PRE FEASIBILITY STUDY REPORT

RAHI CHU HYDRO ELECTRIC PROJECT (25 MW) SIKKIM

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BACKGROUND INFORMATION

The state of Sikkim joined the Indian Union to become the 22nd state in 1975; It is one of the most picturesque regions of Asia. The bowl like, mountain –girdled state in the eastern Himalayas bordered on the west by Nepal, on the north by Tibet, on the east by Bhutan and the south by Darjeeling district of the West Bengal, lies between 270 to 280 north latitude and 880 to 890 east longitudes. Sikkim is a small hill state of India having an area of 7300 Sqkm. It is surrounded by important mountain ranges. The chola range of mountains on its east forms the watershed between it and Bhutan on one side and chumbi valley of Tibet on the other. The well-known singalila ridge is of the great Himalayas peaks. Sikkim is divided into four districts. The most populated area is the Eastern district, which contains the capital town Gangtok followed by Southern and Western districts.

The northern district is sparsely populated because of its inhospitable climate and steep ridges. Lying along the slopes of Himalayas between Tibet and plain of India, cut off from the rest of the world by mighty mountains, Sikkim's scenic beauty has no parallel in the East Sikkim's historic past, mystic religion, sublime monasteries and age old rituals have an attraction hardly to be found anywhere else in the world.

Sikkim is mountainous terrain with cliffs and valleys. Dominating both legend and landscape is the mighty massif of Khanchendzonga known to the outside world as Kanchenjunga, it is the third highest peak in the world, towering at 8550 meters. Sikkim is drained by number of Perennial Rivers. However, the two main river systems are Teesta and Rangit. All other streams eventually join one or the other. Rangit also joins the Teesta just near the border between Sikkim and West Bengal at Melli. Besides the river, there are number of lakes and hot springs which add to the beauty of the region. The important hot springs are Phut sachu, Raeong sachu, Yumthang and Momay.

TOPOGRAPHY

Geographical area of Sikkim State is about 7300 sq. km. The maximum horizontal length from north to south is about 112 Km. whereas the maximum width from east to west is 90 Km. The Tibetan Plateau on the north, Nathula and other passes on the north east, Bhutan on the south east, Darjeeling district of West Bengal on the south and Singalila range of Nepal from the boundaries of this picturesque Himalayan State. It is a hill state having no plain area. The altitude above mean sea level varies from 213m in the south to over 8500m in the northwest. The Khangchedzonga, the third highest peak in the world at an elevation of about 8550m adorns the state with its beautiful range covered with shining snow. Gangtok, the capital is about 1677m above mean sea level. The northern part of the state is cut into deep escarpments. The northern part is not populated except in Lachung and Lachen valleys. Southern Sikkim is, however, more open and fairly well cultivated.

RIVERS

The river Teesta is one of the main Himalayan Rivers, which originates in the glaciers of Sikkim at an elevation of over 8500m above mean sea level. River rises in mountainous terrain and is formed mainly by the union of two hill streams Lachen Chu and Lachung Chu at Chungthang in North Sikkim. After the confluence of Lachen Chu and Lachung chu at Chungthang, the river gradually increases in width and takes a wide flowing down to Singhik, dropping in elevation from 1550m to 750m. At Singhik, the river receives one of the its major tributaries, the Tolung chu on its right. Tolung Chu originates from the Tolung glaciers, which are the part of the Khangchendzonga range. From Singhik, the rivers flow towards Dikchu in a very deep valley and drops from 750mto 550m. From Dikchu the river flows in a big curve again down to the Singtam with a drop of about 200m. The Rongnichu, which drains the Changu lake area joins Teesta from left at Singtam and the river receives Rangpo Chu at Rangpo. After Rangpo, Teesta start widening rapidly and is joined by the great Rangit at Melli bazar on Sikkim – West Bengal border.

During monsoons the otherwise innocuous looking rivers of Sikkim become swollen, swift, muddy and dangerous. The rivers are narrow, serpentine and full of rocks and hence not navigable. With swift currents hitting rocks, the rivers are very noisy. The Teesta finally joins the Brahmaputra (Padma) in Bangladesh.

The rivers are fed by snow melting on the mountains as well as rain in the lower catchment areas during monsoon. Human settlements usually exist much above the rivers flood levels, hence life and property remain safe.

COMMUNICATION

By Air

Bagdogra is the nearest airport of Sikkim. There are regular scheduled flights operated by the Indian airlines and other private airlines between Calcutta, the capital of West Bengal and Bagdogra and also between New Delhi and Bagdogra. Jeep, taxis are available outsides Bagdogra airport for Gangtok. Gangtok is 124 kms from Bagdogra and the journey takes about 4 hours by jeep and 5 hours by bus.

By Rail /Road

The two closest railway stations to Gangtok are Siliguri junction, (Meter Gauge) which is 114km away and New Jailpaiguri (Broad Gauge), which is 125km away. A number of trains are available for Calcutta, Delhi, Guwhati and other important cities of India. Besides jeep taxis, Sikkim National Transport and other private buses ply regularly between Sikkim and Siliguri.

PROJECT PROPOSAL

The Rahi Hydro-Electric Project proposal envisaged on Rahi Rver is a run-of-river development with

(i) a diversion weir
(ii) a desilting basin on the right bank
(iii) Water conductor system on the right bank and
(iv) a powerhouse located on the left bank of the Tolung Chu upstream of its confluence with Teesta river.

LOCATION AND ACCESS TO PROJECT SITE

The project is located on river Rahi Chu, a tributary of Tolung Chu. The Location map is given in the following Figure.

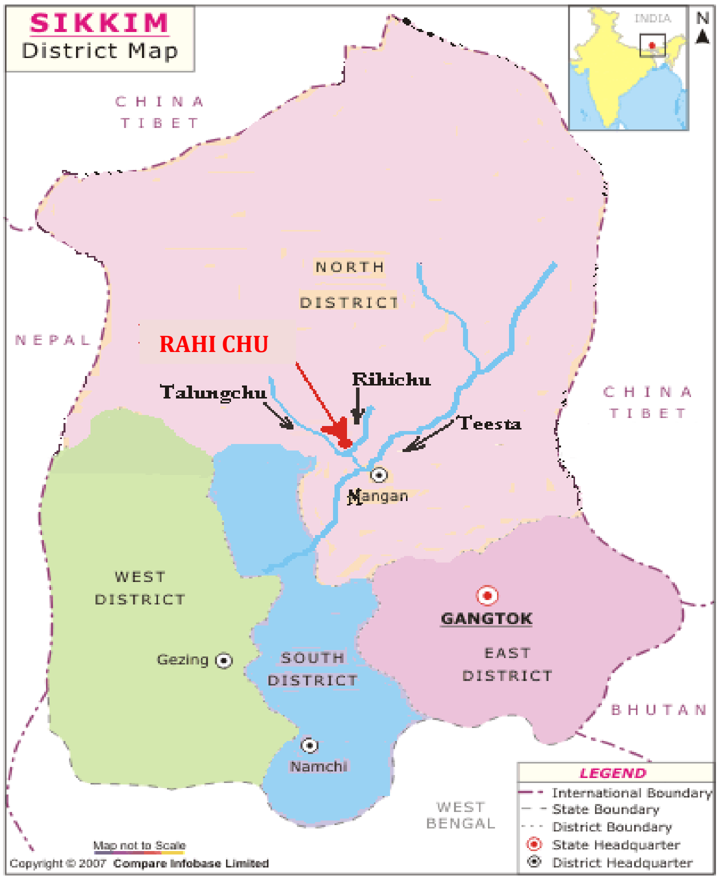


FIGURE 1: LOCATION MAP

The project site is located at about 197 km from Siliguri by road via Singtam & Mangan. Singtam is 100 km from Siliguri (on Siliguri-Gangtok NH-31A) & Singtam to Mangan is about 55 Km. The Diversion site is located at about 42 km from Mangan via Tung Bridge (on River Teesta) & Saffu village. The Diversion site is about 7 km from Saffu village on the Saffu-Sangkalan road presently under construction by BRO. Access road of about 8 Km will be required to be constructed from the Saffu-Sangkalan road to reach the Diversion site.

HYDROLOGY

Hydrological studies and the methodology adopted for establishing various parameters, which are the basic inputs for project planning and design, are presented in this Section. The hydrological analysis has been carried out to:

- Assess the availability of water for power generation i.e., establish long-term stream flow series
- Assess design floods.
- Assess sediment exclusion provisions

THE RAHI CHU BASIN

The Rahi Chu, is a tributary of Tolung Chu, which in turn is a major tributary of the Teesta. The Rahi River has its origin in the glaciers of Sikkim at an elevation of over 3660m above mean sea level. The total length of the Rahi Chu from origin to the proposed dam site is 14 Km with a very steep gradient. The Rahi Chu in general flows in a south-west direction meeting the Tolung Chu almost perpendicularly. The terrain hosts a rich growth of vegetation. Numerous valleys with cultivated terraces are seen in the catchment area. The catchment area up to the dam site is about 50 Km^2 and lies between Longitude 88°32'25"E to 88°30'55"E and Latitude 27°32'58"N to 27°31'55"N.

CLIMATE AND RAINFALL

Sikkim lies in the subtropical and temperate zone. The region is subjected to heavy rainfall due to its location in the direct path of the monsoon. There is a high degree of variation in climate and vegetation, which ranges from subtropical to alpine depending upon the altitude. Altitude is the main factor controlling the climate and weather conditions of the state. Relief features such as high mountains act as barriers for the movements of monsoon winds. Low temperatures, high rainfall on windward slopes, a comparatively dry leeward side, and heavy precipitation in the form of snow at the mountain tops are the main climatic features in Sikkim. Due to a great variation in sharp edged mountains, there is a large variation in rainfall and temperature in the state. The mean annual rainfall varies from 2,000 mm to 4,000 mm with the intensity of rain varying from drizzling showers in low altitude areas to torrential rain at higher altitudes. In the dry upper valleys of Lachung and Lachen annual rainfall is about 1,250 mm. Sikkim falls within the high rainfall zone of the country and during the monsoon, which lasts from the beginning of June to almost the middle of October, the state witnesses a very high precipitation in practically all its parts. Temperatures vary with altitude and slope aspects. The temperature usually varies from a maximum of 22º to 23º C in July and August to a minimum of 3º to 5º C in December and January, as recorded by the Meteorological Station at Gangtok.

