Tamakoshi V Hydroelectric Project

Detailed Engineering Design and Tender Document Preparation

Tamakoshi Jalvidhyut Company Ltd.
Nepal Electricity Authority

July 2019
Detailed Design Report

Executive Summery

SALIENT FEATURES

OUTLINE OF THE PROJECT

The Tamakoshi V HEP is located in Dolakha District of Bagmati Province. The project area is situated within Longitude 86°10'30" to 86°14'30" East and Latitude 27°45'00" to 27°49'50" North. The whole project area lies in Bigu and Gaurisankar Rural Municipality. The project is conceptualized to develop as a tandem operation project with Upper Tamakoshi HEP. The intake site / underground interconnection system with Upper Tamakoshi tailrace outlet is located in Gongar whereas the underground powerhouse lies at the right bank of Tamakoshi River just downstream of the Suri River confluence with Tamakoshi River.

In the following, relevant key data of the project have been compiled based on the results derived from the Detailed Project Design.

❖ PLANT OPERATING CONDITIONS

PLANT RATED CONDITIONS

Rated Gross Head	174.00 m
Rated Net Head	159.10 m
Rated Tailwater Level	984.00 masl
Rated Discharge	66 m^3/s
Rated Head Loss (d/s waterway)	0.80 m
Rated Capacity	94.80 MW
Installed Capacity	99.80 MW

INSTALLED GENERATING EQUIPMENT

No. of Units	4
Rated Discharge of Main Units	22m^3/s
Rated Discharge of Small Hydro Unit	3.3m^3/s
Total Turbine Capacity	99.8MW
Generator Capacity (Main Units)	38MVA
Generator Capacity (Small Hydro Unit, approx.)	6MVA
Transformer Capacity	2 x 40 / 1 x 44 MVA

❖ PROJECT HYDROLOGY

Catchment Area at intake	2139 km^2
Catchment area at PH	2460 km^2

Average Annual Flow	69.51 m³/s
Design Flood at Headworks	6,000 m³/s
Design Flood at Power Station	6,000 m³/s

❖ HEADWORKS

CONNECTING TUNNEL

• length	103.20 m
• width	6.80 m
• maximum depth	3.40m
• invert slope	0.1258 %
• invert elevation at start of horizontal bend	1,155.02 m asl.
• invert elevation at entrance to Headpond	1,154.89 m asl.

HEADPOND

• length	74.01 m
• width	6.80 ~ 12.77 m
• water level at plant rated condition	1,158.00 m asl.
• maximum depth	14.00 m
• invert elevation at end wall	1,144.00 m asl.

❖ SPILLWAY

SPILLWAY WEIR AND COLLECTING CHANNEL

• type	free overflow concrete
• length	55.50 m
• crest level	1,158.20 m asl.
• freeboard at plant rated condition	0.20 m
• maximum surcharge	0.90 m
• design discharge	103m³/s
• weir shape	WES standard

SPILLWAY TUNNEL

• type	free surface flow

•	length	311.50	m
•	channel width	4.40	m
•	channel depth	3.55	m
•	invert level at start section	1,153.11	m asl.
•	invert level at exit section	1,150.21	m asl.
•	channel cross section	rectangular	

SPILLWAY TERMINAL STRUCTURE

•	type	RCC gated box type	
•	length	31.51	m
•	width (box frame)	7.40	m
•	maximum height	11.35	m
•	invert level of apron	1,150.00	m asl.

❖ ACCESS TUNNEL TO CONNECTING TUNNEL (ADIT 1)

•	length	185.92	m
•	width	4.20	m
•	maximum invert slope	10.72	%
•	invert elevation at start of horizontal bend	1,169.18	m asl.
•	invert elevation at entrance to Headpond	1,154.89	m asl.

❖ CONSTRUCTION ADIT TO SPILLWAY TUNNEL

•	length	90.34	m
•	width	4.20	m
•	maximum invert slope	13.69	%
•	invert elevation at start of horizontal bend	1,163.25	m asl.
•	invert elevation at entrance to Headpond	1,152.90	m asl.

❖ WATER CONVEYING TUNNELS & SURGE TANK

HEADRACE TUNNEL

•	Total length of headace tunnel (HRT)	8098.0	m

• Length of shotcrete lined section of HRT	1000.0	m
• length of concrete lined section	7,098.0	m
• inner diameter (concrete lining)	5.60	m
• thickness of concrete lining	0.40	m
• length of steel lined section (incl. valve)	41.90	m
• inner diameter (steel lining)	5.6 to 4.20	m
• longitudinal slope	0.4209	%
• center line elevation at start section	1,149.80	m asl.
• center line elevation at end section	1,114.96	m asl.

❖ SURGE TANK

• type	surge tank- circular	
• top of concrete lining	1,180.00	m asl.
• surge tank bottom	1,129.40	m asl.
• highest upsurge	1,179.30	m asl.
• lowest downsurge	1,130.50	m asl.
• inner diameter	15.00	m asl.
• diameter of connecting shaft	2.50	m asl.

❖ U/S VALVE CHAMBER

• length	20.00	m
• width	11.00	m
• height	16.90	m
• invert elevation	1,110.60	m asl.
• span between crane rails	9.60	m

❖ PRESSURE SHAFT

• type	steel lined shaft	
• length including bends	152.72	m
• center line at start section	1,114.96	m asl.
• center line at end section	976.03	m asl.
• Inner diameter (steel lining)	4.20	m
• Steel Thickness	17 to 36	mm

- excavation diameter 5.00 m
- bend radii 12.60 m

❖ High Pressure Tunnel & Upstream Manifolds

- center line elevation at start section 976.03 m asl.
- diameter at start section (steel lining) 4.20 m
- center line elevation at end section (U1 - U3) 974.48 m asl.
- center line elevation at end section (U4) 975.61 m asl.
- diameter at end section (U1 - U3) 2.425 m
- diameter at end section (U4) 0.95 m
- deflection of manifolds 90 deg.

❖ Downstream Manifolds

- length of manifolds 31.64 … 36.09 m
- manifold diameter 3.30 … 5.60m
- longitudinal slope 1.1 %
- end section elevation 968.74 m asl.
- deflection of branches 45 deg.

❖ Tailrace Tunnel

- length 404.36 m
- diameter 5.60 m
- center line elevation at start section 971.90 m asl.
- center line elevation at end section 976.80 m asl.
- longitudinal slope 1.13 %
- deflection of horizontal bend 45 deg.

