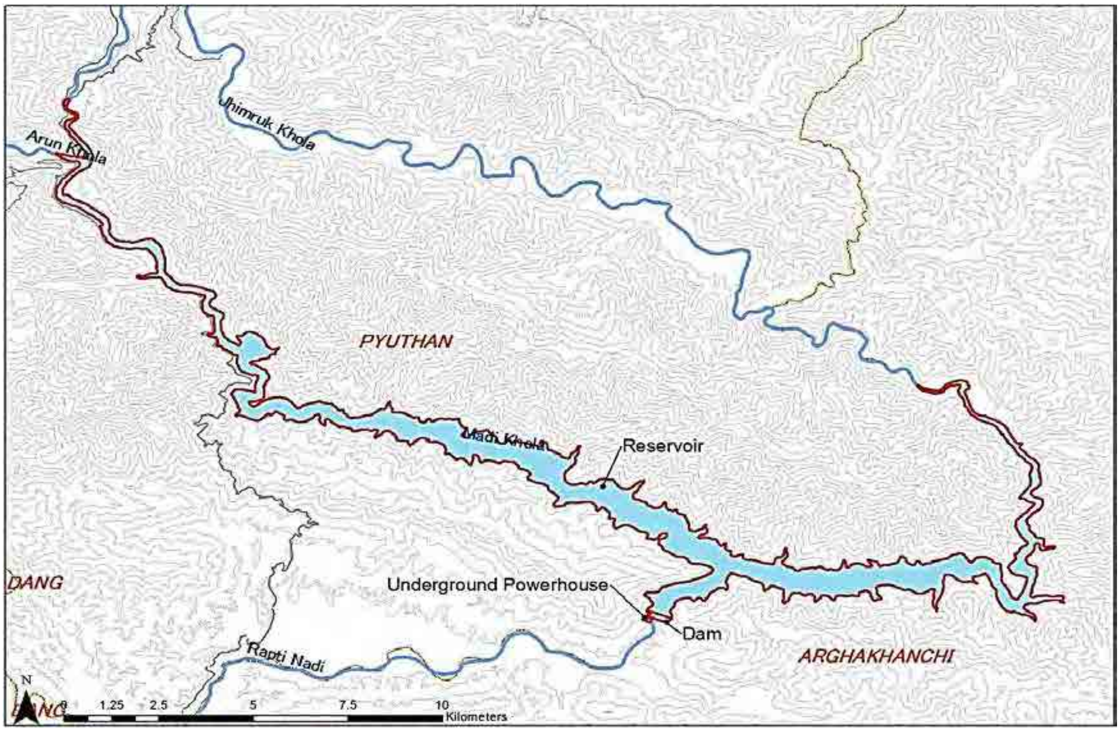


Figure A.2.10-2 General Layout of the Naumure (W. Rapti) Project (W-25)

Table A.2.10-1 Project Description

Item	Unit	Naumure (W.Rapti)	Remarks
Location	(District)	Argakhanchi Pyuthan	
Name of the River	(River)	West Rapti	
Installed Capacity	MW	245.0	
Catchment Area	km^2	3,430	
Location of Dam Site	Longitude/ Latitude	82° 55' 42.9" 27° 55' 6.1"	
Dam Height	m	190.0	
Total Storage Volume	MCM	1,021.0	
Effective Storage Volume	MCM	580.0	
Regulating Capability Factor	%	13.3	
Reservoir Area at FSL	km^2	19.8	
Full Supply Level	m	517.0	
Minimum Operation Level	m	474.2	
Tail Water Level	m	358.0	
Rated Gross Head	m	162.6	
Rated Net Head	m	154.5	
Rated Power Discharge	m^3/s	185.6	
Total Energy	GWh	1,157.5	Estimated by the Study Team.
Dry Energy (December-April)	GWh	309.9	Estimated by the Study Team.
Length of Access Road	km	34.0	
Length of Transmission Line	km	79.0	Estimated by the Study Team.
Number of Household	nos	456	Surveyed by the Study Team in 2012.
Project Cost	MUS$	954.5	Estimated by the Study Team at 2013 price level.
Unit Generation Cost	cent/kWh	8.2	Estimated by the Study Team.
EIRR (8% of Interest Rate, 12NRs/kWh)	%	15.2	Estimated by the Study Team.
FIRR (8% of Interest Rate, 12NRs/kWh)	%	25.3	Estimated by the Study Team

Source: Naumure (W. Rapti) Hydroelectric Project Pre-Feasibility Study, 1990, NEA (except remarked items)

In addition, the summary of natural and social environmental investigation result and its evaluation are shown below. The detailed information is summarized in Appendix 3 and 5.

