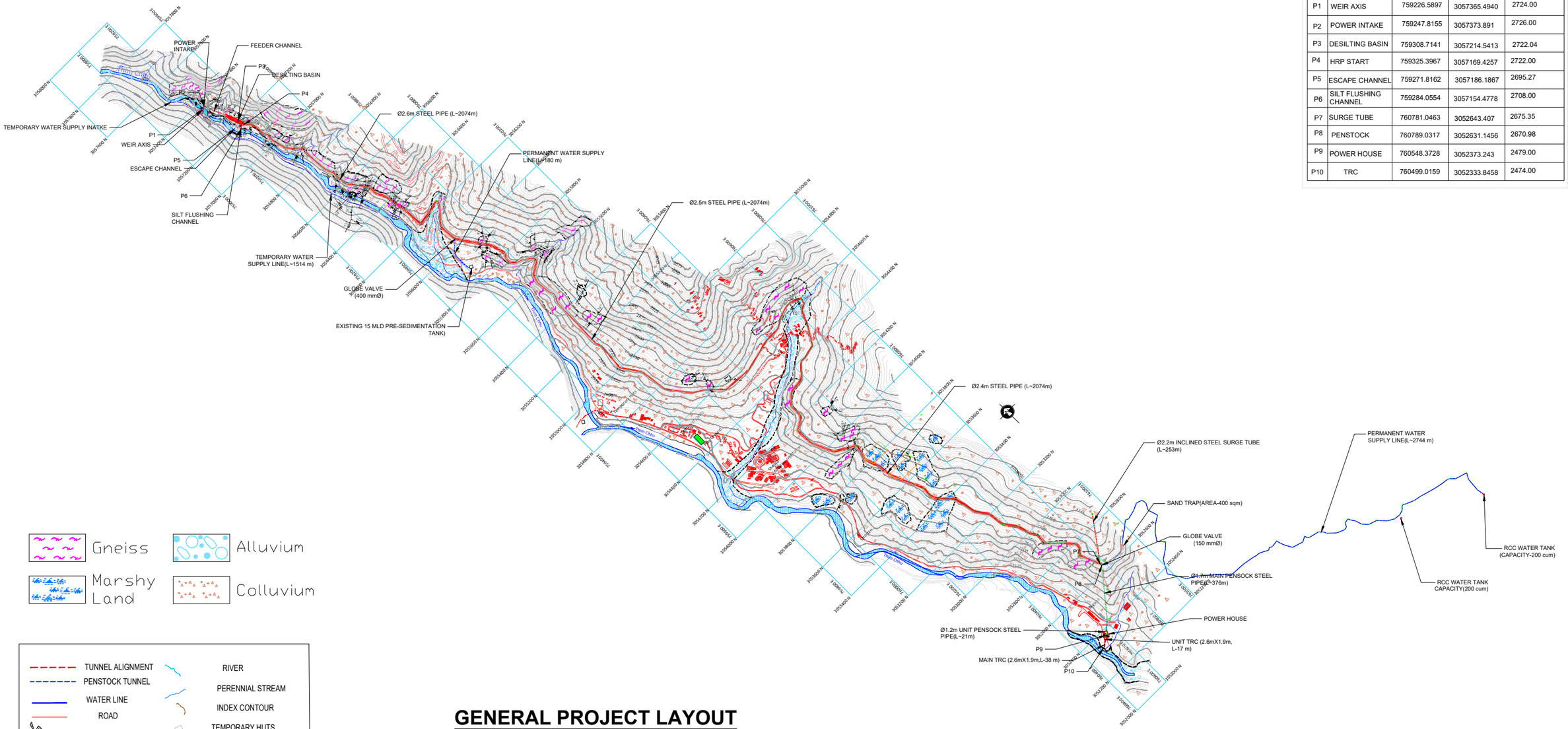
NOTES:-

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

SETTING OUT DETAILS (IN UTM)

Sl.	DESCRIPTION	EASTING	NORTHING	ELEVATION(M)
P1	WEIR AXIS	759226.5897	3057365.4940	2724.00
P2	POWER INTAKE	759247.8155	3057373.891	2726.00
P3	DESILTING BASIN	759308.7141	3057214.5413	2722.04
P4	HRP START	759325.3967	3057169.4257	2722.00
P5	ESCAPE CHANNEL	759271.8162	3057186.1867	2695.27
P6	SILT FLUSHING CHANNEL	759284.0554	3057154.4778	2708.00
P7	SURGE TUBE	760781.0463	3052643.407	2675.35
P8	PENSTOCK	760789.0317	3052631.1456	2670.98
P9	POWER HOUSE	760548.3728	3052373.243	2479.00
P10	TRC	760499.0159	3052333.8458	2474.00



Gneiss
Alluvium
Marshy Land
Colluvium

TUNNEL ALIGNMENT
PENSTOCK TUNNEL
WATER LINE
ROAD
CLIFF
RIVER
PERENNIAL STREAM
INDEX CONTOUR
TEMPORARY HUTS

GENERAL PROJECT LAYOUT
SCALE 1: 20000

200 0 200 400 600 800 1000m

SCALE = 1:20000

FOR FS REPORT

Consultant: DRUK GREEN CONSULTANCY		Owner: DEPARTMENT OF ENERGY, MINISTRY OF ENERGY AND NATURAL RESOURCES	
Date: August 2023	Revised date	Project: **25 MW BEGANA INTEGRATED MULTIPURPOSE SMALL HYDROPOWER PROJECT**, THIMPHU, BHUTAN	
Designed: C.Wangdi	Verified: T.Dorjee		
Reviewed: C.Wangdi	Approved: C.Tenzin	Title: GEOLOGICAL MAP OF HRP ALIGNMENT	
Drawn: C.Wangchuk	Scale: AS SHOWN	Drawing No.	
THIS DRAWING IS MEANT FOR FSR NOT TO BE USED FOR CONSTRUCTION.		BIMSHP-GEO-2023-2	Rev. 0

Cad File No: C:\Users\dhan\AppData\Local\Temp\AcPublish_3264\Longitudinal Sections.dwg

Mar 25, 2024 - 2:44pm

4. Project Geology and Geotechnical Assessment

4.1 Intake and Desilting Chamber

Intake area

The raised weir of crest length 32 m and height 4.5 m above the riverbed level shall be developed to divert Thimchu into WCS/HRP through one intake structures of dimension 3.0 m x 2.6 m and two chambers of the desilter.

