**Annexure I**

# Project Executive Summary Report

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# For

# Jomori Hydropower Project

# JOMORI HYDROPOWER PROJECT (90 MW)
# SAMDRUP JONGKHAR DZONGKHAG

## FEASIBILITY STUDY REPORT

### EXECUTIVE SUMMARY

MARCH 2023

Druk Green Consultancy

Druk Green Power Corporation
Thimphu, Bhutan

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**Prepared by:**
**Druk Green Consultancy**
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**Thimphu: Bhutan**

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# 1. Introduction

## 1.1. Background

The Kingdom of Bhutan has abundant hydropower reserves with overall hydropower potential estimated at 37GW from 155 sites identified in the updated PSMP 2040. The 90 sites having installed capacity of about 33GW have been identified as techno-economically viable for implementation. Sustainable hydropower development is critical for Bhutan to reap the benefits of this huge hydropower reserves. The economic gains as a result of this development to the people of Bhutan in financial, economic, and social terms will be immense. With present installed capacity of 2,326 MW from its six large power plants, the country has harnessed about 7% of the techno-economically feasible hydropower potential. The country today exports about 70% of its electricity to India after meeting the internal demand first. With the addition of 3,042 MW installed capacity from the four large projects and three small-medium projects, currently under different stages of construction, it is expected to further enhance the quantum of export to India and contribute to the country's socio-economic development.

The electricity grid in Bhutan is closely interconnected to the Indian grid which is prone to frequent failures. Bhutan has experienced prolonged power outages in pockets of the country as well as at the national level. With India's increasing investment into renewables such as solar and wind without adequate provision for balancing power support from energy sources such as hydropower, it will only make India's grid more prone to major grid failures. As of now, Bhutan's existing mega hydropower projects cannot operate in a standalone (isolated) mode. Therefore, it has become imperative to plan for an adequate backup power supply to provide essential electricity supply services to each Dzongkhag in an isolated mode. More importantly, there is a need to plan for a robust energy supply system as a preparedness measure for natural hazards and other exigencies. By virtue of its location, Bhutan is prone to natural disasters such as earthquakes, glacial lake outburst floods (GLOF), flash floods, and extreme weather conditions. In the last few decades, Bhutan has experienced major earthquakes of magnitude over 7 on the Richter scale, devastatingly impacting the country's infrastructure and claiming lives. During such events, as an essential service, the availability of a steady power supply is crucial for sustaining people's livelihood and recovery processes.

Recognizing the need for domestic energy security through the facilitation of self-contained supply flexibility for each Dzongkhag to meet the demand of household, institutional consumers and essential service providers in times of exigencies (which at other times could be fed into the grid), Druk Green Power Corporation (DGPC) is undertaking strategic planning of a backup power supply system by harnessing abundantly available renewable hydropower resources through the implementation of small and medium-sized hydropower projects. Further, in the wake of the economic downturn with the Covid-19 pandemic, developing such hydropower projects across the country will not only help stimulate economic activities at the grass root levels but also help generate employment and engagement of the people in these difficult times.

As part of Phase I of the Small Hydropower Initiative, the feasibility study of three hydropower projects namely 54 MW Burgangchhu, 32 MW Yungichhu and 18 MW Suchhu, have been completed in December 2021 and are currently under construction.

Similarly, Phase II initiative is being undertaken by DGPC for small and medium hydropower projects. The techno-economic viability and social consideration was given priority compared to the 60:40 Technical: Social criteria of the Phase I selection process. Accordingly, the projects which have already been studied at either a Pre-Feasibility Study (PFS) or Feasibility Study Report (FSR) level and approved by the Department of Energy (DoE) were considered techno-economically viable. Six projects have been considered under Phase II for FSR study or for updation of existing FSR/DPR.

This report entails the FSR prepared for the 90 MW Jomori Hydropower Project (HPP) in Jomotsangkha Dungkhag under Samdrup Jongkhar.

### 1.2. Previous Studies

The PFS was carried out by the Department of Energy (DoE), the erstwhile Department of Hydropower & Power Systems (DHPS) in collaboration with the National Centre for Hydrology and Meteorology (NCHM), the erstwhile Department of Hydromet Services (DHMS), National Land Commission Secretariat (NLCS), DGPC and the Bhutan Power Corporation (BPC) in 2014-2016.

As per the PFS, the project with an installed capacity of 85 MW and annual design energy of 362.39 GWh was designed as a run-of-the river scheme. The project envisages 42 m high concrete gravity dam, 4,299.60 m long Head Race Tunnel of 4.10 m finished dia., 506.50 m long pressure shaft of 2.7 m dia. feeding water to two Pelton turbines in underground powerhouse of 61.00 m (L) x 18.00 m (B) x 37.00 m (H) operating at net design head of 353 m.

The estimated cost at December 2015 price level was Nu. 5,855.89 million excluding transmission line cost of Nu. 736.89 million with a construction duration of 65 months including preconstruction activity. The levelized tariff accordingly worked out was Nu. 4.63 per kWh.

## 2. Feasibility Study

As part of Phase II Small Hydropower Initiatives, the FSR of Jomori HPP has been undertaken since February 2022 with the objectives to assess the technical, economic, financial viability and environmental acceptability of the project. The scheme envisages a run-of-river hydropower development on Jomori river basin located in Jomotsangkha Dungkhag under Samdrup Jongkhar Dzongkhag. The project is planned and designed as standalone project. The installed capacity of Jomori HPP has increased to 90 MW with the annual energy generation of 367.33 GWh. The increased in installed capacity as compared to PFS is attributed to the inclusion of additional hydrological data and increase in head.

## 2.1. Project Location and Accessibility

The Jomori HPP lies in extreme South-East of Bhutan and is spread over two Gewogs under Jomotsangkha Dungkhag under Samdrup Jongkhar Dzongkhag. The dam complex falls in Lauri Gewog and the powerhouse complex under Serthi Gewog. The location map of the Project is shown below in **Figure 1**.

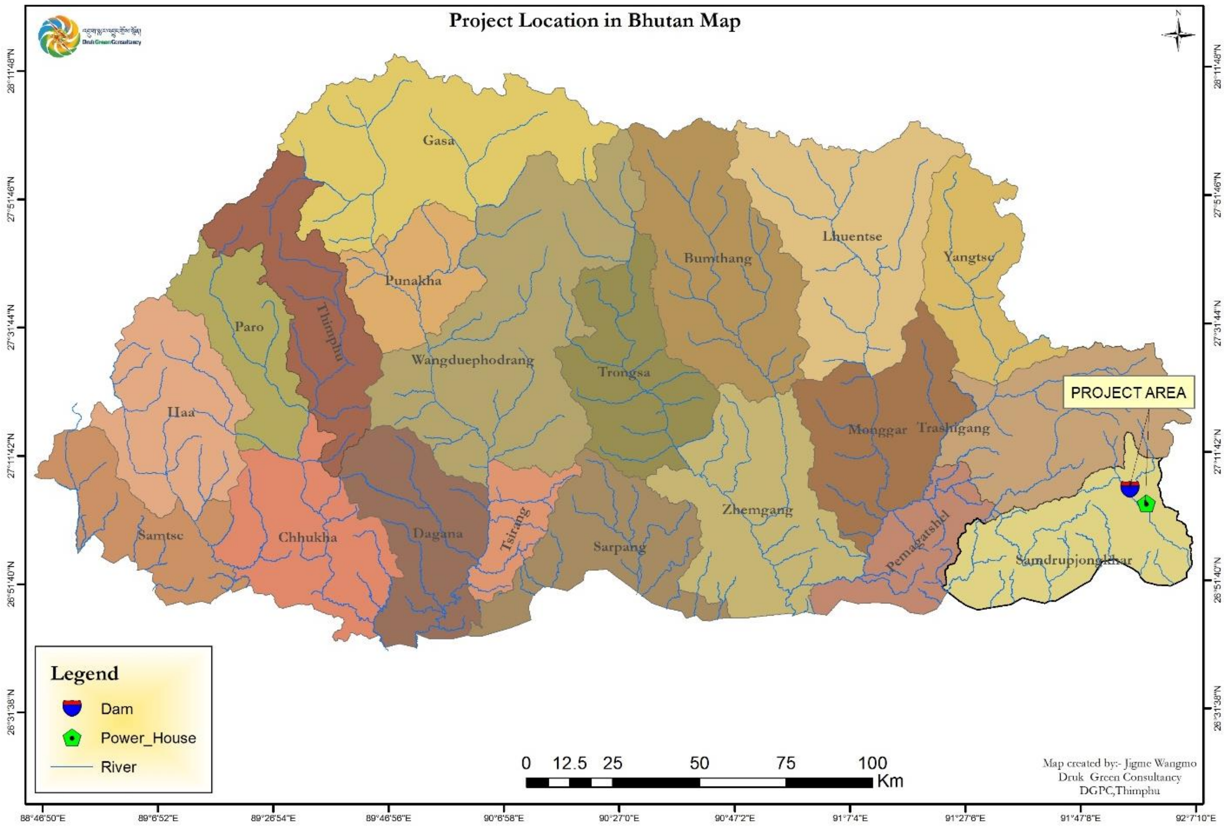



**Figure 1: Project location in Bhutan map**

The nearest road entry point to the project site is from Jomotsangkha satellite town in the east. The distance to Jomotsangkha Dungkhag from the nearest Thromde, Samdrup Jongkhar, is about 191 km via Assam. Alternatively, the construction of internal road of approximately 150 km from Samdrup Jongkhar to Jomotsangkha via Samrang highway is in progress.

## 2.2. Topographical Survey and Mapping

The topographical map and river cross sections of the project area of requisite scale had been prepared to enable proper planning, engineering and design works. Total of 12 new ground control points had been established to facilitate survey works. One control point established during PFS stage was also used as reference control points. The topographical survey covering the whole project area in a scale of 1:5,000 with 5 m control interval and 1:1,000 scale with 1 m contour interval for major project components had been prepared. The longitudinal profiling and cross section survey of the river in requisite scale had been surveyed and drawings prepared.

## 2.3. Geological Appraisal and Construction Material

### 2.3.1. Regional Geology

Regionally, the project area falls under Lesser Himalaya Zone. This zone constitutes 6 geological set up and the current project area falls under Daling-Shumar Group which is overlain by Paro Formation and underlain by Baxa Group. Under Daling-Shumar Group, dam site and powerhouse fall under Orthogneiss unit and Daling formation respectively. For Orthogneiss unit, concordant bodies of mylonitized, granitic orthogneiss at varying stratigraphic levels are anticipated and for Daling formation, it is dominated by schist and phyllite. Quartzite is thin-to medium-bedded, and medium-gray limestone interbeds are rare.

### 2.3.2. Geology at Project Area

To determine the surface and sub-surface geology, geotechnical investigations were carried out which includes detailed surface geological mapping on topographic map of scale 1:5,000 with contour interval of 5 m, geophysical surveys with total of 1,449 m of seismic refraction and 399.50 m of resistivity, 14 numbers of exploratory boreholes with the total depth of 884.80 m, 2 numbers of exploratory drifts at dam abutments and in-situ tests in each drift comprising 1 set of DST and 2 sets of PJT. The boreholes samples have been tested at laboratory to determine geotechnical parameters of rock to be used for engineering designs.

**Table 1: Geological & Geotechnical Investigations**

| Project Components | Exploratory Borehole | | Geophysical Survey | |
|---|---|---|---|---|
| | No. of boreholes | Depth (m) | No. of profiles | Length (m) |
| Dam Complex | 7 | 380.30 | 4 | 577.50 |
| HRT | 2 | 65.00 | 1 | 115.00 |
| Powerhouse Complex | 5 | 439.50 | 9 | 1,156.00 |
| **Total** | **14** | **884.80** | **14** | **1,848.50** |

The Seismotectonic assessment had also been carried out by IIT Roorkee, India to derive the PGA value to be incorporated for the design of dam structure.

**Diversion Tunnel**

Jomori shall be diverted through 330 m long diversion tunnel designed on right bank which is likely to traverse through slightly to moderately weathered augen gneiss intercepted by schist. Same geological rock trend as observed at right abutment for dam site and right bank drift is anticipated with rock dipping NW at 36 °.

**Dam Complex**

Jomori HPP envisages construction of concrete gravity dam of maximum height of 45 m from the deepest foundation level and a crest length of 79.90 m with FRL at El. 1,156.00 m.

The dam area located around 150 m downstream of Zangtheri and Jomori confluence has good exposure of massive rock outcrop predominated by augen gneiss, which is intercepted by Schist with presence of quartz veins on both abutments. The rock mass is traversed by three sets of joints namely J1/F 48°/025°, J2 77°/155° and J3 72°/253°. Continuous rock outcrop is exposed along the river bed which is slightly to moderately weathered, joint aperture ranging from 1 to 5 mm with soft infill of fine material of sand and silt. The spacing and persistence of the rock ranges from 0.2 to 0.6 m and <1->20 m respectively. The joint planes are found slightly rough to rough in nature.

**Intake Structures and Feeder Tunnel**

Massive rock of augen gneiss is outcropped at intake. The rock is slightly to moderately weathered with joint spacing ranging from 0.2 to 0.6 m and has a minimal aperture between each joint sets.

**Desilting Chamber**

The underground desilter chamber area falls on the nose ridge which is also exposed with same rock type as in dam. Entire region of desilter maybe dominated by strong to moderately strong, medium to coarse grained, fresh to slightly weathered augen gneiss interspersed with thin bands of phyllite. Similar to dam area, desilter has three perceptible discontinuities with the rock dipping in N or NW direction.

**Silt Flushing Tunnel**

Massive exposure of gneiss is observed along the left bank, which is in the vicinity of the SFT portal. Same rock quality viz is medium to coarse grained and slightly to moderately weathered rock, as observed in DC is anticipated with rock dipping in NW direction.

**Head Race Tunnel**

It is observed that the 6,355 m long HRT will pass through rock stretch predominated by augen gneiss, phyllite and quartzite. The rock is found to be exposed sporadically along tunnel alignment and generally found to be slightly to moderately weathered with the joint aperture ranging from 0.1 to 5 mm with soft infill of fine material of sand and silt. The spacing and persistence of the rock ranges from <0.06 to 0.20 cm and 1-10 m respectively. The joint planes are found slightly rough to rough in nature. Notable four sets of joints namely J1/F 33°/349°, J2 67°/087°, J377°/181° and J4 67°/280° is observed.

**Surge Shaft and Pressure Shaft**

No massive and competent rock outcrop is observed at surge shaft and pressure shaft area but few readings from rock exposed sporadically at this area has been taken. It is observed that the areas is traversed by four perceptible sets of joints area observed namely J1/F 28°/354°, J2 81°/070°, J3 80°/140° and J4 67°/261° and generally rock is found slightly to moderately weathered with the joint aperture ranging from 0.1 to 5 mm with none to soft infill of fine material of sand and silt. The spacing ranges from <0.06 to 2 m and the persistence of rock is found >20m. The joint planes are found smooth to very rough in nature

**Surface Powerhouse Complex**

The surface powerhouse and TRC will be founded on thick alluvium material composed of rounded to sub-rounded boulders of gneiss and quartzite embedded in a matrix of fine sand.

The slope near the terrace is exposed with a massive outcrop of gneiss interbedded with phyllite and quartzite. The rock mass is traversed by four perceptible sets of joints namely J1/F 28°/354°, J2 81°/070°, J3 80°/140° and J4 67°/261 with rock showing shallow dipping in N to NW direction. Similar to surge shaft and pressure shaft, rock is found slightly to moderately weathered with the joint aperture ranging from 0.1 to 5 mm with none to soft infill of fine material of sand and silt. The spacing ranges from <0.06 to 2 m and the persistence of rock is found >20m. The joint planes are found smooth to very rough in nature.

### 2.3.3. Construction Materials

Two potential quarry sites were assessed and under approval process to obtain suitable aggregates for the construction of various project components. One quarry site is at Arazor which is approximately 8 km upstream from the dam site and other quarry site is at Satsham located about 365 m downstream of the powerhouse location. In order to assess the sufficiency and suitability of the aggregates, detailed construction material survey and laboratory tests for samples collected from the identified quarry sites were carried out.

The quarry site at Arazor has an estimated reserve of 1.194 million tonnes and the quarry site at Satsham near powerhouse complex has an estimated reserve of 0.192 million tonnes. The above reserves are sufficient to meet the project requirements.

## 2.4. Hydrology and Sedimentation Studies

The hydrological studies for the project have been conducted to assess the water availability for power generation, estimate design flood and temporary river diversion flood. The Elevation-Area-Capacity curve for determining the capacity of the reservoir and its submergence and sedimentation studies has also been performed.

The catchment area at Jomori dam site is 486.00 sq.km. For the purpose of establishing water availability for the estimation of power potential, daily discharge derived based on water level and rating equation at Zamtari automatic water level station (AWLS) has been utilized. The data is available from 2014 to 2021 and the catchment area at the gauging station is 574.00 sq.km. The internal and external consistency of the series has been established and data corrected accordingly. The average annual and specific flows for the catchments are provided in **Table 2**.

**Table 2: Flow Parameter at Intake**

| Parameters | Unit | At Intake |
|---|---|---|
| Catchment area | sq.km | 486.00 |
| Average annual flow | cumecs | 22.48 |
| Average maximum flow | cumecs | 165.11 |
| Average lean flow | cumecs | 6.06 |
| Average minimum flow | cumecs | 5.04 |
| Average annual specific runoff | l/s/sq.km | 46.25 |
| Lean period specific runoff | l/s/sq.km | 12.46 |
| Minimum specific runoff | l/s/sq.km | 10.38 |
| Average annual flow volume | MCM | 665.95 |
| Average annual runoff | mm | 1,370.26 |

Since short duration (hourly/3-hourly) gauge discharge and rainfall observed data for any site is not available, derivation of unit hydrograph based on observed hydro-meteorological data is not possible. Hence, design flood for the project has been worked out based on synthetic unit hydrograph derived from the basin characteristics. An estimation of design flood from Bhramaputra basin 2a report, Clark's Method and triangulation method have been adopted for developing the synthetic unit hydrograph for the dam site. The design flood studies have been carried out using hydro-metrological approach.

For Jomori diversion site, since the gross storage capacity is less than 10 MCM and hydraulic head is less than 30 m, diversion structures have been designed for Standard Project Flood (SPF). The SPF of Jomori HPP has been worked out as 3,099 cumecs. The flood for temporary river diversion arrangements has been estimated both for monsoon as well as non-monsoon floods of 25 years return period and the diversion flood is estimated to be 279 cumecs and 263.31 cumecs respectively.

The project-specific sediment data have been collected and the sediment rate estimated including analysis of project-specific mineral content. The feldspar and quartz content in the suspended sediment load is about 60%.

### 2.5. Project Alternative Studies

The project alternatives have been studied considering aspects such as topography, geology, social, environmental, economics and accessibility. Firstly, the suitable locations of the major components have been studied with respect to the above mentioned considerations. After finalizing the location of the major components, alternative project layouts to select the most feasible option has been studied based on preliminary benefit-cost analysis.

The various alternative locations of major project components mainly dam and powerhouse have been studied based on detailed geological and geo-technical investigations to select the most feasible site. The various alternative sites and the most feasible option are provided below.

### 2.5.1. Dam Site

In PFS, only one dam site was considered for the diversion structure of Jomori HPP and the selection of the dam site was based on hydrology, topography and geological consideration. However during FSR, the alternate dam site was explored upstream of the identified dam site. It was determined that shifting of dam site upstream will have to forgo additional hydrological flow from the Zangtheri with the catchment of 225.70 sq. km which accounts for 46.4% of the total catchment area. Further, choosing an alternative site downstream of the PFS dam site shall result in the reduction of head and wider river valley.

The PFS dam site has been assessed to be the most feasible site with details as given in **Table 3** and therefore, selected as the final site.

**Table 3: Location of Dam Site**

| Name | Right Abutment Coordinate | Left Abutment Coordinate | Catchment Area ($km^2$) | Remarks |
|---|---|---|---|---|
| Dam site | E: 395210.98<br>N: 2997860.09 | E: 395291.00<br>N: 2997862.88 | 486.00 | River Bed Elevation is 1,126 masl. |

### 2.5.2. Powerhouse Site

Two (2) alternative powerhouse sites, PH-1 and PH-2 have been studied. PH-1 site is the PFS underground powerhouse option and PH-2 is the surface powerhouse alternative identified during FSR as indicated in **Table 4**.

**Table 4: Location of Powerhouse Site**

| Name | Coordinates | Remarks |
|---|---|---|
| PH-1 | E: 399159.53<br>N: 2994276.65 | Underground Powerhouse before Tsanglari crossing (PFS location) |
| PH-2 | E: 399815.31<br>N: 2993739.06 | Surface Powerhouse after Tsanglari crossing |

The PH-1 site has been ruled out as it entails an underground components such as caverns, MAT, TRT and Adits which will be costlier as compared to surface powerhouse option. Considering the cost, construction time, geological risk, availability of adequate space for surface powerhouse and head gain (13.10 m), the surface powerhouse option (PH-2) has been chosen.

### 2.5.3. HRT Alignment

The HRT alignement has been studied after finalising the location for dam and powerhouse sites. The HRT has been aligned more towards the valley to introduce shorter intermediate construction adits and to maintain requisite covers. The following alignement of HRT has been studied on the left bank of Jomori as given in **Table 5**.

**Table 5: Alternative HRT Alignment**

| Alternative | HRT Length (m) | HRT stretch with high vertical cover (m) | Maximum Vertical cover (m) | Remarks |
|---|---|---|---|---|
| Alternative-2A | 5,965 | 1,547 | 1,020.0 | |
| Alternative-2B | 5,590 | 1,297 | 1,000.5 | |
| Alternative-2C | 6,328 | 1,258 | 798.6 | |
| Alternative-2D | 6,355 | 445 | 760.5 | Shortest HRT stretch through high cover and least maximum cover. |

The Alternative-2D has been selected as the final HRT alignment as it has the shortest stretch (445 m) passing through high vertical cover of 760.50 m. The tunnel alignment with high vertical cover will experience high vertical stress making it vulnerable to geohazards such as rock bursting, slabbing, tunnel squeezing and geothermal condition.

The final project layout is attached at **Annexure 1**.

## 2.6. Power Potential Studies

The project is a run-of-the-river scheme with peaking capability. The reservoir capacity has been fixed to get the peaking capacity for 6 hours during high inflow and 4 hours during lean inflow.

The power potential studies have been carried out using flow series derived based on Zamtari station flow series available for a period of 8 years from 2014 to 2021. The e-flow of 0.51 cumecs has been considered in the power potential study. The basic parameters obtained from the power potential studies are provided in **Table 6**.

**Table 6: Water Levels and Storage**

| Description | Units | Value |
|---|---|---|
| FRL | masl | 1,156.00 |
| MDDL | masl | 1,143.70 |
| MIV/ Machine Centre Line | masl | 778.90 |
| Gross head | m | 370.27 |
| Head Losses | m | 11.27 |
| Net head | m | 359.00 |
| Type of turbine | | Pelton |
| Combined overall efficiency | % | 89.18% |
| Live Reservoir Capacity | MCM | 0.60 |

As per the power potential studies, 90 MW is the optimal installed capacity for the project. The annual design energy based on 90% dependable year with 95% plant availability (PA) works out to 367.33 GWh. The output from power potential studies is as provided in **Table 7**.

**Table 7: Output for 90 MW with 100% PA**

| **Flow Parameters** | **Unit** | **50% Dependability** | **75% Dependability** | **90% Dependability** |
|---|---|---|---|---|
| Net Head | m | 359.00 | 359.00 | 359.00 |
| Plant Efficiency | % | 89.18% | 89.18% | 89.18% |
| Design Flow | cumecs | 28.66 | 28.66 | 28.66 |
| Installed Capacity | MW | 90.00 | 90.00 | 90.00 |
| Annual Energy | GWh | 428.86 | 390.77 | 377.27 |
| Annual PLF | % | 54% | 50% | 47.85% |
| Lean Period Energy | GWh | 48.44 | 45.52 | 45.04 |
| PLF (Lean Season) | % | 19% | 17% | 17% |
| Qd/Qavg | | 1.27 | 1.27 | 1.27 |
| Average Lean Flow | cumecs | 4.92 | 4.92 | 4.92 |
| Firm Power | MW | 15.47 | 15.47 | 15.47 |
| Exceedance probability | **%** | 23.00% | 23.00% | 23.00% |

## 2.7. Civil Engineering Structures

The civil engineering structures are designed for peaking capacity comprising the following components:

- A temporary river diversion arrangement comprises of diversion tunnel of 6.0 m x 6.0 m D-shaped and length of 330 m; and 15 m and 9 m high upstream and downstream cofferdams;
- A concrete gravity dam of 45.0 m high above the deepest foundation level with crest length of 79.9 m comprising of 3 overflow and 3 non-overflow blocks. It's provided with three number spillway radial gates of size 8 m (W) x 11 m (H) to safely discharge SPF of 3,099 cumecs. One high level spillway of size 8 m (W) x 7 m (H) is provided to manage floating debris;
- Two number power intakes are provided with trash rack and trash rack cleaning machine to manage floating debris provided at inlet of power intake. A service gate is provided to regulate flow;
- Two number feeder tunnels of 3.5 m diameter horse shoe shape with flat invert of length 148 m have been provided in between power intake and underground desilting chamber;
- Two numbers of underground desilting chamber of 138 m length including transitions and width of 8 m each designed to exclude sediment size >0.20 mm. The depth varies from 6.0 m to 6.6 m;
- HRT of 4.10 m diameter horse shoe shape with flat invert of total length of 6,355 m and a side adit, 4m diameter, 40 m long is planned. Provided with two intermediate construction adits and one side adit at Tshanglari to facilitate construction of HRT;
- An open to sky surge shaft of 10.0 m diameter with vertical height of 68.9 m.

- A steel lined main pressure shaft of 2.8 m diameter consisting of vertical shaft and horizontal pressure tunnel of lengths 291.00 m and 450.71 m respectively. The horizontal pressure tunnel bifurcates into two-unit pressurised penstock of 2.0 m diameter with the length 30 m each upto MIV;
- A surface powerhouse of 42.0 m (L) x (20 + 5.5 m Annex)(W) x 27.0 m (H);
- Two units tail race channel of 3.0 m x 2.5 m of length about 35 m and main tail race channel of 3.0 (H) m x 3.5 (W) m and length of about 35 m with its outfall level at El. 772.6 m.

## 2.8. Hydro-Mechanical Equipment

The following Hydro-mechanical equipment have been provided for the project:

- One number fixed wheel gate with downstream sealing at inlet of each diversion tunnel of size 6.0 m (W) x 6.0 m (H).
- Three numbers spillway type radial gates of size 8.0 m (W) x 11.0 m (H) as main spillway with hydraulic hoists.
- One number fixed wheel type vertical lift gate of size 8.0 m (W) × 7.0 m (H) as high level spillway with hydraulic hoist.
- One set (5 panels) of slide type stoplogs of size 8.0 m (W) × 11.0 m (H) for main spillways in the dam with electrically operated Gantry Crane.
- Each of the two intake structures with 4 trashrack bays of 2.5 m x 5.0 m (clear opening) with Trash rack cleaning machine (TRCM).
- Two numbers intake emergency gate of size 3.5 m (W) × 3.5 m (H) for Intake with hydraulic hoist.
- Two numbers intake service gate of size 3.5 m (W) × 3.5 m (H) with hydraulic hoists.
- One number fixed wheel gate of size 3.5 m (W) x 3.5 m (H) for desilting chamber outlet with rope drum hoist.
- Four numbers (2 emergency and 2 service) bonnet type slide gate of size 1.0 m x 1.5 m with hydraulic hoist for silt flushing duct.
- Two numbers slide type gate of size 3.0 m (W) x 3.5 m (H) for unit TRC with monorail hoist.
- One number hinge type gate of size 3.0 m (W) × 3.0 m (H) for Adit 1 is provided for inspection and future use.

## 2.9. Electro-Mechanical Equipment

The powerhouse has been designed to house two vertical shaft Pelton turbines having rated output of 2x45 MW under a design head of 359 m at 375 rpm synchronous speed. Each turbine shall be provided with spherical type main inlet valve. The generators shall be synchronous and of the vertical shaft type of 53 MVA rated power at 0.9 power factor and 50 Hz frequency. The generators shall have a speed of 375 rpm and generator voltage of 11 kV.