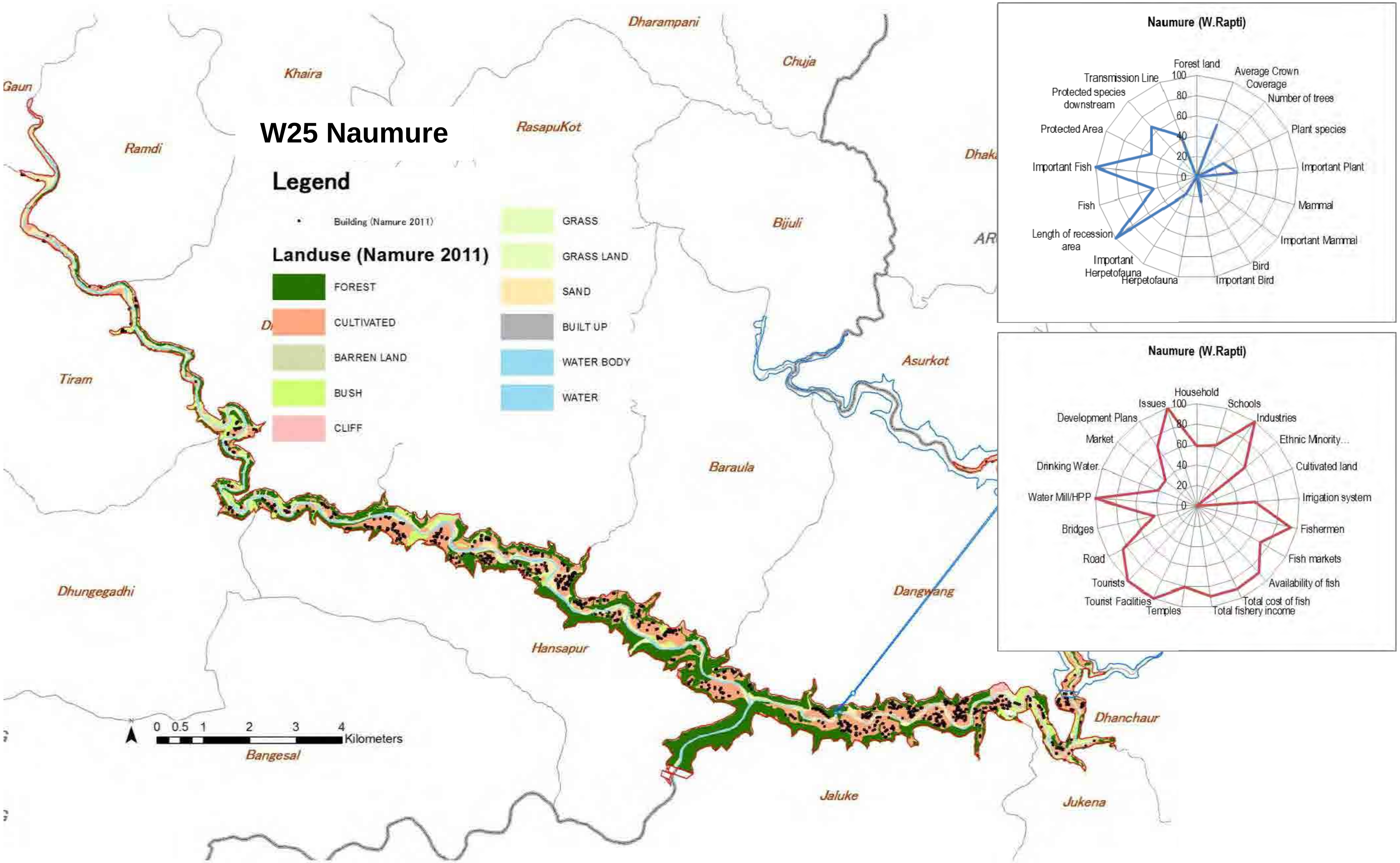


Figure A.2.10-3 Land Use and Buildings in the Reservoir Area of the Naumure Project

(2) Meteorology & Hydrology

With regarding to the Naumure (W. Rapti) project, the meteorological characteristics and the criteria for hydrological evaluation, namely reliability of flow data, risk of a GLOF and sediment impact are mentioned below.

1) Meteorology

The Naumure (W. Rapti) project site is located at the West Rapti river. The districts where the project site is located at are Arghakhachi and Pyuthan.

The Khanchikot climatology station (0715) is located in the Arghakhanchi district. Table A.2.10-2 shows the monthly rainfall at the Khanchikot station.

The Bijuwartar precipitation station (0505) is located in the Pyuthan district. Table A.2.10-3 shows the monthly rainfall at the Bijuwater station.