On the left of the weir axis and intake area, fair and up stream of weir axis, rock mass predominantly comprising of medium to fine grained, slightly to moderately weathered, light grey biotite gneiss with occasional intrusions of pegmatite and quartz band is observed by three set of discontinuities; The characteristic features of major discontinuities are given in **Table 4-1, Figure 4-1**and **Photo 4-1** and **Photo 4-2.**

Table 4-1: Rock Mass Characteristics of Gneiss

Biotite Gneiss	Joint Characteristics						
Joint Type	Orientation	Joint Surface	Weathering	Aperture (mm)	Persistence (m)	Spacing (cm)	Infillings
J1 (foliation)	20-46°/ 013-019°	Rough/ planer	Un–weathered	<0.1–1	>10	10-40	None
J2	58-86°/ 123°-147°	Slightly Rough/ planer	Un–weathered	<0.1–1	10-20	60-100	Roots of tree
J3	50–86°/ 215–256°	Slightly Rough/ planer	Un–weathered	<0.1–1	5-10	20-30	None

On the right bank of the Weir axis, it is covered with colluvium from 1m to 10m thick on top followed by alluvial materials. Colluvium mainly consist of soil, boulders and decomposed plants and approximately 10m downstream of the weir axis exposure of Biotite gneiss with quartz and pegmatite intrusion at some stretches with discontinuities, foliation- 56°/269°, tightly, closely spaced, Joint (J1) 57°/068° and 54°/096° low persistence, slightly open at place, slightly to moderately weathered are observed. About 5m upstream of weir axis, colluvium deposit is observed. Prima facie, looking at trees at the base near the riverbed, the right abutment seems to be stable.

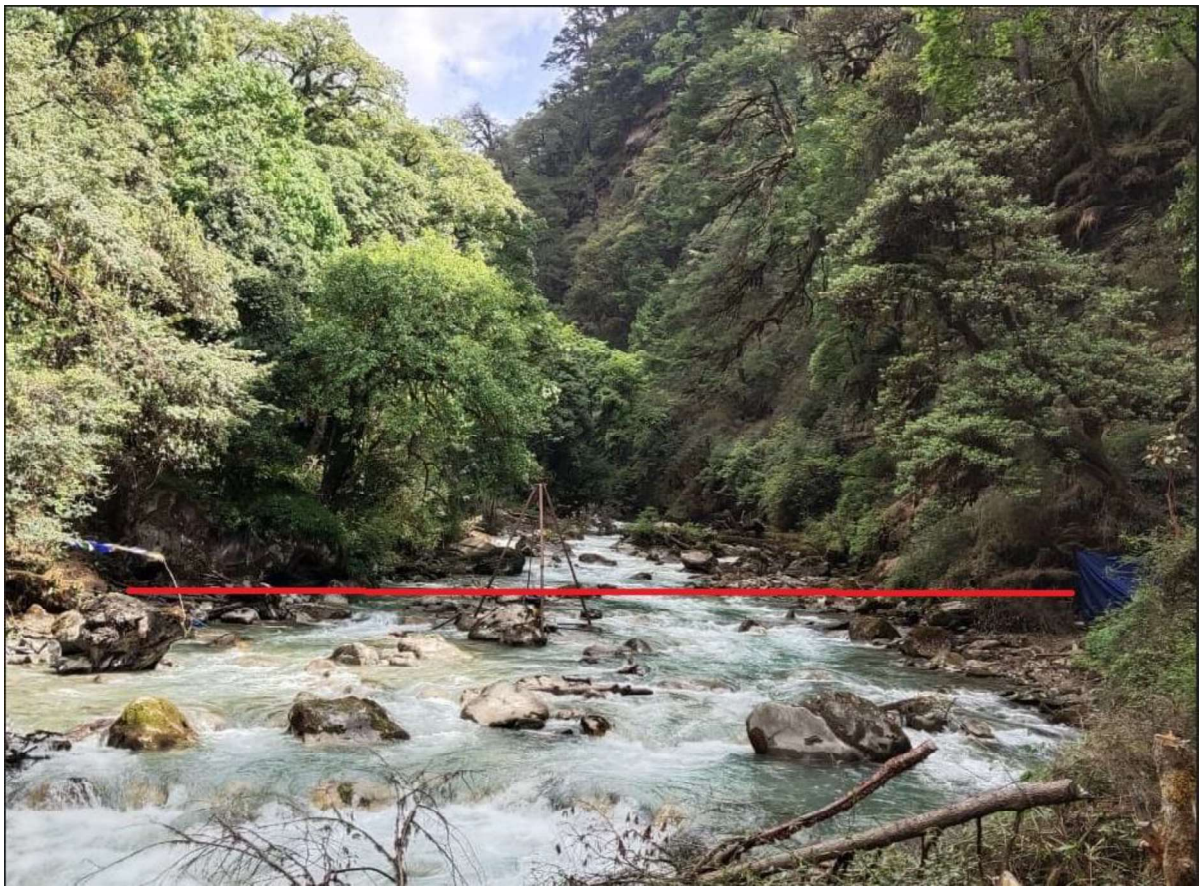


Photo 4-1: Location of weir axis

Photo 4-2: Rock exposure at right bank 10m d/s of weir axis (left) and at intake area (right)

Desilter Chamber

The desilter area is placed on colluvial/alluvial deposit of about 15 m thick. The end part of the desilter is placed on adjacent exposure of biotite gneiss and on talus deposit of angular to sub angular deposit of boulders and alluvium of river borne deposits. Traverse along the desilter and the initial span of the surface HRP from the desilter till the inlet portal has been met with colluvial

deposit of dark grey, coarsed grained soil/sandy soil with few angular gravel and boulders of size 250-600 mm, cobbles and pebbles and no water table observed, **Photo 4-4 and Photo 4-5.**

Sub-surface investigations at Intake and Desilter area

In-order to study the foundation and the rock line, geophysical profiles were carried out; five profile length of 115 m each of SRT has been carried out at intake and desilter area as detailed in **Table 3-2** and **Photo 4-3.** The results of SRT profiles SRT-1, 2, 3, 4 & 5 which is aligned along the intake area till desilter area indicates presence of four contrasting layer with different seismic velocity with varying thickness as described in **Table 4-2.** Detailed report on Geophysical explorations is appended as **Appendix II**.