❖ Outlet Structure

Gate & Access Shaft

- height above waterway liner 32.46 m
- outer diameter 8.40 m
- operation platform level 1,014.00 m asl.

- hoist floor level — 1,003.00 m asl.
- rod storage floor level — 998.00 m asl.
- shaft cross section — circular

OUTLET STRUCTURE TUNNEL

- length of tunnel — 53.00 m
- clear height — 5.60 m
- clear width — 4.40 … 5.60m
- centerline elevation — 976.80 m asl.
- tunnel cross section — rectangular

TAILBAY

- average length of tailbay — 27.28 m
- tailbay floor below tailrace tunnel invert — -1.00 m
- slope of tailbay floor towards end sill — 1 : 2.35
- end sill elevation — 982.80 m asl.
- deflection of side walls — 15 deg.

❖ POWER STATION

POWERHOUSE CAVERN

- Dimension L x W x H — 69.m x 18.m x 33.14 m
- Turbins — 3 x 31.6 + 1 x 5 MW
- Installed Capacity — 99.80 MW
- Over head Crane — 80/15 t
- An Elevator serves the Auxiliary Floor, Turbine Floor, Generator Floor and the Machine Hall Floor.
- Two staircases are located diagonally at the opposite ends of the Powerhouse Cavern. The staircase adjacent to the MAT and the Erection Bay reaches down to the Drainage Gallery.
- The Erection Bay and the Main Access Tunnel are arranged at Machine Hall Floor level.
- The MAT passes through the Powerhouse Cavern and extends up to the Transformer Cavern.
- Two Dewatering / Pump Sumps, one between Units 1 and 2 and one between Units 2 and 3.
- A movement joint separates the Units Bay and the Erection Bay.

The floors in the Powerhouse Cavern are (from top to bottom)

- Crane Runway Floor 989.24 m asl.
- Administration Floor 985.64 m asl.
- Machine Hall Floor 982.19 m asl.
- Generator Floor 978.51 m asl.
- Turbine Floor 975.15 m asl.
- Valve Floor 971.25 m asl.
- Drainage Gallery 967.90 m asl.

❖ TRANSFORMER CAVERN

- dimensions L x W x H 47.6 m x 13.0 m x 17.95 m.
- Bridge Crane 10 t bridge crane.
- The upper floor is accessible by two staircases at either end of the Transformer Cavern.

BUS DUCT GALLERIES

- 3 nos. provided between Powerhouse & Transformer Caverns
- Dimensions length x width x height 23.79 m x 3.00 x 4.00 m

TERMINAL & VENTILATION BUILDING

- Dimensions length x width x height 16.30 m x 15.40 x 15.00 m
- The cable shaft which connects vertically from the Terminal & Ventilation Building extends an additional 32.70 m to either of the two Take-off Yards.
- Three different floor levels were planned in the building.

OPERATION BUILDING

- Dimensions length x width x height 44.50 m x 14.00 x 9.6 m (including the Water Treatment Plant)

WORKSHOP BUILDING

- Dimensions length x width 28.32 m x 31.35 m
- Building Type RCC
- Crane Capacity 10 t crane

TURBINE

•	Type	Francis
•	Number	4 (3 x 31.6 +1 x 5.1)
•	Turbine Axis Level (Vertical Axis)	974.00 m asl.
•	Smaller Unit Axis Level (Horizontal Axis)	976.60 m asl.
•	Discharge per unit in big unit	22 m3/s
•	Discharge Small Unit	3.3 m3/s
•	Efficiency	94 %

GOVERNOR

- Type PID type designed in accordance with latest IEC standard
- Adjustment for Speed Drop Power will be controlled at an accuracy of not less than 1%

GENERATOR

•	Type	IM8425/W41
•	Number	4 (3 x 38 + 1 x 6) MVA
•	Power Factor	0.85
•	Generation Voltage	11 KV
•	Frequency	50 Hz
•	Excitation Type	Static Type
•	Efficiency	98 %

TRANSFORMER

•	Type (outdoor)	3-phase, oil immersed,
•	Rated Capacity	2x40MVA; 1x44 MVA
•	Voltage Ratio	230/11 KV
•	Vector Group	YNd11
•	Frequency	50 Hz
•	Efficiency	99 %

❖ SERVICE TUNNELS

For expediency rock support analysis and design of the Service Tunnels were divided into Type A or Type B.

MAIN ACCESS TUNNEL & ACCESS TUNNEL TO TRANSFORMER CAVERN (TYPE B)

•	The Main Access Tunnel Section	horseshoe section.
•	dimension W xH	6.00 m x 6.00 m
•	A concrete invert is foreseen for the MAT	

CABLE & VENTILATION TUNNEL (TYPE A)

•	The Cable & Ventilation Tunnel Section	horseshoe
•	dimension width x height	4.20 m x 5.80 m.
•	The entire length (consisting of three legs)	138 m.

ESCAPE TUNNEL

•	Escape Tunnel	D-shaped
•	section dimension width x height	2.50 m x 3.00 m.
•	Total length	30 m.

ACCESS TUNNEL TO U/S VALVE CHAMBER & ADIT 4 PLUG (ADIT 4 DURING CONSTRUCTION) (TYPE B)

•	Dimensions width x height x length	5.00 m x 5.80 x 311 m.
•	A gated plug will be installed at the Valve Chamber end.	

VENTILATION TUNNEL TO SURGE TANK (TYPE A)

•	Dimensions width x height x length	4.20 m x 5.60 x 72 m.