The following mechanical and electrical auxiliary equipment would be provided:

- One number EOT crane of 120/10/5 tonnes main & auxiliary hooks are proposed to be provided for handling the assembled rotor along the full length of the powerhouse.
- Cooling water system for generators and generator step up transformers
- Drainage and dewatering systems
- Ventilation and air conditioning system
- Fire protection system
- Compressed air system
- Unit auxiliary and station auxiliary supply system
- D.C supply system
- Control and Monitoring system
- Protection system, etc.

The generation voltage of 11 kV is proposed to be stepped up to 132 kV through a bank of 18 MVA, 11/132 kV single phase transformers 7 (seven) numbers single phase transformers (including one spare) would be installed in the transformer. The low voltage terminals of the transformers would be connected with the generator terminals through 11 kV bus ducts. The high voltage 132 kV terminals of the transformers would be connected to 132 kV Air Insulated Switchgears (AIS) located adjacent to the powerhouse. The two outgoing feeders from 132 kV AIS shall be connected to Phuntshothang Substation

### 2.10. Infrastructure and Construction Organization

The main infrastructure works includes the following:

- Construction of 20.37 km project roads to access various project components.
- Construction of four bailey bridges. One bailey bridge for connectivity to Zamtari along Chumodurdur stream and three bailey bridge along Jomori to connect Powerhouse, adit to Desilting Chamber and adit 1 to HRT.

The construction facilities such as site offices, residential and non-residential buildings, workshops, warehouses/stores, aggregate processing plant (crushing plant) and concrete batching plants, muck disposal area, explosive magazines, construction power, telecommunication, water supply system, security & safety arrangements etc. will be established to facilitate the project construction.

The estimated manpower for contractor during the peak construction period is 1,208. The manpower requirement for project management during pre-construction and peak construction has been estimated to 10 and 44 respectively based on the understanding that Druk Hydro Energy Limited will implement the project.

### 2.11. Construction Program and Scheduling

The construction of main project components is scheduled to start by December 2023 (“Zero date”) after the mobilization period of three (3) months. The major infrastructure works such as roads and bridges for the project components are planned to be completed by “Zero date”. The balance infrastructure works shall be continued and completed in parallel with the initial activities of main civil works. The pre-construction works will take about 8.5 months and tendering and mobilization of Main Civil works will take 8 months. The construction of the project is planned to be completed in 55 months excluding pre-construction activitie. The summary of Key milestones is shown below in **Table 8**.

**Table 8: Project Key Milestones**

| SN | Key Milestones | Duration | Start Date | End Date |
|---|---|---|---|---|
| 1 | River Diversion Ready | 390 days | 28/12/23 | 25/07/24 |
| 2 | Dam structure ready for H&M works | 1080 days | 20/06/24 | 21/02/27 |
| 3 | Completion of Dam in all respects | 270 days | 25/06/26 | 06/05/27 |
| 4 | Intake site ready for H&M works | 150 days | 20/06/24 | 16/06/25 |
| 5 | Completion of intake in all respects | 90 days | 16/05/25 | 29/09/25 |
| 6 | Completion of feeder tunnel in all respects | 340 days | 27/12/23 | 27/01/25 |
| 7 | Completion of DC in all respects excluding the installation of gates | 646 days | 06/03/24 | 30/03/26 |
| 8 | SFT ready for H&M works | 241 days | 04/05/25 | 31/12/25 |
| 9 | DC, GOC and Gate shafts ready for initial filling | 780 days | 27/12/23 | 24/06/26 |
| 10 | Completion of HRT in all respects | 1340 days | 27/12/23 | 07/04/28 |
| 11 | Surge shaft ready in all respects | 1035 days | 27/12/23 | 17/04/27 |
| 12 | Pressure shaft ready for H&M works | 825 days | 06/03/24 | 26/12/26 |
| 13 | Pressure shaft ready in all respects | 625 days | 26/12/26 | 19/02/28 |
| 14 | Site ready for erection of distributor | 375 days | 27/12/23 | 14/05/26 |
| 15 | Site ready for laying of turbine housing | 100 days | 14/05/26 | 27/08/26 |
| 16 | Civil structures in PH ready for installation of EOT crane | 125 days | 14/11/25 | 03/04/26 |
| 17 | Civil structures in TRC ready | 365 days | 27/12/23 | 23/12/24 |
| 18 | TRC ready in all respects | 90 days | 21/03/26 | 02/06/26 |
| 19 | Switchyard and transformer ready | 365 days | 02/11/26 | 22/11/27 |
| 20 | Testing and commissioning of Unit 1 | 30 days | 14/04/28 | 19/05/28 |
| 21 | Testing and commissioning of Unit 2 | 30 days | 19/05/28 | 23/06/28 |
| 22 | Commercial Operation Date | | | 23/06/28 |

The project schedule is in **Annexure- 2**.

## 2.12. Power Evacuation Arrangement

The power from Jomori HPP is planned to be pooled at Phuntshothang Pooling Station through Double Circuit (DC) 132 kV Feeder transmission line of 43 km long. The same transmission line is proposed to be used for the supply of construction power by charging at 33 kV during peak construction as the existing 33 kV line is not reliable and will not be able to cater the peak power load of 4.31 MW.

### 2.13. Environment and Social Impact Assessment

The ESIA was prepared based on the terms of reference endorsed by the National Environment Commission Secretariat (now known as Department of Environment and Climate Change).

- Project area does not fall within any of the Protected Areas and/or Biological Corridors.
- Shannon-wiener diversity index ranges from 1.70 for trees to 3.13 for saplings.
- Aquatic ecology assessment recorded 9 fish species under 3 families. *Schizothorax richardsonii* was the most dominant followed by *Gara birostris* and the least dominant was *Glyptothorax cavia*.
- Total of 22 water quality parameters were analyzed, and were found within the ranges of permissible limits.
- No displacement of households.
- The total land requirement for the project is 199.19 acres of which 195.07 acre (120.89 acre temporary and 78.29 acre permanent) is SRF land and 4.11 acre (2.37 acre temporary (Kamzhing) and 1.74 acre permanent including 0.12 acre of Chuzhing) is private land. Private land of 4.11 acre belongs to 32 landowners mainly falling along the access road.
- Jomori HPP is estimated to reduce emission by 334,270.30 $tCO_2$ annually.

The ESIA report has assessed the direct and indirect potential environmental and social impacts from all aspects of construction and operation of the project including short term and long term impacts. The impacts have been quantified wherever possible in addition to qualitative assessment. Appropriate mitigation measures and environment management plan have been prepared accordingly.

### 2.14. Cost Estimate

The detailed cost estimate has been prepared to arrive at the total cost of the project. The cost estimate is based on the March 2023 Price Level.

The unit rate analysis has been carried out based on the prevailing market rates of construction materials and equipment. The labour rates have been taken as per the prevailing rates in the ongoing hydropower projects in the country. The following guidelines and publications have been referred for preparation of the cost estimate:

- Bhutan Schedule of Rate 2022 Civil (BSR – 2022), by Ministry of Work and Human Settlements, Department of Engineering Services, Thimphu, Bhutan.
- Labour and Material Coefficients 2022 Civil (LMC – 2022), by Ministry of Work and Human Settlements, Department of Engineering Services, Thimphu, Bhutan.
- Guidelines for preparation of project estimates for river valley projects by Central Water Commission, India.
- Guidelines for working out unit rate cost of the construction equipment used for river valley projects by Bureau of Indian Standards, India.
- Guidelines for Development of Hydropower Projects-2018, by DoE, MoENR,

The cost includes all Civil, Hydro-Mechanical and Electro-Mechanical Works, including transmission works.

The total cost of the project is estimated at **Nu. 8,509.00** million including the transmission cost at March 2023 PL. The cost abstract is given in **Table 9**.

**Table 9: Abstract of Project Cost**

| Sl. No. | Description | Cost (Nu. in Millions) |
|---|---|---|
| **DIRECT COST** | | |
| **I** | **Works** | |
| i | Preliminary | 183.96 |
| ii | Land | 20.30 |
| iii | Civil Works | 4,017.16 |
| | Diversion Tunnel and Coffer Dam | 137.36 |
| | Dam | 1,234.59 |
| | Intake Structures | 36.51 |
| | Desilting chamber Adit | 47.60 |
| | Desilting chamber incl. SFT | 262.56 |
| | Access Adits to GOC, SFT chamber, Gate shaft and Access shaft | 29.65 |
| | Feeder and Link Tunnel | 72.96 |
| | Adits Underground | 159.94 |
| | Head Race Tunnel | 1,442.67 |
| | Surge Shaft | 109.12 |
| | Pressure Shaft | 296.09 |
| | Power House Complex | 168.72 |
| | Tail Race Channel | 19.38 |
| iv | Hydro-Mechanical Works | 892.01 |
| v | Building | 94.97 |
| vi | Maintenance during construction @ 1% of total cost of Civil and HM Works, Buildings and Communication | 53.41 |
| vii | Special Tools and Plants | 11.00 |
| viii | Communication (Access Road) | 336.71 |
| ix | Electro-Mechanical Cost including switch yard | 1,493.37 |
| x | Environment and Ecology | 44.98 |
| xi | Losses on Stock @ 0.25% of Civil & HM Works, Buildings, E&M and Communication | 17.09 |
| | **Sub-Total of Works** | **7,164.97** |
| xii | Miscellaneous @ 4% of Works | 286.60 |
| | **Total of Works** | **7,451.57** |
| II | Establishment Cost @ 5% of Works minus Land | 371.56 |
| III | Tool and Plants @ 1% of Works | 74.52 |
| IV | Receipt and Recoveries @ 20% of Special T&P | 2.20 |
| | **Total Direct Cost** | **7,895.45** |
| **INDIRECT COST** | | |
| i | Account and Audit Charges @ 1% of total Works | 74.50 |
| | **Total Indirect Cost** | **74.50** |
| | **Total Cost (Direct and Indirect cost)** | **7,969.95** |
| | **Transmission Lines** | **539.05** |
| | **Grand Total** | **8,509.00** |
| | Installed Capacity in MW | 90.00 |
| | Specific Cost per MW | 94.54 |

## 2.15. Financial Analysis

The financial evaluation of the Jomori HPP has been prepared in accordance with the "Tariff Determination Guidelines 2016" issued by the Energy Regulatory Authority (ERA). The energy cost for hydropower plant comprises of the recovery for annual capacity charges and energy charges. Annual capacity charges consist of interest on loan capital and depreciation. Energy charges consist of operation and maintenance expenses, return on equity and interest on working capital.

The financial evaluation of the Jomori HPP has been prepared in accordance with the "Tariff Determination Guidelines 2016" issued by the Energy Regulatory Authority (ERA). The energy cost for hydropower plant comprises of the recovery for annual capacity charges and energy charges. Annual capacity charges consist of interest on loan capital and depreciation. Energy charges consist of operation and maintenance expenses, return on equity and interest on working capital.

The estimated hard cost of the Jomori HPP at March 2023 PL is **Nu. 8,509.00 million** including transmission cost of Nu. 539.05 million and the cost to completion (CTC) of the project escalated by 3.55% (average inflation rate of Bhutan for last 5 years for non-food items) works out to **Nu. 8,856.08 million** including transmission cost.

The tariff determination of the project has been carried out based on ERA regulation with upfront equity injection and proportionate fund injection. The project cost and the tariff details are given in **Table 10**.

**Table 10: Project Cost and Tariffs**

| SN | Items Description | Upfront Equity | Proportionate Fund |
|---|---|---|---|
| **March 2023 PL** | | | |
| 1 | Total Hard Cost including transmission (Mil Nu) | **8,509.00** | **8,509.00** |
| 2 | Interest during construction (Mil Nu) | 1,124.51 | 1,471.94 |
| **3** | **Total Cost of the project including IDC (Mil Nu)** | **9,633.50** | **9,980.93** |
| 4 | First year Tariff (Nu/kWh) | 5.26 | 5.45 |
| 5 | Levelized Tariff (Nu/kWh) | 4.70 | 4.87 |
| 6 | Specific Cost per MW | 94.54 | |
| **Cost to Completion (June 2028)** | | | |
| 1 | Total Hard Cost including transmission (Mil Nu) | **8,856.08** | **8,856.08** |
| 2 | Interest during construction (Mil Nu) | 1,170.38 | 1,531.98 |
| **3** | **Total Cost of the project including IDC (Mil Nu)** | **10,026.46** | **10,388.06** |
| 4 | First year Tariff (Nu/kWh) | 5.48 | 5.68 |
| 5 | Levelized Tariff (Nu/kWh) | 4.89 | 5.06 |

While the base case for the project has been considered as above, the levelized and first year tariffs for the project has also been determined with CERC guideline 2019, India.

The financial analysis of the project was carried out considering the weighted average market clearing price (MCP) for electricity in the Indian Energy Exchange (IEX) which is Nu 5.47 per unit during 2022, indicating the energy market reality. Therefore, the export tariff of Nu. 5.50 per unit (assuming 10% increase every five years) has been considered. With the increase in the domestic load every year, the energy generated by Jomori HPP will have to be allocated to the domestic grid especially during the lean season (Nov-April) to meet the domestic demand and to reduce the import of energy from India. The energy generated during the lean period accounts to 79.44 million units and the balance energy of 287.89 million units will be exported at the assumed export tariff. Based on the assumed tariffs and energy allocation for both domestic load and export energy, the financials of Jomori HPP work out as given in **Table 11**.

**Table 11: Summary of Financial Viability**

| Particulars | Average DSCR | Min DSCR | Average RoE (%) | NPV (Mil Nu) | Project IRR (%) | Equity IRR (%) | Pay Back |
|---|---|---|---|---|---|---|---|
| Jomori HPP | 1.70 | 1.48 | 29.71 | 689.07 | 10.85 | 14.10 | 12.00 |

With the project internal rate of return (IRR) of 10.85% and positive net present value (NPV) of Nu. 689.07 million, the project is financially viable. With an average debt service coverage ratio (DSCR) of 1.70, the project will generate enough cash to service its debt obligation.

## 2.16. Conclusion and Recommendations

The Jomori HPP is designed as a run-off-river scheme with an installed capacity of 90 MW and annual design energy of 367.33 GWh with Plant Load Factor (PLF) of 47.85 %. The available firm flow is 4.92 cumecs and the corresponding firm power is 15.47 MW. The project is planned for a peaking capacity of up to 6 hours.

Jomori HPP envisages a concrete gravity dam of 45 m high from the deepest foundation level and 79.9 m crest length; 2 nos. underground desilting chamber to exclude sediment size greater than 0.2 mm; 4.1 m diameter horseshoe shape with flat invert HRT of 6,355 m long conveying design discharge of 26.66 cumecs; open to sky 10 m diameter surge shaft of 68.90 m high; steel lined pressure shaft of 2.8 m diameter of 741.71 m long bifurcating into two penstocks of 2 m diameter near the surface powerhouse to feed two vertical axis Pelton turbine operating at net head of 359 m and a tail race channel of 3.0 m (H) x 3.5 m (W), 35 m long with its outfall at El. 772.60 m discharging water back to Jomori. The FRL and MDDL are fixed at El. 1,156.00 m and El. 1,143.70 m respectively providing gross and live storage of 0.79 MCM and 0.60 MCM respectively.

The project has been extensively surveyed, investigated and studied at the level of FSR. The geological and geotechnical investigations by way of extensive borehole drillings, seismic refraction & electrical resistivity tests, lineament & surface mappings of the whole project area, exploratory drifts and requisite laboratory and in-situ tests have been carried out during the FSR period. The major project components have been suitably located and optimized to best suit the topographical and geological conditions of the project area.

Based on the detailed environmental and social impact assessment carried out concurrently with the feasibility study of the project, it has been evaluated that the project will have minimal environmental and social impacts.

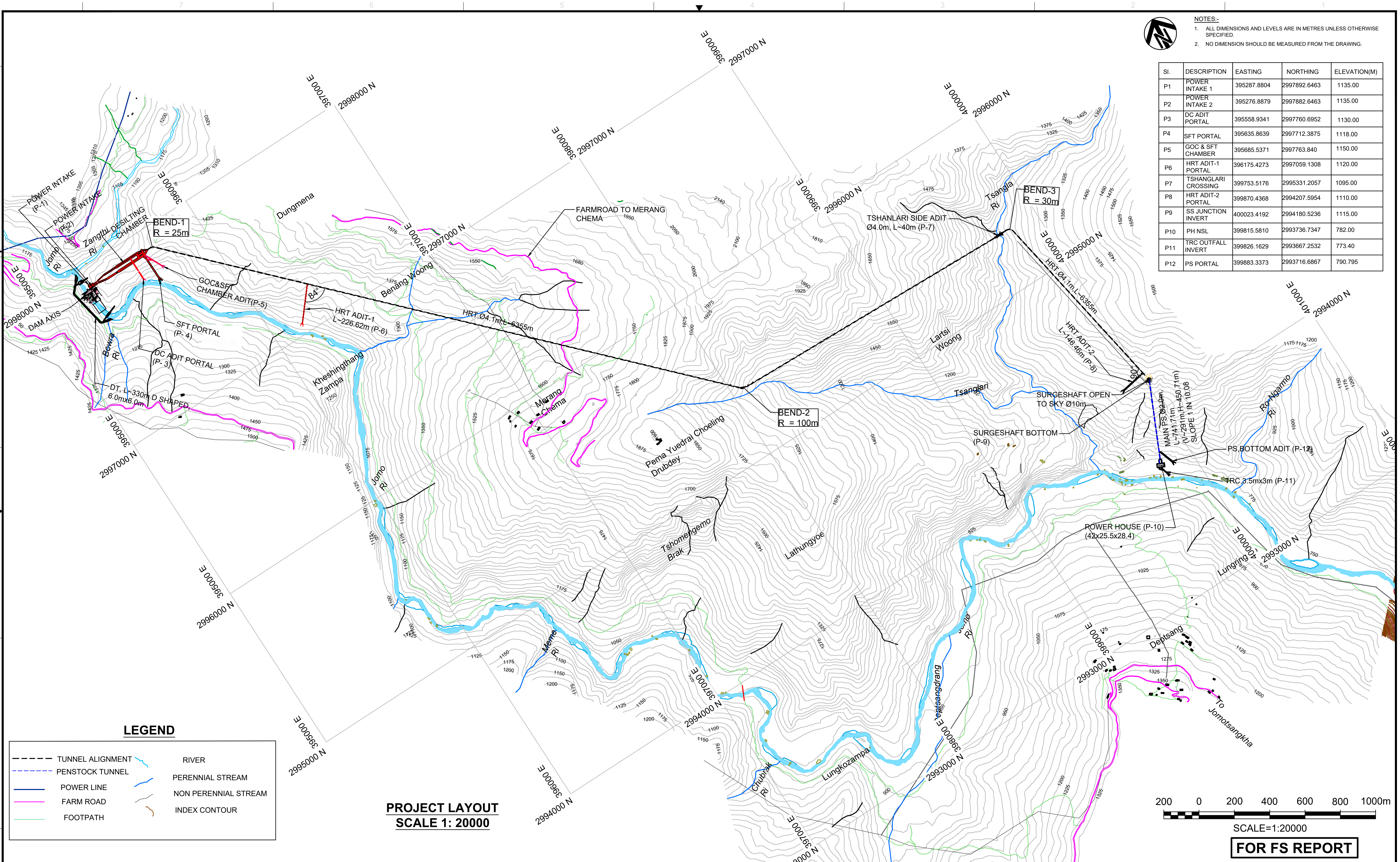
The total construction period is 55 months excluding 8.5 months for preconstruction activities. The total project cost at March 2023 PL has been estimated at **Nu. 9,633.50 million** including IDC of Nu. 1,124.51 million and hard cost of Nu. 8,509.00 million. The first year and levelized tariff has been determined as Nu.5.26 per unit and Nu. 4.70 per unit respectively for upfront equity.

With the project IRR of 10.85% and and positive net present value (NPV), the project is assessed to be financially viable.

In view of the above assessment, it is concluded that the project is techno-economically viable and socio-environmentally acceptable for development. Further, the development of the Jomori HPP will enhance the energy security and power reliability for the country including the achievement of balanced regional development goals of the government.

## 3. Salient Features

The salient feature of the project is in **Annexure-3**.




NOTES:-

1. ALL DIMENSIONS AND LEVELS ARE IN METRES UNLESS OTHERWISE SPECIFIED.
2. NO DIMENSION SHOULD BE MEASURED FROM THE DRAWING.

| Sl. | DESCRIPTION | EASTING | NORTHING | ELEVATION(M) |
|---|---|---|---|---|
| P1 | POWER INTAKE 1 | 395287.8804 | 2997892.6463 | 1135.00 |
| P2 | POWER INTAKE 2 | 395276.8879 | 2997882.6463 | 1135.00 |
| P3 | DC ADIT PORTAL | 395558.9341 | 2997760.6952 | 1130.00 |
| P4 | SFT PORTAL | 395635.8639 | 2997712.3875 | 1118.00 |
| P5 | GOC & SFT CHAMBER | 395685.5371 | 2997763.840 | 1150.00 |
| P6 | HRT ADIT-1 PORTAL | 396175.4273 | 2997059.1308 | 1120.00 |
| P7 | TSHANGLARI CROSSING | 399753.5176 | 2995331.2057 | 1095.00 |
| P8 | HRT ADIT-2 PORTAL | 399870.4368 | 2994207.5954 | 1110.00 |
| P9 | SS JUNCTION INVERT | 400023.4192 | 2994180.5236 | 1115.00 |
| P10 | PH NSL | 399815.5810 | 2993736.7347 | 782.00 |
| P11 | TRC OUTFALL INVERT | 399826.1629 | 2993667.2532 | 773.40 |
| P12 | PS PORTAL | 399883.3373 | 2993716.6867 | 790.795 |

## LEGEND

| | |
|---|---|
| TUNNEL ALIGNMENT | RIVER |
| PENSTOCK TUNNEL | PERENNIAL STREAM |
| POWER LINE | NON PERENNIAL STREAM |
| FARM ROAD | INDEX CONTOUR |
| FOOTPATH | |

**PROJECT LAYOUT**
**SCALE 1: 20000**

200 0 200 400 600 800 1000m

SCALE=1:20000

**FOR FS REPORT**

| | | | |
|---|---|---|---|
| Consultant: Druk Green Consultancy | | Owner: Druk Green Power Corporation Ltd. | |
| Date: March, 2023 | Revised date | Project: **90 MW JOMORI HYDROPOWER PROJECT** SAMDRUP JONGKHAR, BHUTAN | |
| Designed: L.Dhungyel, S.Dorji | Verified: T.Dorjee | Title: GENERAL PROJECT LAYOUT PLAN | |
| Reviewed: S. Zam | Approved: C.Tenzin | | |
| Drawn: J.Wangmo | Scale: AS SHOWN | Drawing No. | |
| THIS DRAWING IS MEANT FOR FSR NOT TO BE USED FOR CONSTRUCTION. | | JHPP-CD-GEN-2023-01 | Rev. 0 |

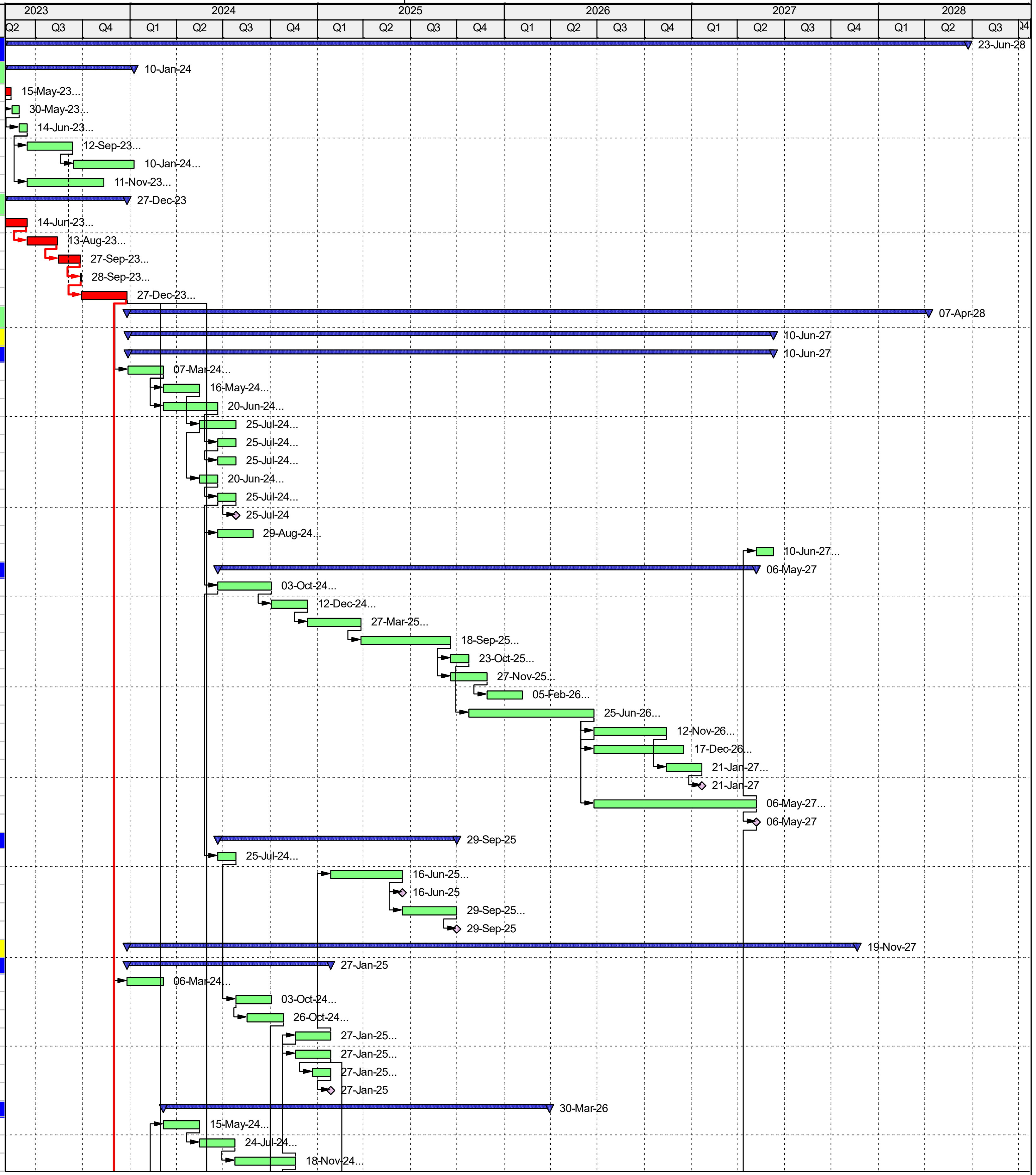
Cad File No: C:\Users\j.wangmo1883\Desktop\27-3-2023 (FINAL GENERAL PROJECT LAYOUT)\GENERAL LAYOUT\JHPP-CD-GEN-2023-01-02.dwg