The rainfall in the north district is comparatively less than in the other districts. Pre-monsoon rain occurs in April-May and the south-west monsoon operates normally from May and continues up to early October. Places with a moderate altitude (1000 m.a.s.l. to 3000 m.a.s.l.) have a more or less pleasant climate from March to June and September to November. The winter months of December- February are very cold. In the higher altitudes of 3000 m.a.s.l. plus, the temperature rarely rises above 15º C. Some of those places are Yakshey Lodge above Lachung, Yumthang valley, Tsango Lake and Dzongri where heavy snowfall occurs during the winter months. Tsango and Yakshey sometimes receive snowfall even during April to mid-November. The mean temperature in the lower altitudinal zone varies from 1.5º to 9.5º C.

Temperature varies with altitude and slope. The maximum temperature is recorded usually during July and August and minimum during December and January. Fog is a common feature in the entire state from May to September. An examination of available rainfall data shows that the mean annual rainfall is minimum at Thangu (82 mm) and maximum at Gangtok (3579 mm). The location of various raingauge and G&D stations has been shown in Figure 5.3 at the end of this section. An isohyetal analysis of these data reveals that there are two maximum rainfall areas:

(i) South-East quadrant, including Mangan, Singhik, Dikchu, Gangtok, Rongli etc.
(ii) South-West corner including Hilly.

Rainfall is heavy and well distributed during the months from May to early October. July is the wettest month in most of the places. The intensity of rainfall during the South-West monsoon season decreases from South to North, while the distribution of winter rainfall is in the opposite direction. The highest annual rainfall for individual stations may exceed 5000 mm and the average number of rainy days (days with rain of 2.5 mm or more) ranges from 100 at Thangu to 184 at Gangtok.

In between the above two regions, there is a low rainfall region e.g. Namchi, where rainfall is about half of that in the former areas. There is an area in North-West Sikkim which receives very little rainfall (even less than 4.9 mm.). This area comprising mainly snow - covered mountains.

PRECIPITATION

There are ten rain gauge stations in and around the project region viz. at Sankalang, Singhik, Yoksum, Pelling Gezing, Dikchu, Lachung, Lachen, Chungthang and Gangtok. Monthly and annual normals based on data of these stations are given in the following Table. Sankalang is the nearest station to the dam site and all stations are outside the catchment.

Month	Sankalang	Singhik	Yoksum	Pelling	Gezing	Dikchu	Lachung	Lachen	Chungthang	Gangtok
	(6 yrs)	(9 yr)	(6 yrs)	(3 yrs)	(14 yrs)	(8 yrs)	(10 yrs)	(9 yrs)	(21 yrs)	(22 yrs)
January	82	95	34	36	13	22	15	71	36	40
February	165	177	22	47	16	71	63	148	122	50
March	241	347	53	90	55	133	186	200	194	127
April	200	296	110	67	108	181	220	116	234	271
May	372	495	198	308	190	440	207	167	293	535
June	578	512	350	465	428	475	333	291	411	650
July	499	942	551	436	462	465	303	265	424	666
August	370	648	489	458	425	360	284	297	412	578
September	354	623	567	363	408	307	220	200	318	429
October	199	205	189	173	162	157	123	155	131	180
November	35	85	65	78	16	34	16	58	37	36
December	34	45	14	9	21	48	10	25	32	17
Annual	3129	4470	2642	2530	2304	2693	1980	1993	2644	3579
Monsoon(May – Oct)	2372	3425	2344	2203	2075	2204	1470	1375	1989	3038
Non-Monsoon(Nov-Apr)	757	1045	298	327	229	489	510	618	655	541

TABLE 1 : PRECIPITATION

SEASONAL DISTRIBUTION

Geography, precipitation and temperature in the Himalayas are the main factors influencing the snowfall, its accumulation and melting. The pattern of precipitation occurring in the Himalayan region indicates seasonality with four distinct seasons.

a. Snow Accumulation Season (Dec – Feb)

Precipitation during this season is caused by a series of western disturbances crossing into North India. These disturbances, remaining at high latitudes, do not ordinarily influence the Himalayas. Their influence is felt only when they come to lower latitude as the season advances, reaching the lowest position of 24º N latitude in January. After February they normally go back to their original position beyond the Himalayan ranges. Precipitation caused intermittently by the westerlies is small as the tracks of disturbances are far removed from the sea. It is generally in the form of snow at the adjoining plains. The Himalayan ranges receive most of the annual snowfall during this season. The precipitation in this season decreases from West to East until they reach the Sikkim mountains. From there, precipitation increases with the availability of additional moisture due to the proximity of the sea. The stream flow during this season is due to the contribution of groundwater supplemented by runoff from rain and snow melt from lower hill ranges.

b. Snowmelt Season (Mar – May/Jun)

Temperatures over the Himalayas start rising and the snow begins to melt in March. Most of the winter snow-cover is melted away during this season. Precipitation is generally in the form of rain and snow in the higher altitude zones. Contribution to stream flow is from snow melt as well as rain in addition to ground water.

c. Monsoon Season (Jun – Jul/Sep)

Very moist air currents from the Bay of Bengal get deflected westwards by the eastern Himalayas. While they travel along the Himalayas, copious precipitation in the form of rain occurs with its magnitude decreasing from east to west. During this season, rivers are in flood. Snow and glaciers at high altitudes continue to melt but their contribution forms an insignificant fraction of total river flows.

d. Post-Monsoon Season (Oct – Nov)

Clear weather prevails in this season with little or no precipitation. The river flows are entirely due to ground water depletion. It is observed that, for hydroelectric power development, catchments in Sikkim and Arunachal are better placed than the catchments in the other Himalayan mountain regions and a higher runoff per Km^2 of catchment in Sikkim can be expected.

TEMPERATURE AND HUMIDITY

Most of the inhabited regions of Sikkim enjoy a temperate climate with temperatures rarely exceeding 28° C in summer or dropping below 0° C in winter. The state enjoys five seasons: Winter, Summer, Spring, Autumn and a monsoon season (June to September). The average annual temperature for most of Sikkim is around 18° C. Sikkim is one of the few states in India to receive regular rainfall. During the monsoon months the state is lashed by heavy rains. The state record for the longest period of non-stop rain is 11 days. In the northern region, because of high altitude, temperatures drop below - 40^{o} C in winter. Fog also affects many parts of the state during winter and the monsoons, making transportation extremely perilous. There is no temperature record available at the dam site. Records available for the Gangtok (Sikkim) and Kalimpong (West Bengal) stations are situated outside the catchment area.

The mean temperatures over major part of the project basin vary and are estimated to be:

13.2º C in winter season (January),
22.1º C during summer (April),
23.9º C in rainy season (July), and
20.5º C towards end of monsoon (October).

The relative humidity is generally high in the monsoon season, being over 80%. In the post-monsoon and in winter season, the humidity is less. The summer is generally the driest part of the year.

WATER AVAILABILITY STUDY

No G&D data of Rahi Chu at the proposed diversion site is available.

Stream flow records (10-daily) of the Tolung Chu at the Sankalang gauge site (Catchment Area = 777 Km^2) are available for the period May 1990 – Apr 2004). These series were checked for consistency and, after eliminating obvious inconsistencies, a reasonable series was derived for Panan HE Project envisaged on Tolung Chu (Catchment Area = 592 Km^2).

The flow series for the Panan Hydro-Electric Project was generated by applying a reduction factor of 0.89the observed stream flow series at Sankalang (1991-91 to 2003-04) with an annual runoff of 4140 mm by applying, thus arriving at 3684 mm.

Assuming that the stream flow is proportional to the catchment area, stream flow (10-daily) for the Rahi diversion site (50 Km^2) have been developed, and 10-daily stream flow series thus obtained are given at the end of this Section.

It is considered prudent to adopt the 10-daily stream flow data for the power planning studies of the Rahi Chu Hydro-Electric Project on the basis of annual flows, using the Weibull distribution. The Years 1997-98 and 1999-2000 have been identified as the 50% and 90% dependable years, respectively. The discharge during the 50% and 90% dependable year are tabulated below:

TABLE 2: 90% & 50% DEPENDABLE YEAR FLOW

10-daily period		50% dependable	90% dependable
		May 1997-April 1998	May 1999-April 2000
Month	**Order of 10-daily**	**Average Discharge (m^3/s)**	**Average Discharge (m^3/s)**
May	I	3.57	2.16
	II	3.65	2.14
	III	4.12	6.63
Jun	I	5.75	4.3
	II	10.7	8.84
	III	13.46	12.67
July	I	13.75	11.36
	II	11.56	8.27
	III	9.55	10.89
Aug	I	10.48	7.86
	II	13.41	10.86
	III	6.31	12.03
Sep	I	9.2	8.67
	II	12.66	6.79
	III	11.09	6.27
Oct	I	6.45	6.32
	II	4.55	7.98
	III	3.38	5.06
Nov	I	2.83	3.02
	II	2.77	2.48
	III	2.65	2.02
Dec	I	2.39	2.36
	II	2.23	2.54
	III	1.8	1.93
Jan	I	1.43	1.09
	II	1.21	1.07
	III	1.13	1.23
Feb	I	1.22	1.24
	II	1.52	1.33
	III	1.53	1.35
March	I	1.73	1.47
	II	1.59	1.72
	III	2.36	2.13
Apr	I	1.94	3.23
	II	2.07	2.9
	III	3.18	3.74

The flow pattern during 90% and 50% dependable year flow is plotted below:

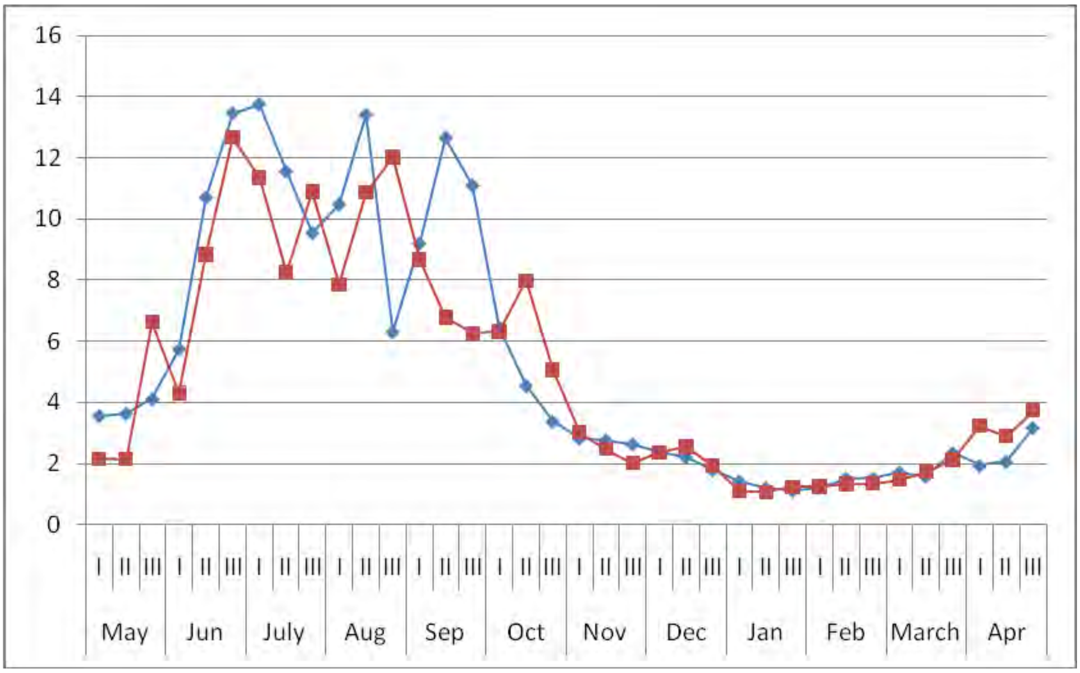


FIGURE 2 : 90% & 50% DEP YEAR FLOW PATTERN

The various parameters of the 50% and 90% dependable year are placed below:

TABLE 3: FLOW PARAMETERS OF 90% & 50% DEP YEAR

Annual Flow (10^6 cum)	137.59MCM	163.48 MCM
Maximum Flow (m^3/s)	12.67	13.75
Minimum Flow (m^3/s)	1.07	1.13
Average lean flow (m^3/s)	2.07	1.85

10 - daily Period		Average Discharge (Cumecs)													
		1990-1991	1991-1992	1992-1993	1993-1994	1994-1995	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004
May	I	5.23	5.94	3.74	4.68	5.22	6.97	5.34	3.57	4.35	2.16	3.54	5.27	3.65	3.84
	II	8.24	5.43	5.09	4.91	4.63	11.53	5.75	3.65	4.03	2.14	5.04	5.75	6.20	3.95
	III	7.17	7.67	4.21	5.07	6.17	11.69	7.83	4.12	6.49	6.63	7.46	8.26	9.17	5.74
June	I	15.26	9.09	4.74	8.60	8.08	10.22	8.82	5.75	7.90	4.30	6.83	12.49	9.91	12.19
	II	14.31	14.78	4.90	7.33	8.80	14.80	8.92	10.70	7.70	8.84	10.80	11.54	12.99	11.08
	III	14.90	15.52	9.86	9.76	9.56	13.30	15.67	13.46	14.34	12.67	11.38	12.98	13.72	14.52
July	I	15.19	18.52	11.34	8.41	7.81	16.74	15.72	13.75	17.95	11.36	16.36	14.28	15.09	17.87
	II	22.15	17.89	9.88	9.12	7.72	15.97	18.19	11.56	13.53	8.27	9.71	13.66	16.01	18.08
	III	17.51	12.00	12.43	14.50	9.61	13.85	17.28	9.55	18.97	10.89	29.65	15.32	17.81	15.65
August	I	13.93	20.90	10.59	12.88	7.89	14.61	14.33	10.48	16.51	7.86	15.98	13.19	14.12	13.23
	II	20.27	19.15	9.36	9.79	9.12	12.18	14.05	13.41	15.26	10.86	12.30	18.84	12.71	12.85
	III	11.06	12.83	11.63	9.96	9.47	14.25	13.00	6.31	20.73	12.03	9.56	17.29	12.03	12.35
September	I	11.78	14.49	8.16	9.47	8.68	10.53	14.15	9.20	14.56	8.67	21.83	12.60	9.28	11.55
	II	11.02	9.28	10.26	8.24	9.03	10.80	12.13	12.66	8.08	6.79	6.44	11.19	7.81	12.78
	III	15.98	8.36	4.79	7.95	7.60	12.29	10.11	11.09	7.11	6.27	6.26	9.56	6.14	9.21
October	I	11.23	7.56	5.49	6.52	5.44	8.82	9.87	6.45	6.87	6.32	3.88	15.17	5.13	6.54
	II	8.07	6.04	5.55	7.07	4.18	7.68	7.24	4.55	7.24	7.98	3.34	10.53	5.22	6.86
	III	5.40	4.65	4.59	4.48	3.02	5.89	5.53	3.38	4.01	5.06	6.47	5.21	4.30	5.83
November	I	3.99	3.62	3.31	3.11	2.74	6.03	3.46	2.83	1.99	3.02	1.71	4.48	3.21	3.86
	II	3.15	3.01	2.46	2.77	2.44	5.18	2.78	2.77	2.65	2.48	1.53	3.05	2.79	3.12
	III	2.39	2.46	2.04	2.44	1.96	2.68	2.55	2.65	2.32	2.02	1.21	2.43	2.50	2.82
December	I	2.24	2.33	1.91	2.06	1.62	2.35	2.24	2.39	2.06	2.36	0.93	6.39	1.93	2.36
	II	1.98	2.18	1.79	1.88	1.58	2.00	2.00	2.23	1.94	2.54	0.78	10.98	1.67	2.03
	III	1.91	2.30	1.60	1.73	1.42	2.01	1.83	1.80	1.76	1.93	0.77	4.69	1.54	1.83
January	I	1.93	1.73	1.58	1.57	1.46	1.91	1.78	1.43	1.82	1.09	0.73	1.65	1.57	1.69

	II	1.82	1.82	1.64	1.49	1.58	1.88	1.70	1.21	1.06	1.07	0.63	1.81	1.35	1.50
	III	1.87	1.74	1.54	1.52	1.63	1.79	1.74	1.13	1.00	1.23	0.62	2.29	1.06	2.01
February	I	2.04	1.93	1.67	1.57	1.46	2.04	1.85	1.22	1.01	1.24	0.82	2.05	1.23	2.00
	II	2.15	1.70	1.87	1.85	3.04	1.99	1.66	1.52	1.04	1.33	0.78	2.36	1.57	2.12
	III	2.90	1.73	1.74	1.92	3.63	2.10	1.83	1.53	1.25	1.35	0.82	2.60	1.79	2.16
March	I	2.67	2.31	1.83	2.29	3.78	2.35	2.28	1.73	1.20	1.47	1.27	2.79	1.80	2.51
	II	3.12	2.94	1.85	2.93	3.35	3.21	3.38	1.59	1.21	1.72	2.14	2.98	2.03	2.24
	III	3.23	3.80	2.46	2.83	5.04	2.95	3.50	2.36	1.37	2.13	2.63	3.57	2.52	3.25
April	I	4.47	3.48	2.59	3.58	3.21	2.69	2.89	1.94	1.75	3.23	3.06	3.66	3.26	2.90
	II	3.85	4.10	2.92	2.90	4.69	3.22	3.00	2.07	1.83	2.90	3.46	3.89	3.41	4.52
	III	3.85	3.36	3.13	3.08	6.15	4.22	3.45	3.18	3.11	3.74	4.01	4.45	5.15	3.94
Annual Flow (MCM)		**244.07**	**221.73**	**150.80**	**164.38**	**157.94**	**226.99**	**214.14**	**163.48**	**194.11**	**137.59**	**138.69**	**223.45**	**140.40**	**157.59**

DESIGN FLOOD ASSESSMENT

The design flood assessment involves the computation of a set of design floods of various return periods ranging from 10 years to the Probable Maximum Flood (PMF) through either the frequency analysis of flood series or through a hydro-meteorological approach using rainfall storm parameters provided by meteorological data and flood discharge records from river gauging units.

The selection of the design flood involves the prescription of a decisive value of characteristic feature/features of flood events for dimensioning of the hydraulic structure to ensure the desired level of safety commensurate with the economic and social objectives and limitations of the data and technology available.

The flood recommended for the Panan HE Project has been considered for estimation of Design Flood at Rahi Chu HE Project. The recommendations made in the Panan HEP are - spillway may be designed to safely pass the SPF/500-yr flood of 1690 m^3/s and adequate freeboard may be provided to ensure that the dam is not over-topped during PMF of 2250 m^3/s.

Pending detailed analysis at this stage, the design flood of Rahi Chu HE Project is estimated applying empirical relations as mentioned herein under:

- **Dicken's Formula**

  $Q = CA^{3/4}$

  Where C = Dicken's constatnt with values ranging from 11 – 14 for North Indian Hilly catchment. A value of 14 has been adopted in the present study

  Q = 302 cumec

- **Ali Nawab Jung Formula**

  $Q = C(0.386A)^{(0.925-1/14\log A)}$ C = 55

  Q = 887 cumec
- **Computation through transposition of Panan Flood.**

  The flood recommended for the Panan HE Project has been considered for estimation of Design Flood at Rahi Chu HE Project. The recommendations made in the Panan HEP are - spillway may be designed to safely pass the SPF/500-yr flood of 1690 m^3/s and adequate freeboard may be provided to ensure that the dam is not over-topped during PMF of 2250 m^3/s.