ACCESS TUNNEL TO HIGH PRESSURE TUNNEL (TYPE B)

- Dimensions width x height x length as for Main Access Tunnel

❖ ADITS TO HEADRACE TUNNEL

•	Adit 2 (temporary)	513.43	m
•	Adit 3 (temporary)	312.69	m

- Adit 4 (permanent) 311.69 m

❖ Transmission Lines

- Voltage 220 kV, double circuit
- Total Length of LILO Arrangement 3.4 km
- Conductor Twin BISON

❖ Generated Annual Energy

Rolwaling not considered

- Annual Energy 495.148 GWh
- Wet Energy 371.658 GWh
- Dry Energy 64.362 GWh
- Additional Energy 59.127 GWh

Rolwaling Considered

- Annual Energy 543.494 GWh
- Wet Energy 370.502 GWh
- Dry Energy 159.454 GWh
- Additional Energy 13.538 GWh

❖ Estimated Project Costs

Item No.	Description	Foreign USD	Local NPR	Total USD
1	Civil Works	38,041,071.58	3,901,346,236	70,552,290
2	Hydromechanical Equipment	2,464,317.92	295,718,150	4,928,636
3	Electro-Mechanical Equipment	22,666,077.00	302,214,360	25,184,530
4	Camp Works	-	325,824,703	2,715,206
5	Transmission Line	-	225,984,000	1,883,200
6	Owner’s Costs	5,196,762.11	1,810,720,000	20,286,095
	Total Base Cost			**125,549,957**

❖ Financial Indicators

Indicators for Base Case Analysis

•	Interest during Construction (IDC)	10.0	%
•	Project IRR	16.40	%
•	Project NPV	4758.214	mil. NRs
•	Benefit/Cost Ratio	1.26	
•	Discounted Payback Period	7.46	yrs

EXECUTIVE SUMMARY

FOREWORD

This Executive Summary Report is conceived as an umbrella document for the Report on the Detailed Engineering Design of the Tamakoshi V Hydroelectric Project. It is aimed at two sets of readers, namely:

- the executive decision makers who require key information without the background detail, and
- the technical readers who require an overview of the design studies and their main conclusions before entering into the detail.

The summary draws its information from the main report components which in turn draw information from the Album of Drawings and the Reports on Design Criteria, Topographic Surveying, Geology, Hydrology, Sediment as well as Cost and Quantity Estimating, which have been prepared within the framework of the present Consulting Contract.

The Tamakoshi V Hydroelectric Project is located in the Dolakha District of the Janakpur Zone along the Tamakoshi River, about 90 (direct) km east of the national capital Kathmandu. By road, the distance from Kathmandu to the project area is some 170 km. The location is shown in Figure 1

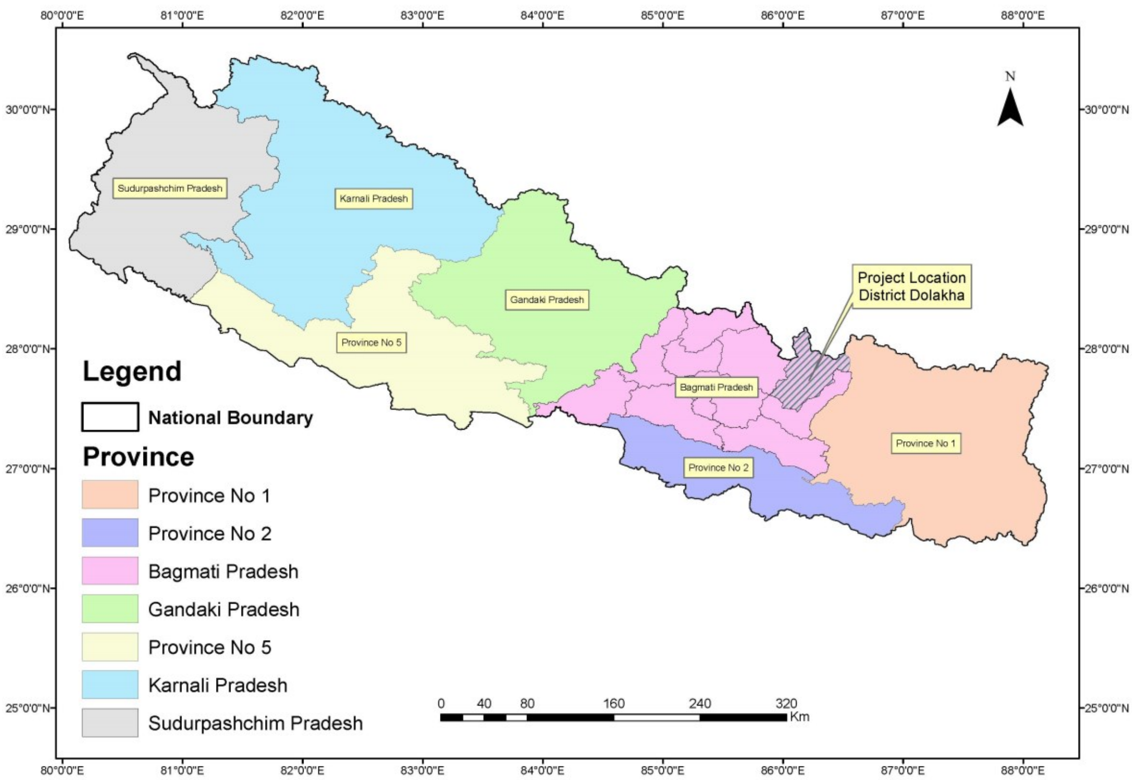

Figure 1: *Location of the Project*

The Tamakoshi V Hydroelectric Project is designed as a tandem (slave) project to the Upper Tamakoshi Hydroelectric Project (UTK HEP) which at the time of release of this report had been under construction since year 2011 and was nearing completion. The principal concept adopted for the slave project was that Tamakoshi V would take the turbine water directly from the tailrace of UTK HEP; because of this concept it was not required to design the Tamakoshi V HEP with a separate dam or river water desanding facilities.

On the other hand, this concept imposes certain restrictions on the design of the Tamakoshi V HEP. The major restriction to be observed are:

- The Tamakoshi V HEP has to be designed for the same rated plant discharge as UTK HEP.
- Operating limits earlier defined for the UTK HEP operation will similarly apply also to Tamakoshi V HEP. This concerns in particular the acceptable river discharge which, when surpassed, will cause UTK HEP to shut down its operation.
- The tailrace tunnel of UTK HEP is designed as channel with free surface flow. The inflow to Tamakoshi V HEP, however, has to be provided as pressurized flow, and this requires to provide a small intermediate pond in front of the Headrace Tunnel intake. Such Headpond was designed for the Tamakoshi V HEP as underground structure.
- A small spillway has to be foreseen at the Headpond for the load case that a plant stoppage occurs at Tamakoshi V while UTK HEP continues to release turbine water. Assuming a sudden load rejection at Tamakoshi V HEP, the Headpond will experience a peak inflow when the release from UTK HEP meets a simultaneous peak reverse flow from a downsurge of the Tamakoshi V Surge Tank.
- The peak inflow into the Headpond will partly be released via the spillway and partly create a backwater in the UTK HEP tailrace tunnel which will propagate upstream. The Headpond and Spillway have to be designed such that the backwater in the tailrace tunnel is limited and does not affect the operation of the UTK HEP turbines.
- The turbine water released from UTK HEP is considered essentially free from sediments. Nevertheless, the desander basins of UTK HEP are designed to trap a preselected portion of sediments of defined grain diameter, which was determined as suitable for the Pelton turbines installed at UTK HEP. Tamakoshi V HEP will be equipped with Francis turbines, which have to be selected with design parameters that suit the operation with turbine water of the same sediment content.