Apr 07, 2023 - 10:38am

Jomori HPP

Annexure 2
Construction Schedule

| Activity ID | Activity Name | Planned Duration | Start | Finish |
|---|---|---|---|---|
| JHPP FSR_Jomori HPP | | 1681 | 01-May-23 | 23-Jun-28 |
| JHPP.1 Pre-construction Activities | | 255 | 01-May-23 | 10-Jan-24 |
| 1.01 | Tendering | 15 | 01-May-23 | 15-May-23 |
| 1.02 | Evalution and Award of Works | 15 | 16-May-23 | 30-May-23 |
| 1.03 | Mobilisation of Man and Machinery | 15 | 31-May-23 | 14-Jun-23 |
| 1.04 | Construction of Approach Road(First Cutting) | 90 | 15-Jun-23 | 12-Sep-23 |
| 1.05 | Completion of Balance work of Approach road(Widening and Drainage) | 120 | 13-Sep-23 | 10-Jan-24 |
| 1.06 | Construction of temporary camps of all Categories | 150 | 15-Jun-23 | 11-Nov-23 |
| JHPP.2 Tendering and Mobilisation of Main Civil Works | | 241 | 01-May-23 | 27-Dec-23 |
| 2.01 | Preparation of tender documents | 45 | 01-May-23 | 14-Jun-23 |
| 2.02 | Notice Inviting Tender and Bid submission | 60 | 15-Jun-23 | 13-Aug-23 |
| 2.03 | Bid Evalution & Contract Negotiation | 45 | 14-Aug-23 | 27-Sep-23 |
| 2.04 | Signing of Contract | 1 | 28-Sep-23 | 28-Sep-23 |
| 2.05 | Mobilization for Civil Works and zero date starts | 90 | 29-Sep-23 | 27-Dec-23 |
| JHPP.3 MAIN CONSTRUCTION ACTIVITIES | | 1340 | 27-Dec-23 | 07-Apr-28 |
| JHPP.3..1 DAM COMPLEX | | 1080 | 28-Dec-23 | 10-Jun-27 |
| JHPP.3..1..1 River Diversion Arrangement | | 1080 | 28-Dec-23 | 10-Jun-27 |
| 3.1.1.01 | Open Excavation, Portal Construction and Slope Stabilization and construction of tempora | 60 | 28-Dec-23 | 07-Mar-24 |
| 3.1.1.02 | Excavation of DT from upstream end(117m) | 60 | 07-Mar-24 | 16-May-24 |
| 3.1.1.03 | Excavation of DT from downstream end(213m) | 90 | 07-Mar-24 | 20-Jun-24 |
| 3.1.1.04 | Reinforcement & Concreting of Inlet structure, first stage embedment | 60 | 16-May-24 | 25-Jul-24 |
| 3.1.1.05 | Invert lining of diversion tunnel | 30 | 20-Jun-24 | 25-Jul-24 |
| 3.1.1.06 | Reinforcement & Concreting of out let structure and removal of temporary bunds | 30 | 20-Jun-24 | 25-Jul-24 |
| 3.1.1.07 | Installation of gates and second stage concreting | 30 | 16-May-24 | 20-Jun-24 |
| 3.1.1.08 | Diversion of river flow and construction of pre coffer dam in 1st Working season | 30 | 20-Jun-24 | 25-Jul-24 |
| 3.1.1.09 | River diversion ready | 0 | | 25-Jul-24 |
| 3.1.1.10 | Construction of main coffer dam in second dry Season and construction of downstream co | 60 | 20-Jun-24 | 29-Aug-24 |
| 3.1.1.11 | Plugging of diversion tunnel | 30 | 06-May-27 | 10-Jun-27 |
| JHPP.3..1..2 Dam | | 900 | 20-Jun-24 | 06-May-27 |
| 3.1.2.01 | Abutment Stripping | 90 | 20-Jun-24 | 03-Oct-24 |
| 3.1.2.02 | Excavation in River Bed | 60 | 03-Oct-24 | 12-Dec-24 |
| 3.1.2.03 | Foundation Treatment | 90 | 12-Dec-24 | 27-Mar-25 |
| 3.1.2.04 | Concreting in 2nd working season EL 1113 to EL 1122 and Consolidation grouting | 150 | 27-Mar-25 | 18-Sep-25 |
| 3.1.2.05 | Repair of cofferdam and removal of muck/debris from dam body | 30 | 18-Sep-25 | 23-Oct-25 |
| 3.1.2.06 | Excavation in Plunge Pool | 60 | 18-Sep-25 | 27-Nov-25 |
| 3.1.2.07 | Concrete Cladding in excavated slope of Plunge Pool | 60 | 27-Nov-25 | 05-Feb-26 |
| 3.1.2.08 | Concreting in 3rd working season EL 1122 to EL 1142 | 210 | 23-Oct-25 | 25-Jun-26 |
| 3.1.2.09 | Curtain grouting + Drainage holes in 3rd working season | 120 | 25-Jun-26 | 12-Nov-26 |
| 3.1.2.10 | Concreting in 3rd working season EL 1142 to EL 1158 | 150 | 25-Jun-26 | 17-Dec-26 |
| 3.1.2.11 | Curtain grouting + Drainage holes in 4th working season | 60 | 12-Nov-26 | 21-Jan-27 |
| 3.1.2.12 | Dam structure ready for HM works | 0 | | 21-Jan-27 |
| 3.1.2.13 | HM installation in 4th working season + Control Room Construction | 270 | 25-Jun-26 | 06-May-27 |
| 3.1.2.14 | Completion of Dam in all respects | 0 | | 06-May-27 |
| JHPP.3..1..3 Intake | | 399 | 20-Jun-24 | 29-Sep-25 |
| 3.1.3.01 | Excavation of Intake | 30 | 20-Jun-24 | 25-Jul-24 |
| 3.1.3.02 | Concreting of intake after Feeder Tunnels concreting | 120 | 27-Jan-25 | 16-Jun-25 |
| 3.1.3.03 | Intake Site Ready for HM works | 0 | | 16-Jun-25 |
| 3.1.3.04 | Installation of gates | 90 | 16-Jun-25 | 29-Sep-25 |
| 3.1.3.05 | Completion of Intake in all respects | 0 | | 29-Sep-25 |
| JHPP.3..2 DESILTING COMPLEX | | 1220 | 27-Dec-23 | 19-Nov-27 |
| JHPP.3..2.1 Feeder Tunnel | | 340 | 27-Dec-23 | 27-Jan-25 |
| 3.2.1.01 | Open excavation,Portal Construction and slope stabilization for Feeder tunnel | 60 | 27-Dec-23 | 06-Mar-24 |
| 3.2.1.02 | Excavation of Feeder Tunnel -1 | 60 | 25-Jul-24 | 03-Oct-24 |
| 3.2.1.03 | Excavation of Feeder Tunnel -2 | 60 | 17-Aug-24 | 26-Oct-24 |
| 3.2.1.04 | Overt Lining of Feeder Tunnel -1 followed by invert lining | 60 | 18-Nov-24 | 27-Jan-25 |
| 3.2.1.05 | Overt Lining of Feeder Tunnel -2 followed by invert lining | 60 | 18-Nov-24 | 27-Jan-25 |
| 3.2.1.06 | Grouting and Cleaning | 30 | 23-Dec-24 | 27-Jan-25 |
| 3.2.1.07 | Completion of Feeder Tunnel in all respects | 0 | | 27-Jan-25 |
| JHPP.3..2.2 Desilting Chamber | | 646 | 06-Mar-24 | 30-Mar-26 |
| 3.2.2.01 | Excavation of DC Adit | 60 | 06-Mar-24 | 15-May-24 |
| 3.2.2.02 | Full Face Excavation of DC-1 | 60 | 15-May-24 | 24-Jul-24 |
| 3.2.2.03 | Benching of DC-1(Cut 2 &3) and removal of ramp(cut 4) | 100 | 24-Jul-24 | 18-Nov-24 |

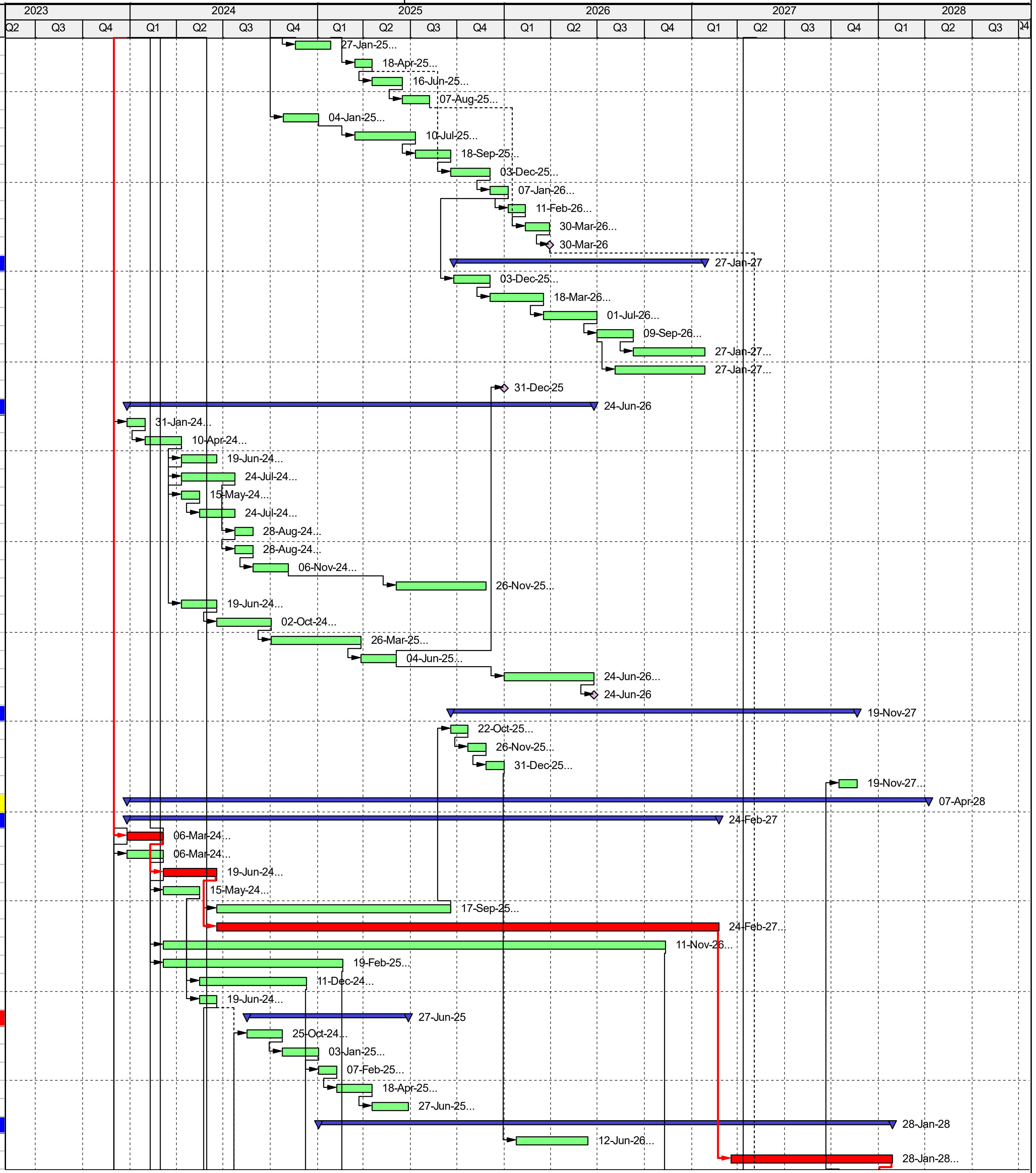



Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone



TASK filter: All Activities

| Activity ID | Activity Name | Planned Duration | Start | Finish |
|---|---|---|---|---|
| 3.2.2.04 | Ramp Development(Cut 4), benching of cut 5 and 6,ramp removal(Cut 4 & 7)-DC1 | 60 | 18-Nov-24 | 27-Jan-25 |
| 3.2.2.05 | Overt Lining of DC-1 | 30 | 14-Mar-25 | 18-Apr-25 |
| 3.2.2.06 | Concreting of hopper walls including flushing duct,DC-1 | 50 | 18-Apr-25 | 16-Jun-25 |
| 3.2.2.07 | Grouting of DC-1 | 45 | 16-Jun-25 | 07-Aug-25 |
| 3.2.2.08 | Full Face Excavation of DC-2 | 60 | 26-Oct-24 | 04-Jan-25 |
| 3.2.2.09 | Benching of DC-2(Cut 2 &3) and removal of ramp(cut 4) | 100 | 15-Mar-25 | 10-Jul-25 |
| 3.2.2.10 | Ramp Development(Cut 4), benching of cut 5 and 6,ramp removal(Cut 4 & 7)-DC2 | 60 | 10-Jul-25 | 18-Sep-25 |
| 3.2.2.11 | Overt Lining of DC-2 | 65 | 18-Sep-25 | 03-Dec-25 |
| 3.2.2.12 | Concreting of hopper walls including flushing duct, DC-2 | 30 | 03-Dec-25 | 07-Jan-26 |
| 3.2.2.13 | Grouting DC-2 | 30 | 07-Jan-26 | 11-Feb-26 |
| 3.2.2.14 | Adit Plugging of DC Adit | 40 | 11-Feb-26 | 30-Mar-26 |
| 3.2.2.15 | Completion of DC in all respects excluding the installation of gates | 0 | | 30-Mar-26 |
| **JHPP.3..2.3 Silt Flushing Tunnel** | | **420** | **24-Sep-25** | **27-Jan-27** |
| 3.2.3.01 | Open Excavation, Portal Construction and Slope Stabilization for silt flushing tunnel | 60 | 24-Sep-25 | 03-Dec-25 |
| 3.2.3.02 | Excavation of main SFT | 90 | 03-Dec-25 | 18-Mar-26 |
| 3.2.3.03 | Excavation of two unit SFTs | 90 | 18-Mar-26 | 01-Jul-26 |
| 3.2.3.04 | Concreting of two unit SFTs | 60 | 01-Jul-26 | 09-Sep-26 |
| 3.2.3.05 | Concreting of main SFT | 120 | 09-Sep-26 | 27-Jan-27 |
| 3.2.3.06 | Grouting of Silt flushing tunnel | 150 | 05-Aug-26 | 27-Jan-27 |
| 3.2.3.07 | SFT Ready for HM Works | 0 | | 31-Dec-25 |
| **JHPP.3..2.4 Gate Operation Chambers(GOC) and Gate Shafts** | | **780** | **27-Dec-23** | **24-Jun-26** |
| 3.2.4.01 | Open Excavation, Portal Construction and Slope Stabilization for adit to GOC | 30 | 27-Dec-23 | 31-Jan-24 |
| 3.2.4.02 | Underground excavation of Adit to GOC for De-silting outlet gates | 60 | 31-Jan-24 | 10-Apr-24 |
| 3.2.4.03 | Excavation of GOC 1 & 2 at El 1158 | 60 | 10-Apr-24 | 19-Jun-24 |
| 3.2.4.04 | GOC crown chamber expansion | 90 | 10-Apr-24 | 24-Jul-24 |
| 3.2.4.05 | Excavation of accesss tunnel towards u/s(65m) | 30 | 10-Apr-24 | 15-May-24 |
| 3.2.4.06 | Excavation of Vertical Inspection Shaft | 60 | 15-May-24 | 24-Jul-24 |
| 3.2.4.07 | Excavation of gate shaft for DC-1 outlet gate | 30 | 24-Jul-24 | 28-Aug-24 |
| 3.2.4.08 | Excavation of gate shaft for DC-2 outlet gate | 30 | 24-Jul-24 | 28-Aug-24 |
| 3.2.4.09 | Concreting of De-silting outlet gate shafts | 60 | 28-Aug-24 | 06-Nov-24 |
| 3.2.4.10 | Installation of De-silting outlet gates | 150 | 04-Jun-25 | 26-Nov-25 |
| 3.2.4.11 | Underground excavation of Adit to GOC for Silt flushing gate | 60 | 10-Apr-24 | 19-Jun-24 |
| 3.2.4.12 | Excavation of GOC for Silt flushing gates | 90 | 19-Jun-24 | 02-Oct-24 |
| 3.2.4.13 | Excavation of gate shaft for Silt flushing gates | 150 | 02-Oct-24 | 26-Mar-25 |
| 3.2.4.14 | Concreting of Silt flushing shafts | 60 | 26-Mar-25 | 04-Jun-25 |
| 3.2.4.15 | Installation of Silt flushing gates | 150 | 31-Dec-25 | 24-Jun-26 |
| 3.2.4.16 | DC,GOC and Gate shafts Ready for Initial Filling | 0 | | 24-Jun-26 |
| **JHPP.3..2.5 Link Tunnel** | | **680** | **17-Sep-25** | **19-Nov-27** |
| 3.2.5.01 | Junction Development | 30 | 17-Sep-25 | 22-Oct-25 |
| 3.2.5.02 | Excavation of Link Tunnel 1 & 2(2*30m) | 30 | 22-Oct-25 | 26-Nov-25 |
| 3.2.5.03 | Concreting of Link Tunnels | 30 | 26-Nov-25 | 31-Dec-25 |
| 3.2.5.04 | Concreting of junction of Link tunnels and HRT | 30 | 15-Oct-27 | 19-Nov-27 |
| **JHPP.3.3 HEADRACE TUNNEL** | | **1340** | **27-Dec-23** | **07-Apr-28** |
| **JHPP.3.3.1 Excavation** | | **990** | **27-Dec-23** | **24-Feb-27** |
| 3.3.1.01 | Open Excavation ,Portal Construction and Slope Stabilization for All Adits | 60 | 27-Dec-23 | 06-Mar-24 |
| 3.3.1.02 | Open Excavation ,Portal Construction and Slope Stabilization for Tshanglari side Adits(Nor | 60 | 27-Dec-23 | 06-Mar-24 |
| 3.3.1.03 | Excavation of Adit to HRT-Adit 1 | 90 | 06-Mar-24 | 19-Jun-24 |
| 3.3.1.04 | Excavation of Adit to HRT-Adit 2 | 60 | 06-Mar-24 | 15-May-24 |
| 3.3.1.05 | Excavation of HRT towards Link Tunnel Through Adit 1(Face 1) | 390 | 19-Jun-24 | 17-Sep-25 |
| 3.3.1.06 | Excavation of HRT towards downstream Through Adit 1(Face 2) | 840 | 19-Jun-24 | 24-Feb-27 |
| 3.3.1.07 | Excavation of HRT towards upstream through side adit north(Face 3) | 840 | 06-Mar-24 | 11-Nov-26 |
| 3.3.1.08 | Excavation of HRT towards downstream through side adit south(Face 4) | 300 | 06-Mar-24 | 19-Feb-25 |
| 3.3.1.09 | Excavation of HRT towards upstream through Adit 2(Face 5) | 180 | 15-May-24 | 11-Dec-24 |
| 3.3.1.10 | Excavation of HRT towards downstream through Adit 2(Face 6) | 30 | 15-May-24 | 19-Jun-24 |
| **JHPP.3.3.1.1 Tshanglari Side Adit** | | **270** | **16-Aug-24** | **27-Jun-25** |
| 3.3.1.1.01 | Excavation Works | 60 | 16-Aug-24 | 25-Oct-24 |
| 3.3.1.1.02 | Construction of Sub Structure Works | 60 | 25-Oct-24 | 03-Jan-25 |
| 3.3.1.1.03 | Construction of Bridge | 30 | 03-Jan-25 | 07-Feb-25 |
| 3.3.1.1.04 | Laying of Steel Pipe | 60 | 07-Feb-25 | 18-Apr-25 |
| 3.3.1.1.05 | Miscellaneous Activities | 60 | 18-Apr-25 | 27-Jun-25 |
| **JHPP.3.3.2 Tunnel Lining** | | **960** | **03-Jan-25** | **28-Jan-28** |
| 3.3.2.01 | Overt Concreting of HRT from Face 1 through Adit 1 followed by invert concreting | 120 | 23-Jan-26 | 12-Jun-26 |
| 3.3.2.02 | Overt Concreting of HRT from Face 2 through Adit 1 followed by invert concreting | 270 | 19-Mar-27 | 28-Jan-28 |

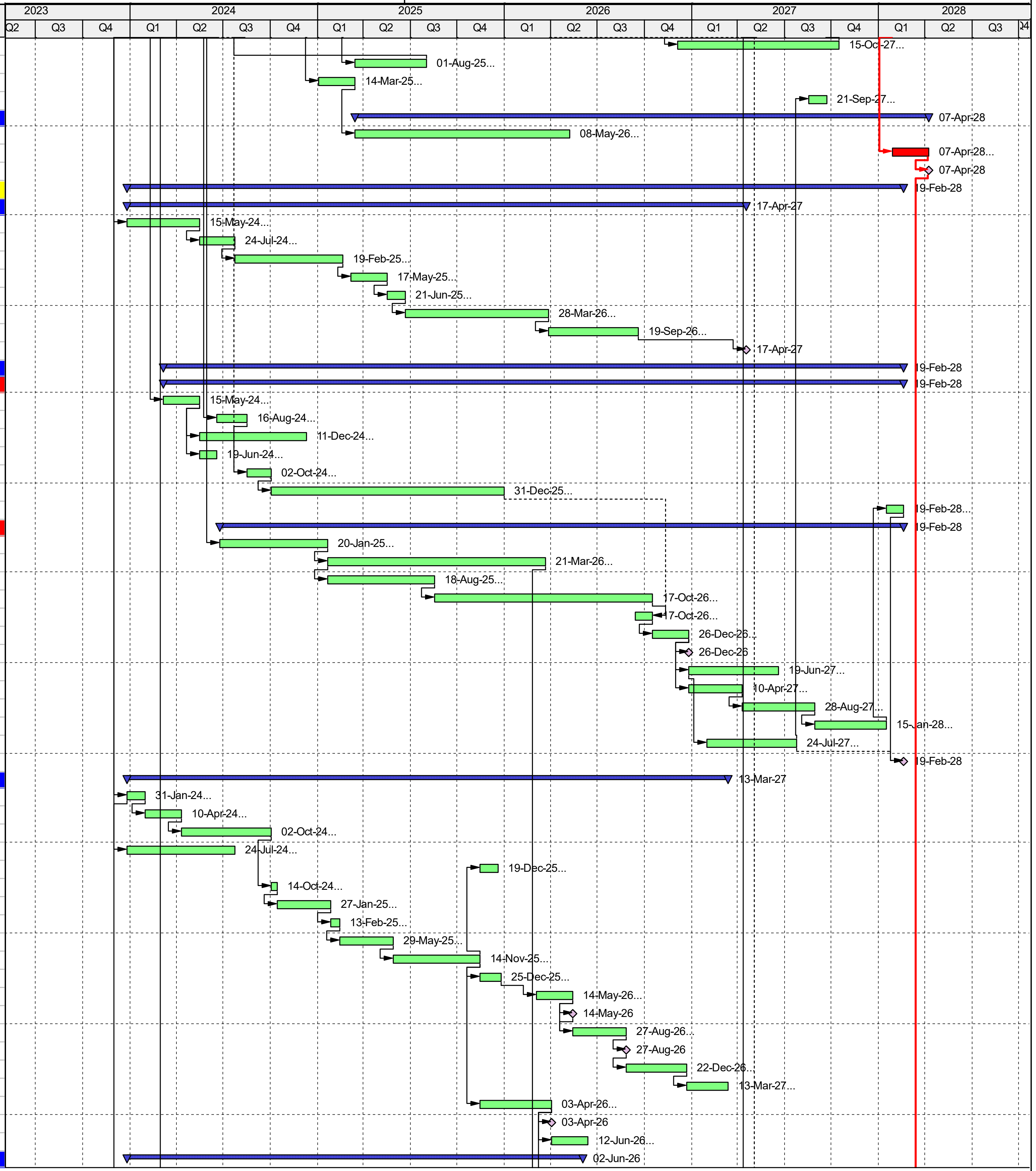



Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone



TASK filter: All Activities

| Activity ID | Activity Name | Planned Duration | Start | Finish |
|---|---|---|---|---|
| 3.3.2.03 | Overt Concreting of HRT from Face 3 through Side Adit (north) followed by invert concreti | 270 | 04-Dec-26 | 15-Oct-27 |
| 3.3.2.04 | Overt Concreting of HRT from Face 4 through Side Adit (south) followed by invert concret | 120 | 14-Mar-25 | 01-Aug-25 |
| 3.3.2.05 | Overt Concreting of HRT from Face 5 through Adit 2 followed by invert concreting | 60 | 03-Jan-25 | 14-Mar-25 |
| 3.3.2.06 | Overt Concreting of HRT from Face 6 through Adit 2 followed by invert concreting | 30 | 17-Aug-27 | 21-Sep-27 |
| **JHPP.3.3.3** | **Grouting,Cleaning and Adit Plugging** | **960** | **14-Mar-25** | **07-Apr-28** |
| 3.3.3.01 | Grouting and Cleaning of HRT and Link Tunnels | 360 | 14-Mar-25 | 08-May-26 |
| 3.3.3.02 | Adit plugging and Gate installation in one adit | 60 | 28-Jan-28 | 07-Apr-28 |
| 3.3.3.03 | Completion of HRT in all respects | 0 | | 07-Apr-28 |
| **JHPP.3.4** | **POWERHOUSE COMPLEX** | **1299** | **27-Dec-23** | **19-Feb-28** |
| **JHPP.3.4.1** | **Surge Shaft** | **1035** | **27-Dec-23** | **17-Apr-27** |
| 3.4.1.01 | Open Excavation and slope stabilisation + Construction of collar beam at top | 120 | 27-Dec-23 | 15-May-24 |
| 3.4.1.02 | Erection of 25 t Gantry Crane | 60 | 15-May-24 | 24-Jul-24 |
| 3.4.1.03 | Excavation of Surge Shaft | 180 | 24-Jul-24 | 19-Feb-25 |
| 3.4.1.04 | Installation of slip form | 60 | 08-Mar-25 | 17-May-25 |
| 3.4.1.05 | Concreting of orifice slab | 30 | 17-May-25 | 21-Jun-25 |
| 3.4.1.06 | Concreting of surge Shaft | 240 | 21-Jun-25 | 28-Mar-26 |
| 3.4.1.07 | Grouting and finishing works | 150 | 28-Mar-26 | 19-Sep-26 |
| 3.4.1.08 | Surge Shaft Ready in all Respects | 0 | | 17-Apr-27 |
| **JHPP.3.4.2** | **Pressure Shaft** | **1239** | **06-Mar-24** | **19-Feb-28** |
| **JHPP.3.4.2.1** | **Excavation** | **1239** | **06-Mar-24** | **19-Feb-28** |
| 3.4.2.1.01 | Excavation of Adit to PS bottom | 60 | 06-Mar-24 | 15-May-24 |
| 3.4.2.1.02 | Widening of Surge Shaft bottom for installation of winch | 50 | 19-Jun-24 | 16-Aug-24 |
| 3.4.2.1.03 | Excavation of bottom Horizontal pressure tunnel | 180 | 15-May-24 | 11-Dec-24 |
| 3.4.2.1.04 | Excavation of Unit Penstock upto Power house | 30 | 15-May-24 | 19-Jun-24 |
| 3.4.2.1.05 | Installation of 10t Winch at top by Civil for excavation of vertical pressure shaft | 40 | 16-Aug-24 | 02-Oct-24 |
| 3.4.2.1.06 | Excavation of vertical pressure shaft form top-down and bottom-up | 390 | 02-Oct-24 | 31-Dec-25 |
| 3.4.2.1.07 | Adit Plugging and Miscellanous Works(Adit to PS bottom) | 30 | 15-Jan-28 | 19-Feb-28 |
| **JHPP.3.4.2.2** | **Fabrication and Erection works** | **1145** | **24-Jun-24** | **19-Feb-28** |
| 3.4.2.2.01 | Tenders & Specifications for PS liner steel | 180 | 24-Jun-24 | 20-Jan-25 |
| 3.4.2.2.02 | Order & Transportation of PS liner steel to site | 365 | 20-Jan-25 | 21-Mar-26 |
| 3.4.2.2.03 | Development of fabrication yard, workshop, hydro testing arrangement, sand blasting and | 180 | 20-Jan-25 | 18-Aug-25 |
| 3.4.2.2.04 | Fabrication of steel ferrule including testing - ultrasonic, radiography and hydro testing | 365 | 18-Aug-25 | 17-Oct-26 |
| 3.4.2.2.05 | Installation of 20t Winch at top by HM Contractor | 30 | 12-Sep-26 | 17-Oct-26 |
| 3.4.2.2.06 | Installation of bottom vertical bend and concreting(M25 grade) | 60 | 17-Oct-26 | 26-Dec-26 |
| 3.4.2.2.07 | Pressure Shaft Ready for HM Works | 0 | | 26-Dec-26 |
| 3.4.2.2.08 | Installation of vertical PS from bottom bend to top of PS and concreting | 150 | 26-Dec-26 | 19-Jun-27 |
| 3.4.2.2.09 | Installation of Horizontal Pressure shaft for Unit Penstock and concreting | 90 | 26-Dec-26 | 10-Apr-27 |
| 3.4.2.2.10 | Installation of unit Pressure tunnel + reducers + thrust collar and concreting | 120 | 10-Apr-27 | 28-Aug-27 |
| 3.4.2.2.11 | Installation of Bifurcation piece +installation of remaining ferrules | 120 | 28-Aug-27 | 15-Jan-28 |
| 3.4.2.2.12 | Grouting | 150 | 30-Jan-27 | 24-Jul-27 |
| 3.4.2.2.16 | PS ready in all respects | 0 | | 19-Feb-28 |
| **JHPP.3.4.3** | **Powerhouse** | **1005** | **27-Dec-23** | **13-Mar-27** |
| 3.4.3.01 | Site Clearing works | 30 | 27-Dec-23 | 31-Jan-24 |
| 3.4.3.02 | Open excavation (benching) | 60 | 31-Jan-24 | 10-Apr-24 |
| 3.4.3.03 | slope stabilization for power house | 150 | 10-Apr-24 | 02-Oct-24 |
| 3.4.3.04 | River Training works | 180 | 27-Dec-23 | 24-Jul-24 |
| 3.4.3.05 | Compacted Backfilling Works | 30 | 14-Nov-25 | 19-Dec-25 |
| 3.4.3.06 | Site ready for laying of earthmat (EM Contractor) | 10 | 02-Oct-24 | 14-Oct-24 |
| 3.4.3.07 | RCC works for Mat and structural foundation footing including raft concreting for both units | 90 | 14-Oct-24 | 27-Jan-25 |
| 3.4.3.08 | Erection of zero stage EPS including housing for both units | 15 | 27-Jan-25 | 13-Feb-25 |
| 3.4.3.09 | Concreting up to MIV floor level for both units | 90 | 13-Feb-25 | 29-May-25 |
| 3.4.3.10 | RCC concreting for Turbine Barrel upto Machine floor including Service Bay | 145 | 29-May-25 | 14-Nov-25 |
| 3.4.3.11 | Concreting up to Distributor Level | 35 | 14-Nov-25 | 25-Dec-25 |
| 3.4.3.12 | Site ready for erection of distributor | 60 | 05-Mar-26 | 14-May-26 |
| 3.4.3.13 | Site Ready for Erection of Distributor | 0 | | 14-May-26 |
| 3.4.3.14 | Concreting around distributor for both units | 90 | 14-May-26 | 27-Aug-26 |
| 3.4.3.15 | Site Ready for laying of turbine housing | 0 | | 27-Aug-26 |
| 3.4.3.16 | Barrel Concreting from Turbine floor upto Machine floor | 100 | 27-Aug-26 | 22-Dec-26 |
| 3.4.3.17 | Erection of first stage EPS including housing for both units | 70 | 22-Dec-26 | 13-Mar-27 |
| 3.4.3.18 | RCC framed structure - Erecting of beams and columns | 120 | 14-Nov-25 | 03-Apr-26 |
| 3.4.3.19 | Civil Structures in PH Ready for Installaton of EOT Crane | 0 | | 03-Apr-26 |
| 3.4.3.20 | Roof truss and roofing works | 60 | 03-Apr-26 | 12-Jun-26 |
| **JHPP.3.4.4** | **Tail Race Channel** | **761** | **27-Dec-23** | **02-Jun-26** |