  The above flood values are transposed at Rahi Chu Diversion site using Dicken's formula and the design flood so estimated are as under:

  SPF/500 yr. return period flood : 304 cumec
  PMF : 404 cumec

- **Fuller's Formula**

  $Q_{max} = C \times A^{0.8} \times (1+0.8 \log T) \times (1+2.66A^{-0.3})$

  Q max for T_{100} = 401 cumec

Comparison of various flood values obtained by various methods:

Sl. No.	Method used	Design Flood (cumec)
1	Dicken's Formula	302 m^3/s
2	Ali Nawab Jung Formula	887 m^3/s
3	Transposition of Panan Flood	304 m^3/s
4	Fuller's Formula	401 m^3/s

For pre-feasibility study, a **design flood of 400 cumec** is considered.

POWER POTENTIAL STUDY

DETERMINATION OF 90% AND 50% DEPENDABLE YEARS

As a first step in energy calculations and optimization studies, the 90% and 50% dependable years are determined from the derived flow series. Method recommended by CEA in their Manual on Best Practices in Hydro Power Engineering, has been used to this effect. As per this manual, the 90% dependable year is defined as the year in which the annual generation has the probability of being equal to or higher than 90% during the expected period of operation of the scheme.

Thus, for determining 90% and 50% dependable years in the present case, annual energy generation for all the 14 hydraulic years (1990-2004) has been computed with unrestricted installed capacity.

BASIC DATA AND ASSUMPTIONS FOR CALCULATION

The following data and assumptions are used in the calculations:

I. **Full Reservoir Level:** Full reservoir level for the project has been fixed at 1259.0 m.

II. **Minimum Drawdown Level:** Minimum drawdown level for the barrage has been fixed at 1255.0 m. This is based on various civil engineering considerations at the selected barrage site.

III. **Tail water Level:** Normal tail water level (all units running) = 820 m

IV. **Head Losses:** Detailed calculations for head loss computation has not been made at this pre-feasibility stage. Pending detailed assessment, a head loss of 10m is considered for power potential assessment.

V. **Design Head :** Given the fact that the reservoir will be spilling in several months of the year, and that on average 80% of the flow will be passed during the monsoon when the reservoir will be at or above FRL, the rated head was calculated as per the following:

Calculation of design head for power potential study is based on the following levels:

$$H_{net} = \left\lfloor 0.8FRL + 0.2\left(\frac{2}{3}(FRL - MDDL)\right) + MDDL \right\rfloor - \Sigma Losses - TWL$$

Full reservoir level, FRL	=	1259.0 m
Minimum drawdown level, MDDL	=	1255.0 m
Normal tail water level, NTWL	=	820.0 m

Gross Head = Average Reservoir Level – Normal Tail Water Level =438.7 m

Net Head = Gross Head – Head Losses = 428.7 m

VI. **Overall plant efficiency:** Considering the head available for power generation, Pelton wheel turbines appear to be the suitable choice at the Project. The following efficiencies applicable for Pelton wheel turbine driven generating units have been considered:

Efficiency of turbine	:	91.0%
Efficiency of generator	:	98.0%
Overall plant efficiency	:	89.2%

VII. **Riparian Flow:** Conforming to the environmental requirements, minimum riparian or ecological flow is considered for release into the river at all times. In the present study, a minimum flow of 15 % of minimum lean discharge is considered as riparian flow throughout the year.

RESULTS

Annual inflows computed have been tabulated in the following table. The 90% and 50% dependable years have been determined on the following basis:

90% Dependable Year: (N+1) x 0.9
50% Dependable Year: (N+1) x0.5

where N is the number of years for which the flow series is considered

In the present case, N=12 and

The 90% Dependable Year: = (14+1) x 0.9 = 14th year.
The 50% Dependable Year: = (14+1) x 0.5 = 8th year.

Based on the above, year 1999-2000 and year 1997-98 have been determined as the 90% and 50% dependable years.

Table-4: Derivation of 90% and 50% Dependable Years

Sl.no	Y E A R			Annual Inflow in M.Cum	Arranged in descending order	% dependability			
1	1990	-	1991	244.07	244.07	6.67	1990	-	1991
2	1991		1992	221.73	226.99	13.33	1995	-	1996
3	1992		1993	150.8	223.45	20.00	2001	-	2002
4	1993		1994	164.38	221.73	26.67	1991	-	1992
5	1994		1995	157.94	214.14	33.33	1996	-	1997
6	1995		1996	226.99	194.11	40.00	1998	-	1999
7	1996		1997	214.14	164.38	46.67	1993	-	1994
8	1997		1998	163.48	163.48	53.33	1997	-	1998
9	1998		1999	194.11	157.94	60.00	1994	-	1995
10	1999	-	2000	137.59	157.59	66.67	2003	-	2004
11	2000		2001	138.69	150.80	73.33	1992	-	1993
12	2001		2002	223.45	140.40	80.00	2002	-	2003
13	2002		2003	140.4	138.69	86.67	2000	-	2001
14	2003		2004	157.59	137.59	93.33	1999	-	2000

DETERMINATION OF THE INSTALLED CAPACITY

The following criteria have been used for determination of the installed capacity:

a) Criterion based on annual energy generation: In this case, ratio of incremental energy to incremental installed capacity should be such that optimal design energy is obtained.
b) Criterion based on peaking energy: In this case, the installed capacity is determined keeping in view the operation of the plant as peaking station

INCREMENTAL ENERGY TO INCREMENTAL INSTALLED CAPACITY (ΔKWH/ΔKW)

One of the most commonly used criterion for optimization of the installed capacity is based on the analysis of incremental energy that is generated with a unit increase in the installed capacity. Although this criterion does not use any economic or financial parameters, it gives a good idea about the "beneficial" installed capacity above which the incremental energy benefits cease to be attractive. A wide range of installed capacity is studied using this criterion and finally installed capacity beyond which incremental energy benefits cease to be attractive is selected.

In this optimization study, energy generation with different installed capacities ranging from 19 MW to 31 MW is analyzed. The energy computations are done for the 90% dependable year and the installed capacities are increased in steps of 2 MW. In each case, gross energy which could be generated in the 90% dependable year with full installed capacity of the generating station is computed.

The results are summarized in Table-2.

Incremental Energy benefits in a 90% Dependable Year

Installed Capacity	Gross Annual Energy- MU	Annual Load Factor - %	Lean Flow Load Factor- % Dec- apr	kWh/kW	δkWh/δ kW	Incremental Energy - MU
19 MW	102.12	61.30	44.55	5374		0
21 MW	108.64	59.05	41.64	5627	3260	6.52
23 MW	115.16	57.15	38.02	5366	3260	6.52
25 MW	121.07	55.28	35.55	5114	2955	5.91
27 MW	125.87	53.21	32.90	4890	2400	4.80
29 MW	130.52	51.37	48.93	4697	2325	4.65
31 MW	134.75	49.55	44.15	4530	2125	4.23

The following parameters are derived from these results and are tabulated in Table-2

- The annual gross energy generation (kWh) for each installed capacity considered,
- The incremental energy generation (**δ**kWh) as the installed capacity is changed; and
- The ratio of incremental energy to incremental installed capacity (**δ**kWh/**δ**kW)

The ratio of incremental energy to incremental installed capacity (**δ**kWh/**δ**kW) is plotted against the installed capacities in Figure-1 and the incremental energy for each 2 MW change in the installed capacity is plotted in Figure-2.

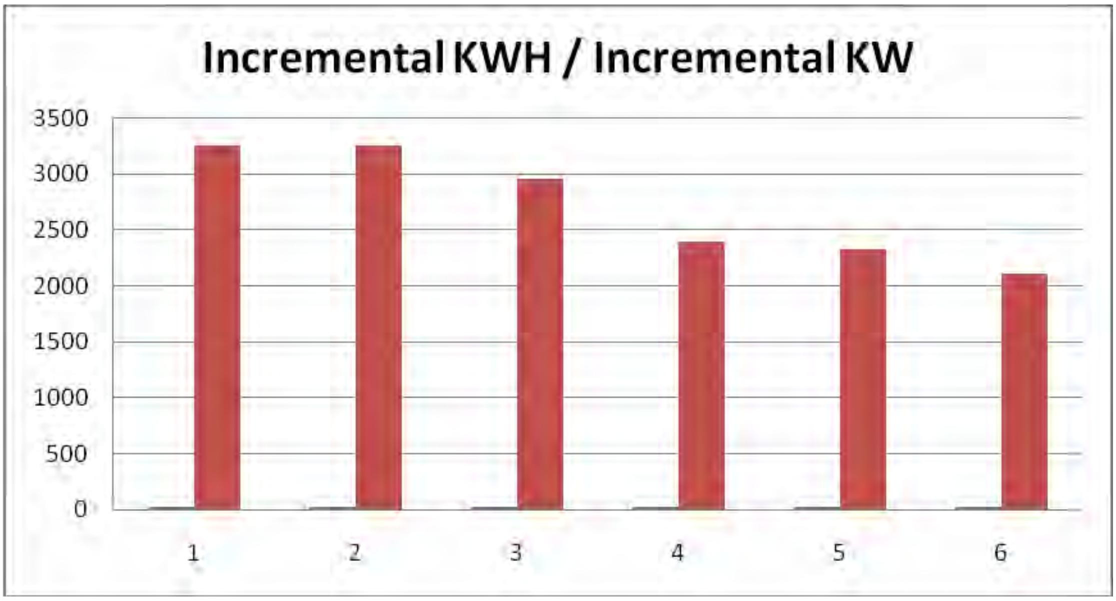


Figure-3: Installed Capacity Vs. δkWh /δkW

LEGEND:

(1) 19 to 21 (2) 21 to 23 (3) 23 to 25(4) 25 to 27(5) 27 to 29(6) 29 to 31- ALL in MW

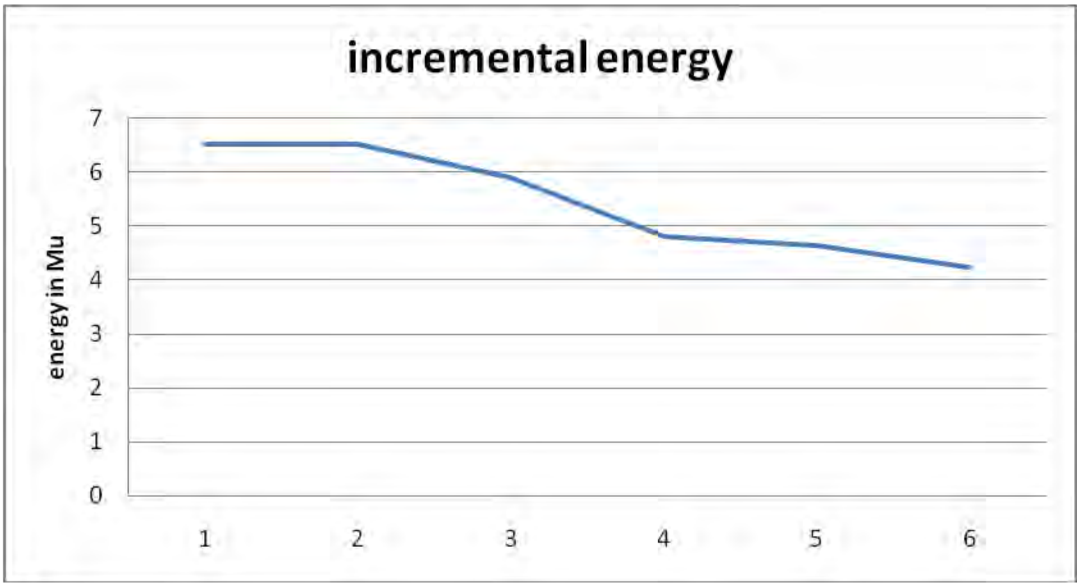


Table 6 : Energy Generation in 90% Dependable Year IC= 25 MW

Month		No. of Days	River Inflow m³/sec	Riparian flow m³/sec	Flow After Riparian losses m³/sec	Net inflow available for generation m³/sec	Design Discharge Q' (m³/sec)	Peaking Energy Generation (MU)	Non-Peaking Energy Generation (MU)	Total Energy (at 95% Plant availability) (MU)
	1	10	4.3	0.30	4.00	4.00	6.33	0.95	2.65	3.60
	11	10	8.84	0.30	8.54	6.33	6.33	0.95	4.75	5.70
Jun	21	10	12.67	0.30	12.37	6.33	6.33	0.95	4.75	5.70
	1	10	11.36	0.30	11.06	6.33	6.33	0.95	4.75	5.70
	11	10	8.27	0.30	7.97	6.33	6.33	0.95	4.75	5.70
Jul	21	11	10.89	0.30	10.59	6.33	6.33	1.05	5.23	6.27
	1	10	7.86	0.30	7.56	6.33	6.33	0.95	4.75	5.70
	11	10	10.86	0.30	10.56	6.33	6.33	0.95	4.75	5.70
Aug	21	11	12.03	0.30	11.73	6.33	6.33	1.05	5.23	6.27
	1	10	8.67	0.30	8.37	6.33	6.33	0.95	4.75	5.70
	11	10	6.79	0.30	6.49	6.33	6.33	0.95	4.75	5.70
Sep	21	10	6.27	0.30	5.97	5.97	6.33	0.95	4.42	5.37
	1	10	6.32	0.30	6.02	6.02	6.33	0.95	4.47	5.42
	11	10	7.98	0.30	7.68	6.33	6.33	0.95	4.75	5.70
Oct	21	11	5.06	0.30	4.76	4.76	6.33	1.05	3.67	4.71
	1	10	3.02	0.30	2.72	2.72	6.33	0.95	1.50	2.45
	11	10	2.48	0.30	2.18	2.18	6.33	0.95	1.01	1.96
Nov	21	10	2.02	0.30	1.72	1.72	6.33	0.95	0.60	1.55
	1	10	2.36	0.30	2.06	2.06	6.33	0.95	0.90	1.85
	11	10	2.54	0.30	2.24	2.24	6.33	0.95	1.07	2.02
Dec	21	11	1.93	0.30	1.63	1.63	6.33	1.05	0.57	1.61
	1	10	1.09	0.30	0.79	0.79	6.33	0.71	0.00	0.71
	11	10	1.07	0.30	0.77	0.77	6.33	0.69	0.00	0.69
Jan	21	11	1.23	0.30	0.93	0.93	6.33	0.92	0.00	0.92
	1	10	1.24	0.30	0.94	0.94	6.33	0.85	0.00	0.85
	11	10	1.33	0.30	1.03	1.03	6.33	0.93	0.00	0.93
Feb	21	8	1.35	0.30	1.05	1.05	6.33	0.76	0.00	0.76
	1	10	1.47	0.30	1.17	1.17	6.33	0.95	0.10	1.05
	11	10	1.72	0.30	1.42	1.42	6.33	0.95	0.33	1.28
Mar	21	11	2.13	0.30	1.83	1.83	6.33	1.05	0.77	1.81
Apr	1	10	3.23	0.30	2.93	2.93	6.33	0.95	1.69	2.64

	11	10	2.9	0.30	2.60	2.60	6.33	0.95	1.39	2.34
	21	10	3.74	0.30	3.44	3.44	6.33	0.95	2.15	3.10
	1	10	2.16	0.30	1.86	1.86	6.33	0.95	0.72	1.67
	11	10	2.14	0.30	1.84	1.84	6.33	0.95	0.71	1.66
May	21	11	6.63	0.30	6.33	6.33	6.33	1.05	5.22	6.27
							Total	**33.93**	**87.14**	**121.07**

Figure-4: Incremental Energy Vs. Installed Capacity

A perusal of the results of the incremental energy study indicates that 25MW appears to be the possible threshold beneficial value for the installed capacity at the project.

FINAL CHOICE OF INSTALLED CAPACITY

It is inferred from the studies carried out above that:

(i) On the basis of incremental energy benefits i.e. the energy that could be generated in the 90% dependable year with full installed capacity of the generating station, the installed capacity of the Rahi Chu Hydro Electric project could be 25MW ;

The installed capacity at Rahi Chu HE Project is, therefore, proposed to be 25 MW. and the corresponding design discharge is 6.33cumec. This will ensure a generation of 124 MU (121.07 MU at 95% plant availability with an annual PLF of 55.28 %. The lean period PLF of 35.53 % is also reasonable.

NUMBER OF GENERATING UNITS

The following factors have been taken into consideration for arriving at the unit sizes.

(i) Units of same size should be provided to minimize costs through multiplicity of units, reduce inventory of spare parts & special tools required for operation and maintenance and ease of interchangeability.

(ii) The units should be as large as possible to obtain the benefits of scales but on the other hand the penstocks, turbines and generators should not be so large that their components cannot be transported and assembled at site.

(iii) The Pelton turbines should not be so large that they have to run at low efficiencies for a large period of time. For better performance the firm power should be at least 40% of the capacity of one unit or in other words unit size should not far exceed twice the figure of average firm power during the lean period from Dec-Feb.

Keeping in view the above factors and for flexibility in operation and maintenance as well as limitations on transportation of equipment in hilly terrain, 3 units of 14 MW each, are proposed to be provided.

GEOLOGY

GENERAL

The geological classification and stratigraphic position of the rock units of the Sikkim Himalayas are still a matter of academic debate, evaluation and re-evaluation, because of their tectonic complexity, polyphase metamorphism and unfossiliferous nature of most of the lithounits (older ups are overlain by younger groups).The geological formations from south to north are disposed in reverse tectonic order. In the northern part of the state, the rocks have been tectonostratigraphically differentiated in three belts viz, inner belt, axial belt and trans-axial belt. The state of Sikkim is mostly covered by Proterozoic-Precambrian metamorphic rocks of low to medium grade (Daling Group), high grade Gneisses (Darjeeling Gneiss and Kanchanjunga Gneiss), Chunthang formation (Quartzite, Calc-Silicate rocks, Marbles, Graphite Schist and occasionally Amphibolites) with intrusive Granites (Lingtse Granite Gneiss) and Phanerezoic rocks including Gondwana and Tethyan rocks. There is also a fossiliferous Palaeozoic and Mesozoic (Tethyan) sequence of north-eastern part of Sikkim. The Gondwana Group of Permian age contains Sandstone, Shale and Carbonaceous Shale with occasionally thin bands of coal and pebbly shale horizons.

The Daling Group of rocks has been classified into three formations:

(i) Gorubathan Formation: characterized by Quartz-Chlorite-Sericite Schists, Phyllites and Quartzites.

(ii) Reyang Formation: characterized by Quartzites occasionally Calcareous, Phyllites interbanded with Carbonaceous Slate and

(iii) Buxa Formation: characterized by the presence of Dolomite Limestone-occasionally interbanded with Phyllites.

The Darjeeling Group comprises medium to high grade metamorphic rocks namely Migmatized Gneisses, Kyanite-Sillimonite Schists and Gneisses; Kyanite, Staurolite Gneisses, Garnet Schists with bands of Amphibolite. The Staurolite-Garnet and Garnet Schist forms the lower member of the Darjeeling Formation showing effects of shearing and mylonisation and depict retrogression and inverted metamorphism.

The Chungtang Formation is highly deformed metamorphic rocks consisting of Calc-Quartzite, Calc Silicates, Marble Graphite Schists, Calc Granulites and Gneisses.