Tamakoshi V HEP is designed considering all the above conditions

SCOPE OF SERVICES

Nepal Electricity Authority hired Tractebel Engineering GmbH (Former Lahmeyer International GmbH) to carry the detailed engineering design of the Tamakoshi V Hydroelectric Project and, concurrently with the elaboration of that design, to prepare Tender Documents for international competitive tendering in accordance with the Government of Nepal’s Standard Bidding Procedures.

This report relates to the detailed engineering design and in this particular regard, the scope of services covered the following:

To conduct topographic surveys, hydrological studies and geological investigations to serve as the basis for the design of the hydropower scheme taking into account all relevant previous planning studies,

To carry out the optimization of selected project components (like the optimization of the alignment and diameters of the power waterways, the number and sizing of generating units, etc.) to support NEA in identifying the preferred project configuration,

To conduct a full detailed design, including an update of the Environmental Impact Assessment prepared for the project at feasibility design level,

To prepare a Construction Schedule and an Engineer's Cost Estimate for the optimized project configuration, and

To conduct a financial analysis of the optimized project configuration.

TOPOGRAPHIC SURVEY

Detailed topographic survey was carried out on key components of the hydropower project (powerhouse area, tunnel alignment, tailrace alignment, surge tank, tansmission line and camp facilities). The ground control points were established using GNSS and detail topographic survey was carried out using total station. The detail topographical survey covered total area of 312 ha which includes the strip survey of headrace tunnel alignment in 1:5000 scale, strip survey of adit tunnel alignment, necessary coverage of other components of the hydropower project in 1:500 scale and strip survey of transmission line in 1:1000 scale. Topographical map was prepared in Auto CAD using SW DTM software.

River cross section was surveyed along the axis of Tailrace and upstream and downstream of the Tamakoshi River. Cross sections were done at 50 m intervals if the location allowed, otherwise at suitable location. On the upstream river cross section was extend up to 190 m and on the downstream the river cross section was extended up to 755 m of tailrace axis.

HYDROLOGICAL STUDY

The project catchment lies in the Khare, Orang and Lamabagar rural municipalities (RM) of Dolakha District, just downstream of the Upper Tamakoshi HEP (456 MW), with a significant part of the catchment located in the Tibetan Autonomous Region of the Peoples' Republic of China (PRC. The total catchment area delineated by GIS is 2,139 km² at the intake site and 2,460 km² at the powerhouse site.

The reference hydrological station for the hydrological analysis of TK-V HEP was considered as the Tamakoshi River at Busti (Station Number 647) from with data from 1971 to 2015. The catchment area ratio analysis shows higher values compared to observed values. So, flow ratio values are used to obtain average monthly flow at the dam Site of UTKHEP. The average annual rainfall in the project catchment is about 2331 mm and average annual flow is about 69.51 m^3/s.

The designed discharge of project at 32% of probability of exceedance without considering rolwaling diversion is 66m^3/s and the Q40 discharge with consideration of Rolwaling diversion is 62.79 m^3/s. Energy corresponding to Q40 discharge is considered to lock the energy for PPA which meets 6/6 months dry and wet season tariff and the remaining energy corresponding to additional discharge more than Q40 discharge is considered for another tariff.

The design flood of 1000 years retun period at Head pond and Tailrace are 1455 m^3/s and 2042 m^3/s respectively. The flood with retun period of 50 years having magnitude of 202m^3/s and 283.5 $m^3/$ at headpond and tailrace respectively was adopted as a construction flood. In the event of a worst case scenario of the PMF occurring simultaneously with the GLOF from the Tsho Rolpa Glacier, the instantaneous flood value magnitude can increase by around 3,500 m^3/s, which will result in a combined flood value of around 7,000 m^3/s at the head-pond section of the Tamakoshi V HEP.

GEOLOGICAL INVESTIGATION

The rock mass of the project area can be divided into two basic categories. They are medium-to high-grade Higher Himalayan crystalline rock sequence and low-grade metamorphic rocks of the Lesser Himalayan rock sequence. The rock sequence of Lesser & Higher Himalaya are delineated by the Main Central Thrust (MCT) near the Tallo Jagat village.

At the proposed powerhouse site, massive augen gneisses occur with sporadic phyllite or chlorite schist partings with almost horizontal foliation and the rock forms the Tamakoshi Dome. These rocks were called the Suri Dobhan augen gneiss by Schelling (1987). The Chlorite schists continues from Suri Dovan the Andheri Khola up to the Jamune village. About 2860 m length of HRT stretch is anticipated to pass through the chlorite schist rock type. Further north is seen another band of augen gneiss termed as the Chagu-Chilangka Augen Gneiss where presence this rock sequence is anticipated for approximately 253 m lengtho of HRT. The rock is followed up-section by chlorite schist, meta-sandstone and quartzite. A succession of medium- to thin-banded pale grey to white, very fine Quartzite occurs towards the top of the last sequence. These rocks belong to the Laduk phylllte of Schelling (1987). This rock sequence in the tunnel stretch is anticipated to be approximately for 901 m length. To the south of the Tatopani, dark grey to black, parallel-laminated meta-sandstones and graphitic schists exist. The meta-carbonate band is alternating with black graphitic schist. The graphitic schist with meta-sandstone bands continues further north and further two more Meta-carbonate bands appear. The grade of metamorphism gradually increases upwards, and the rock gradually changes from chlorite schist to biotite schist and then to garnet schist. This succession of graphitic schists, garnet schists, amphibolites, and quartzites was classified under the Khare Phyllites by Schelling (1987). These rock sequences in the tunnel stretch is anticipated to be approximately for 3026 m length. Finally, at Tallo Jagat village, kyanite schist and gneiss of the Higher Himalayan succession overrides the Lesser Himalayan sequence along the MCT. Schelling (1987) classified the Higher Himalayan crystallines of this section under the Alampu schists and

Rolwaling migmatites. This rock sequence in the tunnel stretch is anticipated to be approximately 1215 m long.