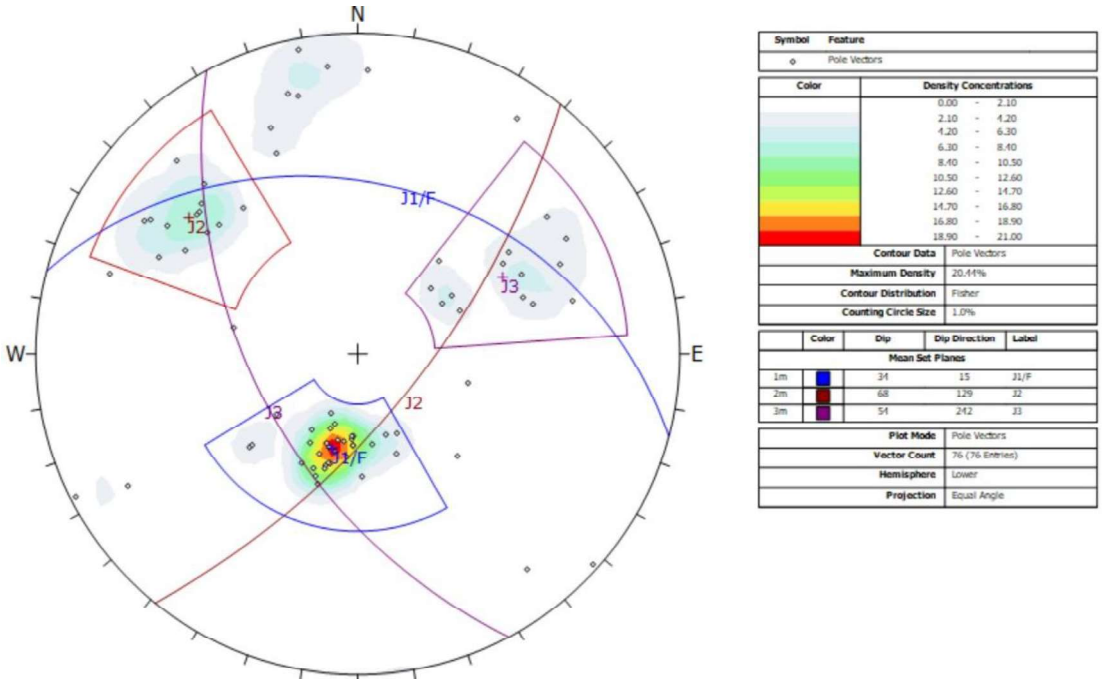


Figure 4-1: Stereographic projection of discontinuities at Weir, Intake area and desilting chamber


Photo 4-3: Geophysical Profile layout and geophone location collected using RTK

Table 4-2: Interpretation of lithology w.r.t seismic velocity

Site Location	Seismic Line	Layer No	Velocity Range (m/sec)		Layer Thickness (m) Range		Interpreted Lithology
			From	To	From	To	
Weir (L/B)	**SRT 1**	1	500	1,200	8	20	Overburden as slope debris/River born material
		2	1,300	2,400	10	12	Slightly compact slope debris comprising highly weathered rock fragments
		3	2,750	3,100	2	4	Foliated, Jointed and Weathered Gneiss/Quartzite/Schist
		4	3,750	4,750	-		Gneiss/Quartzite Bedrock
Weir (R/B)	**SRT 2**	1	590	1,000	6	11	Overburden as slope debris/River born material
		2	1,200	2,200	10	22	Slightly compact slope debris comprising highly weathered rock fragments
		3	2,350	3,100	2	6	Foliated, Jointed and slightly to moderately Weathered Gneiss/Quartzite/Schist
		4	3,500	3,700	-		Gneiss/Quartzite Bedrock
Weir Axis	**SRT 3**	1	250	1,000	2	12	Overburden as slope debris/River born material

Site Location	Seismic Line	Layer No	Velocity Range (m/sec)		Layer Thickness (m) Range		Interpreted Lithology
			From	To	From	To	
(Across the River)		2	1,200	2,250	4	20	Slightly compact slope debris comprising highly weathered rock fragments
		3	2,350	3,000	2	4	Foliated, Jointed and slightly to moderately weathered Gneiss/Quartzite/Schist
		4	3,500	4,750	-		Gneiss/Quartzite Bedrock Boulder
Desilting Chamber	**SRT 4**	1	400	900	2	15	Overburden as slope debris/River born material
		2	1,100	1,800	5	20	Slightly compact slope debris/rock slumps comprising highly fractured and weathered rock fragments
		3	2,000	2,200	3	8	Highly fractured, and weathered in-situ rock mass
		4	2,600	3,200	-		Moderately fractured, moderately weathered to slightly weathered, jointed Biotite Gneiss/Quartzite
Across Desilting Chamber	**SRT 5**	1	500	1,000	5	30	Overburden as slope debris/River born material
		2	1,200	2,250	5	45	Slightly compact slope debris comprising highly weathered rock fragments
		3	2,900	3,100	2	5	Foliated, Jointed and slightly to moderately weathered Insitu bedrock (Gneiss)
		4	3,750	4,750	-		Gneiss/Quartzite Bedrock

In situ plate load test (PLT) were also carried out to determine the safe bearing capacity and associated laboratory test were also conducted, **Photo 4-6**. The safety bearing capacity (SBC) at PLT-01 at right bank of weir axis for foundation width 2 m, 4 m, 6 m and 8 m is 200 kN/m², 180 kN/m², 170 kN/m² and 156 kN/m² respectively with average cumulative settlement of 8.56 mm; PLT-02 at left bank of weir axis for foundation width 2 m, 4 m, 6 m and 8 m is 260 kN/m² , 232 kN/m² , 212 kN/m² and 204 kN/m² respectively with average cumulative settlement of 6.99 mm; PLT-03 and PLT-04 at desilter area computed SBC of 248 kN/m² , 220 kN/m² , 208 kN/m² and 196 kN/m² with average cumulative settlement of 5.97mm and 268 kN/m² , 240 kN/m² , 218 kN/m² and 204 kN/m² with average cumulative settlement of 5.72 mm for foundation width of 2, 4, 6 and 8 m respectively. The summarised resulted are tabulated above in **Table 3-5** and **Table 3-6** and detail report is attached as **Appendix IV**.