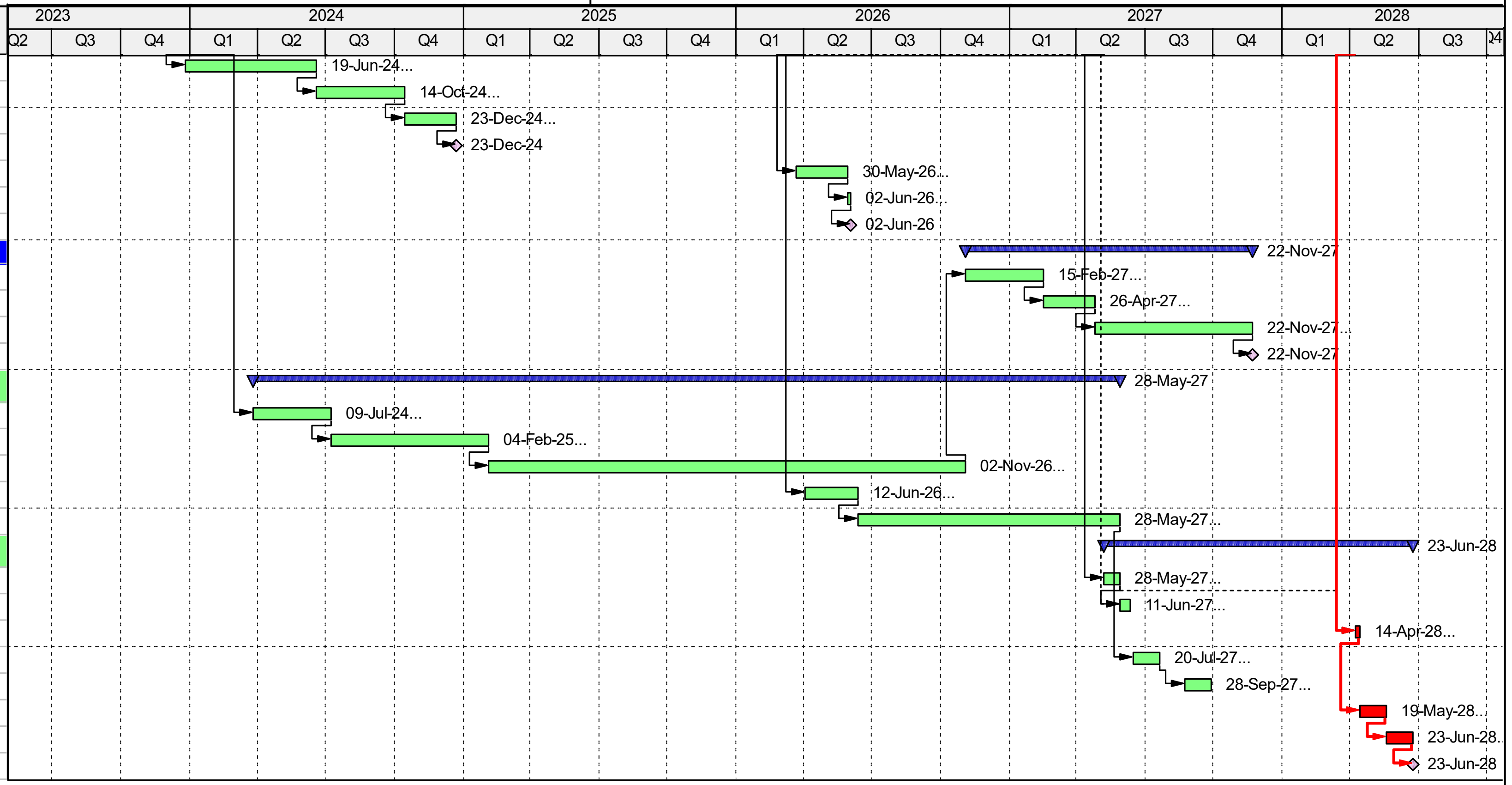



Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone



TASK filter: All Activities

| Activity ID | Activity Name | Planned Duration | Start | Finish |
|---|---|---|---|---|
| 3.4.4.01 | Excavation including slope protection works | 150 | 27-Dec-23 | 19-Jun-24 |
| 3.4.4.02 | RCC works | 100 | 19-Jun-24 | 14-Oct-24 |
| 3.4.4.03 | Backfilling works | 60 | 14-Oct-24 | 23-Dec-24 |
| 3.4.4.04 | Civil Structure of TRC Ready | 0 | | 23-Dec-24 |
| 3.4.4.05 | Assembling and Erection of Gates | 60 | 21-Mar-26 | 30-May-26 |
| 3.4.4.06 | Dry Testing | 2 | 30-May-26 | 02-Jun-26 |
| 3.4.4.07 | TRC ready in all respects | 0 | | 02-Jun-26 |
| **JHPP.3.4.5** | **Switchyard and Transformer** | **330** | **02-Nov-26** | **22-Nov-27** |
| 3.4.5.01 | Surface Excavation and slope protection works | 90 | 02-Nov-26 | 15-Feb-27 |
| 3.4.5.02 | Drainage and flooring works | 60 | 15-Feb-27 | 26-Apr-27 |
| 3.4.5.03 | Erection of Substations | 180 | 26-Apr-27 | 22-Nov-27 |
| 3.4.5.04 | Switchyard and Transformer Ready | 0 | | 22-Nov-27 |
| **JHPP.4** | **ELECTRO-MECHANICAL WORKS** | **993** | **26-Mar-24** | **28-May-27** |
| 4.01 | Award of E&M works | 90 | 26-Mar-24 | 09-Jul-24 |
| 4.02 | Design and Engineering | 180 | 09-Jul-24 | 04-Feb-25 |
| 4.03 | Manufacturing,inspection and delivery at site | 545 | 04-Feb-25 | 02-Nov-26 |
| 4.04 | Erection of EOT Crane | 60 | 03-Apr-26 | 12-Jun-26 |
| 4.05 | Erection at site | 300 | 12-Jun-26 | 28-May-27 |
| **JHPP.5** | **FILLING OF WCS & COMMISSIONING** | **355** | **06-May-27** | **23-Jun-28** |
| 5.01 | Filling of Reservoir | 19 | 06-May-27 | 28-May-27 |
| 5.02 | Filling of DC | 12 | 28-May-27 | 11-Jun-27 |
| 5.03 | Filling of WCS | 6 | 07-Apr-28 | 14-Apr-28 |
| 5.04 | Dry Commissioning of Unit-I | 30 | 15-Jun-27 | 20-Jul-27 |
| 5.05 | Dry Commissioning of Unit-II | 30 | 24-Aug-27 | 28-Sep-27 |
| 5.06 | Wet Commissioning of Unit-I | 30 | 14-Apr-28 | 19-May-28 |
| 5.07 | Wet Commissioning of Unit-II | 30 | 19-May-28 | 23-Jun-28 |
| 5.08 | Commercial Operation Date | 0 | | 23-Jun-28 |




Actual Work | Critical Remaining Work | Summary
Remaining Work | Milestone



TASK filter: All Activities

**Annexure- 3**

**Salient Features of Jomori Hydropower Project**

| | | |
|---|---|---|
| **A.** | **GENERAL** | |
| | Location | Jomori |
| | Country | Bhutan |
| | District/Dzongkhag | Samdrup Jongkhar |
| | River | Jomori |
| | Nearest Village (Dam site) | Woongthig |
| | Nearest Village (Power House Site) | Deptshang |
| | Nearest Airport, Domestic | Yonphula, Bhutan |
| | Nearest Airport, International | Paro, Bhutan & Guwahati, Assam, India |
| | Nearest Railhead (Broad gauge) | Rangiya, Assam, India |
| | **Location of Dam (at Dam Axis in UTM)** | |
| | **Right Bank** | |
| | Easting | 395210.98 |
| | Northing | 2997860.09 |
| | **Left Bank** | |
| | Easting | 395291.00 |
| | Northing | 2997862.88 |
| | **Location of Power House (Center of Building in UTM)** | |
| | Easting | 399815.31 |
| | Northing | 2993739.06 |
| **B.** | **HYDROLOGY** | |
| | Catchment area | 486.40 $km^2$ |
| | Probable Maximum Flood | 4,120 $m^3/s$ |
| | Design flood (SPF) | 3,099 $m^3/s$ |
| | Diversion Flood | 279 $m^3/s$ |
| **C.** | **CIVIL WORKS** | |
| | **Reservoir** | |
| | Full Reservoir Level (FRL) | El. 1,156 m |
| | Minimum Draw Down Level (MDDL) | El. 1,143.70 m |
| | Live storage | 0.6 MCM |
| | Peaking | 6 hrs. |
| | Gross Storage (FRL) | 0.79 MCM |
| | Reservoir Surface Area (FRL) | 4,399 $m^2$ |
| | Length of reservoir (FRL) | 780 m |
| | Gross head | 370.27 m |
| | Net head | 359 m |
| | **Temporary River Diversion Arrangement** | |
| | **Diversion Tunnel** | |

| | |
|---|---|
| Number/Location | 1 No. / Right Bank |
| Diameter & shape | 6 m dia., D shaped |
| Length | 330 m, slope 1 in 66 |
| Diversion discharge (1 in 25-year non-monsoon) | 279 $m^3/s$ |
| Gate type | Vertical lift fixed wheel type |
| Number of gates | 1 |
| Gate size | 6 m (W) x 6 m (H) |
| **Upstream Coffer Dam** | |
| Type | Random fill concrete facing |
| Top Level | El. 1,141 m |
| Height/Crest Length | 15 m / 33.70 m |
| **Downstream Coffer Dam** | |
| Type | Masonry fill concrete facing |
| Top Level | El. 1,132 m |
| Height/Crest Length | 9 m / 40 m |
| **Main Dam** | |
| Type | Concrete gravity |
| Dam Top | El. 1,158 m |
| River Bed Level at dam site | El. 1,126 m |
| Max. Dam Height (above deepest foundation level) | 45 m |
| Dam height (above river bed level) | 32 m |
| Length of Dam at Crest Level | 79.9 m |
| **Spillway** | |
| Design flood (SPF) | 3,099 $m^3/s$ |
| Crest Level of Main Spillway | El. 1,128 m |
| Crest Level of Auxiliary Spillway | El. 1,149 m |
| Type<br>Main Spillway<br>Auxiliary Spillway | <br>Orifice with Breast wall<br>Overflow |
| Number & size of lower-level spillway opening (W x H) | 3 Nos & 8 m x 11 m |
| Number & size of Auxiliary spillway opening (W x H) | 1 No & 8 m x 7 m |
| Energy Dissipater | Trajectory Bucket Type |
| Number of Radial gates | 3 Nos |
| Size of Radial gates (W x H) | 8 m x 11 m |
| **Stop Log Gate** | |
| Number | 3 Nos |
| Size | 8 m x 11 m |
| Type of Hoist | Gantry Crane |

| | |
|---|---|
| **Power Intake & Feeder Tunnels** | |
| Number of Feeder Tunnels | 2 Nos., Left bank & concrete lined |
| Shape & Size of Tunnel | 3.5 m dia. (Modified Horseshoe shaped with flat invert) |
| Trash rack sill level | El. 1,135 m |
| Length of Feeder tunnels | 151 m |
| Intake invert level | El. 1,135 m |
| Discharge Capacity | 32.959 $m^3/s$ |
| Number of Intake trash rack | 2 sets |
| Size of Intake trash rack | 5 m x 5 m |
| Number of Intake service gate | 2 sets |
| Size of Intake service gate | 3.5 m x 3.5 m |
| Number of Intake emergency gate | 2 sets |
| Size of Intake emergency gate | 3.5 m x 3.5 m |
| **Desilting Chamber** | |
| Type and Number | 2 Nos |
| Size (L x W x D) | 138 m x 8 m x 9.5 m |
| Design discharge (Installed Capacity at MDDL) | 28.66 $m^3/s$ |
| Total flushing discharge (15%) | 4.299 m3/s |
| Total diversion discharge | 28.66 $m^3/s$ |
| Average design discharge in one Chamber | 14.33 $m^3/s$ |
| Sediment size to be removed | ≥ 0.2 mm |
| Number of Desilting outlet gates | 2 |
| Size of Desilting outlet gates | 3.5 m (W) x 3.5 m (H) |
| **Silt Flushing Tunnel** | |
| Unit Tunnel – Number | 2 Nos |
| Unit Tunnel – Size (W x H) | 1 m x 1.5 m |
| Unit Tunnel – Length | Unit tunnel 1(left) – 68 m, Unit tunnel 2 (right) – 41 m |
| Main Tunnel – Size (W x H) | 3 m x 3 m |
| Main Tunnel – Length | 115 m |
| SFT outfall invert level | El. 1,118 m |
| Number of SFT gates | 4 (2 EG + 2 SG) |
| SFT Gate size (W x H) | 1.0 m x 1.5 m |
| Adit to SFT gate Chamber- length | 35 m (From GOC adit) |
| Shaft to SFT Gate - Size and Height | 8 m dia, 19.5 m |
| **Link Tunnel** | |
| Number | 2 Nos |
| Size | 3.5 m |
| Length | 51 m |

| | |
|---|---|
| Shaft at Desilting Outlet gate – Numbers / Diameter / Height | 2 Nos/3.5 m/20.5 m |
| **Head Race Tunnel** | |
| Number | 1 No. |
| Size & Type | 4.1 m dia., flat bottom horseshoe |
| Design Discharge | 28.66 $m^3/s$ |
| Length | 6,355 m |
| Slope (u/s of Tshanglari side adit) | 1 in 131.69 |
| Slope (d/s of Tshanglari side adit) | 1 in 60.90 |
| Number of adit plug (vehicle gate) | 1 |
| Number of permanent plugs in HRT | 1 |
| Number of adit plug (vehicle gate) and size | Hinged gate, 3 m (W) x 3 m (H) |
| **Construction Adits** | |
| DC Adit (5 m x 5 m) (Length) | 145 m |
| SFT & GOC chamber Adit (5 m x 5 m) (Length) | 154 m |
| HRT Adit 1 (5 m x 5 m) (Length) | 225 m |
| HRT Adit 2 (5 m x 5 m) (Length) | 145 m |
| PS Bottom Adit (5 m x 5 m) (Length) | 112 m |
| **Side Adit** | |
| Diameter | 4 m |
| Bottom Level | El. 1,095 m |
| Length | 40 m |
| Type of steel | ASTM A517 |
| Liner Thickness | 16 mm |
| **Surge Shaft** | |
| Number | 1 No. |
| Type | Open to sky |
| Top Level | El. 1,190 m |
| Bottom Level | El. 1,121.10 m |
| Surge shaft - Diameter | 10 m |
| Surge shaft – Height (excluding orifice slab) | 68.90 |
| Orifice slab thickness | 2 m |
| Orifice Diameter | 1.6 m |
| Total height of surge shaft | 70.9 m |
| **Pressure Shaft** | |
| Type | Underground, Vertical and Horizontal steel Lined |
| Number | 1 No |
| Main Pr. Shaft - Diameter | 2.8 m |
| Main Pr. Shaft - Length | 741.71 m |
| Unit Pr. Shaft - Diameter | 2 m |

| | | |
|---|---|---|
| | Unit Pr. Shaft - Length | 30 m |
| | Type of Steel | ASTM A537 Class II & ASTM A517 Gr F |
| | Liner Thickness | 10 mm to 34 mm |
| | **Power House** | |
| | Type of Turbine | Pelton |
| | Machine centre line level | El. 778.90 m |
| | PH Size (Lx W x H) | 42 m x (20+5.5 m Annex) x 28.4 m |
| | **Main Inlet Valve** | |
| | Type | Spherical |
| | Number | 2 Nos. |
| | **Tail Race Outfall** | |
| | Type | TRC |
| | Number | 1 No. |
| | Size and Shape (HxW) | 3 m x 3.5 m |
| | Length of Main TRC | 35 m |
| | Outfall invert level | El. 772.60 m |
| | TRC Outlet Gate | Vertical lift slide type |
| | Number and Size of TRC outlet gate | 2 Nos, 3 m (H) x 3.5 m (W) |
| **D.** | **ELECTRO-MECHANICAL EQUIPMENT** | |
| | **Turbine** | |
| | Type of Turbine | Vertical Shaft Pelton |
| | Number of turbines | 2 Nos. |
| | Rated net head | 359 m |
| | Rated Output | 90 MW |
| | Rated Speed | 375 rpm |
| | **Generator** | |
| | Type of Generator | Synchronous, Vertical Shaft |
| | Rated power | 53 MVA |
| | Power Factor | 0.85 |
| | Generation Voltage | 11 kV |
| | Number of Phases | 3 phases |
| | Frequency | 50 Hz |
| | Efficiency | 98 |
| | **Power Transmission and Distribution** | |
| | Transmission Line Voltage | 132 kV |
| | Total line length | 78.08 km |
| | Conductor type | Panther |
| | **Power Generation** | |
| | Design Energy in 90% dependable year with 95% Plant Availability | 367.33 GWh |

| | | |
|---|---|---|
| | 50% dependable year Energy | 428.88 GWh |
| | Annual Plant Load Factor | 47.85 % |
| | Lean season Plant Load Factor | 17.23 % |
| | Probability of Exceedance | 23.00 % |
| | Firm Power | 15.47 MW |
| **E.** | **CONSTRUCTION SCHEDULE** | |
| | Preconstruction period | 8.5 months |
| | Mobilization of main civil work | 3 months |
| | Main work construction duration | 55 months |
| **F.** | **COST AND FINANCIALS** | |
| | **March 2023 PL (Upfront Equity)** | |
| | Total Hard Cost including transmission | Nu. 8,509.00 million |
| | Total Project Cost including IDC | Nu. 9,633.50 million |
| | First year tariff | Nu. 5.26 per unit |
| | Levelized tariff | Nu. 4.70 per unit |
| | Specific cost per MW | Nu. 94.54 million |
| | **Cost to Completion- June 2028 (Upfront Equity)** | |
| | Total Hard Cost including transmission | Nu. 8,856.08million |
| | Total Project Cost including IDC | Nu. 10,026.46 million |
| | First year tariff | Nu. 5.48 per unit |
| | Levelized tariff | Nu. 4.89 per unit |

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# Executive Summary

# For

# Druk Bindu I Hydropower Project

# 1. Executive Summary

## 1.1. Background

The Kingdom of Bhutan has abundant hydropower reserves with techno-economically viable potential of 33 GW as per the Power System Master Plan 2040 (PSMP-2040). The overall hydropower potential was estimated as 37 GW from 155 sites, out of which 90 sites having installed capacity of about 33 GW have been identified as techno-economically viable for implementation. Sustainable hydropower development is critical for Bhutan to reap the benefits of this huge hydropower reserves. The economic gains as a result of this development to the people of Bhutan in financial, economic, and social terms will be immense. With present installed capacity of 2,326 MW from its seven large power plants, the country has harnessed about 7% of the techno-economically feasible hydropower potential. The country today exports about 70% of the electricity to India after meeting its internal demand first. With addition of 2,938 MW installed capacity from the four projects, currently under different stages of construction, it is expected to further enhance the quantum of export to India and contribute to the socio-economic development of the country.

The electricity grid in Bhutan is closely interconnected to the Indian grid that is prone to frequent failures. Bhutan has experienced prolonged power outages in pockets of the country as well as at the national level. With India's increasing investment into renewables such as solar and wind without adequate provision for balancing power support from energy sources such as hydropower, it will only make India's grid more prone to major grid failures. As of now, Bhutan's mega hydropower projects with BHEL technology cannot operate in an isolated mode. Therefore, it has become imperative to plan for a backup power supply that is adequate to provide essential electricity supply services to each Dzongkhag in an isolated mode. More importantly, there is a need to plan for robust energy supply system as a preparedness measure for natural hazards and other exigencies. By virtue of its location, Bhutan is prone to natural disasters such as earthquake, glacial lake outburst flood (GLOF), flash flood, and extreme weather conditions. In the last few decades, Bhutan has experienced major earthquakes of magnitude over 7 on the Richter scale which had devastating impacts on the country's infrastructure and has claimed lives. During such events, as an essential service, availability of steady power supply is crucial for sustenance of livelihood of people as well as for recovery processes.

Recognizing the need for domestic energy security through facilitation of self-contained supply flexibility for each Dzongkhag to meet the demand of household, institutional consumers and essential service providers in times of exigencies (which at other times could be fed into the grid), DGPC is undertaking strategic planning of a backup power supply system by harnessing abundantly available renewable hydropower resources through implementation of small and medium sized hydropower projects. Further, in the wake of the economic downturn with the Covid-19 pandemic, development of small hydropower projects across the country will not only help to stimulate economic activities at the grass root levels but also help generate employment and engagement of the people in these difficult times.

As part of Phase I of the Small Hydropower Initiative, the feasibility study of three hydropower projects have been completed in December 2021 and are currently under different stages of construction.

With regard to Phase II of the undertaking, the techno-economic viability of projects was given priority compared to the 60:40 Technical: Social criteria of the Phase I selection process. Accordingly, the projects which have already been studied at either a Pre-Feasibility (PFS) or Feasibility (FSR) level and approved by the Department of Hydropower and Power Systems were considered techno-economically viable and proposed for selection. Subsequent to further field assessments, six projects have been considered under Phase II for FSR study or for updation of existing FSR/DPR.

This report entails the updation of the Detailed Project Report (DPR) of 18 MW Druk Bindu I Hydropower Project (HPP) located in Tendu Gewog under Samtse Dzongkhag.

## 1.2. Previous Studies

The Feasibility Study of Druk Bindu I Small Hydropower Project (Druk Bindu HPP) in Tendu, Samtse Dzongkhag was conducted by Bhutan Power Corporation Limited (BPC) in 2009-2010 (FSR-2011). As per the report, the project envisages diversion of water from Kachin river (El. 978 m) via an open channel to Druk Bindu river (El. 966 m). Two separate trench weirs and intake structures have been proposed to utilize the water from both the rivers for power generation. The water from the main intake at Druk Bindu river at El. 966 m has been planned to be diverted through a Glass Reinforced Pipe (GRP) of 145 m length with designed flow of 9.75 $m^3/s$ till the surface desilter. The head race GRP of 2,567 m and 2.0 m diameter has been designed to convey discharge of 8.58 $m^3/s$ from desilter to forebay tank. The full supply level and minimum draw down level has been worked out to be El. 960.42 m and El. 956.42 m respectively. A steel pipe main penstock of about 300 m in length, 1.7 m in diameter and unit penstock of 3 x 67 m has been proposed. A surface powerhouse of 30 m x 18 m x 13 m with service bay at El. 771.448 m has been proposed. The Francis type horizontal axis turbine of 3 x 4 MW have been proposed to generate an installed capacity of 12 MW. The BPC in 2014 has further updated the hydrological, power potential and cost estimation part of the FSR-2011. As per this update, no changes were made in the design. The updated estimated cost of the project worked out at 2014 price level was Nu. 732.74 million including transmission line cost. The levelized tariff accordingly worked out was Nu. 2.90 per kWh.

Subsequently, Druk Green Power Corporation undertook the preparation of DPR of the project towards the end of 2015. The project with an installed capacity of 18 MW and annual design energy of 76.51 GWh has been designed as a run-of-the river scheme. The project envisages trench weir type intake at Druk Bindu river with additional diversion of flow from Kachin river through 198 m long, 2 m D-shape transfer tunnel for generation augmentation; Feeder channel of 208 m long (2.80 m x 2.10 m) diverting water from intake to surface desilting chambers; 3,086.40 m long headrace water conductor GRP pipe of 2.30 m Ø conveying design discharge of 9.35 $m^3/s$ water from desilting chamber to forebay tank; Forebay tank of 40m x 14m x 8.20m is provided with 3 minutes storage for meeting varying load demand and also absorb surges during transient condition; Steel penstock of 502 m long, 1.60m Ø feeding water to two Pelton turbines in surface powerhouse operating at design head of 219 m; and a tailrace channel of 148 m discharging water back to Druk Bindu at an outfall level of El. 726 m. The updated estimated cost of the project worked out at December 2016 price level was Nu.1,186.72 million excluding transmission line cost of Nu.145 million. The levelized tariff accordingly worked out was Nu. 5.22 per kWh.

## 1.3. Updation of Detailed Project Report of Druk Bindu I Hydropower Project

As part of phase II of the Small Hydropower Initiative, DGPC undertook the updation of the DPR in July 2022, with particular focus on the optimization of the layout and designs, updation of environmental and social impact assessment and updation of cost estimate. All major changes and optimizations in the designs, findings of additional investigations and studies, and the impact of cost updation on the financial viability of the project have been captured as part of the DPR updation.

This report shall serve as a supplemental report and shall be read in conjunction with the existing DPR (hereafter referred to as DPR-2016). The project layout and salient features as finalized in the updated DPR is at **Annexure 1-1** and **Annexure 1-2** respectively.

### 1.3.1. Project Location and Accessibility

Druk Bindu HPP is located in Tendu Gewog under Samtse Dzongkhag. It is a small hamlet bordered by Namgaycholing Gewog in the east, Norgaygang Gewog in the northwest, Haa Dzongkhag in the north and Indian State of West Bengal in the southwest.