The shear zone passes through a deep gorge at Tatopani. The gorge is having width of approximately 60 m and striking east - west with dip angle approximately of 75^0 towards South. The shear joint is one of the main joint sets in this area.

During feasibility study, core drilling of about 270 m was carried out and during detail engineering design, five boreholes with total length of 277m were executed in the locations of the Spillway Terminal Structure (SP-1), Outlet Structure (TT-1), along the Headrace Tunnel (HB-1' near a fractured zone and HB-2' near Oran Khola) and the Tailrace Tunnel (SW 1). Similarly, about 2185m ERT was carried out during feasibility study and furthermore about 1788m length of additional 2D Electrical Resistivity survey was carried out during detail engineering design phase at Tailrace, Powerhouse and Headrace tunnel.

A Test Adit of length 175.7m, having design shape of inverted 'D' and size of 2.5m x 2.5m was constructed as powerhouse area. The chainage from 125 m to 175.7 m of the adit lies in the proposed powerhouse cavern. The rock mass class of III to IV were encountered at the adit. Hydro-fracture test, Direct Shear test and Plate Load test are carried out in test Adit.

OPTIMIZED PROJECT CONFIGURATION

The optimized project configuration was determined in several consecutive steps focusing on (a) the alignment of the Headrace Tunnel, (b) the alignment of the Tailrace Tunnel and location of the Outlet Structure, (c) the selection of the number and sizes of the generating units, and (d) the verification of the diameters of the power waterways. These optimizations were principally carried out for Tamakoshi V HEP operating at rated condition, i.e. at a plant (turbine) discharge of 66 m^3/s, which corresponds to the discharge released from UTK HEP during peak operation.

Especially the selection of the number and sizes of the generating units, however, required extensive clarifications in regard to the intended operation of the upstream project Upper Tamakoshi HEP. From these clarifications it became obvious that UTK HEP is foreseen to operate during the dry season over a substantial part of the time at a minimum plant discharge of only 1.5 m^3/s. This discharge is considered as a spinning reserve discharge which shall allow the turbines to ramp up within shortest time if power demand in the grid requires such action.

Whereas the above minimum discharge can be turbined at UTK HEP while operating one of the six Pelton turbines at minimum flow condition, this was found unfeasible for Tamakoshi V HEP. For the downstream project the equipment configuration comprising three Francis turbines of equal size was determined to match the unit installation at UTK HEP best and to feature the most favourable operation conditions over the expected range of partial plant discharges. Since, however, the Francis turbines designed at this size do not allow to be operated at the mentioned UTK minimum release, the equipment configuration for Tamakoshi V principally comprising three main turbine units was supplemented by a small unit which is designed to operate at specifically small discharges. The overall equipment configuration was scrutinized in detailed energy generation simulations, and the provision of the small hydro unit was verified as feasible.

Given the above findings derived from the equipment combination considerations the optimized project configuration was determined to comprise 3 Francis type generating units for a rated discharge of 22 m^3/s, with a rated capacity of 31.6 MW, and 1 Francis type generating unit for a rated discharge of 3.3 m^3/s, with a rated capacity of 5.0 MW.

Above installed capacities refer to the power available at the main transformer high voltage terminals. The total installed plant capacity is determined as 99.8 MW at the main transformer high voltage side.

PHYSICAL PROJECT SETTING

The Tamakoshi V HEP will be constructed and operated in rather remote area in the central part of the Dolakha district, with its Power Station located some 20 km north east of the district capital Charikot and about 4 km away from the next larger village Singati Bazar. In the project area the Tamakoshi valley experienced some development during the (still ongoing) construction of the UTK HEP further upstream, predominantly marked out by the construction of the access road from Charikot via Singati to Gongar village near the UTK powerhouse. This road, which directly passes by the Tamakoshi V Power Station and Headpond areas, improved the access conditions to the site significantly.

The project area is characterised by a narrow valley with steep, sometimes vertical, rock slopes, narrow and deeply incised side valleys, alpine forests as well as farm land and grazing meadows at higher altitude. Much of the Tamakoshi V structures are constructed underground, and no direct influence on the landscape is expected. Indirect impacts are, nevertheless, caused by tunnel portals and associated access roads, quarry and deposit areas, on-surface buildings and temporary structures.

The physical conditions at the sites of the individual project structures and in the surrounding area within which the project will be constructed and operated have been assessed by walk-trough surveys. The main conclusions of that assessment are:

In the surrounding of the Headworks the Spillway Terminal Structure (STS) will be the only permanent structure at surface. Its construction will require the temporary deviation of the public road Singati-Gongar; once construction of the STS is complete the road will be relocated back to its original alignment and pass over the deck slab of the STS.

Two access roads will be constructed along the route of the Headrace Tunnel (HRT). They require bridges to be constructed across Tamakoshi River, since the public road follows the left river bank where the right bank accesses are planned. The access routes are generally foreseen as temporary routes.

Some land take is foreseen on the right bank of Tamakoshi River between the confluence of Oran Khola and the Jamune bridge. This land will be used for the construction of the Employer's and Engineer's Permanent Camp.

The most prominent need for land at surface is at Suritar, a right bank terrace area along Tamakoshi River directly downstream from the confluence with Khare Khola. This land will be used as Service Area to accommodate the Power Station outdoor structures, i.e. the Terminal & Ventilation Building, the portal of the Main Access Tunnel, the Operation Building and the Workshop Building (to mention the most important structures). In addition, some area will be occupied by the deck slab of the Outlet Structure, which is located directly adjacent on the mountain side of the public road. Service roads and parking areas will need further land for their arrangement. All areas will be located at flood safe level or, where this is not possible, protected by respective flood protection walls.

Some land will be required for temporary use opposite of the Outlet Structure on the left bank of Tamakoshi River. The Outlet Structure will have to be protected by a cofferdam during its construction, and this dam will likely narrow down the river cross section over a short (estimated 200 m long) stretch. The affected area on the left bank is presently used as a gravel quarry and meadow, however, generally uncultivated; it can be reinstated to original condition upon removal of the cofferdam.