Photo 4-4: Desilter area covered with tree, bushes and boulders

Photo 4-5: Exposure at Desilter area

Photo 4-6: PLT set up at different locations

Total of three (3) numbers of bore holes were drilled whereby two were drilled at the intake (BH-01 & BH-02) and one at the desilter area (BH-03). The summarized geological details of bore holes are presented in
Table 4-3**, Photo 4-11** and **t**he detailed drilling report will be attached as **Appendix III** after the completion of drilling works along with laboratory test results.

Table 4-3: Summary of exploratory core drilling

Location	Co-ordinates (X, Y, Z)	Total depth/ bedrock depth (m)	Type of Overburden	Bedrock characteristics
Right bank of weir axis	759220.644E 3057359.113N 2722.632m	25/12	Overburden continues till 12.0 m depth which consists matrix of sand soil with gneissic and quartzite boulders. The recovery varies from 20 % to 99 %. Coefficient of permeability varies from 0.45x 10^-3 till 35 x 10^-3 cm/s.	Bedrock intercepted from the depth of 12.0m consists thinly foliated, strong to moderately strong Biotite and Augen Gneiss with quartz infillings along the foliation. Slightly Fractured. Core recovery varies from 90 % to 100 %. WPT varies from 7.42 to 13.81

Location	Co-ordinates (X, Y, Z)	Total depth/ bedrock depth (m)	Type of Overburden	Bedrock characteristics
				Lugeon values. Lugeon values. Lugeon value show presence of few partly open discontinuities.
Center of river	759229.996E 3057364.276N 2772.428	Ongoing	Overburden continues till 10.8 m depth which consists matrix of sand soil with boulders of biotite gneiss and quartzite gneiss. The recovery varies from 26 % to 100 %.	Bedrock intercepted from the depth of 10.8m consists thinly foliated, strong to moderately strong Biotite and Quarzitic Gneiss, slightly fractured along foliation. Core recovery varies from 0 % to 93.3 %. WPT is found to be 1.10 Lugeon value at 15-18 m depth. Lugeon value show presence of tight rock mass.
Desilter area	759313.039E 3057202.749N 2725.054m	25/6	Overburden continues till 6m depth which consists matrix of silty clay soil and sandy soil with gneissic and micaceous gneissic boulders. The recovery varies from 18% to 90%. Coefficient of permeability varies from 15.97x 10^-3 cm/s till 19.66 x 10^-3 cm/s.	Bedrock intercepted from the depth of 6m consists of slightly to highly weathered, medium to coarse grained, strong to moderately strong Gneiss with quartz infillings, Micaceous gneiss and Granite gneiss. Core recovery varies from 60% to 100%. WPT varies from 10.08 to 24.47 Lugeon values. Lugeon value show presence of few partly open to some open discontinuities.

4.2 Head Race Pipe (HRP)

The geology along 6,223 m long, 2.4 to 2.6 m diameter, HRP alignment comprises dominantly of colluvial/alluvial deposits with very limited stretches passing through rock outcrops comprising biotite Gneiss and Quarzitic gneiss. It is observed that 60 % of HRP alignment falls within colluvial

deposits, 5 % would be laid on alluvial deposit and the remaining 35 % passes through biotite gneiss and quarzitic gneiss outcrops. The HRP alignment starting from the from desilter outlet till RD 4,500 m comprises of colluvial/alluvial deposit and through biotite gneiss and quarzitic gneiss with the general attitude of foliation varying from N25º- 45ºW with dip 30º to 45º towards NE which is dipping towards the hill. The HRP also passes through an active perineal stream at RD 1,125 m and 3,750 m. The colluvial deposit varies from thin layer to thick deposits with the slope gradient varying between to 30-65 degrees at most part and 80- 85 degree at some locations, **Photo 4-7, Photo 4-8, Photo 4-9 and Photo 4-10.** At RD 750 m of HRP, below the alignment marshy/dipping of water was observed, so to verify the water table/zone of saturation, one profile of 235 m length electric resistivity tomography (ERT-02) was carried out.

From the ERT profile, it was observed that the topmost layer may be interpreted as overburden comprising of river deposits/slope debris of Gneiss/Quartzite mixed with Gneiss/Quartzite boulders outcropping at the surface having a resistivity of the order of 382 Ωm to 26873 Ωm extended up to varying depth from 5 m to 20 m. In the topmost layer, a very high resistivity zone between chainage 40.0 m to 110 m and 135 m to 230 m with resistivity ranging from 14,638 Ωm to 2,6873 Ωm can be interpreted as strong to moderately strong faulted Gneiss/Quartzite outcropping at/near the surface which seems to be undergoing weathering and fracturing with a higher degree of jointing which can be interpreted with the decreasing resistivity value in the surrounding area of the boulder with increasing depth. The thickness of this zone varies from 5 m to 15 m. The lower resistivity zone below this layer between chainage 105 m to 195m with resistivity ranging from 382 Ω m to 782 Ωm may indicate the presence of a Zone of Saturation. The lower resistivity zone of this zone may be interpreted as a highly fractured zone of Gneiss/quartzite under saturation. Along the same layer, between chainage 12.5 m to 40 m and 55 m to 100 m, two slightly weak zones have been detected with resistivity ranging from 1,280 Ωm to 2,366 Ωm which can be interpreted as slightly compacted, highly fractured, and weathered rock fragments. The thickness of this zone varies from 5 m to 10 m. The top layer is followed by a layer between chainage 40 m to 225 m with resistivity ranging from 3,000 Ωm to 8,000 Ωm which may be interpreted as in-situ rock mass with varying degrees of weathering and fracturing and jointing. A zone from chainage 40 m to 235 m with resistivity ranging from 3,000 Ωm to 4,300 Ωm has been detected which can be interpreted as fractured and weathered Gneiss/Quartzite. The lower resistivity indicated a higher degree of weathering and fracturing, and higher resistivity indicates jointed, slightly weathered, and fractured in-situ Gneiss/Quartzite. Between this medium resistivity zone, a moderately high resistivity zone between chainage 60 m to 185 m with resistivity ranging from 7,973 Ωm to 10,000 Ωm which indicates fresh un-weathered, Gneiss/Schist/Quartzite bedrock with varying degree of jointing. Below this zone, from chainage 45 m to 150 m a zone with resistivity ranging from 6,000 Ωm to 3,000 Ωm jointed/fractured Gneiss/Quartzite. The higher value indicates moderately strong, moderately jointed Gneiss/Quartzite/Schist whereas the lower value indicates weak to strong Gneiss/Quartzite with a higher degree of fracturing and jointing. No, water table was detected from the ERT profile. Although Zone of Saturation/Weak zone from chainage 105 m to 195 m with resistivity ranging from 300 Ωm to 750 Ωm was detected. The entire slope does not have signs of major instability.