A streaky, sheared Granite Gneiss known as ‘Lingtse Gneiss’ occurs as a NE-SW trending strip of rocks. It forms a general line of separation between the Daling and the high-grade Darjeeling Gneiss. However, some bands of this streaky Gneisses are seen within the Darling Formations. The Tethyan sediments are exposed in the north district of Sikkim and are represented by Everest Phyllite series (shale/phyllite), and the Mount Everest limestone series. The stratigraphic sequence established by the Geological Survey of India on the basis of Geological mapping is given in followingTable.

The site for the Rahi Chu Hydro-Electric Project falls within the axial belt of the Central Crystalline Zone of the North Sikkim Himalayas where the rock types are mainly high grade Gneisses having interbands of Metasedimentaries represented by Calc-Silicate/Quartzite, high grade Schist and their fine interlaminations. The Metasedimentaries occur as enclaves in the high grade Gneisses in the area around the proposed project. All these rock types are often intruded by discordant tourmaline bearing Quartz veins and Pigmatite.

TABLE 5: STRATIGRAPHIC SUCCESSION SOUTH OF AXIAL BELT

Group	Age Period	Lithology
Gondwana	Upper Carboniferrous to lower Permian	Sandstone, Shale and Carbonaceous Shale with occasionally thin beds of Coal and pebbly horizon.
Daling	Upper Proterozoic	Interbedded quartzite and chlorite sericite phyllite/schist.
Chungthang	Proterozoic	Interbedded quartzite and garnetiferous Quartz-biotite schist. calc-silicate rock/marble
Central crystalline Gneissic Complex	Older Proterozoic	Banded Gneiss with Augen Gneiss and Quartz-biotite gneiss.

STRUCTURES AND TECTONICS

The area exposes a sequence of gneissic rocks and associated meta-sedimentary rocks from the central crystalline belt of North Sikkim. The structural fabric element observed pertain to features in the area predominated by high-grade litho facies which have undergone poly phase deformation and metamorphism. The primary structures include compositional banding. The gneisses show lithological banding which can be attributed to metamorphic differentiation. Bedded characters are observed only in calc-silicate-quartzite multilayer. The high grade schists also show compositional banding of alternate quartz rich and calasilicate-rich bands. There is no evidence to indicate that these bandings are a relict of primary sedimentary banding. However, broad paralleism of the bandings and later imposed pervasive planes, S2, indicates that these could be transposed.The secondary structure include planar surfaces like gneisses foliation, schistosity which include bedding schistosity (S1), regional schistosity (S2) and fracture cleavage (S3). Gneissic foliation forms the most prominent fabric element of high grade metamorphic tectonics. These 'S' surfaces are marked by parallel lithological layering and preferred dimensional orientation of minerals. The gneissic foliation in the area generally trends NE-SW with moderate NW dips.

The meta-sedimentaries associated with the gneisses show a pervasive schistosity where lithological layering is absent. The fabric is defined by preferred orientation of tabular mica crystals. Bedding schistosity (S1) is incipient and is parallel to the compositional banding in meta-sedimentaries. This S1 surface could not be related to any tectonic structure in the area and could be described as another inherited fabric element along with bedding. The regional schistosity (S2) is the most pervasive structural element in the meta-sedimentaries. The axial plane schistosity is symmetrically oriented with respect to axial planes of folds (F1). The trend of regional schistosity is parallel to the gneissic foliation. The fracture cleavage (S3) is defined by discrete parallel fractures and are also axial plane cleavages (S3) surfaces varies with respect to regional schistosity (S2). The linear structure include stripping lineation, pucker axis lineation and mineral lineation.

The area comprises a sequence of high grade meta-sedimentaries and gneisses that show evidence of having undergone poly phase deformation with a complex pattern of folds due to repeated superimposition of successive fold forms. Grouping of different generation of folds on the basis of styles and spatial attitudes has not been possible due to their complex forms. Broadly three generations of fold movement could be deciphered. F1 folds, the earliest recognizable folds have been compositional banding and bedding schistosity as their form surface and consist of tight isoclinal reclined to inclined folds. Their style and spatial orientation, as observed in the area, is comparable to those observed in the Daling group of rocks exposed south of the project area. The F2 folds have involved all the above mentioned surfaces. These show a variety of styles ranging from oppressed isoclinals folds to open warps, small scale chevron folds or multi hinge disharmonic folds. The calc silicate/marble quartzite bands show regional warps along NW-SE axis due to this phase of folding. The effects of F3 folds have been observed mainly on a regional scale. On a macro scale they are of the nature of minor broad wraps that have folded the weakly developed S3 planes. No planar surface related to this phase of folding are apparent. F3 warps are only locally developed in high grade meta-sedimentaries and have an N-S oriented axis.

Zones of intense mylonisation have been observed in the gneisses but there is no basis to conclude that these could represent planes of thrusting on the basis of evidence like distinct truncation of lithounits reorientation of major folds (F2), development of small scale faults etc.. Chakarborty and Banerjee (1982) have marked NNW-SSE trending thrust near Manual and NW-SE trending thrust near Naga. Neogi et al (1984) observed minor slips and faults occurring commonly within gneisses and metasedimentaries along S3 planes near the hinge zone of F2 folds. The slips are more common where folds are tight. A meso scale normal vertical fault trending N-S has been found within low grade metasedimentaries about 2 Km north of Brabg village. Silicification, chloritization and mylonitasion are found along this fault plane.

SURVEYS AND INVESTIGATIONS

This chapter provides a summary of detailed surveys and investigations proposed to be carried out for the preparation of Detailed Project Report. This includes discussion on topographical surveys, geological investigations, construction materials surveys, power evacuation surveys etc.

TOPOGRAPHICAL SURVEYS

The topographical surveys of all project components, submergence area, access roads, project colonies, quarry and borrow area etc shall be carried as per existing guidelines. The quality of the surveys will be monitored by different managerial and technical tools. A permanent Bench Mark (BM) will be transferred to the diversion site from Survey of India Bench Mark and will be used for the detailed surveys. Scale and contour intervals for detailed surveys for different project area shall be taken as per guidelines, and to fulfill the purpose.

Following Topographical surveys are planned:

TABLE 6: TOPOGRAPHICAL SURVEY PLAN

Sl. no	Description of Survey Required	Scale, Contour Interval
1	Locating and Shifting of benchmark to project site	-
2	Contour Survey for Colony/Office area	1 : 1,000 ; 2 m
3	Contour Survey for Dam, Powerhouse, HRT, Diversion Tunnels, Tail Race Channel, Switchyard and all other structures on both the river banks.	1 : 500 ; 1 m
4	River Cross sections, 20 m apart, 100m u/s & d/s of dam axis and then 50m apart, rest of the part between 500m u/s of dam axis to 1km d/s.	1 : 1000(V) 1: 2000(H)

GEOLOGICAL INVESTIGATIONS

A detailed geological explorations comprising of drilling, geo-physical surveys etc have been planned and will be undertaken to assess the geotechnical parameters for the design of various types of structures. The layout of the project will be reviewed, if required after completion of proposed geo-technical surveys and investigations. Details of geological investigations as now proposed for freezing the geological investigation for the purpose of framing a bankable DPR is detailed below:

DRILLING PROGRAM

Investigation by drilling will be conducted to assess subsurface rock mass condition around major structures and their foundations. Each drill hole will have a specific purpose and will be suitably located in relation to the proposed civil structures. The actual location and extent of drill holes will be decided after finalization of the best suitable project scheme with finalization of location for diversion structure, HRT alignment, Construction adit(s), Surge Shaft and Power house.

Core logging will be done on a regular basis. Cores will be placed in appropriate well marked boxes, transported and stored at site in a manner to keep them protected and undisturbed.

CONSTRUCTION MATERIAL SURVEYS

Surveys for availability of construction materials in required quantities will be carried out. Due to presence of very large quantities of river boulders in the riverbed near the diversion structure axis, it is possible that it may be sufficient for the concrete structures. The quantities of available RBM will be assessed. However alternative Quarries for coarse aggregate and fine aggregate (river sand) are also being identified. Sampling and Testing of different materials shall be carried out as per the relevant BIS codes and quality and quantities of the same would be firmed up in the DPR.

PROJECT PLANNING

GENERAL

The layout of the project is dictated by the topographical & geological features, optimization of valley for power benefits, the presence of Khangchendzonga National Park etc. All structures of the project are planned in manner so as to avoid encroachment of the Khangchendzonga National Park. The conceptual layout of the project is shown below:

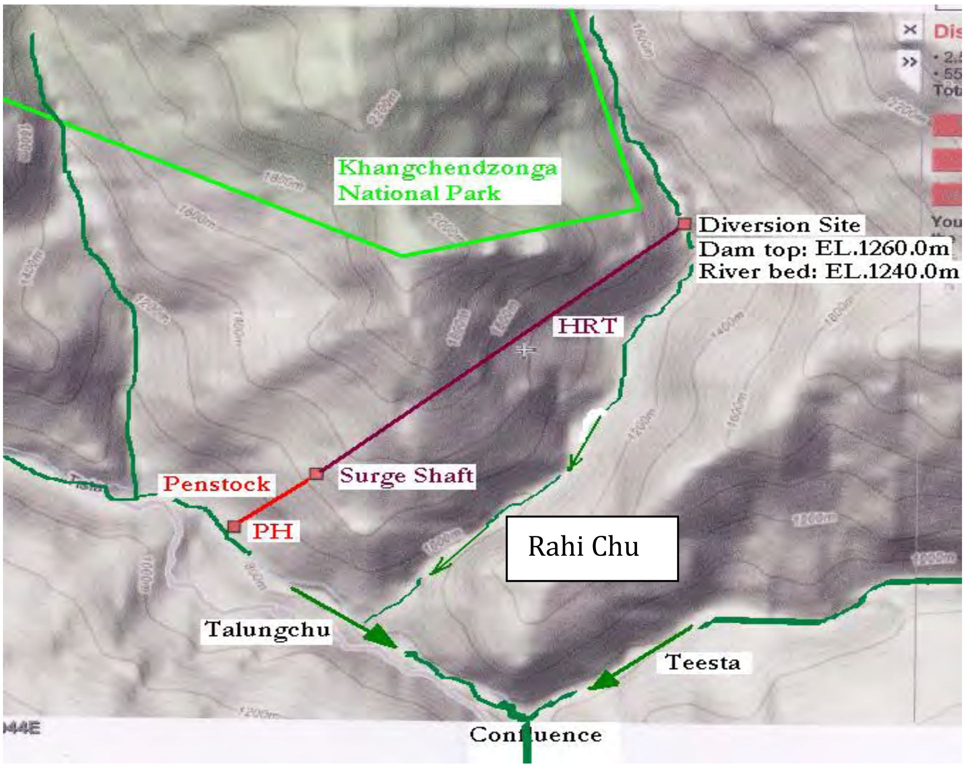


FIGURE 5: PROJECT LAYOUT

DIVERSION DAM

Site for diversion structure, has been tentatively selected keeping in view the topographical features. Various alternatives were studied and the proposed alternative is selected as the best possible alternative for the proposed scheme. The exact location and type of the diversion structure shall be finalised at the time of detailed investigations and geology encountered.