Further land is required for temporary use by site installations, or permanently influenced since foreseen as spoil tip or stone quarry areas. The respective land plots are almost exclusively located in direct vicinity of the course of Tamakoshi River and are not expected to significantly impair the availability of land used by the local communities for living or farming.

It is considered as a major advantage associated with the design concept adopted for the Tamakoshi V Hydroelectric Project that this project does not require a separate dam structure in the river course. Consequentyl, all side impacts associated with such dam structure, like the creation of a reservoir, the provision of a spillway dimensioned for a design flood of noteworthy peak discharge, or the provision of flushing facilities which may be required for reservoir sedimentation management are obsolete.

The river channel of the Tamakoshi River between the Headworks and the Outlet Structure are thereby widely left untouched by the implementation of the Tamakoshi V HEP.

PROJECT LAYOUT

The main components of the Tamakoshi V HEP when proceeding from up- to downstream are listed in the following short description together with some key data. A respective complete set of data and salient features of these components is compiled in Chapter 4 further below.

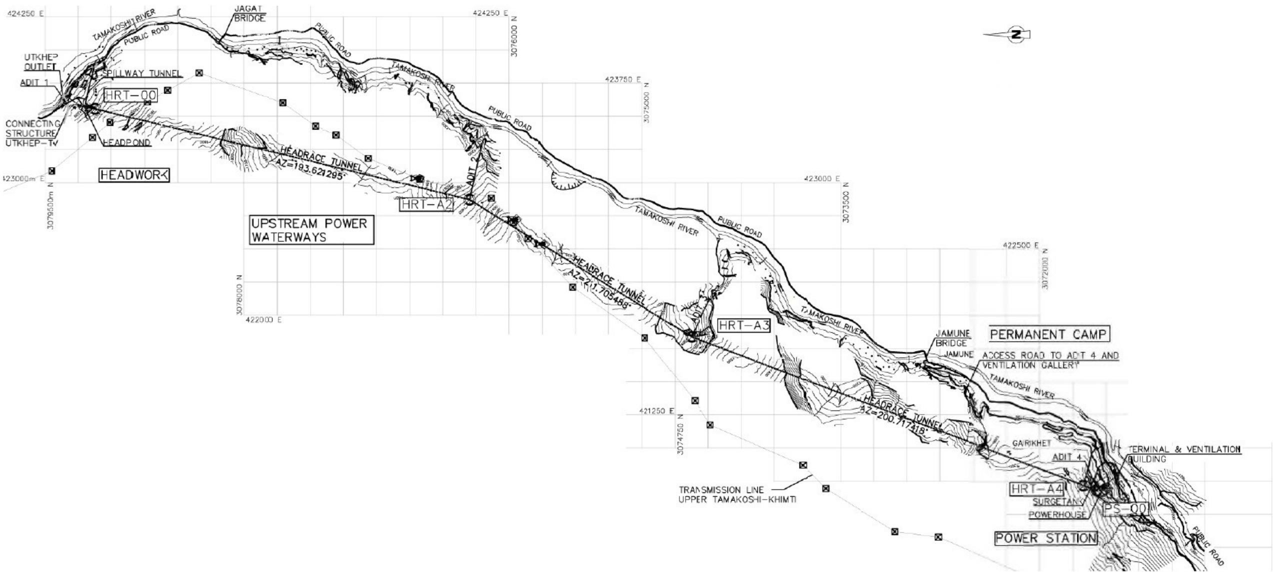

Figure 2: *Project Layout, Overview*

➢ HEADWORKS

The Headworks comprise the Connecting Tunnel, the Headpond and the Spillway as hydraulic structures. The Spillway itself can be separated into the lateral Spillway Weir, the Spillway Tunnel and the Spillway Terminal Structure. All these structures except the Spillway Terminal Structure are arranged underground.

For construction and servicing purposes two tunnels are provided in the Headworks area: These are (1) the Access Tunnel to Connecting Tunnel and (2) the Spillway Aeration Tunnel. The Access Tunnel to Connecting Tunnel (Adit 1 during construction) branches off from the Access Tunnel to the Connecting Structure, a gated underground structure which is foreseen to direct the UTK tailrace flow either into the Connecting Tunnel of Tamakoshi V HEP or back into the Tamakoshi River. Due to this design, the Access Tunnel to Connecting Tunnel does not feature a separate tunnel portal at surface.

➢ UPSTREAM POWER WATERWAYS

The Upstream Power Waterways include the about 8.1 km long Headrace Tunnel (HRT), the Upstream Surge Tank, the Upstream Valve Chamber, the Pressure Shaft (PS), the High Pressure Tunnel (HPT) and the Upstream Manifolds. The HRT is designed as concrete lined tunnel with 5.60 m diameter, the Surge Tank as concrete lined shaft structure with 15 m diameter and almost 50 m effective height. Downstream from the Surge Tank the steel lined part of the waterway begins, which is designed along the PS and HPT with 4.20 m inner diameter. The steel lined manifolds comprise three main branches to the main generating units and one small branch pipe to the small hydro unit.

The Upstream Valve Chamber is located immediately downstream from the start of the steel lined tunnel. The main butterfly valve which can be used to isolate the HRT from the PS will be installed here; it can be used for emergency closure and allows to keep the HRT filled with water when the PS shall be accessed for inspection.

For construction purposes four access tunnels are foreseen to be constructed to the different points along the waterway. Three of them are at high elevation, denominated as Adits 2, 3 and 4, where Adits 2 and 3 are temporary structures. Adit 4 will during the operation phase provide a downstream access to the HRT close to the Surge Tank and through a branch tunnel access to the Upstream Valve Chamber. The fourth access is at low level, leading to the HPT which it meets directly upstream from the first bifurcator. This latter access will be used to bring in the liner cans for the lower part of the steel lined waterway.

- **DOWNSTREAM POWER WATERWAYS**

The Upstream Power Waterways consist of the Downstream Manifolds and the about 440 m long Tailrace Tunnel (TRT). The TRT is designed as concrete lined tunnel with the same diameter as the HRT; the concrete lined manifolds feature diameters which are associated with similar flow velocities as computed for the TRT under plant rated conditions.

One access tunnels to the TRT is foreseen for construction purposes. It will allow to excavate the TRT towards the Powerhouse Cavern as well as in direction to the Outlet Structure from underground, leaving a short rock plug in the Outlet Tunnel section in place over most of the construction period. The safety against flooding of the underground structures in the Power Station area is thereby significantly improved.