From RD 4,500 to 5,500 m of HRP alignment, the presence of marshy area was observed. The HRP alignment would be laid over colluvial deposit/marshy area. The thickness of colluvial deposit varies from 5 m to 25 m thick. The sub-surface features along HRP have been explored

by geo-physical survey comprising seismic refraction and electrical resistivity tomography methods **(Appendix-II),** one SRT profile of 115 m length (SRT-06) and one ERT profile of 235 m length (ERT-01). From the SRT profile the findings has been tabulated below in **Table 4-4.**

Table 4-4: Interpretation of lithology w.r.t seismic velocity

Site Location	Seismic Line	Layer No	Velocity Range (m/sec)		Layer Thickness (m) Range		Interpreted Lithology
			From	To	From	To	
HRP	**SRT 6**	1	550	1,050	5	25	Overburden as slope debris/River born material
		2	1,350	2,500	3	13	Slightly compact slope debris comprising highly weathered rock fragments
		3	2,800	3,125	1	3	Foliated, Jointed and slightly to moderately weathered Insitu bedrock (Gneiss/Schist)
		4	3,500	5,000	-		Gneiss/Quartzite/Schist Bedrock

From the ERT profile, it is observed that the topmost layer between chainage 0.0 m to 230 m, may be interpreted as overburden comprising of river deposits/slope debris of Gneiss/Quartzite mixed with Gneiss/Quartzite boulders outcropping at the surface having a resistivity of the order of 144 Ωm to >4,727 Ωm extended up to varying depth from 5 m to 25 m extending laterally and vertically. In the topmost layer, a very high resistivity zone between chainage 90 m to 120 m, 130 m to 150 m, 165 m to 195 m, and 220 m to 225 m with resistivity ranging from 2,900 Ωm to >4,700 Ωm can be interpreted as strong to moderately strong faulted Gneiss/Quartzite boulder outcropping at/near the surface which seems to be undergoing weathering and fracturing with a higher degree of jointing that can be interpreted with the decreasing resistivity value in the surrounding area of the boulder with increasing depth. The thickness of this zone varies from 5m to 10m. Along the same layer and below from chainage 5 m to 35 m, 45 m to 85 m and 120 m to 165 m a layer with resistivity ranging from 200 Ωm to 400 Ωm was detected which indicates the presence of Zone of Saturation which comprises highly fractured and highly weathered Gneiss/Quartzite under saturation. The thickness of this zone varies from 5 m to 15 m. Along the same layer from chainage 35 m to 165 m, 195 m to 220 m a sub layer with resistivity ranging from 500 Ωm to 1,000 Ωm has been detected which indicates highly weathered and fractured Gneiss/Quartzite. The lower resistivity value indicates a higher degree of weathering and fracturing. Below the top layer, between chainage 85 m to 225 m resistivity ranging from 1,100 Ωm to 2,900 Ωm has been detected which can be interpreted as in-situ rock mass with varying degrees of weathering and fracturing and jointing. A sub layer from chainage 85 m to 155 m, and 155 m to 220 m with resistivity ranging from 1,100 Ωm to 2,800 Ωm has been detected which can be interpreted as highly to moderately jointed/ fractured/ weathered Gneiss/Quartzite. The lower resistivity value indicates a higher degree of fracturing, jointing, and weathering. To validate these result of geophysical survey, two numbers of exploratory core drillings has been carried out. The summarized geological log of the exploratory boreholes has been tabulated below in
Table 4-5.

Table 4-5: Summary of exploratory core drilling

Location	Co-ordinates (X, Y, Z)	Total depth/ bedrock encountered (m)	Type of Overburden	Bedrock characteristics
BH-04 (HRP alignment)	760498.055E 3053706.113N 2736.062m	45/23	Overburden continues till 23m of the drill depth which consists sludge, fragments of biotite gneiss, pegmatite. The recovery varies from 0-86%. Coefficient of permeability is between 0.002569 to 1.408484 cm/s.	Bedrock consists moderately to highly weathered, stained, light grey, medium to fine-grained, moderately strong to strong, slightly to highly fractured biotite Gneiss with quartz veins and slightly to moderately weathered, Stained, reddish, light grey, medium to fine-grained, moderately strong, fractured feldspar/ biotite gneiss. Core recovery varies from 46% to 100%. WPT varies from 11.90 to 18.71 Lugeon values and water table has been encountered from 29.1m depth. Lugeon value show presence of few partly open to some open discontinuities.
BH-05 (HRP alignment)	Ongoing	35/28.5	Overburden continues till 28.5m of the drill depth which consists sludge, fragments of biotite gneiss, pegmatite. The recovery varies from 0-72%. Coefficient of permeability is between 0.0020 to 0.0098 cm/s.	Bedrock consists of slightly to moderately weathered, Stained, light grey, medium to fine grained, moderately strong to strong biotite Gneiss, slightly to moderately fractured core pieces. Core recovery varies from 10% to 100%. WPT varies from 16.84 to 17.28 Lugeon values and water table has been

Location	Co-ordinates (X, Y, Z)	Total depth/ bedrock encountered (m)	Type of Overburden	Bedrock characteristics
				encountered from 16.5m depth. Lugeon value show presence of some open discontinuities.

Further, the stretch from 5,500 m to 6,250 m will again be accommodated approximately 20 m thick colluvial deposits. The slope gradient is found to gentle along this stretch. The HRP length from 5,875m till 6,000 m and close to the surge tube would be place over biotite gneiss, slightly to moderately weathered, dark yellowish colored stained, light grey, medium to fine-grained, moderately strong to strong.