Table A.2.10-2 Monthly Rainfall at the Khanchikot Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
KHANCHIKOT	0715	Arghakhanchi	CLIMATOLOGY	Jan, 71	27.93	83.15	1,760

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
26.9	35.4	30.2	36.6	105.7	280.0	495.1	390.0	269.2	67.2	12.5	23.6	1,772.3

Source: Department of Hydrology and Meteorology: DHM

Table A.2.10-3 Monthly Rainfall at the Bijuwartar Station

Name	Index	District	Type of Station	Start to Record	Location		Elevation
					Latitude	Longitude	(m)
BIJUWAR TAR	0505	Pyuthan	PRECIPITATION	Jan, 73	28.10	82.87	823

Precipitation (mm)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
23.4	27.2	25.5	35.7	78.2	234.5	314.4	265.6	156.0	42.5	6.6	11.0	1,220.4

Source: Department of Hydrology and Meteorology: DHM

2) Reliability of flow data

As there is no gauging station near the Naumure (W. Rapti) project site, the flow of the project is calculated by the Regional Analysis. The reliability of flow data of the Naumure (W. Rapti) project is relatively low.

Table A.2.10-4 shows the monthly flow data used for energy calculation.

Table A.2.10-4 Flow Data of the Naumure (W. Rapti) Project

(m^3/s)

Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ave.
33.41	28.91	27.92	32.80	52.52	143.57	363.64	434.89	303.94	134.16	65.15	43.30	138.68

3) Risk of GLOF

There is no potentially critical glacier lake which may cause a GLOF in the upstream area of the Naumure (W. Rapti) project site.

4) Sedimentation

The specific sediment yield of the Jhimruk Hydroelectric Project which is located near the project site is adopted as the specific sediment yield of the Naumure Project. According to the FS report, the specific sediment yield of the Jhimruk Hydroelectric Project is from 5,000 to 6,500 t/km^2/year. Therefore, the average value, 5,750 t/km^2/year, was adopted for calculation of the life of reservoir. By using this yield, the life of the reservoir is estimated. The life of reservoir is an index to evaluate the sediment impact to reservoir and calculated dividing total storage volume by mean annual sediment yield.

Table A.2.10-5 shows the calculation result of the life of reservoir. The life of reservoir of the Naumure project is estimated to be 78 years.

Table A.2.10-5 Life of Reservoir

a) Specific Sediment Yield	5,750 t/km^2/yr
b) Sediment Yield (Catchment Area × Specific Sediment Yield / Sediment Density)	13.1× 10^6 m^3/yr (3,430 km^2× 5,750 t/km^2/yr / 1.5 t/m^3)
c) Total Storage Volume	1,021× 10^6 m^3
d) Life time of Storage (Total Storage Volume / Sediment Yield)	78 years (1,021× 10^6 m^3 / 13.1× 10^6 m^3/yr)

(3) Geology

1) Site Geology

a) Site Geology

The Naumure project area belongs to the Arghakahchi district and the Pyuthan District, west in Nepal. The dam site is located in the valley of the Rapti river about 3 km downstream of the confluence of the Madi river and the Jhimruk river. The powerhouse site is located immediately downstream of the dam site. According to the field geological survey and the Pre-FS report (1990), geology and engineering geology of the project area are as follows.

The geological map of the project area is shown in Figure A.2.10-4. MBT extend east to west direction and divide the project area into the Lesser Himalayan Zone and the Sub Himalayan Zone. The Lesser Himalayan Zone is underlain by shale, slate, phyllite, quartzite, limestone and dolomite. The Sub Himalayan Zone is underlain by sandstone, siltstone and mudstone of the Lower Siwaliks Formation and the Middle Siwaliks Formation.

The reservoir and its surrounding area are located along MBT extending in WNW-ESE direction. Above mentioned rocks or formations are distributed parallel to MBT. The reservoir area is watertight, because the southern bank of the reservoir is underlain by the Lower Siwaliks Formation and the Middle Siwaliks Formation, which is generally impervious. The engineering geological map of the reservoir and its surrounding area is shown in Figure A.2.10-5. As indicated by some landslides, slopes in reservoir and its surrounding area are rather unstable, because underlying rocks are sheared by the movement of MBT.

The dam site is mainly underlain by sandstone of the Middle Siwaliks Formation. Bedding planes, which strikes are parallel to the dam axis, incline toward upstream at angles about 60 degrees. Bed rock is medium hard and slightly permeable. The thickness of river deposits was confirmed to be 20 m by a boring.

The headrace tunnel route passes on the right bank of the Rapti river, where is mainly underlain by sandstone of the Middle Siwaliks Formation. Overburden of this tunnel is up to 60 m. The bedrock around this site would not be strong enough for an underground powerhouse site.

The powerhouse site is located on the right bank about 300 m downstream of the dam site. The bedrock of this site is composed of sandstone and siltstone of the Middle Siwaliks Formation. Bedding planes, which strikes are almost perpendicular to the slope, incline toward upstream at angles about 40 degrees. The bedrock around this site would not be strong enough for underground power house. The depth of river deposits is assumed to be about 20 m.