The Rahi Chu H.E. Project has been planned giving due considerations to the following factors:

1. Tapping of Optimum Power Potential
2. Topographical and Geotechnical considerations
3. Techno-economic Viability
4. Submergence

TYPE OF DAM:

As rock is available on the right and left bank of the river, concrete weir cum central spillway with undersluice is found attractive proposition and therefore adopted.

SEISMICITY

As per IS 1893-1984, the project area falls under Seismic Zone IV for which basic seismic coefficient of 0.05 is recommended. Accordingly, the stability analysis of dam section at PFR stage has been carried out by pseudo-static method assuming horizontal seismic coefficient of 0.15g.

DAM LAYOUT & FEATURES:

1. The weir length along the proposed axis works out to 80m comprising of an undersluice and 3 nos overflow blocks (pier width:2.5m). The Overflow Blocks has a net length of 15 m. The location of overflow blocks along the axis has been optimally fixed at the middle of the river. 3 Nos radial gates of size 5.00 (W) x 5.55 (H) m are proposed with crest level at El 1252.50 m. The undersluice crest level is provided at El. 1240.0 (almost at river bed level). The spillway and the undersluice are designed to pass a flood discharge of 400 cumecs considering one spillway gate inoperative. FRL is kept at El.1258.00 m. The MWL will be at El.1258.05m. Top of dam is proposed at El 1260.00m keeping in view the freeboard requirements.
2. The foundation profile of different blocks has been finalized keeping in view the guidelines indicated in BIS 11155-94 and from considerations of access provisions to dam foundation. Deepest foundation level of Overflow Block is proposed at El 1237.00 m beneath overflow portion. The detailed exploration will be required at the time of preparation of detailed project report to fix the foundation level.

The hydraulic parameters used in hydraulic design are as follows:

a.	Design Discharge (Q_d)	:	6.33	m^3/s
b.	100 year flood at intake (Q_{500})	:	400	m^3/s
c.	Construction Flood (1 in 10 years) (Q_{10})		67.5	m^3/s

However, the intake is designed for 8 cumec considering 25% additional required for flushing the desilter

The head over the weir during the flood period has been calculated on the assumption that the flood passes through both the overflow spillway and the undersluice.

The top levels of the wing walls and check levels of undersluice are fixed above the 100 year flood level with a freeboard of 1m.

The discharge through the undersluice shall not be less than two times the design discharge or within 10-20% of Q_{500}.

The discharge passing through the intake has been calculated under submerged orifice condition.

Fixing of Levels

Pond level: The level of water, immediately u/s of the Barrage/weir, required to facilitate withdrawal in to the Water Conductor System. In modern design of a barrage, the entire ponding is done by gates which are opened during floods and the crest level of the undersluice is kept at almost the river bed level. No raised crest is generally provided for the undersluice. A raised crest, however, if provided would improve the coefficient of discharge.

The bed level of the river being at El.1240 m, the crest level of the undersluice is fixed at the same level.

Accordingly, in order to pass the design discharge of 6.88 cumec, the crest level of the diversion spillway is fixed at El.1253m

Head over Weir during High Flood

The total waterway length has been fixed as 17m from the topographical features of the site, of which 10m is the net length of spillway and 5m is the net length of undersluice.

The total discharge passing through the spillway is given by:

$$Q = C_d L H^{3/2}$$

where

Q	: Discharge passing through the weir
C_d	: Discharge coefficient
L	: Effective length of weir
H	: Head over weir incl. head of velocity of approach

As the upstream end of the weir will be filled with sediment, the weir will act as a broad crested weir. Therefore the value of C_d is taken as 1.71 for the design head.

The velocity of approach V_a is given by: $V_a = \frac{Q}{L h_a}$, where h_a is ht of water level from crest

and velocity head is : $H_v = \frac{V_a^2}{2g}$

The effective length of water way is calculated as:

$L_e = L - 2(K_a + nK_p)H$

where

K_a	: Abutment contraction coefficient = 0.1
K_p	: Pier Contraction coefficient = 0.01
n	: No. of piers = 1 Nos.

The discharge passing through undersluice is given by:

$$Q = C_d A \sqrt{2gh} \qquad C_d = \frac{C_c}{\sqrt{1 + C_c (a/h)}}$$

where

Q	: Discharge passing through undersluice
C_d	: Discharge Coefficient
C_c	: Contraction Coefficient =0.61
h	: Head over undersluice crest
A	: Area of opening
a	: Height of opening

The detail calculations are presented in Table G-1.

The result shows that the total head over the weir during the 100 year flood will be 5.55m and correspondingly, the high Flood Level will be 1258.55 m.

Considering a freeboard of 1.5m, the deck level of the structure is fixed at 1260.1m

DETERMINATION OF MWL (Table- G1)

Design Flood	Q_d	:	400	m^3/s
Net Length of Spillway	L_w	:	10	m
Net Length of Undersluice	L_u	:	5	
Undersluice Gate opening height		:	3	
Bed level			1240	m
Crest level of weir	E_w	:	1253	m
Crest level of undersluice	E_u	:	1240	m
No. of Span for Spillway	N_u	:	2	nos.
Abutment contraction coefficient	K_a	:	0.1	
Pier contraction coefficient	K_p	:	0.01	
Contraction coefficient	C_c	:	0.61	
Bed level after sediment deposition	E_s	:	1250.5	m
Depth below crest level	P	:	2.5	
Ratio of P/H_0	P/H_0	:	0	
Discharge coefficient	C_d	:	1.71	

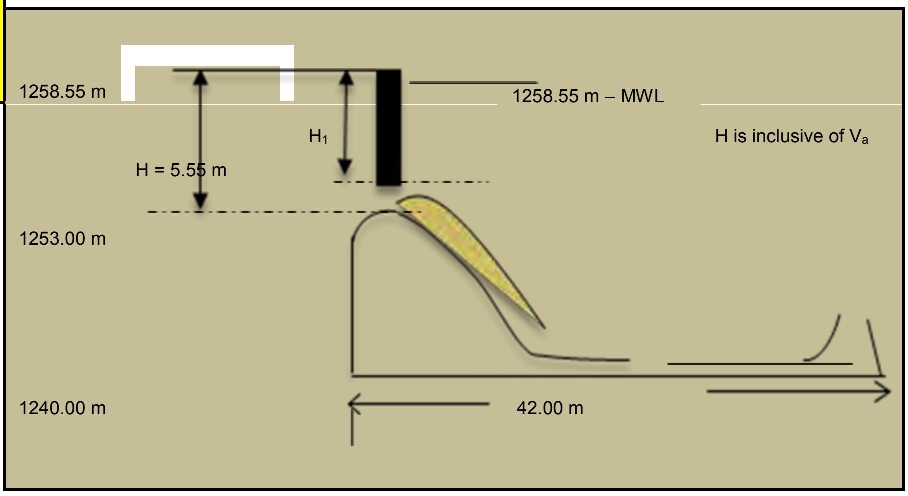
Sl. No.	Eff. Head	Energy Level	Weir portion				Undersluice portion					Total Discharge	Corresponding WL
			Water level	Eff. Length	C_d	Discharge	Full Opening	Ratio (h/a)	C_d	Area	Discharge		
1	0.50 m	1255.00 m	1255.00 m	9.89 m	1.71	6.0 m3/s	3 m	4.998	0.576	15.00 m2	141 m3/s	147.0 m3/s	1255.00 m
2	1.50 m	1255.00 m	1254.87 m	9.67 m	1.71	30.4 m3/s	3 m	4.958	0.576	15.00 m2	141 m3/s	171.0 m3/s	1254.87 m
3	2.50 m	1255.50 m	1255.13 m	9.45 m	1.71	63.9 m3/s	3 m	5.042	0.576	15.00 m2	143 m3/s	207.0 m3/s	1255.13 m
4	3.50 m	1256.50 m	1255.98 m	9.23 m	1.71	103.3 m3/s	3 m	5.326	0.578	15.00 m2	149 m3/s	252.0 m3/s	1255.98 m
5	4.50 m	1257.50 m	1256.83 m	9.01 m	1.71	147.1 m3/s	3 m	5.610	0.579	15.00 m2	154 m3/s	301.0 m3/s	1256.83 m
6	5.00 m	1258.00 m	1257.25 m	8.90 m	1.71	170.2 m3/s	3 m	5.752	0.580	15.00 m2	157 m3/s	327.0 m3/s	1257.25 m
7	5.50 m	1258.50 m	1257.68 m	8.79 m	1.71	193.9 m3/s	3 m	5.893	0.581	15.00 m2	159 m3/s	353.0 m3/s	1257.68 m
8	6.00 m	1259.00 m	1258.11 m	8.68 m	1.71	218.1 m3/s	3 m	6.035	0.581	15.00 m2	162 m3/s	380.0 m3/s	1258.11 m
9	6.37 m	1259.37 m	1258.56 m	8.60 m	1.71	236.2 m3/s	3 m	6.187	0.582	15.00 m2	163 m3/s	**400.0 m3/s**	1258.56 m
10	7.00 m	1260.00 m	1258.96 m	8.46 m	1.71	267.9 m3/s	3 m	6.319	0.583	15.00 m2	166 m3/s	434.0 m3/s	1258.96 m