Photo 4-7: Marshy area along the HRP alignment

Photo 4-8: Alluvial deposit and vegetation cover along HRP alignment

Photo 4-9: Exposure along the HRP alignment

Photo 4-10: Quarzitic Gneiss exposure along HRP

Photo 4-11: Core Drilling at Intake and Power House

4.3 Surge tube and Penstock alignment

The area for placing 2.2 m diameter and 253 m long surge tube and 1.7 m diameter and 376 m long penstock exhibits moderate to steep gradient slope which comprises of colluvial deposit along with vegetation of pine trees. The colluvial deposit is of approximately 2-20 m thickness. The entire slope does not have any signs of major instability. The penstock alignment was explored by carrying out two seismic refraction tomography profiles of 115 m each (SRT-07 & 08). The observations are tabulated below in **Table 4-7**. Total of three number of exploratory bore holes BH-06, 07 & 08 has been drilled at Surge Tube and Penstock alignment, the summary is tabulated below in **Table 4-6.**

Table 4-6: Summary of exploratory core drilling

Location	Co-ordinates (X, Y, Z)	Total depth/ bedrock encountered (m)	Type of Overburden	Bedrock characteristics
BH-06 (Surge Tube alignment)	760806.551E 3052640.285N 2687.915 m	30/6	Overburden continues till 6 m of the drill depth which consists sludge, fragments of biotite gneiss and soil with clay content. The recovery varies from 20-72%. Coefficient of permeability is between 0.0025 to 0.0127 cm/s.	Bedrock consists moderately to highly weathered, stained, light grey, medium to fine-grained, moderately strong to strong, slightly to highly fractured biotite Gneiss with quartz veins and slightly to moderately weathered, Stained, reddish, light grey, fine-grained, moderately strong. Quarzitic Gneiss slightly fractured and stained along the joint. Core recovery varies from 30% to 94%. WPT varies from 9.20 to 14.68 Lugeon values and water table not encountered. Lugeon value show presence of partly open to some open discontinuities.
BH-07 (Penstock alignment)	760716.059E 3052418.731N 2588.044 m	25/6	Overburden continues till 6 m of the drill depth which consists sandy soil, soil with clay content, and fragments of biotite gneiss. The	Bedrock consists of slightly to moderately weathered, Stained, light grey, medium to fine grained, moderately strong to strong biotite

Location	Co-ordinates (X, Y, Z)	Total depth/ bedrock encountered (m)	Type of Overburden	Bedrock characteristics
			recovery varies from 14-50%. Coefficient of permeability is between 0.0048 to 0.0119 cm/s.	Gneiss fractured core pieces along foliation and joint. Core recovery varies from 64% to 100%. WPT varies from 7.39 to 12.88 Lugeon values and water table not encountered. Lugeon value show presence of partly open to some open discontinuities.
BH-08 (Penstock Junction)	760621.048E 3052523.616N 2503.389 m	20/9.5	Overburden continues till 9.5 m of the drill depth which consists sandy soil, alluvial deposits with sub-angular, angular, pebbles, cobbles size fragments and boulders of biotite and quarzitic gneiss. The recovery varies from 24-96%. Coefficient of permeability is between 0.0024 to 0.0042 cm/s.	Bedrock consists of slightly to moderately weathered, medium to fine grained, moderately strong to strong, slightly fractured along foliation, Biotite Gneiss with thick band of quartz intrusion. Core recovery varies from 46% to 100%. WPT varies from 1.64 to 12.41 Lugeon values and water table not encountered. Lugeon value show presence of tight to few partly open discontinuities.

Table 4-7: Interpretation of lithology w.r.t seismic velocity

Site Location	Seismic Line	Layer No	Velocity Range (m/sec)		Layer Thickness (m) Range		Interpreted Lithology
			From	To	From	To	
Penstock	**SRT 7**	1	500	1,000	2	18	Overburden as slope debris/River borne material
		2	1,300	2,600	5	35	Slightly compact slope debris comprising highly weathered rock fragments

Site Location	Seismic Line	Layer No	Velocity Range (m/sec)		Layer Thickness (m) Range		Interpreted Lithology
			From	To	From	To	
		3	2,800	3,100	2	10	Foliated, Jointed and slightly to moderately weathered Gneiss
		4	3,500	4,500	-		Gneiss Bedrock
	SRT 8	1	650	1,000	2	12	Overburden as slope debris/River borne material.
		2	1,250	2,250	4	28	Slightly compact slope debris comprising highly weathered rock fragments
		3	2,750	3,250	2	5	Foliated, Jointed and slightly to moderately weathered Gneiss
		4	3,600	4,500	-		Gneiss bedrock

4.4 Power House and Tail Race Channel

Power House

The proposed site for the power house complex, 39 m (L) x 20 m (B) x 26 m (H) is covered with 27 m to 28 m thick alluvial deposits comprising boulders, cobbles, gravels and silty sand, **Photo 4-12**. The power house area has been explored by two bore holes i.e. BH-09 & 10 where the geo-physical profile SRT-09 has been conducted. The summary of geological logs is provided in **Table 4-8** and summary of interpretation of geophysical profile in **Table 4-9.** The site has also been examined by three no. of plate load test viz. PLT-05, PLT-06 and PLT-07. Safe bearing capacity and laboratory test results are tabulated in **Table 3-5** and **Table 3-6** respectively.

Table 4-8: Summary of exploratory core drilling

Location	Co-ordinates (X, Y, Z)	Total depth/ bedrock encountered (m)	Type of Overburden	Bedrock characteristics
BH-09 (Power House)	760556.303E 3052375.828N 2484.465m	30/28.33	Overburden continues till 28m of the bore hole depth which consists alluvial deposits with sub- angular, angular, pebbles, cobbles size fragments and boulders of gneiss, migmatites. The recovery varies from 22-	Bedrock consists of highly fractured biotite gneiss, stained along joints, light grey, slightly to moderately weathered, medium to fine grained,

Location	Co-ordinates (X, Y, Z)	Total depth/ bedrock encountered (m)	Type of Overburden	Bedrock characteristics
			100%. Coefficient of permeability is between 0.007024 to 0.10107.	moderately strong to strong. Core recovery found to be 100%. Water Table not encountered.
BH-10 (Power House)	760552.617E 3052343.03N 2484.323m	30/27.1	Overburden continues till 28m of the bore hole depth which consists alluvial deposits with sub- angular, angular, pebbles, cobbles size fragments and boulders of gneiss, migmatites. The recovery varies from 20-98%. Coefficient of permeability is between 0.001996 to 0.009794.	Bedrock consists of fresh to slightly weathered, stained, light grey, medium to fine grained, moderately strong to strong biotite Gneiss. Core recovery found to be 28 to 60%. Water Table not encountered.