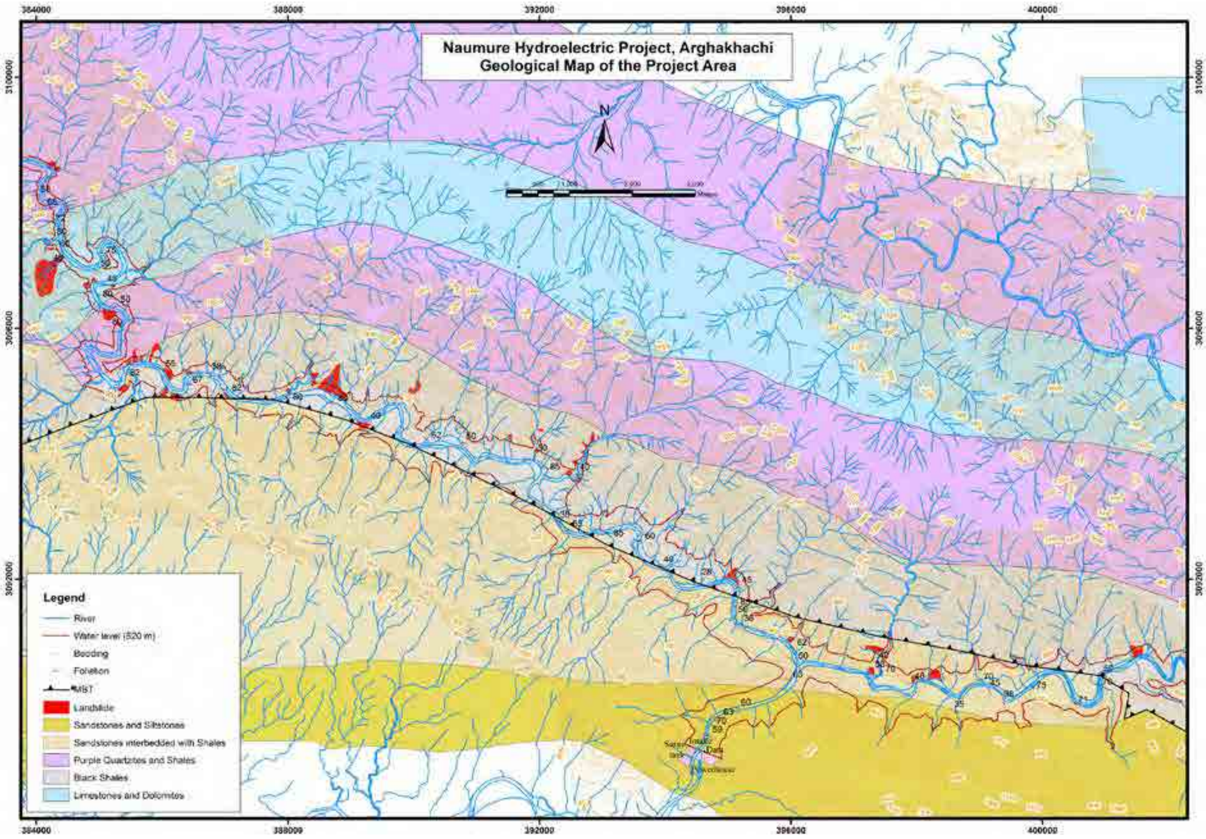
Enough volume of gravel suitable for coarse aggregates distributed in the vicinity of the dam site and near the confluence of the Madi river and the Jhimruk river. Sand suitable for fine aggregate is distributed 5 km downstream. Sandstone distributed 2 km downstream of the dam site is available for rock materials. Soil materials are distributed in borrow areas 2 km downstream of the dam site.

b) Thrust and Fault

Among large tectonic thrust, MBT is located to the north of the dam site at a distance of 3 km. A local major fault has not been found in the vicinity of the dam site.