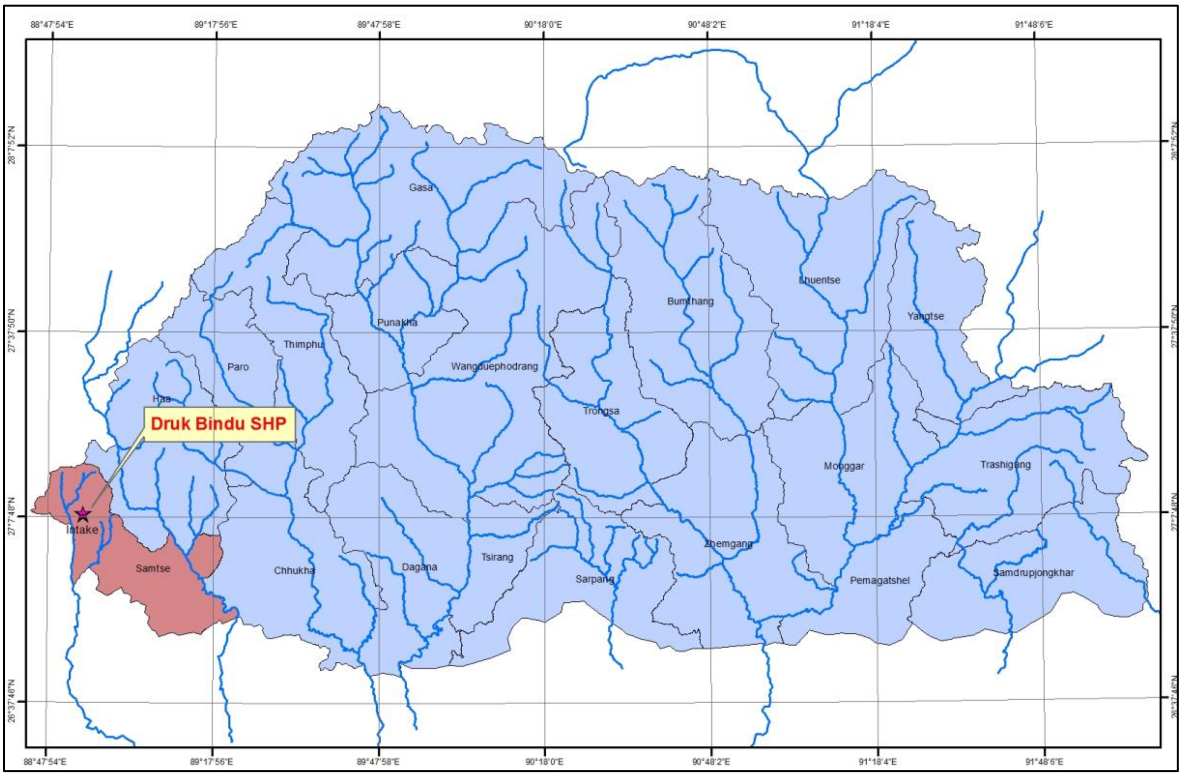



**Figure 1-1: Druk Bindu project location**

The project site is connected to Samtse town by secondary national highway of 73 km. This route can be used to transport construction materials, equipment, machineries and labour for the project. Samtse is well connected with Indian national highway NH 31C. The weir site is located about 300 m away from the existing Samtse-Tendu road while the powerhouse is below Tendu town.

### 1.3.2. Topographical Survey

No additional topographical survey was carried out during the period of DPR update since adequate survey maps prepared during DPR-2016 are available. Maps from DPR-2016 were used for the studies.

In DPR-2016, 10 control stations was established within the project area and mainly placed within the vicinity of major project components. Based on satellite image and ground survey, the topographical map in a scale 1:5,000 with 5 m contour interval and 1:1,000 scale with 1 m contour interval was produced including the river cross sections and longitudinal profile.

### 1.3.3. Geological and Geotechnical Investigation

Since no substantial changes in project layout and design has been made, except for replacement of forebay with surge tube, the geological appraisals of the project will remain same as reflected in DPR-2016 except for the additional geotechnical investigations and studies carried out as part of DPR update. The necessary changes and appraisal have been made in relevant sections as given below.

**Regional Geology**

Druk Bindu Small Hydropower Project is located in Tendruk in Samtse Dzongkhag of South Eastern Bhutan. Geologically the project area falls within the higher Himalayan sequence namely Surey Formation under Thimphu Group.

**Geology of Project Area**

The detailed geological mapping of the various project components was carried out on a scale of 1:1,000 with 1 m contour interval to explore the surface and subsurface geological conditions.

**Diversion Intake structure, Trench weir (Kachin River)**

The trench weir 10 m (L) x 2.0 m (B) with top level at El. 967.5 m has been placed in a moderately wide (40 m-50 m) river valley comprising boulders of gneiss and quartzite of varying sizes ranging from 0.5 m to 4 m. The rock has been exposed on both the banks comprising medium grained, high strength gneiss.

**Transfer Tunnel**

The 198 m long and 2.0 m dia., D shaped transfer tunnel will be accommodated in moderately jointed, medium to coarse grained, high strength, grayish colored and foliated gneiss. The observed rock mass exhibits blocky nature. Minor staining has also been observed at places. The UCS Strength of the rock mass on the basis of Schmidt hammer number was found to range between 100–200 MPa. The tunnel direction from intake end is trending 350°N and driving against dip direction w.r.t the foliation joint (35°/063°). The major part of the tunnel will fall in Class II with few shear seams and fractures.

**Diversion Outfall structure, Trench weir (Druk Bindu River)**

The trench weir at diversion outfall, 20 m (L) x 2.8 m (B) with top level at El. 962.0 m lies in a moderately wide valley roughly 50-60 m comprising boulders of gneiss and quartzite of varying sizes ranging from 0.5 m to 4 m. No significant rock exposure has been observed on the right bank requiring slope protection measures. Moderate to thick alluvium cover has been anticipated at trench weir location.

**Feeder Channel**

Feeder channel of 208.0 m length and 2.1 m width connecting intake structure at Druk Bindu river to Desilting basin would be laid on thick pile of alluvium with approximate thickness of 25-35 m comprising cobbles and boulders of gneiss in sandy silty matrix. The upslope of the feeder channel has to be provided with retaining structures as well as the lower part with RCC walls.

**Desilting Basin**

About 60.0 m in length and 4.8 m wide twin chamber surface desilting basin, placed at an El. of 952.5 m over approx. 18 m thick cover alluvial deposit consisting of dark brown colored, loose silty sand with presence of sub-angular gravels, cobbles and boulders of gneiss, quartzite and mica schist. The in-situ plate load test result shows the safe bearing capacity (SBC) of the material within the range 10.8 to 15.2 ton/m$^2$ with corresponding settlement value of 15.225 mm for 2 m foundation width. The permeability range from 1.08x10$^{-3}$cm/s to 5.20x10$^{-3}$cm/s shows moderate to high water conductivity indicating presence of void spaces. The ground water table as obtained from the drill hole is around 4 m from the NSL. The upstream part of the desilter falls in the alluvial fan deposit of the perennial stream flowing on the northern flank of the desilter. Necessary drainage and protection measures be provided. The cut slope along the desilter should be treated with 25 mm thick shotcrete and wire mesh with horizontal drainage pipes to avoid erosion and destabilization.

**Head Race Pipe Including Penstock**

3,192.52 m long GRP head race system of 2.3 m dia and steel penstock (437.54 m long) with 1.6m dia. will be constructed. The HRP throughout its course including penstock till power house complex would come across different lithology types at regular intervals. About 74% of HRP stretch is anticipated to pass through alluvium and colluvium with thickness range from 20 m to 40 m. The rest 26% would be accommodated initially in high strength, good quality gneiss/micaceous quartzite of Suray Formation.

HRP stretch of 1027 m from Chukarp to Dorleni village has been anticipated as highly unstable region in the area in view of the presence of colluvial deposit having thickness of about 35 m with saturated zones at shallow depths having moderate to heavy seepage conditions with moderate slope. One small and active landslide zones were observed near to the tunnel portal at Dorleni. Provisions for drainage network and retaining structures in the form of gabions are to be provisioned.

**Connection Tunnel**

Approximately 98 m long, 3.5 m dia., D-shaped head race tunnel has been proposed from RD 2,398 m to 2,496 m in view of the project geology and topography. The tunnel is anticipated to accommodate in moderately jointed, un-weathered, high strength fair to good quality gneiss with presence of three prominent discontinuities viz. J1(f)-29º/171º, J2-69º/268º and J3-86º/183º (Dorleni Khola side). No exposure is observed at its inlet portal so the initial 50 m is expected to be in alluvial deposit. The rock mass classification along the HRT is anticipated as 4 % of class II, 55 % of class III and 5 % of class IV & below.

**Surge Tube**

The geology in the surge tube area consists of 40 m thick cover of alluvial deposit comprising of dark brown colored, loose silty sand with presence of sub-angular gravels, cobble and boulders of gneiss, quartzite and mica schist.

**Power House**

The surface power house complex of 31 m (L) x 14 m (B) x 20 m (H) with service bay level at El.732.86 m will be placed over 10 to 15 m thick alluvial cover. The overburden primarily consisting of gravelly sand with presence of sub-angular gravels, cobbles and boulders of gneiss, quartzite and mica schist. The power house comprises two units of 9 MW each. The in-situ plate load test result shows the safe bearing capacity (SBC) of the over burden material in the range of 20.4 to 27.6 ton/$m^2$ with corresponding settlement value of 15.225 mm for 2 m foundation width. The permeability (1 $x10^{-3}$cm/sec) in the over burden ranges from 22.30-172 indicating very high to extremely high-water conductivity. The ground water table is expected to range from 0.5 m to 5.16 m as observed from the drill data.

Since the excavation is going below the river level and the materials being very pervious, recharge from the river cannot be ruled out. Therefore, on top of the pumps, cut off walls be provided on upstream side as well as the face towards the river to prevent the water inflow.

**Tail Race Channel**

The geological map of the project area indicates that the TRC would be accommodated over approx. 30 m thick pile of alluvium comprising sub-angular gravels, cobbles and boulders of gneiss, quartzite and mica schist.

**Construction Materials**

The construction materials will be sourced (Jiti river) as identified in DPR-2017 (Druk Bindu II) and if not sufficient, it will be sourced from either from Diana/Damdum area (River-borne material)- it is found suitable for wearing surfaces. The estimated quantity of coarse and fine aggregates required for the projects is 21,000 MT and 11, 000 MT respectively.

### 1.3.4. Hydrology and Power Potential Studies

The specific runoff for the project catchment was estimated to be 81 l/s/sq. km based on the rainfall runoff analysis in DPR – 2016. This was reviewed during DPR update stage based on additional data available from the completion of DPR in 2016 till 2021. The specific runoff of the catchment based on additional data considering rainfall runoff correlation was estimated to be 98.35 l/s/sq. km while using the gauging station data of Druk Bindu river from the period January 2016 till June 2019 (3.5 years) works out to 84.17 l/s/sq. km. Since the flow series observed from Druk Bindu river was assessed to be reliable, the specific runoff of 84.17 l/s/sq. km was used to transpose flow series of Chuba to the intake site of Druk Bindu. There are no major changes in the water availability for the project with adoption of revised flow series at the intake sites.

The design flood for the project that was computed in DPR – 2016 has been reviewed mainly in line with the Bhutan Hydropower Development guidelines 2018. The design floods for Druk Bindu and Kachin as per DPR- 2016 was estimated at 458 cumecs and 284 cumecs respectively. Adopting the above guidelines, the flood values for Druk Bindu and Kachin has been estimated as 405 cumecs and 214 cumecs respectively.

The temporary river diversion flood for the project has also been reviewed in line with Hydropower Guidelines 2018. The diversion flood for the Druk Bindu and Kachin has been reworked as 14 cumecs and 7 cumecs respectively.

In the DPR- 2016, the Manual on Development of Small Hydro Electric Project published by Central Board of Irrigation and Power (CBIP publication 305), 2009 was adopted for power potential studies. The PPS was further reviewed based on the Guidelines for Development of Hydropower Projects, 2018 which uses Flow Duration Concept as against on dependable year concept. Adopting the FDC Concept, the Installed Capacity remains the same while the design energy reduces from 76.51 MU to 75.83 MU (less than 1%).

### 1.3.5. Project Alternatives, Civil & HM Design

As per the DPR-2016, the hydropower project development at Druk Bindu river was proposed as integrated tandem scheme with two stages, where the tailrace water of Druk Bindu I is conveyed directly into the headrace system of Druk Bindu II. As part of the DPR update study, reassessment of the area beyond the Druk Bindu I forebay has been carried out with the view to develop the project as a single stage. The single stage development envisages construction of HRP passing through two geologically critical stretches. Based on the site assessment and investigations, the single stage scheme was not found feasible and it was decided to adopt the same project layout (two stage tandem development) that was finalized in the DPR-2016.

Except for some optimization in the alignment of HRP and replacement of forebay by surge tube with other associated changes, there is no major changes in project layout and designs of the Druk Bindu I. The design discharge from Kachin and Druk Bindu intake will be conveyed through feeder channel of length 208 m up to surface desilting chamber designed to exclude sediment particle size of 0.2 mm and larger. The design discharge of 9.36 cumecs from the desilter is conveyed to the surge tube via a 2.3 m dia. 3.2 km long Glass Reinforced Plastic (GRP) pipe. A surge tube of 1.8 m – 2.8 m diameter of 154 m inclined length at the end of the GRP pipe has been provided to accommodate transient in the Water Conducting System (WCS) which is connected to the powerhouse through a 437.5 m long, 1.6 m dia. steel penstock. A surface powerhouse of 31.0 m (L) x 14.0 m (W) x 20 m (H) located on the right bank of Druk Bindu accommodates two vertical shaft Pelton turbines generating 2 x 9 MW power, operating at 218 m net head and generating annual design energy of 75.83 GWh.

Except for the removal of valves for the forebay and inclusion of flap gates for the surge tube manhole, there is no change in the H&M components of the project.

The summary of the project components is as given below:

The Civil Engineering structure for the project comprises the following:

- Kachin Trench Weir: A trench weir of 10 m (L) x 2 m (B) has been provided across Kachin river at RBL El. 967.5 m.
- Kachin Trench Weir: A trench weir of 20 m (L) x 2.8 m (B) has been provided across Kachin river at RBL El. 962.0 m.
- Transfer Tunnel: A 2.0 m diameter, 198 m long D-shaped tunnel has been provided to divert water from Kachin intake to the main intake at Druk Bindu.
- Feeder Channel: The water from the main intake will be fed by a 208 m long, 2.8 m (W) x 2.1 m (H) feeder channel into the surface desilting basin.
- Desilting Basin: A surface Desilting Basin comprising of 2 chambers of size 60 m (L) x 4.8 m (W) has been provided downstream of the main intake. Silt flushing arrangement has also been provided.
- Head Race Pipe: A 3.2 km long Glass Reinforced Pipe (GRP) of 2.3 m diameter has been designed to divert 9.36 $m^3/s$ of water from Desilting Basin to Surge tube. The HRP shall also pass through a 98.00 m, 3.5 m D-Shaped connection tunnel.

- Surge tube: To manage surges during transient condition, a surge tube of 154 m long, 1.8-2.4 m dia has been provided to manage the surge in the system.
- Penstock: A 437.54 m long single main steel penstock of internal diameter 1.6 m will bifurcate into two unit penstock of 14 m long ,1.0 m internal diameter. The shell thickness varies from 20 mm to 8 mm.
- Power House: A surface power house of 31.0m (L) x 14.0 m (B) x 20.0 m (H) size has been provided to accommodate the electro-mechanical equipment. The machine center line is fixed at El. 731.00 m.
- Tail Race Channel: The tail race water from the machine will be integrated to Druk Bindu II through an integration tank or release from surplus escape arrangement while not in use.

Following hydro-mechanical equipment has been provided for flow regulation, sediment management and maintenance:

- One number trash rack arrangement on trench weir of size 10.00 m (L) x 2.00 m (W) for Kachin.
- One number fixed wheel vertical lift slide gate with 3T rope drum hoist at the end of trench weir of size 1.50 m (W) x 1.50 m (H).
- One number fixed wheel vertical lift slide gate with 2T rope drum hoist at the end of collection chamber of size 1.50 m (W) x 1.80 m (H).
- One number vertical lift slide shingle flushing gate with 0.50 T motorized screw hoist of size 0.50 m x 0.50 m.
- One number trash rack arrangement on trench weir of size 20.00 m (L) x 2.80 m (W) for Druk Bindu.
- One number fixed wheel vertical lift slide gate with 4T rope drum hoist at the end of trench weir of size 3.00 m (W) x 2.00 m (H).
- One number fixed wheel vertical lift slide gate with 3T rope drum hoist at the end of collection chamber of size 3.00 m x 1.80 m (H).
- Two numbers fine screen at desilting chamber outlet of size 3.86 m (W) x 3.62 m (inclined length)
- One number vertical lift slide shingle flushing gate with 0.50T screw hoistin feeder channel of size0.50 m (W) x 0.50 (H).
- Two numbers vertical lift slide gate with 3T motorized screw hoist at the inlet of desilting chamber of size 1.40 m (W) x 2.10m (H).
- Two numbers vertical lift slide gate with 4.5T motorized screw hoist at the outlet of desilting chamber of size 1.50 m (W) x 2.10 m (H).
- Two numbers vertical lift slide silt flushing gate with 2T motorized screw hoist at desilting chamber size of 0.80 m (W) x 1.00 m (H)
- One number flap gates for the surge tube maintenance
- Two numbers vertical lift slide gate with 4T motorized screw hoist at unit tail race channel of size 2.50 m (W) x 1.95 m (H).

### 1.3.6. Electro-Mechanical Equipment and Power Evacuation

Based on the review and update of the hydrological and power potential studies of the project including recent changes in the equipment designs and market condition, the E&M and power evacuation arrangements of the project has been reviewed and necessary changes have been made in the report.

Some of the major changes made in the DPR update includes revision of transformer sizing, change of the communication system from PLCC to OPGW and redesign of switchgear to accommodate evacuation of Druk Bindu II power.

The power house shall accommodate two vertical Pelton type turbines having rated output of 9 MW under a weighted average net head of 217.82 m at 428.57 rpm synchronous speed. Each turbine shall be provided with butterfly type main inlet valve. The generators shall be synchronous and of the vertical shaft type of 9 MW rated power at 0.9 power factor and 50 Hz frequency. The generators shall have a speed of 428.57rpm and generator voltage of 11 kV.

The following mechanical and electrical auxiliary equipment will be provided:

- One number 40T/5T EOT crane in the Power House for installation and maintenance of the heavy equipment
- Cooling water system for generators
- Drainage and dewatering systems
- Ventilation and air conditioning system
- Fire protection system
- Unit auxiliary and station auxiliary supply system
- D.C supply system
- Control and Monitoring system
- Protection system, etc.

The power generated at 11 kV would be stepped-up to 66 kV through 7 numbers (one is spare) of single-phase transformer each of 11 MVA, 11/66/√3 kV capacity. The LV side of the generator transformers would be connected to Generator and the HV side to the 66 kV AIS through oil to $SF_6$ bushings.

### 1.3.7. Infrastructure, Construction Planning and Schedule

The infrastructure and construction facilities for the project has been reviewed and updated keeping in the view the existing infrastructures and development in the area. The major changes with respect to DPR-2016 are in the area of re-alignment of access road to project components, widening of secondary national highway near HRP crossing, shifting of colony areas and construction facilities, and manpower planning.

The main infrastructure works includes the following:

- About 4.63 km of project roads to access various project components.

- One bailey bridge (43 m span,18 R) to facilitate the construction of Kachin Intake.
- Construction facilities such as site offices, residential and non-residential buildings, workshops, warehouses/stores, aggregate processing plant (APP) and concrete batching plants, muck disposal area, explosive magazines, construction power, telecommunication, water supply system, security & safety arrangements etc.

The construction methodology has been reviewed and elaborated in detail in the updated DPR. The construction schedule has also been reviewed and retained as in the DPR-2016 with a total duration of 36 months including 6 months for preconstruction activities.

#### 1.3.8. Environment and Social Impact Assessment

The Environmental and Social Impact Assessment undertaken as a part of the Detailed Project Report of Druk Bindu I Hydropower Project in 2016 has been updated in line with the Terms of Reference endorsed by the National Environment Commission Secretariat.

Baseline information (physical, biological and socio-economic environment) was collected through field surveys in collaboration with relevant agencies. Based on terrestrial biodiversity survey conducted in association with Tashichholing Forest Range Office under Samtse Territorial Forests Division, Department of Forests and Park Services, Shannon-wiener diversity index ranges from 0.64 to 2.08. Aquatic biodiversity assessment (monsoon and post-monsoon seasons) recorded a total of 330 fishes belonging to 8 species under 3 families from 30 sampling stretches. *Schizothorax richardsonii* was the most dominant (*n*=330, *Relative Abundance [RA]*=84.85%) followed by *Schistura scaturigina* (*n*=15, *RA*=4.55%) and the least dominant was *Aborichthys garoensis* (*n*=2, *RA*=0.61%). The overall species diversity of the project sites was *H'*=0.70, species evenness $E_H$=0.33 and species richness $S_R$=2.78. A total of 26 water quality parameters (7 physical, 16 chemical and 3 microbiological) were analyzed for the water samples collected from 8 sampling sites. Overall, the water quality was found to be within the ranges of the national (Ambient Water Quality Criteria 2020 and Bhutan Drinking Water Quality Standard 2016) and international standards (EPA and WHO) with few parameters in few sampling sites deviating from the permissible limits. The socio-economic information is also updated through a socio-economic survey covering 105 households from 4 chiwogs under Tendu Gewog.

The total land requirement for the project is 93.938 acres of which 86.662 acres (20.338 acre temporary and 66.324 acre permanent) is State Reserve Forest (SRF) land, 1.932 acres (permanent) is Community Forest (Amaley Community Forest) and 5.344 acres (1.178 acre temporary and 4.166 acre permanent) is private land. Private land (5.048 acres kamzhing and 0.296 acre orange/orchard) belongs to 15 landowners.

The environmental and social impacts were assessed quantitatively in terms of their direction, magnitude, extend, duration and frequency to the extent possible. Accordingly, mitigation measures were formulated as a part of Environmental Management Plan (EMP). The cost to implement EMP is estimated as Nu. 27.97 million and cost for land substitute, compensation and lease is estimated as Nu. 16.87 million. Additional studies, Environmental Valuation and

Greenhouse Gas Emission Reduction and Environmental Risk Assessment have also been updated.

### 1.3.9. Cost Estimate and Financial Evaluation

The cost estimate has been updated at the price level of December, 2022 based on latest available data, market condition and guidelines. The project estimate has been framed broadly on basis of "Guidelines for preparation of project estimates for River Valley Projects" dated March 1997 by Central Water Commission, Government of India and Standards/manuals/guidelines for small hydro development published by Ministry of New and Renewable Energy, Government of India in group effort with Alternate Hydro Energy Center, Indian Institute of Technology Roorkee.

The total hard cost of the project is estimated at Nu. 1,950.66 million at December 2022 price level comprising of Nu. 1,328.59 million for Civil & HM works, Nu. 429.91 million for E&M works and Nu. 186.17 million for transmission line.

The financial evaluation of Druk Bindu I Hydropower Project has been prepared in accordance with the "Terms and Conditions of Tariff Determination Guidelines 2016" issued by Bhutan Electricity Authority (BEA). Accordingly, with design energy of 75.83 Million Units, the first year and levelized tariff of the project works out to Nu. 5.08 per unit and Nu. 4.79 per unit respectively for upfront equity investment and Nu. 5.19 per unit and Nu. 4.89 per unit respectively for proportionate fund investment. The financial evaluation based on CERC guideline has also been assessed.

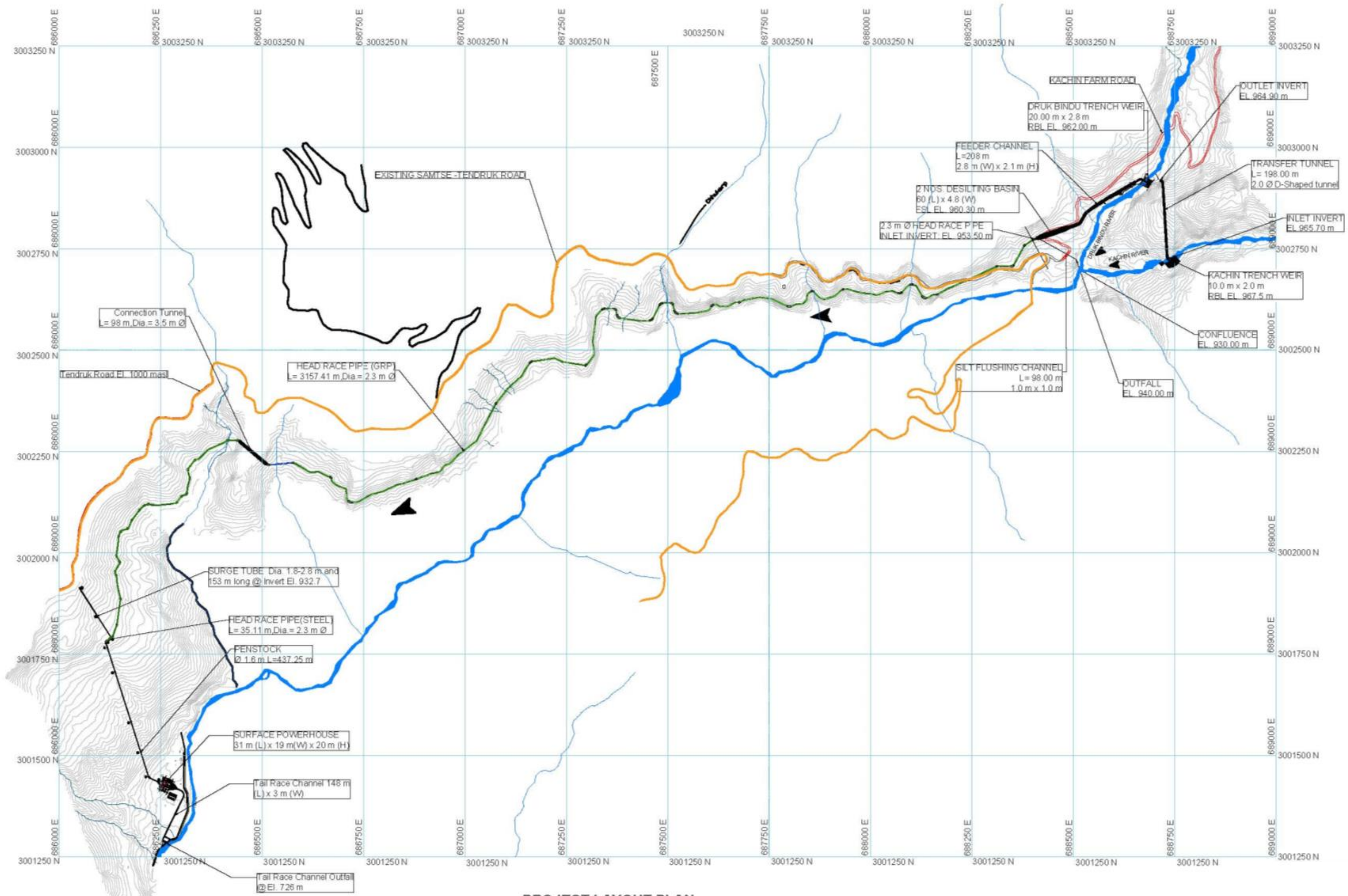
### 1.3.10. Conclusion and Recommendation

The existing DPR was prepared by DGPC between 2015 and 2016. With the availability of additional data due to time lapse of about 6 years since its preparation, the DPR-2016 was further reviewed and updated in 2022. While review and updation of the DPR was carried out covering all aspects, the major changes and updation were made in hydrological analysis, optimisation of civil engineering structures, construction methodology, cost estimation, and financial analysis.

The revised cost estimation of the project has been prepared based on latest available data, market condition and guidelines. The estimated hard cost of the project at December 2022 Price Level is Nu. 1950.66 million. Accordingly, with design energy of 75.83 Million Units, the first year and levelized tariff of the project works out to Nu. 5.08 per unit and Nu. 4.79 per unit respectively for upfront equity investment and Nu. 5.19 per unit and Nu. 4.89 per unit respectively for proportionate fund investment.