Table 4-9: Interpretation of lithology w.r.t seismic velocity

Site Location	Seismic Line	Layer No	Velocity Range (m/sec)		Layer Thickness (m) Range		Interpreted Lithology
			From	To	From	To	
Power House	**SRT 9**	1	800	1,200	6	16	Overburden as slope debris/River born material
		2	1,600	2,400	5	25	Slightly compact slope debris comprising highly weathered rock fragments to weathered in-situ bedrock
		3	3,700	5,800	-		Gneiss/Granite Bedrock

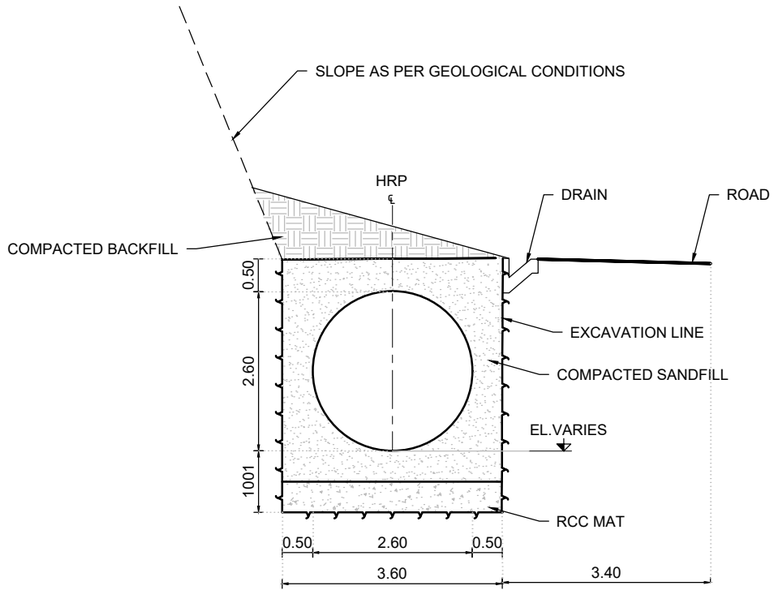
Photo 4-12: Penstock and Power House Locations

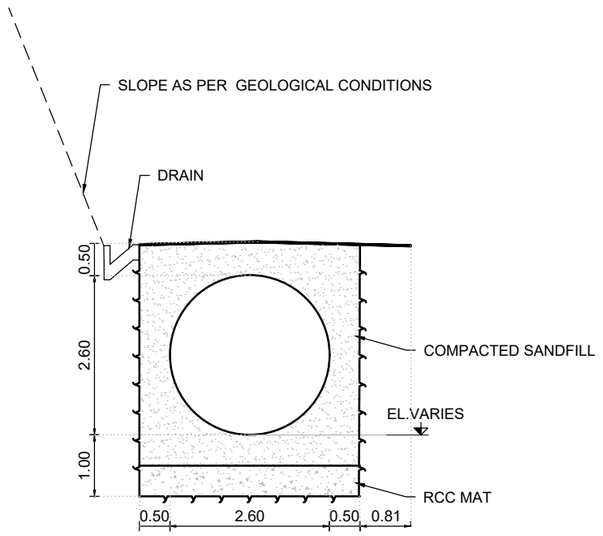
Tail Race Channel (TRC)

The geology along the 38 m long, 2 m X 1.9 m rectangular shape TRC is marked with the presence of approximately 25 m to 30 m thick alluvium consisting of boulders, gravels and pebbles of gneiss, quartzite and pegmatite of varying sizes along with loam. The topography shows moderate to gentle slope conditions.