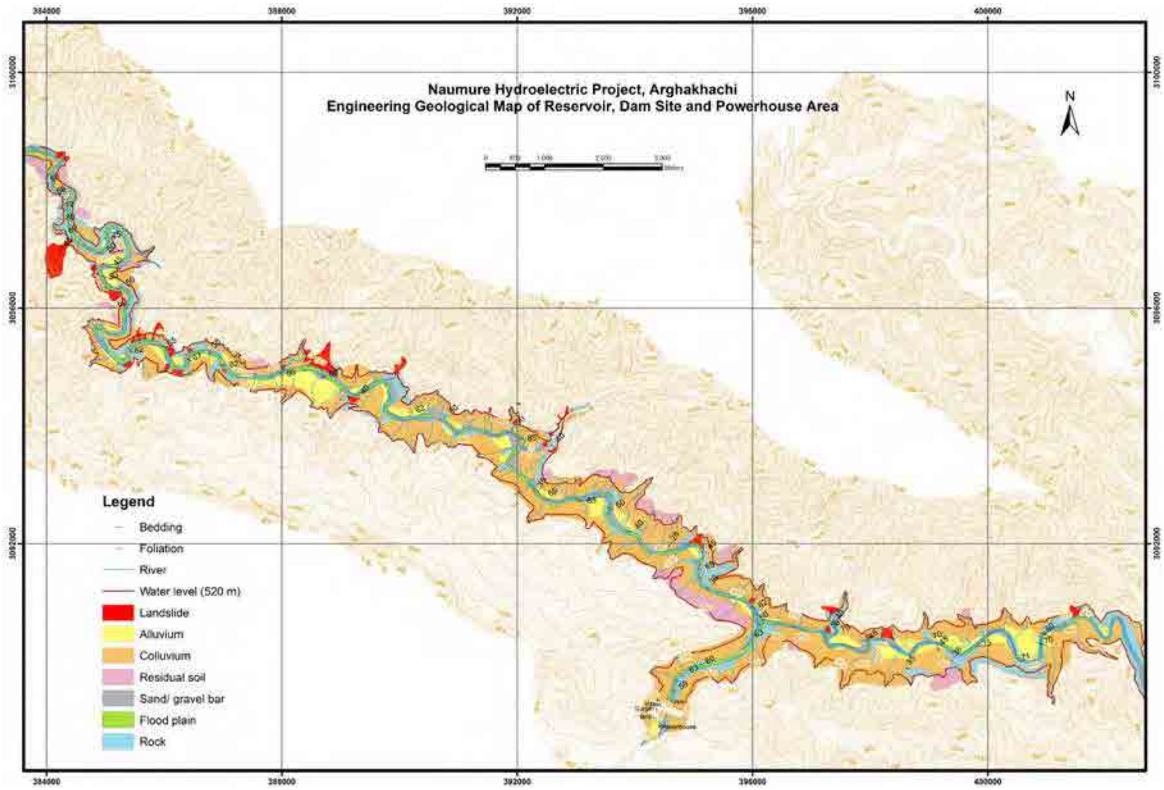
c) Seismicity

The dam site is located in the Lesser Himalaya. The horizontal ground acceleration of this area is 130 mgal according to the Seismic Hazard Map of Nepal. The nearest epicenter of M $\geqq$4 to the dam site is located to the northeast at a distance of about 40 km.



Source: NESS Field Survey, 2012

Figure A.2.10-4 Geological map of the project area



Source: NESS Field Survey, 2012

Figure A.2.10-5 Engineering geological map of the reservoir and its surrounding region

(4) Development Plan

The Naumure (W.Rapti) Project is a dam and waterway-type hydropower project. Since the study level stays at pre-feasibility study level, the detailed design drawings are not available.