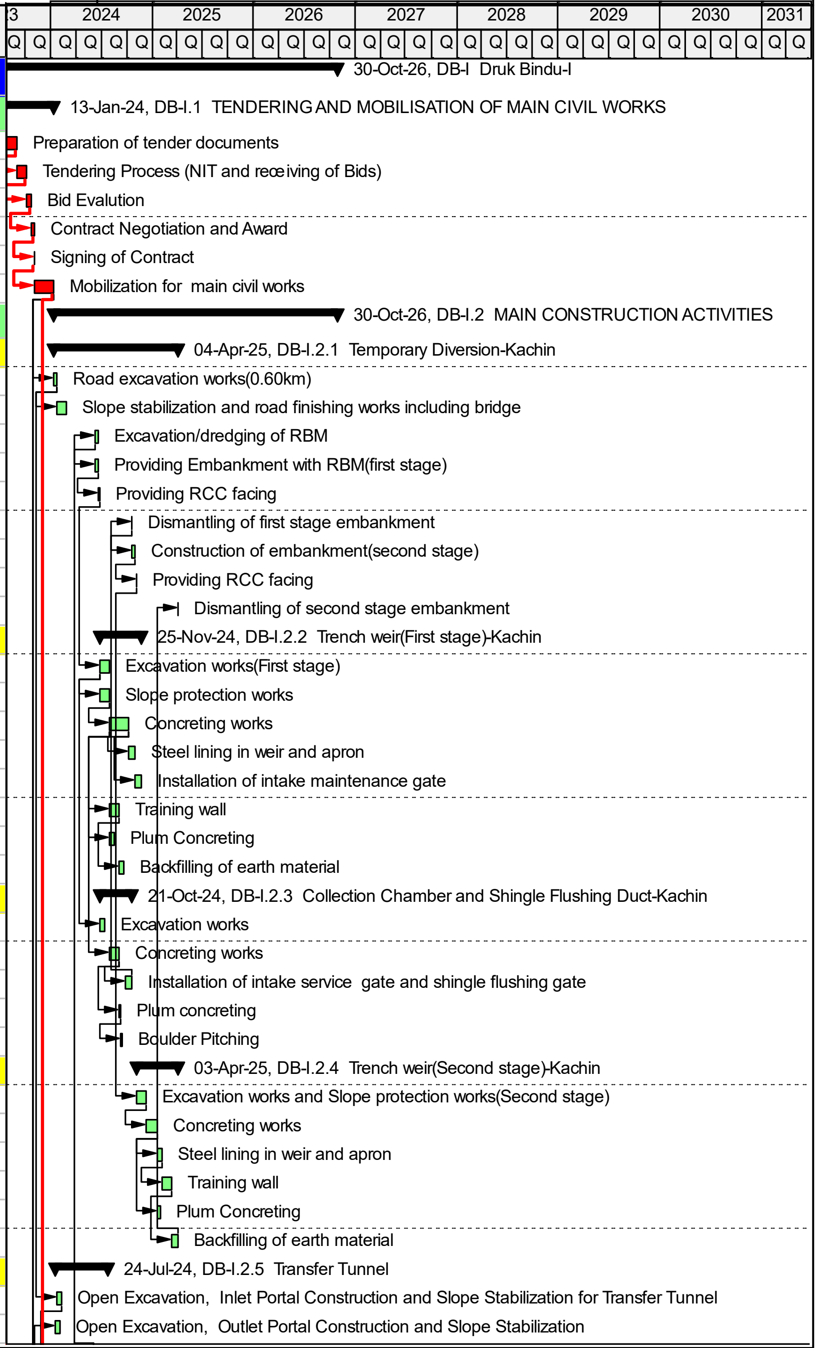
In view of the above assessment, the updated DPR study has concluded that the project is techno-economically viable and socio-environmentally acceptable for development.

## Annexure 1-1: Project Layout




PROJECT LAYOUT PLAN
SCALE 1: 10000

| Druk Bindu Small Hydropower Project-Stage I | Project Schedule | | | |
|---|---|---|---|---|
| **Activity ID** | **Activity Name** | **Planned Duration** | **Start** | **Finish** |
| **DB-I Druk Bindu-I** | | 1028 | 20-Jul-23 | 30-Oct-26 |
| **DB-I.1 TENDERING AND MOBILISATION OF MAIN CIVIL WORKS** | | 153 | 20-Jul-23 | 13-Jan-24 |
| 1.1 | Preparation of tender documents | 40 | 20-Jul-23 | 04-Sep-23 |
| 1.2 | Tendering Process (NIT and receiving of Bids) | 30 | 05-Sep-23 | 09-Oct-23 |
| 1.3 | Bid Evalution | 15 | 10-Oct-23 | 26-Oct-23 |
| 1.4 | Contract Negotiation and Award | 7 | 27-Oct-23 | 03-Nov-23 |
| 1.5 | Signing of Contract | 1 | 04-Nov-23 | 04-Nov-23 |
| 1.6 | Mobilization for main civil works | 60 | 06-Nov-23 | 13-Jan-24 |
| **DB-I.2 MAIN CONSTRUCTION ACTIVITIES** | | 875 | 15-Jan-24 | 30-Oct-26 |
| **DB-I.2.1 Temporary Diversion-Kachin** | | 383 | 15-Jan-24 | 04-Apr-25 |
| 2.1.1 | Road excavation works(0.60km) | 10 | 15-Jan-24 | 25-Jan-24 |
| 2.1.2 | Slope stabilization and road finishing works including bridge | 30 | 26-Jan-24 | 29-Feb-24 |
| 2.1.3 | Excavation/dredging of RBM | 10 | 08-Jun-24 | 19-Jun-24 |
| 2.1.4 | Providing Embankment with RBM(first stage) | 10 | 08-Jun-24 | 19-Jun-24 |
| 2.1.5 | Providing RCC facing | 5 | 20-Jun-24 | 25-Jun-24 |
| 2.1.6 | Dismantling of first stage embankment | 1 | 22-Oct-24 | 22-Oct-24 |
| 2.1.7 | Construction of embankment(second stage) | 10 | 23-Oct-24 | 02-Nov-24 |
| 2.1.8 | Providing RCC facing | 5 | 04-Nov-24 | 08-Nov-24 |
| 2.1.9 | Dismantling of second stage embankment | 1 | 04-Apr-25 | 04-Apr-25 |
| **DB-I.2.2 Trench weir(First stage)-Kachin** | | 131 | 26-Jun-24 | 25-Nov-24 |
| 2.2.1 | Excavation works(First stage) | 30 | 26-Jun-24 | 30-Jul-24 |
| 2.2.2 | Slope protection works | 30 | 26-Jun-24 | 30-Jul-24 |
| 2.2.3 | Concreting works | 60 | 31-Jul-24 | 08-Oct-24 |
| 2.2.4 | Steel lining in weir and apron | 20 | 09-Oct-24 | 31-Oct-24 |
| 2.2.5 | Installation of intake maintenance gate | 20 | 02-Nov-24 | 25-Nov-24 |
| 2.2.6 | Training wall | 30 | 31-Jul-24 | 03-Sep-24 |
| 2.2.7 | Plum Concreting | 15 | 31-Jul-24 | 16-Aug-24 |
| 2.2.8 | Backfilling of earth material | 15 | 04-Sep-24 | 20-Sep-24 |
| **DB-I.2.3 Collection Chamber and Shingle Flushing Duct-Kachin** | | 101 | 26-Jun-24 | 21-Oct-24 |
| 2.3.1 | Excavation works | 15 | 26-Jun-24 | 12-Jul-24 |
| 2.3.2 | Concreting works | 30 | 31-Jul-24 | 03-Sep-24 |
| 2.3.3 | Installation of intake service gate and shingle flushing gate | 20 | 28-Sep-24 | 21-Oct-24 |
| 2.3.4 | Plum concreting | 5 | 04-Sep-24 | 09-Sep-24 |
| 2.3.5 | Boulder Pitching | 5 | 10-Sep-24 | 14-Sep-24 |
| **DB-I.2.4 Trench weir(Second stage)-Kachin** | | 125 | 09-Nov-24 | 03-Apr-25 |
| 2.4.1 | Excavation works and Slope protection works(Second stage) | 30 | 09-Nov-24 | 13-Dec-24 |
| 2.4.2 | Concreting works | 30 | 14-Dec-24 | 17-Jan-25 |
| 2.4.3 | Steel lining in weir and apron | 15 | 18-Jan-25 | 04-Feb-25 |
| 2.4.4 | Training wall | 30 | 05-Feb-25 | 11-Mar-25 |
| 2.4.5 | Plum Concreting | 10 | 18-Jan-25 | 29-Jan-25 |
| 2.4.6 | Backfilling of earth material | 20 | 12-Mar-25 | 03-Apr-25 |
| **DB-I.2.5 Transfer Tunnel** | | 160 | 20-Jan-24 | 24-Jul-24 |
| 2.5.1 | Open Excavation, Inlet Portal Construction and Slope Stabilization for Transfer Tunnel | 15 | 26-Jan-24 | 12-Feb-24 |
| 2.5.2 | Open Excavation, Outlet Portal Construction and Slope Stabilization | 15 | 20-Jan-24 | 06-Feb-24 |

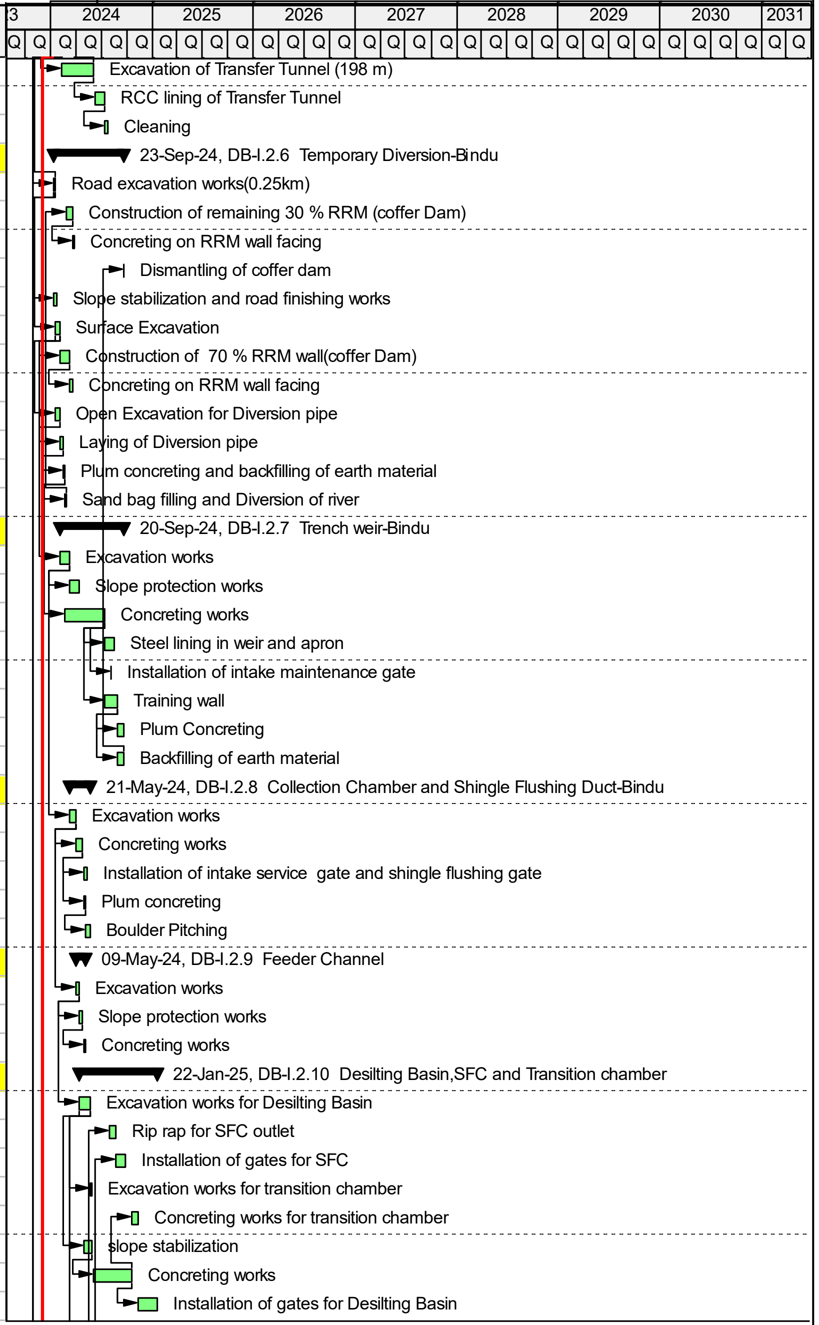



Actual Level of Effort | Remaining Work | Actual Work | Critical Remaining Work



TASK filter: All Activities

| Activity ID | Activity Name | Planned Duration | Start | Finish |
|---|---|---|---|---|
| 2.5.3 | Excavation of Transfer Tunnel (198 m) | 100 | 13-Feb-24 | 07-Jun-24 |
| 2.5.4 | RCC lining of Transfer Tunnel | 30 | 08-Jun-24 | 12-Jul-24 |
| 2.5.5 | Cleaning | 10 | 13-Jul-24 | 24-Jul-24 |
| **DB-I.2.6** | **Temporary Diversion-Bindu** | **217** | **15-Jan-24** | **23-Sep-24** |
| 2.6.1 | Road excavation works(0.25km) | 5 | 15-Jan-24 | 19-Jan-24 |
| 2.6.10 | Construction of remaining 30 % RRM (coffer Dam) | 20 | 01-Mar-24 | 23-Mar-24 |
| 2.6.11 | Concreting on RRM wall facing | 2 | 25-Mar-24 | 26-Mar-24 |
| 2.6.12 | Dismantling of coffer dam | 2 | 21-Sep-24 | 23-Sep-24 |
| 2.6.2 | Slope stabilization and road finishing works | 10 | 15-Jan-24 | 25-Jan-24 |
| 2.6.3 | Surface Excavation | 15 | 20-Jan-24 | 06-Feb-24 |
| 2.6.4 | Construction of 70 % RRM wall(coffer Dam) | 30 | 07-Feb-24 | 12-Mar-24 |
| 2.6.5 | Concreting on RRM wall facing | 10 | 13-Mar-24 | 23-Mar-24 |
| 2.6.6 | Open Excavation for Diversion pipe | 15 | 20-Jan-24 | 06-Feb-24 |
| 2.6.7 | Laying of Diversion pipe | 10 | 07-Feb-24 | 17-Feb-24 |
| 2.6.8 | Plum concreting and backfilling of earth material | 5 | 19-Feb-24 | 23-Feb-24 |
| 2.6.9 | Sand bag filling and Diversion of river | 5 | 24-Feb-24 | 29-Feb-24 |
| **DB-I.2.7** | **Trench weir-Bindu** | **195** | **07-Feb-24** | **20-Sep-24** |
| 2.7.1 | Excavation works | 30 | 07-Feb-24 | 12-Mar-24 |
| 2.7.2 | Slope protection works | 30 | 13-Mar-24 | 16-Apr-24 |
| 2.7.3 | Concreting works | 120 | 24-Feb-24 | 12-Jul-24 |
| 2.7.4 | Steel lining in weir and apron | 30 | 13-Jul-24 | 16-Aug-24 |
| 2.7.5 | Installation of intake maintenance gate | 2 | 07-Aug-24 | 08-Aug-24 |
| 2.7.6 | Training wall | 40 | 13-Jul-24 | 28-Aug-24 |
| 2.7.7 | Plum Concreting | 20 | 29-Aug-24 | 20-Sep-24 |
| 2.7.8 | Backfilling of earth material | 20 | 29-Aug-24 | 20-Sep-24 |
| **DB-I.2.8** | **Collection Chamber and Shingle Flushing Duct-Bindu** | **60** | **13-Mar-24** | **21-May-24** |
| 2.8.1 | Excavation works | 20 | 13-Mar-24 | 04-Apr-24 |
| 2.8.2 | Concreting works | 20 | 05-Apr-24 | 27-Apr-24 |
| 2.8.3 | Installation of intake service gate and shingle flushing gate | 15 | 29-Apr-24 | 15-May-24 |
| 2.8.4 | Plum concreting | 10 | 29-Apr-24 | 09-May-24 |
| 2.8.5 | Boulder Pitching | 10 | 10-May-24 | 21-May-24 |
| **DB-I.2.9** | **Feeder Channel** | **30** | **05-Apr-24** | **09-May-24** |
| 2.9.1 | Excavation works | 10 | 05-Apr-24 | 16-Apr-24 |
| 2.9.2 | Slope protection works | 10 | 17-Apr-24 | 27-Apr-24 |
| 2.9.3 | Concreting works | 10 | 29-Apr-24 | 09-May-24 |
| **DB-I.2.10** | **Desilting Basin,SFC and Transition chamber** | **241** | **17-Apr-24** | **22-Jan-25** |
| 2.10.1 | Excavation works for Desilting Basin | 30 | 17-Apr-24 | 21-May-24 |
| 2.10.10 | Rip rap for SFC outlet | 20 | 31-Jul-24 | 22-Aug-24 |
| 2.10.11 | Installation of gates for SFC | 30 | 24-Aug-24 | 27-Sep-24 |
| 2.10.2 | Excavation works for transition chamber | 10 | 22-May-24 | 01-Jun-24 |
| 2.10.3 | Concreting works for transition chamber | 20 | 21-Oct-24 | 12-Nov-24 |
| 2.10.4 | slope stabilization | 30 | 29-Apr-24 | 01-Jun-24 |
| 2.10.5 | Concreting works | 120 | 03-Jun-24 | 19-Oct-24 |
| 2.10.6 | Installation of gates for Desilting Basin | 60 | 14-Nov-24 | 22-Jan-25 |

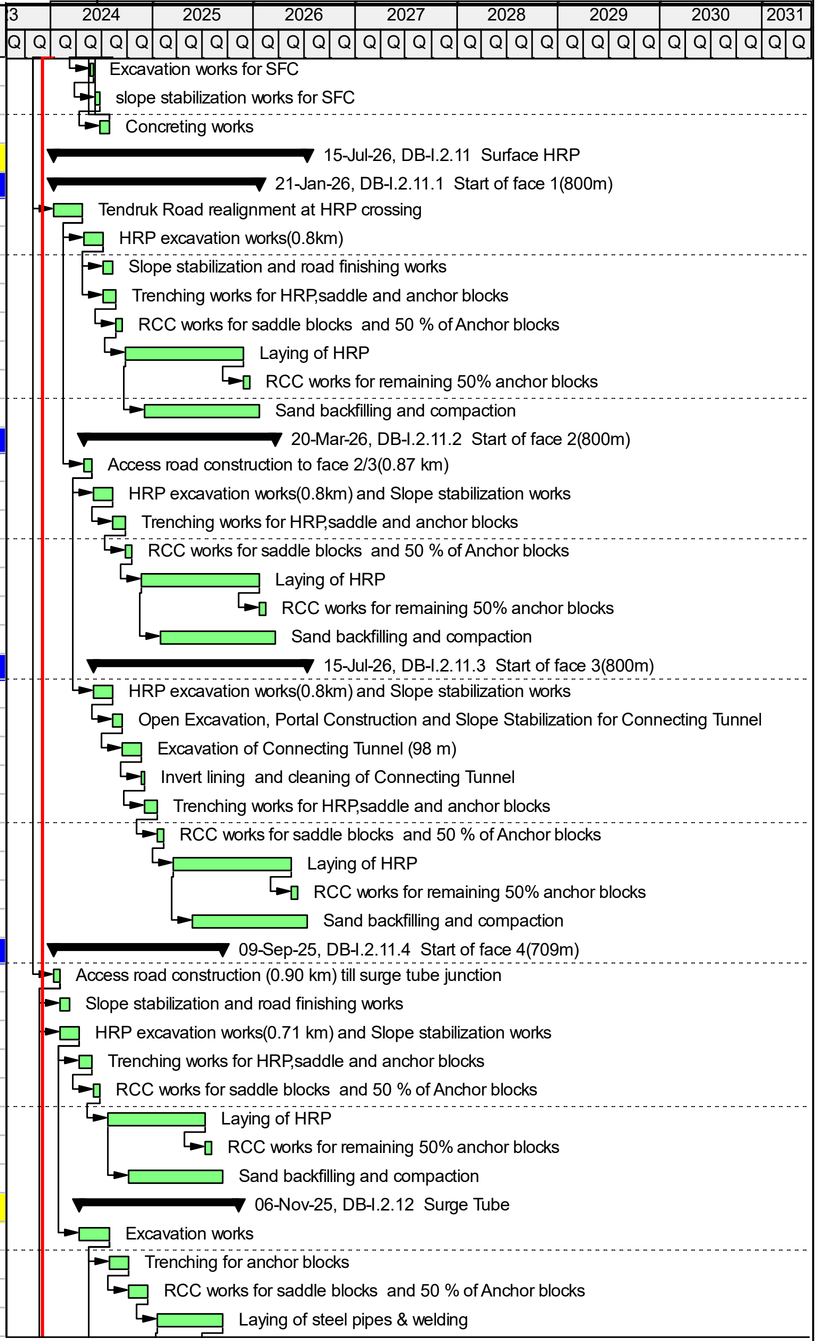



Actual Level of Effort | Remaining Work
Actual Work | Critical Remaining Work



TASK filter: All Activities

| Activity ID | Activity Name | Planned Duration | Start | Finish |
|---|---|---|---|---|
| 2.10.7 | Excavation works for SFC | 15 | 22-May-24 | 07-Jun-24 |
| 2.10.8 | slope stabilization works for SFC | 15 | 08-Jun-24 | 25-Jun-24 |
| 2.10.9 | Concreting works | 30 | 26-Jun-24 | 30-Jul-24 |
| **DB-I.2.11** | **Surface HRP** | **783** | **15-Jan-24** | **15-Jul-26** |
| **DB-I.2.11.1** | **Start of face 1(800m)** | **633** | **15-Jan-24** | **21-Jan-26** |
| 2.11.1.1 | Tendruk Road realignment at HRP crossing | 90 | 15-Jan-24 | 27-Apr-24 |
| 2.11.1.2 | HRP excavation works(0.8km) | 60 | 29-Apr-24 | 06-Jul-24 |
| 2.11.1.3 | Slope stabilization and road finishing works | 30 | 08-Jul-24 | 10-Aug-24 |
| 2.11.1.4 | Trenching works for HRP,saddle and anchor blocks | 40 | 08-Jul-24 | 22-Aug-24 |
| 2.11.1.5 | RCC works for saddle blocks and 50 % of Anchor blocks | 20 | 23-Aug-24 | 14-Sep-24 |
| 2.11.1.6 | Laying of HRP | 365 | 25-Sep-24 | 24-Nov-25 |
| 2.11.1.7 | RCC works for remaining 50% anchor blocks | 20 | 25-Nov-25 | 17-Dec-25 |
| 2.11.1.8 | Sand backfilling and compaction | 355 | 04-Dec-24 | 21-Jan-26 |
| **DB-I.2.11.2** | **Start of face 2(800m)** | **593** | **29-Apr-24** | **20-Mar-26** |
| 2.11.2.1 | Access road construction to face 2/3(0.87 km) | 30 | 29-Apr-24 | 01-Jun-24 |
| 2.11.2.2 | HRP excavation works(0.8km) and Slope stabilization works | 60 | 03-Jun-24 | 10-Aug-24 |
| 2.11.2.3 | Trenching works for HRP,saddle and anchor blocks | 40 | 12-Aug-24 | 26-Sep-24 |
| 2.11.2.4 | RCC works for saddle blocks and 50 % of Anchor blocks | 20 | 27-Sep-24 | 19-Oct-24 |
| 2.11.2.5 | Laying of HRP | 365 | 22-Nov-24 | 21-Jan-26 |
| 2.11.2.6 | RCC works for remaining 50% anchor blocks | 20 | 22-Jan-26 | 13-Feb-26 |
| 2.11.2.7 | Sand backfilling and compaction | 355 | 31-Jan-25 | 20-Mar-26 |
| **DB-I.2.11.3** | **Start of face 3(800m)** | **663** | **03-Jun-24** | **15-Jul-26** |
| 2.11.3.1 | HRP excavation works(0.8km) and Slope stabilization works | 60 | 03-Jun-24 | 10-Aug-24 |
| 2.11.3.2 | Open Excavation, Portal Construction and Slope Stabilization for Connecting Tunnel | 30 | 12-Aug-24 | 14-Sep-24 |
| 2.11.3.3 | Excavation of Connecting Tunnel (98 m) | 60 | 16-Sep-24 | 23-Nov-24 |
| 2.11.3.4 | Invert lining and cleaning of Connecting Tunnel | 10 | 25-Nov-24 | 05-Dec-24 |
| 2.11.3.5 | Trenching works for HRP,saddle and anchor blocks | 40 | 06-Dec-24 | 21-Jan-25 |
| 2.11.3.6 | RCC works for saddle blocks and 50 % of Anchor blocks | 20 | 22-Jan-25 | 13-Feb-25 |
| 2.11.3.7 | Laying of HRP | 365 | 19-Mar-25 | 18-May-26 |
| 2.11.3.8 | RCC works for remaining 50% anchor blocks | 20 | 19-May-26 | 10-Jun-26 |
| 2.11.3.9 | Sand backfilling and compaction | 355 | 28-May-25 | 15-Jul-26 |
| **DB-I.2.11.4** | **Start of face 4(709m)** | **518** | **15-Jan-24** | **09-Sep-25** |
| 2.11.4.1 | Access road construction (0.90 km) till surge tube junction | 20 | 15-Jan-24 | 06-Feb-24 |
| 2.11.4.2 | Slope stabilization and road finishing works | 30 | 07-Feb-24 | 12-Mar-24 |
| 2.11.4.3 | HRP excavation works(0.71 km) and Slope stabilization works | 60 | 07-Feb-24 | 16-Apr-24 |
| 2.11.4.4 | Trenching works for HRP,saddle and anchor blocks | 40 | 17-Apr-24 | 01-Jun-24 |
| 2.11.4.5 | RCC works for saddle blocks and 50 % of Anchor blocks | 20 | 03-Jun-24 | 25-Jun-24 |
| 2.11.4.6 | Laying of HRP | 300 | 29-Jul-24 | 12-Jul-25 |
| 2.11.4.7 | RCC works for remaining 50% anchor blocks | 20 | 14-Jul-25 | 05-Aug-25 |
| 2.11.4.8 | Sand backfilling and compaction | 290 | 07-Oct-24 | 09-Sep-25 |
| **DB-I.2.12** | **Surge Tube** | **488** | **17-Apr-24** | **06-Nov-25** |
| 2.12.1 | Excavation works | 90 | 17-Apr-24 | 30-Jul-24 |
| 2.12.2 | Trenching for anchor blocks | 60 | 31-Jul-24 | 08-Oct-24 |
| 2.12.3 | RCC works for saddle blocks and 50 % of Anchor blocks | 60 | 09-Oct-24 | 17-Dec-24 |
| 2.12.4 | Laying of steel pipes & welding | 200 | 20-Jan-25 | 09-Sep-25 |