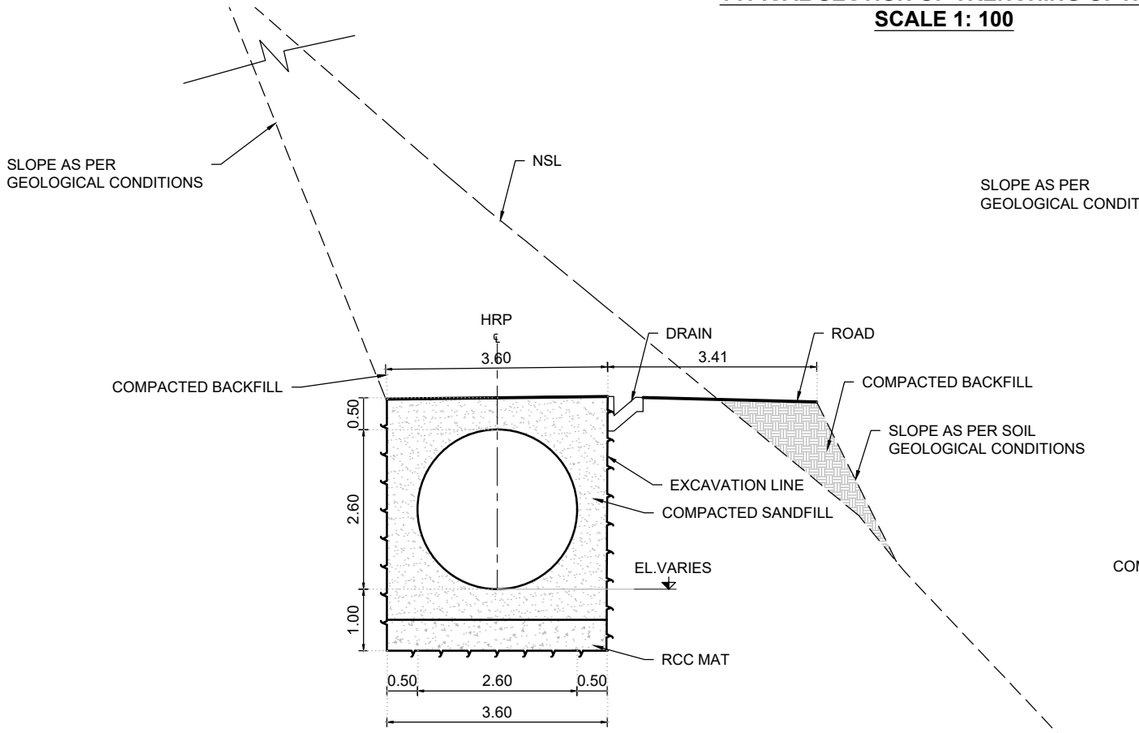
NOTES:-

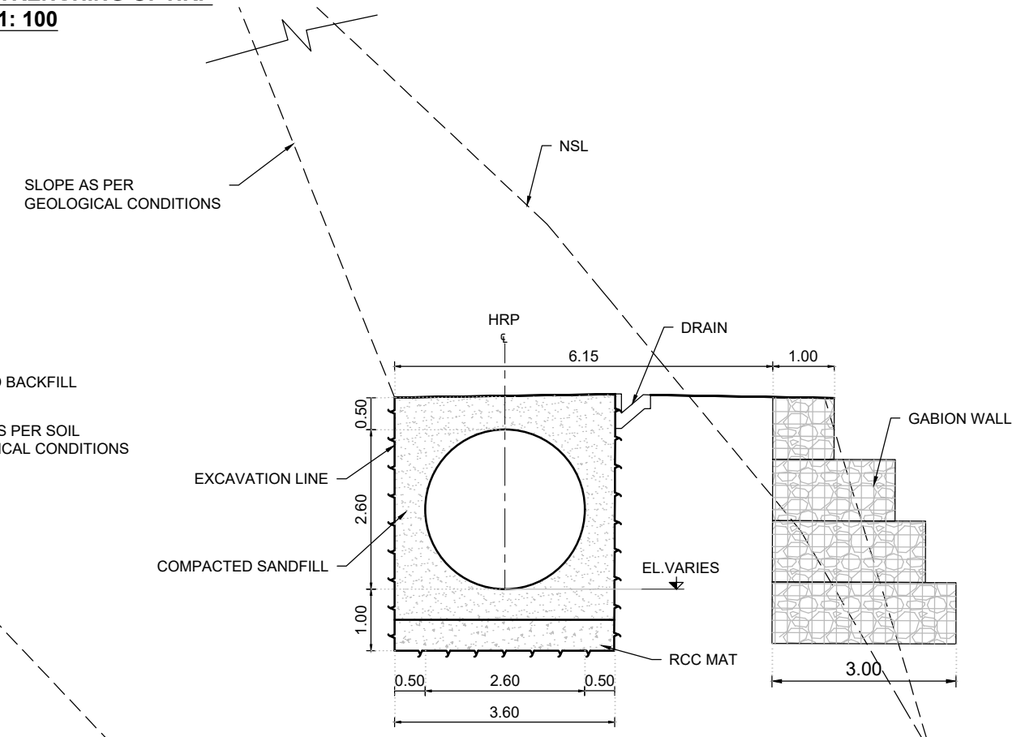
1. ALL DIMENSIONS AND LEVELS ARE IN METRES UNLESS OTHERWISE SPECIFIED.
2. NO DIMENSION SHOULD BE MEASURED FROM THE DRAWING.





TYPICAL SECTION OF TRENCHING OF HRP
SCALE 1: 100





TYPICAL SECTION OF ROAD WITH HRP
SCALE 1: 100

SCALE 1:100 1 0 1 2 3 4 5

FOR FS REPORT

Consultant: DRUK GREEN CONSULTANCY		Owner: DEPARTMENT OF ENERGY, MINISTRY OF ENERGY AND NATURAL RESOURCES	
Date: August 2023	Revised date	Project: 25 MW BEGANA INTEGRATED MULTIPURPOSE SMALL HYDROPOWER PROJECT, THIMPHU, BHUTAN	
Designed: G.Gajmer	Verified: T.Dorjee	Title: TYPICAL CROSS SECTIONS OF HEADRACE PIPE	
Reviewed: D.Singer	Approved: C.Tenzin		
Drawn: G.Gajmer	Scale: AS SHOWN	Drawing No.	
THIS DRAWING IS MEANT FOR FSR NOT TO BE USED FOR CONSTRUCTION.		BIMSHP-CD-HRP-2023-03	Rev. 0

Monthly and Annual Rainfall (mm)

Name of Station:	**Begana**	**Latitude:**	**27:34:23**
Station Number:		**Longitude:**	**89:38:33**
Type:	**Class C**	**Elevation (masl):**	**2520**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
2008	16	0	28	5	30	135	265.2	295.7	84	32	3	0	893.9
2009	0	13.5	15.5	20	172.4	100.1	349.4	396.4	104.4	42	0	0	1213.7
2010	0	0	22.2	20	87.6	386.4	323.4	232.3	82.1	21.9	0	0	1175.9
2011	0	0	0	9.5	12	120	302.6	333.6	187.2	12.2	0	0	977.1
2012	0	0	0	18	0	39.2	597.5	104.9	64.6	0	0	0	824.2
2013	0	0	0	22.2	39.4	88	302.6	145.6	11.4	128.6	0	0	737.8
2014	-	-	-	9.3	113.7	-	317.7	180.8	160.8	0	0	0	782.3
2015	22	0	38.4	69.7	19.8	182.8	224.8	166.8	56.2	2.3	0	0	782.8
2016	0	0	75.6	15.2	25	46.4	411.5	202.9	229	84.2	13	0	1102.8
2017	0	0	7.4	5	75.6	142	260.6	184	86.4	19	0	0	780
2018	1	12.4	12	32.2	65.3	120.76	180.5	250.98	90.38	6.05	0	0	771.57
2019	0	0	0	495	213.5	55.1	208.2	310.2	147.8	39.5	0	7	1476.3
2020	15	13.3	1.7	63.1	139.2	208.3	174.9	114.7	153.6	23.3	0	4	911.1
2021	0	3.2	32.6	20.7	153.2	225.1	304.2	161.6	80.5	114.7	-	0	1095.8
AVG	4.2	3.3	18.0	57.5	81.9	142.2	301.7	220.0	109.9	37.6	1.2	0.8	966.1
MAX	22	13.5	75.6	495	213.5	386.4	597.5	396.4	229	128.6	13	7	1476.3
MIN	0	0	0	5	0	39.2	174.9	104.9	11.4	0	0	0	737.8
Missing Data Are Highlighted in Yellow													