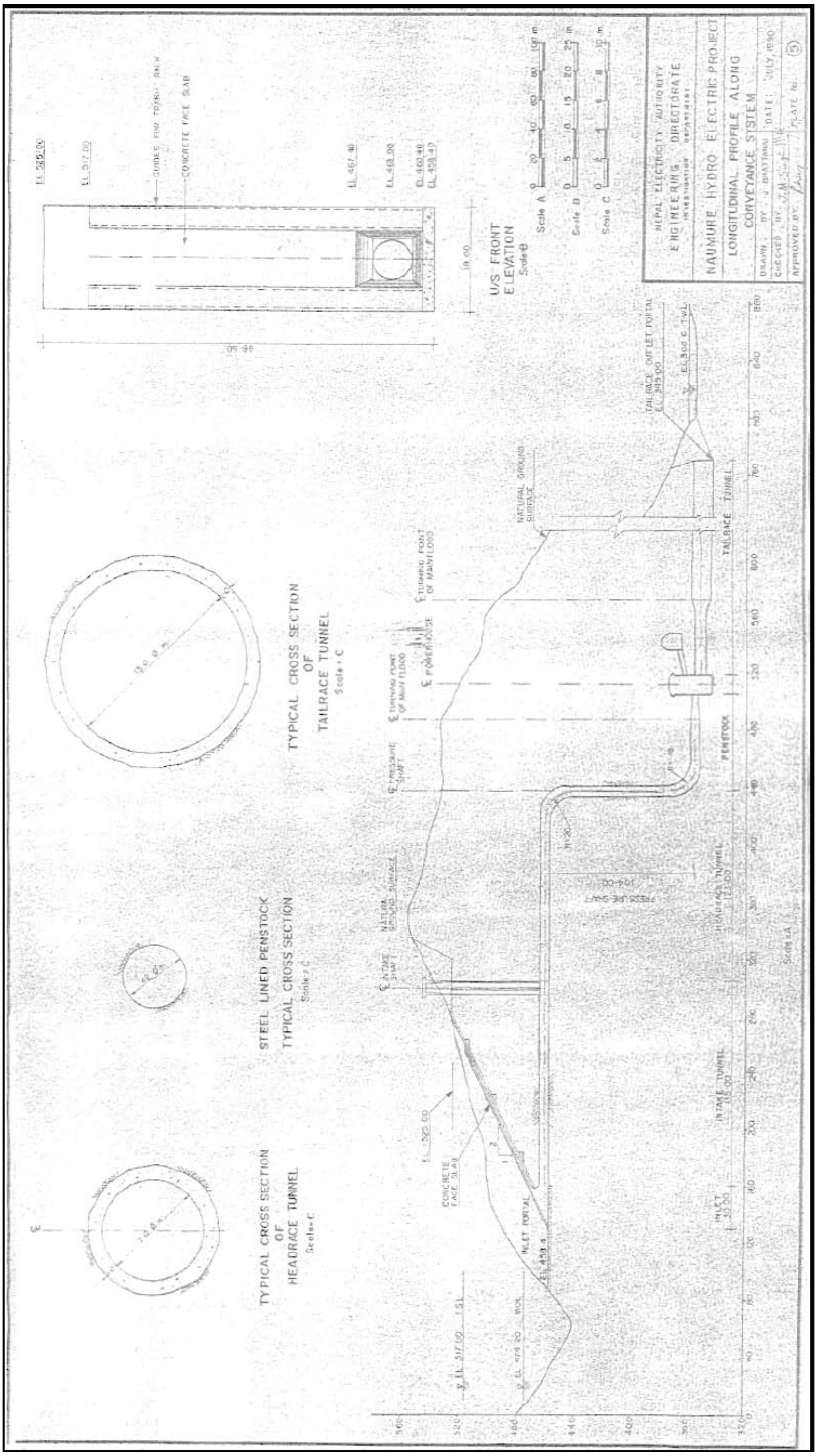
The salient features of principal layout and basic layout drawing of the project are as follows:

Table A.2.10-6 Salient Features

Item	Unit	Naumure	Remarks
Reservoir			
Reservoir Area at FSL	km^2	19.8	
Total Storage Capacity	MCM	1,021.0	
Effective Storage Capacity	MCM	580.0	
Full Suply Level (FSL)	m	517.0	
Minimum Operating Level (MOL)	m	474.2	
Dam			
Type of Dam	-	Rockfill	
Dam Volume	MCM	13.2	
Total Dam Height	m	190	
River Bed Level at Dam Axis	m	-	
Spillway Type	-	Gated Spillway	Controlled ogee
Waterway & Powerhouse			
Intake Type	-	Normal Pressure Intake	Bell mouth
Concrete Lined Headrace Tunnel Length	m	125	
Circular Tunnel Diameter	m	7	
Penstock Length	m	120	D = 4.2m
Type of Powerhouse	-	Underground	W14m × L58m × H30.4m
Turbine Type	-	Francis	
Installed Capacity	MW	245.0	3 × 81.67MW
Design Discharge	m^3/s	185.6	
Rated Net Head	m	109.3	
Tail Water Level	m	358.0	
Tailrace Length	m	220.0	D = 13m (Circular lined)