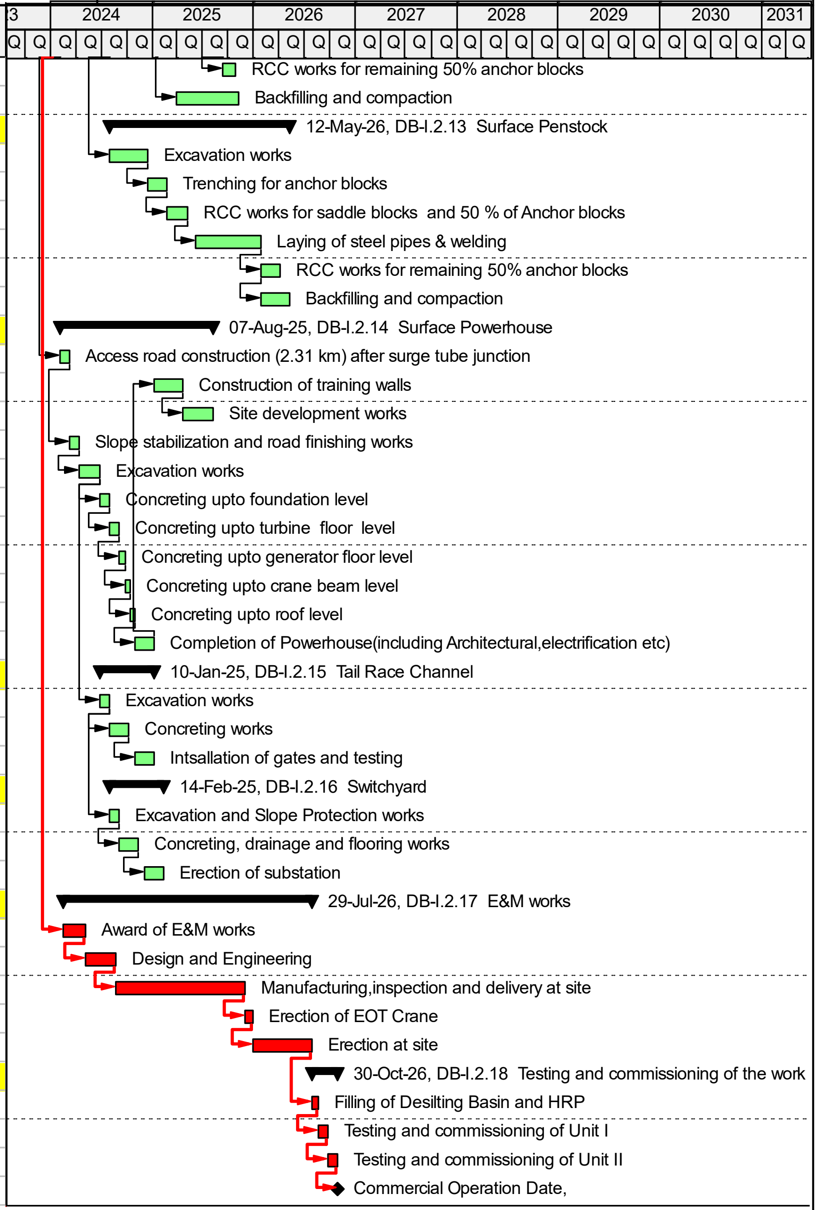



Actual Level of Effort
Actual Work
Remaining Work
Critical Remaining Work



TASK filter: All Activities

| Druk Bindu Small Hydropower Project-Stage I | | Project Schedule | | |
|---|---|---|---|---|
| **Activity ID** | **Activity Name** | **Planned Duration** | **Start** | **Finish** |
| 2.12.5 | RCC works for remaining 50% anchor blocks | 40 | 10-Sep-25 | 25-Oct-25 |
| 2.12.6 | Backfilling and compaction | 190 | 31-Mar-25 | 06-Nov-25 |
| **DB-I.2.13 Surface Penstock** | | **558** | **31-Jul-24** | **12-May-26** |
| 2.13.1 | Excavation works | 120 | 31-Jul-24 | 17-Dec-24 |
| 2.13.2 | Trenching for anchor blocks | 60 | 18-Dec-24 | 25-Feb-25 |
| 2.13.3 | RCC works for saddle blocks and 50 % of Anchor blocks | 60 | 26-Feb-25 | 06-May-25 |
| 2.13.4 | Laying of steel pipes & welding | 200 | 09-Jun-25 | 27-Jan-26 |
| 2.13.5 | RCC works for remaining 50% anchor blocks | 60 | 28-Jan-26 | 07-Apr-26 |
| 2.13.6 | Backfilling and compaction | 90 | 28-Jan-26 | 12-May-26 |
| **DB-I.2.14 Surface Powerhouse** | | **470** | **07-Feb-24** | **07-Aug-25** |
| 2.14.1 | Access road construction (2.31 km) after surge tube junction | 30 | 07-Feb-24 | 12-Mar-24 |
| 2.14.10 | Construction of training walls | 90 | 10-Jan-25 | 24-Apr-25 |
| 2.14.11 | Site development works | 90 | 25-Apr-25 | 07-Aug-25 |
| 2.14.2 | Slope stabilization and road finishing works | 30 | 13-Mar-24 | 16-Apr-24 |
| 2.14.3 | Excavation works | 60 | 17-Apr-24 | 25-Jun-24 |
| 2.14.4 | Concreting upto foundation level | 30 | 26-Jun-24 | 30-Jul-24 |
| 2.14.5 | Concreting upto turbine floor level | 30 | 31-Jul-24 | 03-Sep-24 |
| 2.14.6 | Concreting upto generator floor level | 20 | 04-Sep-24 | 26-Sep-24 |
| 2.14.7 | Concreting upto crane beam level | 15 | 27-Sep-24 | 14-Oct-24 |
| 2.14.8 | Concreting upto roof level | 15 | 15-Oct-24 | 31-Oct-24 |
| 2.14.9 | Completion of Powerhouse(including Architectural,electrification etc) | 60 | 01-Nov-24 | 09-Jan-25 |
| **DB-I.2.15 Tail Race Channel** | | **171** | **26-Jun-24** | **10-Jan-25** |
| 2.15.1 | Excavation works | 30 | 26-Jun-24 | 30-Jul-24 |
| 2.15.2 | Concreting works | 60 | 31-Jul-24 | 08-Oct-24 |
| 2.15.3 | Intsallation of gates and testing | 60 | 02-Nov-24 | 10-Jan-25 |
| **DB-I.2.16 Switchyard** | | **171** | **31-Jul-24** | **14-Feb-25** |
| 2.16.1 | Excavation and Slope Protection works | 30 | 31-Jul-24 | 03-Sep-24 |
| 2.16.2 | Concreting, drainage and flooring works | 60 | 04-Sep-24 | 12-Nov-24 |
| 2.16.3 | Erection of substation | 60 | 07-Dec-24 | 14-Feb-25 |
| **DB-I.2.17 E&M works** | | **765** | **19-Feb-24** | **29-Jul-26** |
| 2.17.1 | Award of E&M works | 70 | 19-Feb-24 | 09-May-24 |
| 2.17.2 | Design and Engineering | 90 | 10-May-24 | 22-Aug-24 |
| 2.17.3 | Manufacturing,inspection and delivery at site | 400 | 23-Aug-24 | 02-Dec-25 |
| 2.17.4 | Erection of EOT Crane | 25 | 03-Dec-25 | 31-Dec-25 |
| 2.17.5 | Erection at site | 180 | 01-Jan-26 | 29-Jul-26 |
| **DB-I.2.18 Testing and commissioning of the work** | | **80** | **30-Jul-26** | **30-Oct-26** |
| 2.18.1 | Filling of Desilting Basin and HRP | 20 | 30-Jul-26 | 21-Aug-26 |
| 2.18.2 | Testing and commissioning of Unit I | 30 | 22-Aug-26 | 25-Sep-26 |
| 2.18.3 | Testing and commissioning of Unit II | 30 | 26-Sep-26 | 30-Oct-26 |
| 2.18.4 | Commercial Operation Date | 0 | | 30-Oct-26 |




Actual Level of Effort — Remaining Work
Actual Work — Critical Remaining Work



TASK filter: All Activities

**Annexure 1-2: Salient Features**

| Parameter | Description |
|---|---|
| **A. General** | |
| **Location** | |
| Country | Bhutan |
| Dzongkhag | Samtse |
| River | Druk Bindu |
| Nearest Town in Bhutan | Tashichholing |
| Nearest City in India | Siliguri |
| Nearest Village (Weir Site) | Tendu |
| Nearest Village (Power House Site) | Tendu |
| Nearest International Airport | Bagdogra, India |
| Nearest Rail head (Broad gauge) | NJP, India |
| Location of Weir Site | 27°8'9.15" N, 88°54'13.73" E |
| Location of Power House | 27°7'22.15" N, 88°52'45.28" E |
| Seismic Zone | V |
| **B. Hydrology** | |
| Catchment Area (Kachin) | 28 $km^2$ |
| Catchment Area (Druk Bindu) | 53 $km^2$ |
| Annual Inflow | 219.10 MCM |
| Design Flood (1 in 100 years) | 214 $m^3/s$ (Kachin)<br>405 $m^3/s$ (Druk Bindu) |
| Diversion Flood (Non-monsoon) | 6.99 $m^3/s$ (Kachin)<br>13.98 $m^3/s$ (Druk Bindu) |
| Environmental Flow | 0.15 $m^3/s$ |
| **C. Civil and HM works** | |
| **Kachin Intake** | |
| River Bed Level (RBL) | El. 967.50 m |
| Normal Water Level | El. 966.90 m |
| Trench Weir Top | El. 967.50 m |
| Trench Weir | 10 m (L) x 2.0 m (B) |
| Collection Chamber | 7.5 m (L) x 1.5 m (B) |
| Collection Chamber Top | El. 975.00 m |
| Maintenance Gate &Type | 1.5 m (B) x 1.5 m (H)<br>Fixed wheel vertical lift |
| Service Gate &Type | 1.5 m (B) x 1.8 m (H)<br>Fixed wheel vertical lift |
| Crest Level (Surplus Escape) | El. 966.90 m |

| Parameter | Description |
|---|---|
| Crest Length (Surplus Escape) | 5.0 m |
| Discharging Capacity (Surplus Escape) | 27.0 $m^3/s$ |
| Shingle Excluder Gate & Type | 0.5 m (B) x 0.5 m (H)<br>Vertical Slide |
| **Transfer Tunnel** | |
| Number | 1 |
| Diameter & Shape | 2.0 m, D-Shaped |
| Length& Slope | 198.00 m, 1 (V) in 280 (H) |
| Inlet Invert | El. 965.70 m |
| Outlet invert | El. 964.90 m |
| **Druk Bindu Intake** | |
| River Bed Level (RBL) | El. 962.00 m |
| Normal Water Level | El.961.30 m |
| Trench Weir Top | El. 962.00 m |
| Trench Weir | 20 m (L) x 2.8 m (B) |
| Collection Chamber | 15 m (L) x 3.0 m (B) |
| Collection Chamber Top | El. 968.00 m |
| Maintenance Gate &Type | 3.0 m (B) x 2.5 m (H)<br>Fixed wheel vertical lift |
| Service Gate &Type | 3.0 m (B) x 1.8 m (H)<br>Fixed wheel vertical lift |
| Crest Level (Surplus Escape) | El. 961.30 m |
| Crest Length (Surplus Escape) | 12.0 m |
| Discharging Capacity (Surplus Escape) | 65.0 $m^3/s$ |
| Shingle Excluder Gate & Type | 0.5 m (B) x 0.5 m (H)<br>Vertical Slide |
| **Temporary River Diversion** | |
| Type | RRM with RCC cladding |
| River Bed Level (RBL) | El. 968.00 m |
| Top Level | El. 970.70 m |
| Height & Crest Length | 2.7 m, 22.0 m |
| Diversion Pipe | 1.5 m dia. concrete Hume pipe, 97.0 m (L) |
| **Feeder Channel** | |
| Design discharge | 12.17 $m^3/s$ |
| Number of Feeder Channel, Location & Type | 1 No., Right Bank &RCC |
| Shape & Size of Channel | 2.8 m (B) x 2.1 m (H) (Rectangular) |
| Length & Slope of Feeder Channel | 208 m, 1 (V) in 500 (H) |

| Parameter | Description |
|---|---|
| Inlet Invert | El. 959.50 m |
| Outlet Invert | El. 958.80 m |
| **Desilting Basin** | |
| Number of Basins | 2 Nos. |
| Sizes of Main Basin | 60 m (L) x 4.8 m (B) |
| Full Supply Level (FSL) | El. 960.30 m |
| Desilting Basin Top | El. 961.00 m |
| Basin Inlet Gate | 2 Nos., 1.4 m (B) x 2.1 m (H)<br>Vertical Slide |
| Basin Outlet Gate | 2 Nos., 1.5 m (B) x 2.1 m (H)<br>Vertical Slide |
| Silt Flushing Gate & Type | 2 Nos., 0.8 m (B) x 1.0 m (H)<br>Vertical Slide |
| **Head Race Pipe (HRP)** | |
| Number & Type | 1 No., Glass Reinforced Plastic (GRP) Pipe |
| Size & Shape | 2.3 m dia. Circular |
| Design Discharge | 9.36 $m^3/s$ |
| Length | 3,192.52 m |
| Slope | 1 in 700 |
| Invert level at 0.00 m RD | El. 953.50 m |
| Invert level at HRP end (3,192.52 m RD) | El. 932.70 m |
| Connection Tunnel (Length and Diameter) | 98.00 m, 3.5 m D-Shaped |
| **Surge Tube** | |
| Size & Shape | Circular (1.8 m dia. @ angle of 12.69$^o$) RD 0-75<br>Circular (2.8 m dia. @ angle of 30.78$^o$) RD 75-154 |
| Surge Tube Top | El. 992.00 m |
| Maximum Surge Level | El. 989.00 m |
| Minimum Surge Level | El. 937.00 m |
| Flap Gate (Manhole gate) | 1.2m @ HRP and Surge Tube junction |
| **Penstock** | |
| Type & Shape | ASTM 537 Class-II, Circular |
| Design Discharge | 9.36 $m^3/s$ |
| Number | 1 no. (bifurcating into two near power house) |
| Main Penstock (dia., length, thickness) | 1.6 m dia., 437.54 m long, 8 mm to 20 mm |
| Unit Penstock | 1.0 m dia., 14 m each, 20 mm |

| Parameter | Description |
|---|---|
| **Powerhouse** | |
| Type | Surface Powerhouse |
| Maximum Tail Water Level (Full load) | El. 728.00 m |
| Center Line of Turbine | El. 731.00 m |
| Turbine Floor Level | El. 732.56 m |
| Service Bay Level | El. 732.56 m |
| Generating Units (Installed Capacity) | 2 x 9 MW (18 MW) |
| Size (Machine Hall) | 31.0 m (L) x 14.0 m (B) x 20.0 m (H) |
| MIV Type& number | Butterfly, 2 Nos. |
| **Switch Yard** | |
| Size | 20.0 m (L) x 15.0 m (B) |
| Voltage Level | 66 kV |
| **Tail Race Channel** | |
| Type | Open Channel |
| Number | 1 no. |
| Shape & Size | Rectangular, 3.0 m (B) x 2.25 m (H) |
| Length<br>Slope | 148.0 m &<br>1 in 1,000 |
| TRC Outfall | El. 726.00 m |
| TRC Gate | 2 Nos., 2.5 m (B) x 1.95 m (H) |
| **D. Electro Mechanical Equipment** | |
| **Turbine** | |
| Type of Turbine | Vertical Pelton |
| Number of Turbines | 2 (Two) |
| Rated Net Head | 218.00 m |
| Rated Output | 2 x 9 MW |
| Rated Speed | 428.56 rpm |
| **Generator** | |
| Type of Generator | Synchronous, Salient pole type |
| Rated Power | 9 MW |
| Power Factor | 0.9 lagging |
| Generation Voltage | 11.0 kV |
| Number of Phases | 3 (Three) |
| Frequency | 50 Hz |
| Insulation | Class F |
| Type of Cooling | Air cooled (Air cooled by water) |

| Parameter | Description |
|---|---|
| **Transformer** | |
| Transformer Rating and Type | 11 MVA 4 Nos. (Oil Natural Air Natural) |
| Number of Transformers | 3+1 (Single Phase) |
| Voltage Ratio | 11.0 kV/ 66/ sqrt (3) |
| Vector Group | YnD11 |
| Transmission Voltage | 66 kV |
| EOT Crane | 40 MT/5 MT |
| **E. Power Evacuation** | |
| Switch Yard Voltage Level | 66 kV |
| Outgoing Bays<br>Size of Switch Yard | 1<br>15 m (B) x 20 m (L) |
| Number of Transmission Line Feeders | Single Circuit |
| Type of Conductor | WOLF |
| Length | 15.4 km |
| **F. Power Generation** | |
| Design Discharge | 9.36 $m^3/s$ |
| Firm Flow | 1.38 $m^3/s$ |
| Gross Head | 229.3 m |
| Head Loss | 11.38 m |
| Design Head | 218 m |
| Annual Design Energy | 75.83 GWh |
| Firm Power | 2.68 MW |
| Annual PLF | 49% |
| Exceedance Probability | 28 % |
| **G. Construction Schedule** | |
| Construction Period | 36 months including 6 months of pre-construction activities. |
| **H. Project Cost** | |
| Cost of Civil & HM Works | Nu. 1,328.59 million |
| Cost of E&M Works | Nu. 429.91 million |
| Total Hard Cost excluding Transmission Cost at **Dec 2022 PL** | Nu. 1,758.5 million |
| Cost of Transmission Line | Nu. 186.17 million |
| Total Hard Cost including Transmission Line at **Dec 2022 PL** | Nu. 1,950.66 million |
| IDC (Upfront Equity) | Nu. 151.50 million |
| IDC (Proportionate Fund Investment) | Nu. 195.39 million |

| Parameter | Description |
|---|---|
| Capital Cost (Upfront Equity) | Nu. 2,158.56 million (With Cost to Completion) |
| Capital Cost (Proportionate Fund Investment) | Nu. 2,202.45 million (With Cost to Completion) |
| **Tariffs for upfront equity** | |
| First Year Tariff | Nu.5.08/Unit |
| Levelized Tariff | Nu. 4.79/Unit |
| **Tariffs for proportionate fund investment** | |
| First Year Tariff | Nu. 5.18/Unit |
| Levelized Tariff | Nu. 4.89/Unit |

# Executive Summary

# For

# Druk Bindu II Hydropower Project

# 1. Executive Summary

## 1.1. Background

The Kingdom of Bhutan has abundant hydropower reserves with techno-economically viable potential of 33 GW as per the Power System Master Plan 2040 (PSMP-2040). The overall hydropower potential was estimated as 37 GW from 155 sites, out of which 90 sites having installed capacity of about 33 GW have been identified as techno-economically viable for implementation. Sustainable hydropower development is critical for Bhutan to reap the benefits of this huge hydropower reserves. The economic gains as a result of this development to the people of Bhutan in financial, economic, and social terms will be immense. With present installed capacity of 2,326 MW from its seven large power plants, the country has harnessed about 7% of the techno-economically feasible hydropower potential. The country today exports about 70% of the electricity to India after meeting its internal demand first. With addition of 2,938 MW installed capacity from the four projects, currently under different stages of construction, it is expected to further enhance the quantum of export to India and contribute to the socio-economic development of the country.

The electricity grid in Bhutan is closely interconnected to the Indian grid that is prone to frequent failures. Bhutan has experienced prolonged power outages in pockets of the country as well as at the national level. With India's increasing investment into renewables such as solar and wind without adequate provision for balancing power support from energy sources such as hydropower, it will only make India's grid more prone to major grid failures. As of now, Bhutan's mega hydropower projects with BHEL technology cannot operate in an isolated mode. Therefore, it has become imperative to plan for a backup power supply that is adequate to provide essential electricity supply services to each Dzongkhag in an isolated mode. More importantly, there is a need to plan for robust energy supply system as a preparedness measure for natural hazards and other exigencies. By virtue of its location, Bhutan is prone to natural disasters such as earthquake, glacial lake outburst flood (GLOF), flash flood, and extreme weather conditions. In the last few decades, Bhutan has experienced major earthquakes of magnitude over 7 on the Richter scale which had devastating impacts on the country's infrastructure and has claimed lives. During such events, as an essential service, availability of steady power supply is crucial for sustenance of livelihood of people as well as for recovery processes.

Recognizing the need for domestic energy security through facilitation of self-contained supply flexibility for each Dzongkhag to meet the demand of household, institutional consumers and essential service providers in times of exigencies (which at other times could be fed into the grid), DGPC is undertaking strategic planning of a backup power supply system by harnessing abundantly available renewable hydropower resources through implementation of small and medium sized hydropower projects. Further, in the wake of the economic downturn with the Covid-19 pandemic, development of small hydropower projects across the country will not only help to stimulate economic activities at the grass root levels but also help generate employment and engagement of the people in these difficult times.

As part of Phase I of the Small Hydropower Initiative, the feasibility study of three hydropower projects have been completed in December 2021 and are currently under different stages of construction.

With regard to Phase II of the undertaking, the techno-economic viability of projects was given priority compared to the 60:40 Technical: Social criteria of the Phase I selection process. Accordingly, the projects which have already been studied at either a Pre-Feasibility (PFS) or Feasibility (FSR) level and approved by the Department of Hydropower and Power Systems were considered techno-economically viable and proposed for selection. Subsequent to further field assessments, six projects have been considered under Phase II for FSR study or for updation of existing FSR/DPR.

This report entails the updation of the Detailed Project Report (DPR) of 8 MW Druk Bindu II Hydropower Project (BHP) located in Tendu Gewog under Samtse Dzongkhag.

## 1.2. Previous Studies

The Feasibility Study of Druk Bindu Small Hydropower Project was conducted by Bhutan Power Corporation Limited (BPC) in 2009-2010 (FSR-2011). As per the FSR-2011 of BPC, a second stage development of hydropower potential with an estimated head of 100 m up to the existing intake of Jaldhaka Hydel was envisaged.

Subsequently, Druk Green during the DPR study of Druk Bindu I has studied the total development of hydropower potential till Jaldhaka intake. Druk Bindu II was proposed as a tandem run-of-river hydropower scheme using the tail water of Druk Bindu I with an installed capacity of 8 MW and annual design energy of 34.34 GWh. The project envisages a construction of integration tank at the end of the tailrace channel of Stage I to regulate flows to Stage II; 1,352.00 m long headrace water conductor GRP pipe of 2.30 m Ø to convey design discharge of 9.36 $m^3/s$ water from integration tank to forebay tank; forebay tank of 80 m x 5.5 m x 9.0 m to accommodate varying load demands and to absorb surges during transient condition; steel penstock of 167 m long, 1.60 m Ø feeding water to two Pelton turbines in semi-underground powerhouse operating at design head of 99 m; and a tailrace channel of 155 m discharging water back to Druk Bindu river at an outfall level of El. 615.30 m.

## 1.3. Updation of Detailed Project Report of Druk Bindu I Hydropower Project

As part of phase II of the Small Hydropower Initiative, DGPC undertook the updation of the DPR in July 2022, with particular focus on the optimization of the layout and designs, updation of environmental and social impact assessment and updation of cost estimate. All major changes and optimizations in the designs, findings of additional investigations and studies, and the impact of cost updation on the financial viability of the project have been captured as part of the DPR updation.

This report shall serve as a supplemental report and shall be read in conjunction with the existing

DPR (hereafter referred to as DPR-2017). The project layout and salient features as finalized in the updated DPR is at **Annexure 1-1** and **Annexure 1-2** respectively.

### 1.3.1. Project Location and Accessibility

Druk Bindu HPP is located in Tendu Gewog which is about 73 km north-west of Samtse town. It is a small hamlet bordered by Namgaycholing Gewog in the east, Norgaygang Gewog in the northwest, Haa Dzongkhag in the north and Indian State of West Bengal in the southwest.

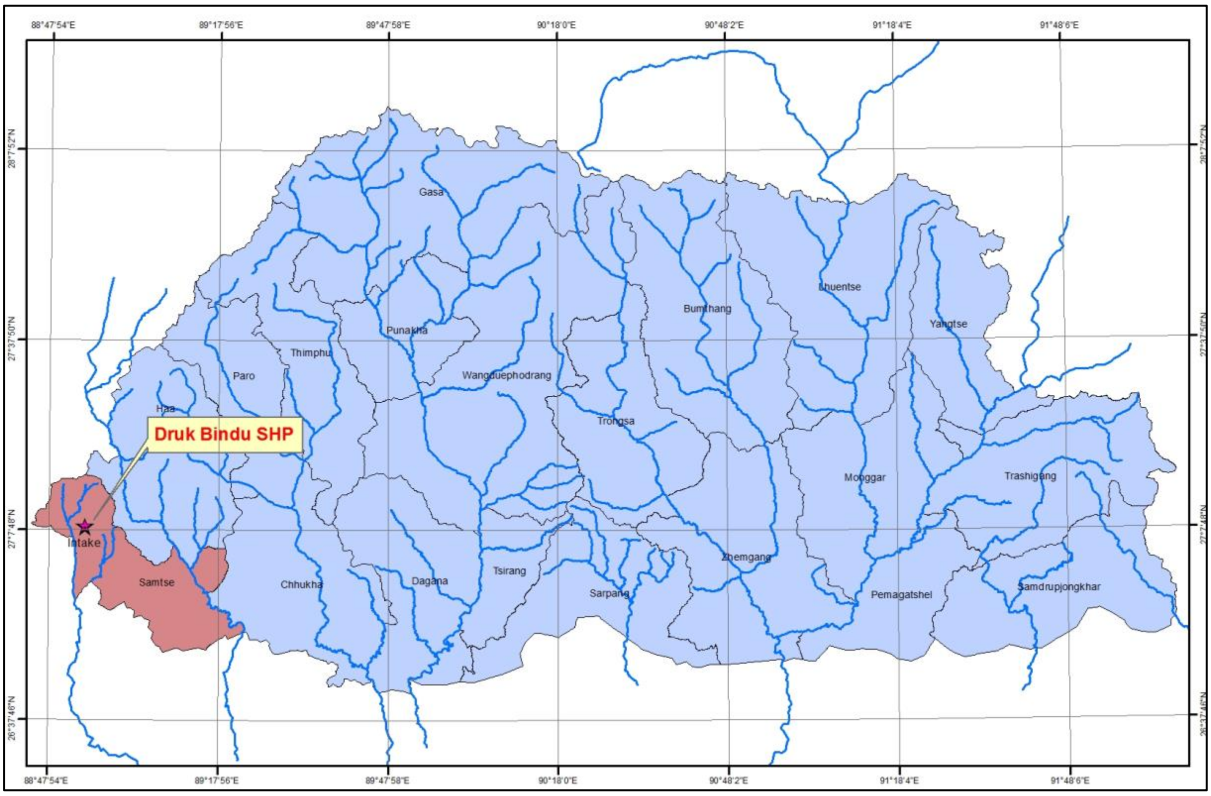


**Figure 1-1: Druk Bindu project location**

The project site is connected to Samtse town by secondary national highway of 73 km. This route can be used to transport construction materials, equipment, machineries and labour for the project. Samtse is well connected with Indian national highway NH 31C. The weir site is located about 300 m away from the existing Samtse-Tendu road while the powerhouse is below Tendu town.

### 1.3.2. Topographical Survey

No additional topographical survey was carried out during the period of DPR update since adequate survey maps are available prepared during DPR-2017. Maps from DPR-2017 were used for the studies.

In DPR-2017, 12 control stations was established within the project area and mainly placed within the vicinity of major project components. Based on satellite image and ground survey, the topographical map in a scale 1:5,000 with 5 m contour interval and 1:1,000 scale with 1 m contour interval was produced including the river cross sections and longitudinal profile.

### 1.3.3. Geological and Geotechnical Investigation

Since no substantial changes in project layout and design has been made, except for replacement of forebay with surge tube, the geological appraisals of the project will remain same as reflected in DPR-2017. The geological appraisals as per DPR-2017 are as given below:

**Regional Geology**

Geologically, the project area falls within the higher Himalayan sequence namely Sure Formation under Thimphu Group.

**Geology of Project Area**

The detailed geological mapping of the various project components were carried out on a scale of 1:1,000 with 1 m contour interval to explore the surface and subsurface geological conditions. The rock types encountered the project area are quartzite with bands of granite gneiss and mica schist of sure formation, Thimphu Group of rocks with alluvial and colluvial deposits.

**Integration Tank**

About 10.0 m in length and 3.0 wide integration tank placed at an El. of 726.00 m over approximately 18 m thick cover alluvial deposit consisting of dark brown colored, loose silty sand with presence of sub-angular gravels, cobbles and boulders of gneiss, quartzite and mica schist. The safe bearing capacity (SBC) of the material falls within the range of 10.8 to 15.2 ton/m$^2$ with corresponding settlement value of 15.225 mm for 2 m foundation width. The permeability range from 1.08 x $10^{-3}$ cm/s to 5.20 x $10^{-3}$ cm/s showing moderate to high water conductivity.