- **OUTLET STRUCTURE**

This structure can be distinguished into the Gate & Access Shaft, the Outlet Structure Tunnel and the Tailbay. The deck of the Gate & Access Shaft is located directly adjacent to the public road and thus easily accessible also by heavy weight vehicles. The Outlet Structure Tunnel is aligned at low elevation and exits into the Tailbay at an elevation that secures sufficient water cover above the tunnel soffit at all operation conditions. The water level in the Tailbay will be controlled by the Tailbay end sill and the river water level.

Access to the construction pit of the Tailbay and most downstream section of the Outlet Structure Tunnel has been foreseen along a construction road placed on the downstream slope of the cofferdam.

- **POWER STATION WITH SERVICE TUNNELS AND TRANSMISSION LINE CORRIDORS**

The Power Station comprises all major structure required for the generation of energy, i.e. the Powerhouse Cavern, the Transformer Cavern and the Bus Duct Galleries underground, and the

Terminal & Ventilation Building with Take-off Yards, the Operation Building and the Workshop Building above ground in the Service Area. The Powerhouse Cavern accommodates the four generating units and all auxiliary equipment required to operate the units, whereas the Transformer Cavern provides space for the main transformers and Gas Insulated Switchgear (GIS). The energy is transferred from the generating units to the main transformers at medium voltage level through the bus ducts, and from the main transformers via the GIS to the outdoor Take-off Yards at high voltage level via XLPE cables installed in the Cable & Ventilation Tunnel (CVT).

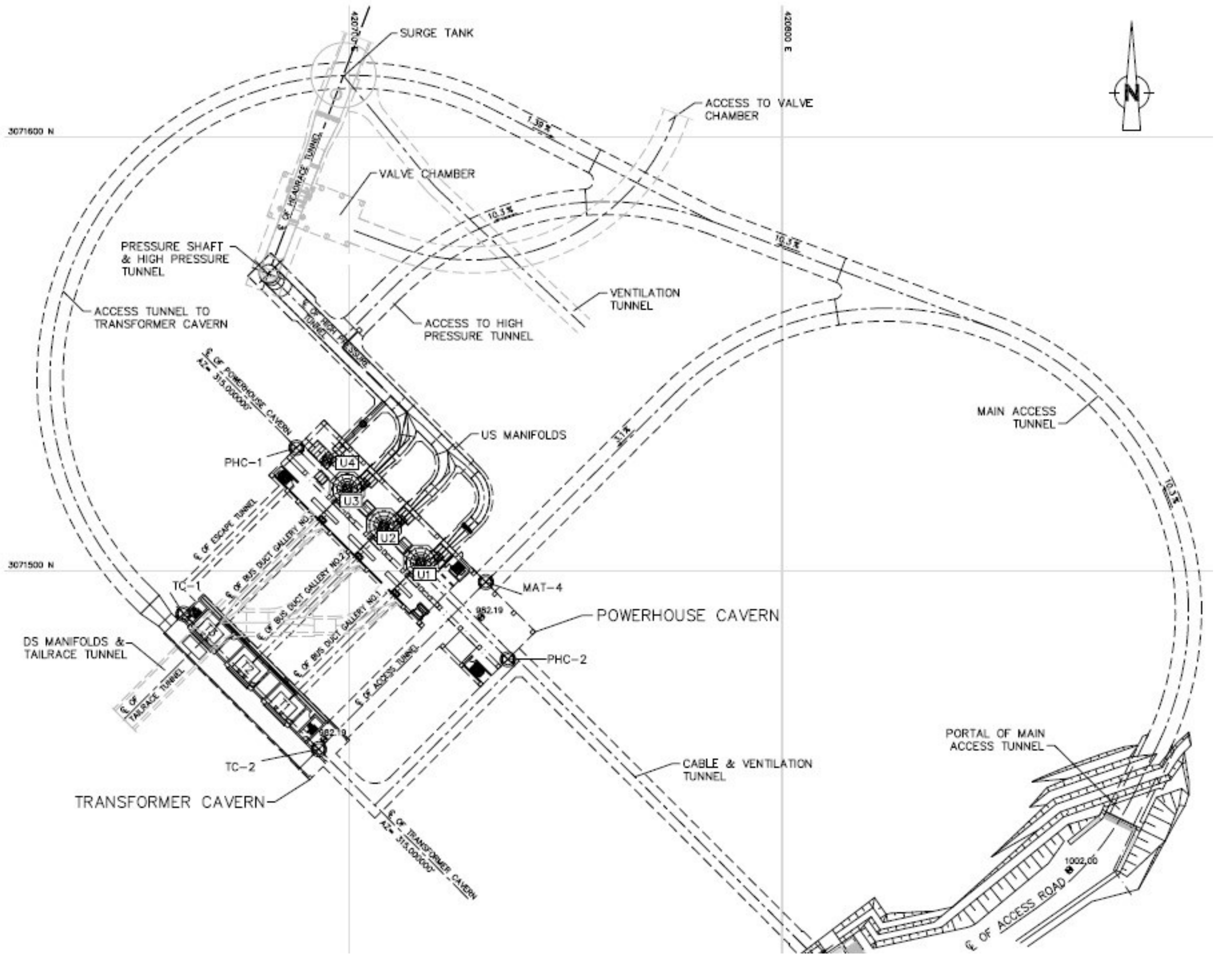

Figure 3: *Structures in the Power Station Area, Layout*

Several Service Tunnels are foreseen in the Power Station Area. The Main Access Tunnel (MAT) to the Powerhouse and Transformer Caverns, together with branches to the High Pressure Tunnel and rear end of the Transformer Cavern, provides paved driveways to the underground locations to which access for vehicles needs to be established (whether for construction or operation purposes). The CVT is a multi-purpose tunnel serving for cable and service pipe routing, ventilation, access and escape way provision. The Escape Tunnel and Bus Duct Galleries are foreseen in the direct vicinity of the two caverns as functional tunnel routes.

All the above tunnels have also been foreseen to provide during construction early access to the various locations of underground construction activities. In this phase, redundant access to the locations is especially important since the tunnels may be temporarily blocked when the tunnel linings and finishings are installed.