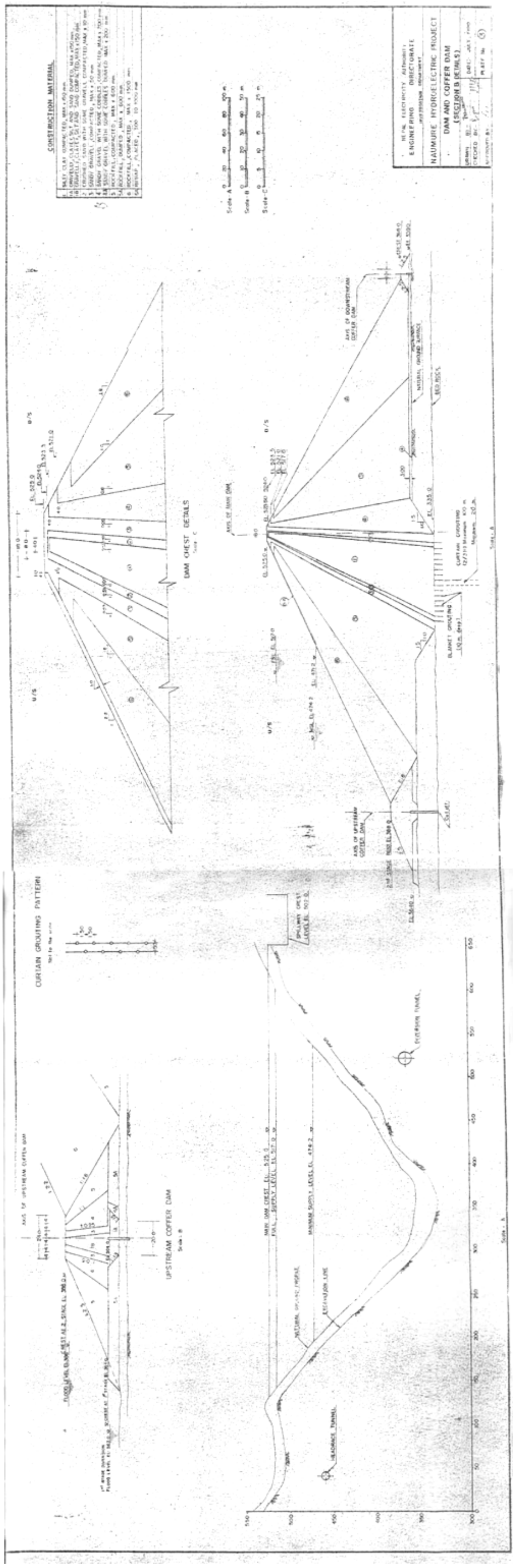
Source: Naumure (W. Rapti) Hydroelectric Project Pre-Feasibility Study, 1990, NEA

Where, as for the Naumure Project, there is information that government of Nepal and government of India exchanged letters in terms of finance for the project development.



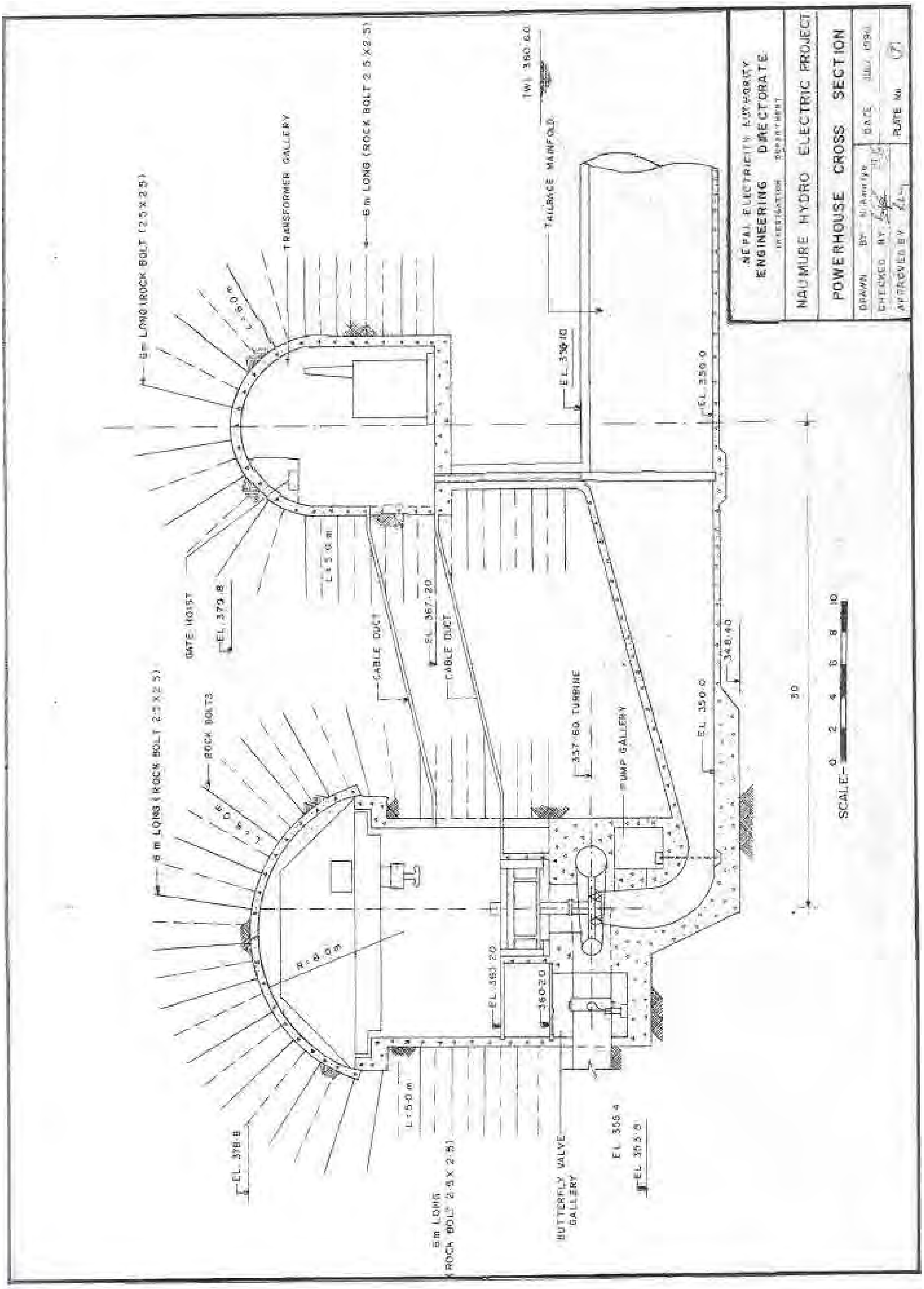
Source: Naumure (W. Rapti) Hydroelectric Project Pre-Feasibility Study, 1990, NEA