**Head Race Pipe and Penstock**

1,420 m long GRP headrace system of 2.3 m diameter and 147 m long steel penstock with 1.6 m diameter till powerhouse comprises 54% colluvium and alluvium with thickness ranging from 20 m to 40 m and 46% in rock (quartzite). The quartzite is of medium grained, high strength and good quality with three sets of discontinuities

**Surge Tube**

The geology in the forebay area consists of over 30 m thick cover of colluvial deposit comprising of dark brown colored, loose silty sand with presence of sub-angular gravels, cobble and boulders of gneiss, quartzite and mica schist. The safe bearing capacity of the overburden obtained by plate load test is 28 ton/m$^2$ with corresponding settlement of 15.23 mm for a footing of 2 m foundation width and 27.2 ton/m$^2$ with corresponding settlement of 15.08 mm for a footing of 6 m foundation width. From the analysis of the soil samples, the soil is classified as, cohessionless sandy gravel having friction angle 35°.

**Powerhouse**

The semi-underground powerhouse complex of 30 m x 13 m x 16.5 m with service bay level at El. 621.96 m will be placed over 30 m thick alluvial cover. The overburden primarily consists of gravelly sand with presence of sub-angular gravels, cobbles and boulders of gneiss, quartzite and mica schist. The powerhouse comprises two units of 4 MW each. The plate load tests revealed safe bearing capacity and settlement of footing in the alluvium ranging from 42-48 ton/m² and 15.23 mm for 2 m foundation width and 40.4-46.4 ton/m$^2$ and 15.08 mm for 6 m foundation width respectively. However, the soil density is expected to increase with depth and the higher value of SBC should be taken for design purposes.

Since the excavation is below the river bed level and the materials being relatively pervious, recharge from the river cannot be ruled out. Therefore, on top of the pumps, RCC cut off wall has been provisioned on the upstream side abutting on the in-situ rocks to prevent possible water ingress.

**Tail Race Channel**

A tailrace system comprises main TRC of 3 m (W) x 2.5 m (H) including a 50 m, 2m dia., D shaped tunnel. The invert level of TRC outfall is provided at El. 615.30 m to carry tail water discharge from the powerhouse to Druk Bindu river.

The geology along the tailrace tunnel alignment falls in alluvium and quartzite. The alluvium comprises dark grey, loose and friable silty sand with clasts of quartzite, granite gneiss and mica schist. The rock mainly comprises quartzites and falls almost 100 % in class III indicating relatively good for tunneling purpose. The appropriate support measures for rock mass class III are being proposed.

**Construction Materials**

The construction materials will be sourced (Jiti river) as identified in DPR-2017 (Druk Bindu II) and if not sufficient, it will be sourced from either from Diana/Damdum area (River-borne material)- it is found suitable for wearing surfaces with adequate reserves.

### 1.3.4. Hydrology and Power Potential Studies

Since the water directly from TRC of Druk Bindu I is directly fed into the HRP of Druk Bindu II through an integration tank, the hydrological analysis for Druk Bindu I remains valid for Druk Bindu II. The design discharge adopted for Druk Bindu II is same as that of Druk Bindu I at 9.36 cumecs.

In the DPR- 2017, the Manual on Development of Small Hydro Electric Project published by Central Board of Irrigation and Power (CBIP publication 305), 2009 was adopted for power potential studies. The PPS was further reviewed based on the Guidelines for Development of

Hydropower Projects, 2018 which uses Flow Duration Concept as against on dependable year concept. Adopting the FDC Concept, the Installed Capacity remains the same at 8 MW while the design energy reduces from 34.34 MU to 33.99 MU (less than 1%).

### 1.3.5. Project Alternatives, Civil and Hydro-Mechanical Designs

As per the DPR-2017, the hydropower project development at Druk Bindu river was proposed as integrated tandem scheme with two stages, where the tailrace water of Druk Bindu I is conveyed directly into the headrace system of Druk Bindu II. As part of the DPR update study, reassessment of the area beyond the Druk Bindu I forebay has been carried out with the view to develop the project as a single stage. The single stage development envisages construction of HRP passing through two geologically critical stretches. Based on the site assessment and investigations, the single stage scheme was not found feasible and it was decided to adopt the same project layout (two stage tandem development) that was finalized in the DPR-2017.

Except for some optimization in the alignment of HRP and replacement of forebay by surge tube with other associated changes, there is no major changes in project layout and designs of the Druk Bindu II. The design discharge of 9.36 cumecs from the TRC of Druk Bindu I is conveyed to an integration tank, from where the water is conveyed to the HRP via a 2.3 m dia. 1.4 km long Glass Reinforced Plastic (GRP) pipe. A surge tube of 2.4 m – 3.4 m diameter of 61 m inclined length at the end of the GRP pipe has been provided to accommodate transient in the Water Conducting System (WCS) which is connected to the powerhouse through a 147 m long, 1.6 m dia. steel penstock. A semi underground powerhouse of 30.00 m (L) x 13.00 m (B) x 16.5 m (H) located on the right bank of Druk Bindu accommodates two vertical shaft Pelton turbines generating 2 x 4 MW power, operating at 99 m net head and generating annual design energy of 33.99 GWh.

Except for the removal of valves for the forebay and inclusion of flap gates for the surge tube manhole, there is no change in the H&M components of the project.

The summary of the project components is as given below:

The Civil Engineering structure for the project comprises the following:

- 10 m long, 3 m wide rectangular-shaped integration tank for collecting water from tail race channel of Stage-I and diverting discharge to HRP of Stage-II and tail race channel for spillage of excess water.
- 1,420 m long headrace water conductor GRP pipe of 2.30 m conveys water from integration tank to forebay tank.
- Surge tube of 61 m long, 2.4-3.4 m dia is located at the end of headrace system to absorb surges during transient condition.
- Penstock: A 147 m long single main steel penstock of internal diameter 1.6 m will bifurcate into two-unit penstock of each 14 m long, 1.0 m internal diameter.
- Semi-Underground powerhouse of 30.00 m (L) x 13.00 m (B) x 16.5 m (H) has been provided on right bank of Druk Bindu river.

- Tailrace channel comprise a 50 m long, 3 m D shaped tunnel, and a main tail race channel of 155.00 m of 3 m x 2.5 m.

Following hydro-mechanical equipment has been provided for control/isolation of flow for maintenance works and sediment management:

- One number Fixed Wheel Vertical Lift Maintenance Gate of 3 m (W) x 2.7 m (H) with 5T Rope Drum Hoist at Escape Channel connected to TRC of Stage I and upstream of Integration Tank for maintenance of Service Gate.
- One number Fixed Wheel Vertical Lift Service Gate of 3 m (W) x 2.7 m (H) with 5T Rope Drum Hoist downstream of Maintenance Gate for releasing flow through Escape Channel when Stage II is non-operational.
- One number Fixed Wheel Vertical Lift Inlet Gate of 3 m (W) x 2.5 (H) at the inlet of Integration Tank to stop and allow flow from Stage I to Stage II.
- One number flap gates for the surge tube maintenance
- One common Vertical Lift Slide Gate of size 2.5 m (W) x 1.4 m (H) for two units with 3T Monorail Crane for isolation of any of the two units from the tailrace side.

### 1.3.6. Electro-Mechanical Equipment and Power Evacuation

Based on the review and update of the hydrological and power potential studies of the project including recent changes in the equipment designs and market condition, the E&M and power evacuation arrangements of the project has been reviewed and necessary changes have been made as detailed in the report.

Some of the major changes made in the DPR update includes removal of transformers, change of the communication system from PLCC to OPGW and removal of 66 kV system.

The powerhouse shall accommodate two vertical pelton type turbines having rated output of 4 MW under a weighted average net head of 99.0 m at 250 rpm synchronous speed. Each turbine shall be provided with butterfly type main inlet valve. The generators shall be synchronous and of the vertical shaft type of 4 MW rated power at 0.9 power factor and 50 Hz frequency. The generators shall have a speed of 250 rpm and generator voltage of 11 kV.

The following mechanical and electrical auxiliary equipment will be provided:

- One number 25T/5T EOT crane in the powerhouse for installation and maintenance of the heavy equipment
- Cooling water system for generators
- Drainage and dewatering systems
- Ventilation and air conditioning system
- Fire protection system
- Unit auxiliary and station auxiliary supply system
- D.C supply system
- Control and monitoring system

- Protection system, etc.

The power generated at 11 kV would be stepped-up to 66 kV through four numbers (one is spare) of single-phase transformer each of 11 MVA, 11/66/√3 kV capacity located at switch yard of Druk Bindu I HPP. The LV side of the generator transformers would be connected to Generator and the HV side to the 66 kV AIS through oil to $SF_6$ bushings.

#### 1.3.7. Infrastructure, Construction Planning and Schedule

The infrastructure and construction facilities for the project has been reviewed and updated keeping in the view the existing infrastructures and development in the area. The major changes with respect to DPR-2017 are in the area of shifting of construction facilities and manpower planning.

The main infrastructure works includes the following:

- About 4.63 km of project roads to access various project components.
- One bailey bridge (43 m span,18 R) to facilitate the construction of Kachin Intake.
- Construction facilities such as site offices, residential and non-residential buildings, workshops, warehouses/stores, aggregate processing plant (APP) and concrete batching plants, muck disposal area, explosive magazines, construction power, telecommunication, water supply system, security & safety arrangements etc.

The construction methodology has been reviewed and elaborated in detail in the updated DPR. The construction schedule has also been reviewed and retained as in the DPR-2017 with a total duration of 29 months including 5 months for preconstruction activities. However, with the implementation of both Druk Bindu I & II together, the construction schedule of Druk Bindu II needs to be aligned with Druk Bindu I as its construction duration is 36 months.

#### 1.3.8. Environment and Social Impact Assessment

The Environmental and Social Impact Assessment undertaken as a part of the Detailed Project Report of Druk Bindu II in 2017 has been updated in line with the Terms of Reference endorsed by the National Environment Commission Secretariat.

Baseline information (physical, biological and socio-economic environment) was collected through field surveys in collaboration with relevant agencies. Based on terrestrial biodiversity survey conducted in association with Tashichholing Forest Range Office under Samtse Territorial Forests Division, Department of Forests and Park Services, Shannon-wiener diversity index ranges from 0.64 to 2.08. Aquatic biodiversity assessment (monsoon and post-monsoon seasons) recorded a total of 330 fishes belonging to 8 species under 3 families from 30 sampling stretches. *Schizothorax richardsonii* was the most dominant (*n*=330, R*elative Abundance [RA]*=84.85%) followed by *Schistura scaturigina* (*n*=15, *RA*=4.55%) and the least dominant was *Aborichthys garoensis* (*n*=2, *RA*=0.61%).

The overall species diversity of the project sites was *H'*=0.70, species evenness $E_H$=0.33 and species richness $S_R$=2.78. A total of 26 water quality parameters (7 physical, 16 chemical and 3 microbiological) were analyzed for the water samples collected from 8 sampling sites. Overall, the water quality was found to be within the ranges of the national (Ambient Water Quality Criteria 2020 and Bhutan Drinking Water Quality Standard 2016) and international standards (EPA and WHO) with few parameters in few sampling sites deviating from the permissible limits. The socio-economic information is also updated through a socio-economic survey covering 105 households from 4 chiwogs under Tendu Gewog.

The total land requirement for the project is 26.232 acres of which 23.429 acres (6.178 acres temporary and 17.251 acres permanent) is State Reserve Forest (SRF) land and 2.803 acres (0.704 acre temporary and 2.099 acres permanent) is private land. Private land (2.260 acres kamzhing, 0.127 acre chhuzhing and 0.416 acre orange/orchard) belongs to 3 landowners.

The environmental and social impacts were assessed quantitatively in terms of their direction, magnitude, extend, duration and frequency to the extent possible. Accordingly, mitigation measures were formulated as a part of Environmental Management Plan (EMP). The cost to implement EMP is estimated as Nu. 9.98 million and cost for land substitute, compensation and lease is estimated as Nu. 5.69 million. Additional studies, Environmental Valuation and Greenhouse Gas Emission Reduction and Environmental Risk Assessment have also been updated.

### 1.3.9. Cost Estimate and Financial Evaluation

The cost estimate has been updated at the price level of December, 2022 based on latest available data, market condition and guidelines. The project estimate has been framed broadly on basis of "Guidelines for preparation of project estimates for River Valley Projects" dated March 1997 by Central Water Commission, Government of India and Standards/manuals/guidelines for small hydro development published by Ministry of New and Renewable Energy, Government of India in group effort with Alternate Hydro Energy Center, Indian Institute of Technology Roorkee.

The total hard cost of the project is estimated at Nu. 703.83 million at December 2022 price level comprising of Nu. 326.65 million for Civil & HM works and Nu. 239.91 million for E&M works.

The financial evaluation of Druk Bindu II HPP has been prepared in accordance with the "Terms and Conditions of Tariff Determination Guidelines 2016" issued by Bhutan Electricity Authority (BEA). Accordingly, with design energy of 33.99 Million Units, the first year and levelized tariff of the project works out to Nu. 4.01 per unit and Nu. 3.79 per unit respectively for upfront equity investment and Nu. 4.09 per unit and Nu. 3.85 per unit respectively for proportionate fund investment.

The financial evaluation of the integrated project of Druk Bindu I&II was also prepared considering the total costs of the two projects and in line with the "Terms and Conditions of Tariff Determination Guidelines 2016". Accordingly, with design energy of 109.82 Million Units, the first year and levelized tariff of the project works out to Nu. 4.76 per unit and Nu. 4.52 per unit respectively for upfront equity investment and Nu. 4.85 per unit and Nu. 4.62 per unit respectively for proportionate fund investment.

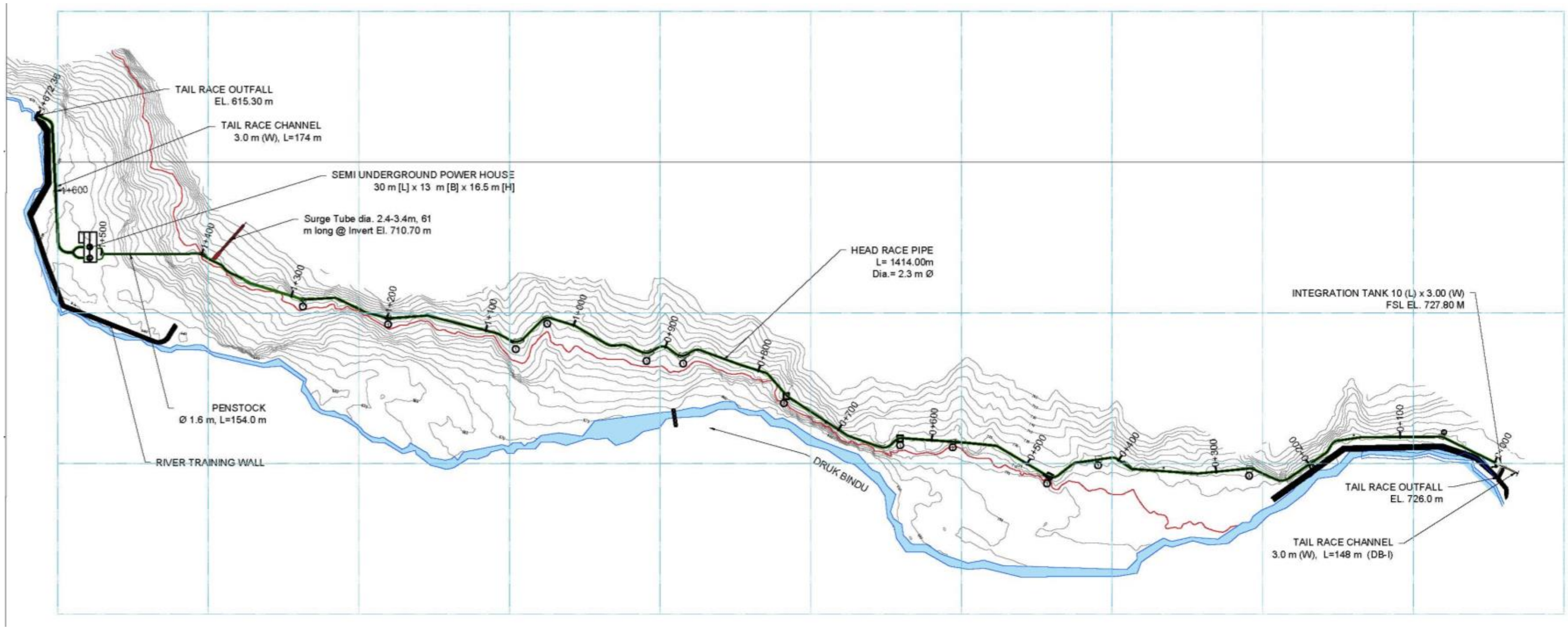
### 1.3.10. Conclusion and Recommendation

The existing DPR was prepared by DGPC in 2017 in continuation to the DPR-2016 prepared for Druk Bindu I HPP. With the availability of additional data due to time lapse of about 5 years since its preparation, the DPR-2017 was further reviewed and updated in 2022. While review and updation of the DPR was carried out covering all aspects, the major changes and updation were made in hydrological analysis, optimisation of civil engineering structures, construction methodology, cost estimation, and financial analysis.

The revised cost estimation of the project has been prepared based on latest available data, market condition and guidelines. The estimated hard cost of the project at December 2022 Price Level is Nu. 703.83 million. Accordingly, with design energy of 33.99 Million Units, the first year and levelized tariff of the project works out to Nu. 4.01 per unit and Nu. 3.79 per unit respectively for upfront equity investment and Nu. 4.09 per unit and Nu. 3.85 per unit respectively for proportionate fund investment.

In view of the above assessment, the updated DPR study has concluded that the project is techno-economically viable and socio-environmentally acceptable for development.

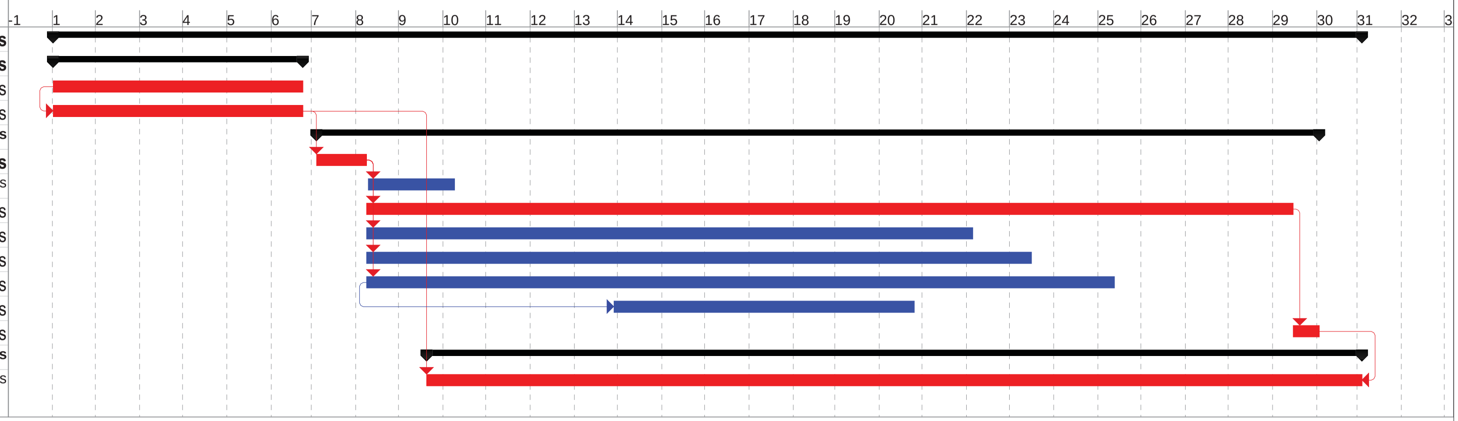
## Annexure 1-1: Project Layout




GENERAL LAYOUT PLAN
SACEL1:4000

**Annexure 11.1**

| ID | Task Name | Duration |
|---|---|---|
| 1 | **Construction of Druk Bindu SHP (Stage-II)** | **785 days** |
| 2 | **Preconstruction Works** | **150 days** |
| 3 | Construction of Basic Infrastructure | 150 days |
| 4 | Tendering Process for Main Works | 150 days |
| 5 | **Construction of Main Works** | **602 days** |
| 6 | Mobilization of Contractor | **30 days** |
| 7 | Integration Tank | 52 days |
| 8 | Head Race System upto Forebay Tank | 557 days |
| 9 | Forebay and Surplus Escape Pipe | 365 days |
| 10 | Penstock and Support System | 400 days |
| 11 | Powerhouse Building | 450 days |
| 12 | Tailrace Channel and River Training Works | 180 days |
| 13 | Initial Charging of Water Conductor System | 15 days |
| 14 | **E&M** | **562 days** |
| 15 | Supply, Erection, Testing and Commissioning | 562 days |




Project: Project Schedule
Date: Sat 8/19/17

Legend: Task; Critical Task; Milestone; Summary; Rolled Up Task; Rolled Up Critical Task; Rolled Up Milestone; Rolled Up Progress; Split; External Tasks; Project Summary; Group By Summary; Inactive Milestone; Inactive Summary; Manual Task; Duration-only; Manual Summary Rollup; Manual Summary; Start-only; Finish-only; External Tasks; External Milestone; Progress; Deadline

**Annexure 1-2: Salient Features**

| Parameter | Description |
|---|---|
| **A. General** | |
| **Location** | |
| Country | Bhutan |
| Dzongkhag | Samtse |
| River | Druk Bindu |
| Nearest Town in Bhutan | Tashichholing |
| Nearest City in India | Siliguri |
| Nearest Village (Weir Site) | Tendruk |
| Nearest Village (Power House Site) | Tendruk |
| Nearest International Airport | Bagdogra, India |
| Nearest Rail head (Broad gauge) | NJP, India |
| Location of Weir Site | 27°8'9.15" N, 88°54'13.73" E |
| Location of Power House | 27°6'31.93" N, 88°52'36.02" E |
| Seismic Zone | V |
| **B. Hydrology** | |
| Catchment Area (Kachin) | 28 $km^2$ |
| Catchment Area (Druk Bindu) | 53 $km^2$ |
| **C. Civil and Hydro-Mechanical Works** | |
| **Integration Tank** | |
| Size & Shape | Rectangular (10 m (L) x 3 m (B)) |
| Invert Level at 0.00 RD El. | 726.00 m |
| Invert Level at HRP Inlet El. | 724.17 m |
| Inlet Gate | 3 m (W) x 2.5 m (H) |
| Escape Channel – Maintenance Gate (TRC Druk Bindu I) | 3 m (W) x 2.7 m (H) |
| Escape Channel – Service Gate (TRC Druk Bindu I) | 3 m (W) x 2.7 m (H) |
| **Head Race Pipe (HRP)** | |
| Number & Type | 1 No., Glass Reinforced Plastic (GRP) Pipe |
| Size & Shape | 2.3 m dia. Circular |
| Design Discharge | 9.36 $m^3/s$ |
| Length | 1,420 m |
| Slope | 1 in 105.42 |

| Parameter | Description |
|---|---|
| Invert level at 0.00 m RD | El. 724.17 m |
| Invert level at HRP end (1420 m RD) | El. 710.70 m |
| **Surge Tube** | |
| Size & Shape | Circular (3.4 m dia. @ angle of 62.90º) RD 0-18 m<br>Circular (2.4 m dia. @ angle of 26.90º) RD 18-61m |
| Length | 61 m |
| Surge Tube Top | El. 752.00 m |
| Surge Tube Bottom | El. 714.30 m |
| Maximum Surge Level | El. 749.03 m |
| Minimum Surge Level | El. 716.55 m |
| Flap Gate (Manhole gate) | 1.2 m @ HRP and Surge Tube junction |
| **Penstock** | |
| Type & Shape | ASTM 537 Class-II, Circular |
| Design Discharge | 9.36 $m^3/s$ |
| Number | 1 no. (bifurcating into two near power house) |
| Main Penstock (dia., length, thickness) | 1.6 m dia., 147 m long, 8 mm to 10 mm |
| Unit Penstock | 1.0 m dia., 14 m each, 10 mm |
| **Powerhouse** | |
| Type | Semi Underground Powerhouse |
| Maximum Tail Water Level (Full load) | El. 617.49 m |
| Center Line of Turbine | El. 620.00 m |
| Turbine Floor Level | El. 621.96 m |
| Service Bay Level | El. 621.96 m |
| Generating Units (Installed Capacity) | 2 x 4 MW (8 MW) |
| Size (Machine Hall) | 30.0 m (L) x 13.0 m (B) x 16.5 m (H) |
| MIV Type & number | Butterfly, 2 Nos. |
| **Tail Race Channel** | |
| Type | Cut & Cover |
| Number | 1 no. |
| Shape & Size | Rectangular, 3.0 m (W) x 2.5 m (H) - Main<br>Rectangular, 2.5 m (W) x 1.9 m (H) - Unit<br>Tunnel 3 m D-Shaped, 50 m length |
| Length<br><br>Slope | 155.0 m (including 50 m tunnel) - Main<br>19 m - Unit<br>1 in 1,000 |

| Parameter | Description |
|---|---|
| TRC Outfall | El. 615.3 m |
| Unit TRC Gate | 1 Nos., 2.5 m (B) x 1.4 m (H) |
| **D. Electro Mechanical Equipment** | |
| **Turbine** | |
| Type of Turbine | Vertical Pelton |
| Number of Turbines | 2 (Two) |
| Rated Net Head | 99.00 m |
| Rated Output | 2 x 4 MW |
| Rated Speed | 250 rpm |
| **Generator** | |
| Type of Generator | Synchronous, Salient pole type |
| Rated Power | 4 MW |
| Power Factor | 0.9 lagging |
| Generation Voltage | 11.0 kV |
| Number of Phases | 3 (Three) |
| Frequency | 50 Hz |
| Insulation | Class F |
| Type of Cooling | Air cooled (Air cooled by water) |
| EOT Crane | 25 MT/5 MT |
| **E. Power Evacuation** | |
| Length of XLPE Cable | 2 km |
| **F. Power Generation** | |
| Design Discharge | 9.36 $m^3/s$ |
| Firm Flow | 1.38 $m^3/s$ |
| Gross Head | 108.70 m |
| Head Loss | 9.71 m |
| Design Head | 99 m |
| Annual Design Energy | 33.99 GWh |
| Firm Power | 1.21 MW |
| Annual PLF | 49% |
| Exceedance Probability | 28 % |
| **G. Construction Schedule** | |
| Construction Period | 29 months including 5 months of pre-construction activities. |

| Parameter | Description |
|---|---|
| **H. Project Cost** | |
| **Druk Bindu II** | |
| Cost of Civil & HM Works | Nu. 419.31 Million |
| Cost of E&M Works | Nu. 239.91 million |
| Total Hard Cost at Dec 2022 PL | Nu. 703.83 million |
| Cost of Transmission Line | Cost of XLPE cables connecting to Druk Bindu I power evacuation system included in E&M cost |
| IDC (Upfront Equity) | Nu. 41.82 million |
| IDC (Proportionate Fund Investment) | Nu. 55.83 million |
| Capital Cost (Upfront Equity) | Nu. 763.83 million (With Cost to Completion) |
| Capital Cost (Proportionate Fund Investment) | Nu. 777.83 million (With Cost to Completion) |
| **Tariffs for upfront equity** | |
| First Year Tariff | Nu. 4.01/Unit |
| Levelized Tariff | Nu. 3.79/Unit |
| **Tariffs for proportionate fund investment** | |
| First Year Tariff | Nu. 4.09/Unit |
| Levelized Tariff | Nu. 3.85/Unit |
| **Druk Bindu I & II integrated** | |
| Total Hard Cost at Dec 2022 PL | Nu. 2,654.48 million |
| IDC (Upfront Equity) | Nu. 193.35 million |
| IDC (Proportionate Fund Investment) | Nu. 251.22 million |
| Capital Cost (Upfront Equity) | Nu. 2,922.41 million (With Cost to Completion) |
| Capital Cost (Proportionate Fund Investment) | Nu. 2,980.28 million (With Cost to Completion) |
| **Tariffs for upfront equity** | |
| First Year Tariff | Nu. 4.76/Unit |
| Levelized Tariff | Nu. 4.52/Unit |
| **Tariffs for proportionate fund investment** | |
| First Year Tariff | Nu. 4.85/Unit |
| Levelized Tariff | Nu. 4.61/Unit |