The link to the existing transmission line from UTK HEP to Khimti SS was designed as loop in / loop out (LILO) arrangement. The transmission line coming from UTK HEP will be aligned downslope to Take-off Yard no. 1, from where XLPE cables lead to the GIS in the Transformer Cavern. In similar manner, XLPE cables will lead from the GIS to Take-off Yard no. 2, where the starting point of the outgoing line to Khimti SS is located; the transmission line will from this point be routed uphill to join the existing line route at high elevation. A Switching Station provided in the Service Area will allow to bypass the Tamakoshi V scheme and connect the UTK HEP and Khimti line sections directly.

- **PERMANENT CAMP**

The Employer's and Engineer's Permanent Camp was decided to be located in an area on the right bank of the Tamakoshi River between the side valley of Oran Khola and the Jamune bridge. The camp location can easily be reached via a project road which will branch of from the public road close to Jamune bridge and be constructed along the right river bank. This road will be implemented under the same contract which will concluded for the construction of the camp itself.

ENERGY GENERATED BY THE PROJECT

The energy which will be generated by the Tamakoshi V HEP has been estimated for two different scenarios, which principally take into account whether water will be available from the partial diversion of the Rolwaling River into the Upper Tamakoshi reservoir or not. In both cases, the energy was estimated after deduction of loses and outages. The total energy generated by the project is divided into two part, energy from Q40 design discharge and additional wet season energy, for the purpose of Power Purchase Agreement (PPA) tariff. The total annual energy finalized with Power Purchase Department were as follows:

Descriptions	Total Energy	Q40 Energy		Spill Energy (Difference between Q32 and Q40)
		Wet Energy	Dry Energy	
Without Rolwaling (8 months wet season & 4 months dry season energy)	495.148	371.658	64.362	59.127
With Rolwaling(6 months wet season & 6 months dry season energy)	543.494	370.502	159.454	13.538

PROJECT COST

The table on the following page provides an overview over the estimates of the total project cost of the Tamakoshi V Hydroelectric Project.

The individual cost components were calculated using a conversion rate of 1.00 USD = 120 NPR which was determined as average conversion rate for the 2020 May. Miscellaneous costs were generally assumed to be 3% of estimated base cost for civil works and 2% of the estimated base costs for HM, EM and TL. The EPC Cost includes contingency and Miscellaneous Expenses. The Contingency is assumed at 1% on civil works, Hydro-Mechanical, Mechanical and Electrical works, 5% on Transmission line towards any exigencies. The Project Base Cost (excluding taxes& duties, financing charges and IDC) is Summarized in Equivalent US Dollars in the below Table:

Table 1: Project Base Cost is Summarized in Equivalent US Dollars

Item No.	Description	Foreign USD	Local NPR	Total USD
1	Civil Works	38,041,071.58	3,901,346,236	70,552,290
2	Hydromechanical Equipment	2,464,317.92	295,718,150	4,928,636
3	Electro-Mechanical Equipment	22,666,077.00	302,214,360	25,184,530
4	Camp Works	-	325,824,703	2,715,206
5	Transmission Line	-	225,984,000	1,883,200
6	Owner's Costs	5,196,762.11	1,810,720,000	20,286,095
	Total Base Cost			**125,549,957**

FINANCING SCENARIOS

Different financing scenarios were investigated to check for the financial viability of the Tamakoshi V HEP. In these scenarios the energy sales conditions were adopted in line with communicated NEA sales tariffs for dry and wet season energy, with all generated wet season energy being sold to NEA at its respective tariff. The interest rate was assumed at 10%, the repayment period as 15 years. The economic life of the project was considered with 30 years.

Based on these assumptions the following financial indicators were obtained which show the project to be financially viable.

Table 2: Financial Viability Indicators (Base Case)

Parameters	Unit	Values(Base Case)	Rolwaling 1-year Delayed	Rolwaling 2-year Delayed
Project IRR	%	16.4%	16.1%	15.8%
Project NPV	Million NRs	4758.214	4597.146	4434.203
Benefit to Cost Ratio		1.26	1.25	1.25
Payback Period Discounted	Years	7.46	7.49	7.52

The investigated sensitivity scenarios showed that the project's financially viability varies depending on the assumptions adopted for the individual sensitivity cases. The investigated sensitivities included the payment of additional charges for transmission line losses to Upper Tamakoshi HPP, the increase in project costs, the prolongation of the construction time, the increase in the interest rate for project financing and increase in outages.

ENVIRONMENTAL IMPACT STUDY

Environment and Social Studies Department (ESSD), NEA has carried out Environmental Impact Assessment of the project for 87 MW capacity. The EIA report was approved by the respectable Ministry of Population and Environment (MOPE) through ministerial level decision on 2073/03/08. However, during detail engineering design the project capacity was further increase to 99.8 MW and to address the changed dimension of environmental impacts that have occurred due to in the project alteration of configuration and layout, existing approved EIA was updated.The Supplementary Environmental Impact Assessment (SEIA) has been prepared to abide by the mandatory requirement of Environment Projection Act (EPA) 1997 and Environment Protection Rule (EPR) 1997 (its fifth amendment) to incorporate changes in project design brought about during detail design and consequently the environmental aspects that include both existing environmental conditions and dimensions of environmental impacts. SEIA report was approved by the respectable Ministry of Forests and Environment (MOFE) through ministerial level decision on 2077/02/19.

PROJECT IMPLEMENTATION

The project implementation was studied by assuming construction methods which will most likely be chosen in order to meet the target of an overall construction period of estimated four years. It was strictly adhered to that the construction methods foreseen for individual activities match the assumptions made in relation to these operations when preparing the cost estimate.

The studies were based on an assumed start date of 1st July 2021. They revealed that the critical path for construction will pass along the excavation of the Tailrace Tunnel for early mucking access to the powerhouse cavern, the excavation & concreting of the powerhouse cavern, the installation of the generating units, and the sequential commissioning of the generating units. For the study it was assumed that the commissioning of the small hydro unit will be carried out in parallel with the main units and will not control the project completion date. With this construction program the project completion date is expected to be 3rd May 2025.

In order to facilitate the swift implementation of the Tamakoshi V Hydroelectric Project, the following tasks should be complete at the earliest time possible:

Land acquisition for all permanent surface components of the project, including access roads, transmission line, the camp for the Employer and the Engineer, and all adit and tunnel portals and spoil areas.

Conclude lease agreements for lands required for temporary facilities such as camps and yards for the contractor(s).

Conclude the contract for the implementation of the camp for the Employer and the Engineer including the access road to and within the camp area.