Figure A.2.10-6 General Layout



Source: Naumure (W. Rapti) Hydroelectric Project Pre-Feasibility Study, 1990, NEA

Figure A.2.10-7   Dam Section



Source: Naumure (W. Rapti) Hydroelectric Project Pre-Feasibility Study, 1990, NEA

Figure A.2.10-8 Powerhouse Section

(5) Electrical/Mechanical Equipment and Transmission Line

1) General

Rated effective head, power discharge and installed capacity of the Naumure Project are as follows;

Rated Effective Head	: 154.50 m
Rated Power Discharge	: 185.60 m^3/s
Installed Capacity	: 245 MW

The HD Wiz (developed by J-POWER, based on existing hydropower plant data around world) has been used for reviewing design of electrical/mechanical equipment taking above information into consideration. Turbine efficiency and generator efficiency have been improved in recent years and installed capacity exceeded above-mentioned 245 MW consequently.

2) Unit Capacity and Number of Unit

Generally, for the turbine-generator, a large unit capacity is said to be more economical merits of scale. However, optimum unit capacity of the turbine-generator is determined in consideration of influence to the power system, development timing and transportation restriction.

In this project, all electrical and mechanical equipment will be transporting from foreign countries via Indian national road and un-maintained Nepalese national road to the project site. Therefore maximum unit capacity shall be set as around 100 MW and number of 3 units plan has been adopted for the project.

3) Turbine

a) Turbine Output

Rated turbine output at rated effective head of 154.40m and rated power discharge of 61.87 m^3/s per unit can be calculated as follow;

$$\begin{aligned} Pt &= 9.8 \times Hn \times Qt \times \eta t \\ &= 9.8 \times 154.50 \times 61.87 \times 0.927 \\ &\approx 86{,}800 \text{ kW} \end{aligned}$$

where

Pt	: Rated turbine output per unit (kW)
Hn	: Rated effective head (m)
Qt	: Rated power discharge per unit (m^3/s)
ηt	: Turbine efficiency

b) Type of Turbine

Generally, type of turbine can be determined by close relation between effective head and turbine output. Vertical shaft Francis type turbine can be selected taking rated effective head and turbine output into consideration.

c) Runner Material

Stainless steel anti-corrosion type such as 13 chrome high nickels stainless steel is recommended to be applied for the runner material. Surface of runner and wear ring shall be coated (hard or soft) in case of water quality. Detailed coating method shall be specified in the detailed design stage.

d) Installed Capacity

Installed capacity can be calculated from aforementioned turbine output per unit as follow;

$$86{,}800 \text{ kW} \times 3 = 260{,}400 \text{ kW}$$

Review of energy calculation is conducted by using above installed capacity.

4) Generator

A three phase alternating current synchronous generator with vertical shaft rated capacity of 94,300 kVA and power factor of 90% lag are selected.

a) Generator Capacity

Rated generator capacity can be calculated from rated turbine output, power factor and generator efficiency as follows;

$$\begin{aligned} Pg &= Pt \times \eta g / p.f \text{ (kVA)} \\ &= 86{,}800 \times 0.978 / 0.90 \\ &\approx 94{,}300 \text{ kVA} \end{aligned}$$

where

- Pg : Rated generator capacity (kVA)
- Pt : Rated turbine output (kW)
- ηg : Generator efficiency
- p.f : Power factor, lag

As the results of above calculation, rated generator capacity is 94,300kVA.

5) Transmission Line

Regarding designing of the transmission line, transmission line shall be connected to the closest substation based on 400 kV Transmission Line Power Development Plan by the NEA. And also thermal capacity and maximum surface potential gradient have been taken into consideration for designing of the transmission line and following specifications have been adopted. As for the transmission line length, the direct length from project area to closest substation was measured from map. Therefore, some allowance has been taken into consideration.

Connected Substation	: Butwal Substation
Transmission Line Voltage	: 220 kV
Length of Transmission Line	: 79 km
Conductor Type	: Bison × 1, 2 circuits