STILLING BASIN CALCULATIONS

Design Flood	Q_{100}	:	400	m^3/s
Upstream Energy Level	$TEL_{u/s}$	:	1259.37	M
Upstream Bed Level	E_u	:	1240.00	M
Downstream Bed Level	E_d	:	1235.00	M
Invert Level of Stilling Basin	E_s	:	1242.00	M
Width of Stilling Basin	W_s	:	10.00	M
MWL		:	1258.55	M

Sl. No.	USTEL	Q	Total H	Water Depth y_1	Velocity	F_r	Water Depth y_2	WLAJ	Velo. Head	DSTEL	DSWL
1	1255.00	147	13.00	12.93	1.14	0.10	0.26	1242.26	165.22	1407.48	1070.04
2	1255.00	171	13.00	12.91	1.32	0.12	0.35	1242.35	122.88	1365.23	1112.47
3	1255.50	207	13.50	13.38	1.55	0.14	0.47	1242.47	98.24	1340.71	1137.23
4	1256.50	252	14.50	14.34	1.76	0.15	0.60	1242.60	88.74	1331.34	1146.86
5	1257.50	301	15.50	15.30	1.97	0.16	0.75	1242.75	81.69	1324.45	1154.06
6	1258.00	327	16.00	15.78	2.07	0.17	0.83	1242.83	78.82	1321.65	1157.01
7	1258.50	353	16.50	16.26	2.17	0.17	0.91	1242.91	76.70	1319.61	1159.21
8	1259.00	380	17.00	2.23	17.02	3.64	10.42	1252.42	0.68	1253.10	1244.74
9	1259.00	400	17.00	2.36	16.95	3.52	10.64	1252.64	0.72	1253.36	1244.91
10	1260.00	434	18.00	17.69	2.45	0.19	1.15	1243.15	72.38	1315.53	1163.77

Results		
Prejump depth	2.36	m
Post jump depth	10.64	m
Length of Jump	42	m



TEMPORARY RIVER DIVERSION

River diversion during construction of dam has been planned through diversion tunnel of 3m dia of about 500m length.

SEDIMENT MANAGEMENT: DESILTING TANK

The C/I ratio being insignificant, the Rahi Chu HEP reservoir will not trap any sediment. As the river is carrying large quantity of silt during monsoon season, in order to eliminate silt particles above 200 microns size, 2 Dufour Type desilting chambers of 4 m width at top, 80m length and 9.5 m depth is proposed. Water from the reservoir is drawn into the desilting basin through an inlet feeder tunnel of 3m dia. The proposed desilting chamber is underground type. Transition length of water conductor system between intake channel and desilting tank is kept as 12 m.

The efficiency of trap is plotted below:

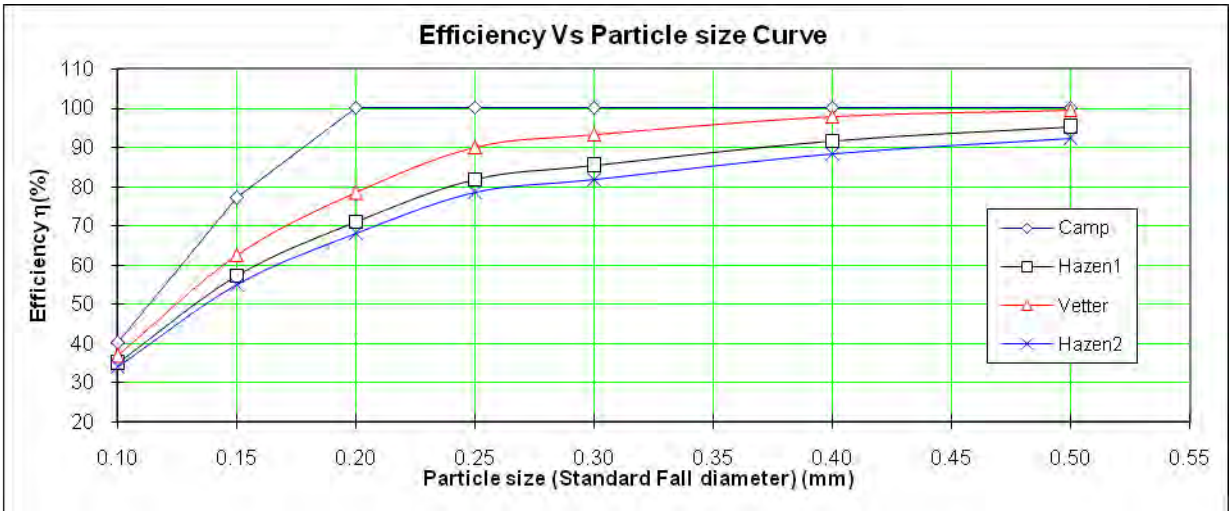


FIGURE 6: TRAP EFFICIENCY

INTAKE STRUCTURE AND WATER CONDUCTOR SYSTEM

The intake structure is proposed on the right bank of the river near the dam site and the water would be drawn through the HRT after the desilting chambers on the right bank itself. The water conductor system has been contemplated to comprise of a 2.7Km long Head Race Tunnel (HRT) off taking from right bank carrying water into a surge shaft.

A steel lined pressure shaft/penstock will carry water from the surge shaft to power house bifurcating twice near power house to feed three units of 8.33 MW each. The water after generating power shall flow to the Tolung chu river through a suitably designed tail race channel. The detail of the various components is as under:

The Head Race Tunnel (HRT) has been designed to carry design discharge of 6.33 cumec with 20% over rated discharge. Keeping in view the economy and ease of construction and hydraulic consideration, the economic dia works out to 3.0m. Keeping in view the construction requirement, HRT has been designed as concrete lined D-shape of 2.5m diameter. The alignment has been fixed keeping in view the requirement of cover. The normal design velocity of flow in HRT will be 1.3 m/s.

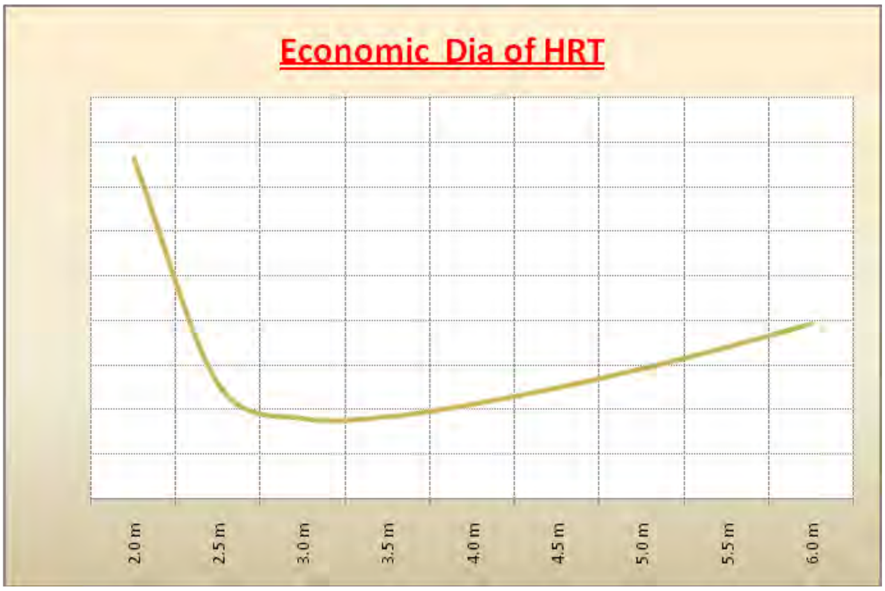


FIGURE 7: ECONOMIC DIA OF HRT

Rock Support System with following broad specification:

Lining:	200mm thick
finished dia:	2500 mm

rock support for different conditions of rock:

VERY GOOD: Spot bolt: 25mm dia, 2000mm long.

GOOD ROCK: 50mm tk shotcrete locally +25mm dia rockbolts, 2000mm long spacing as per site condition staggered in crown.

FAIR: 50mm thick shotcrete locally +25mm dia rockbolts, 2500mm long spacing as per site condition, staggered whole tunnel

POOR: 100mm thick shotcrete locally +25mm dia rockbolts, 2500mm long spacing as per site condition, staggered. ISMB 150 support @ 500/750/1000mm c/c if required.

VERY POOR: 100mm thick shotcrete locally +25mm dia rockbolts, 2500mm long spacing as per site condition, staggered. ISHB 150 support @ 500/750/1000mm c/c if required.

SURGE SHAFT

The length of the water conductor system necessitated a surge tank. The preliminary studies indicate that a surge shaft of 8.0m dia shall be sufficient to absorb the transient effect. Accordingly, it is proposed to provide a restricted orifice type concrete lined surge tank of 6.0m dia with orifice of 1.5m dia and 70m high(appx.) at a location marked on layout plan. The design of the surge shaft shall be firmed up after detailed study in DPR stage.

PRESSURE SHAFT / PENSTOCK

A steel lined pressure shaft is envisaged to take off from surge shaft and will emerge as surface type penstock at a suitable location. The diameter of main penstock has been fixed as 1.5 m with a velocity of flow of 3.6 m/s. Near the power house the penstock shall doubly bifurcate into three branches each to feed 3 units of 8.33 MW each. Steel plates of ASTM -A537 class II have been chosen as the fabrication material for penstock liner and specials with thickness varying from 10 mm to 20 mm. The layout of the pressure shaft/penstock will be finalised after detailed topographical survey.

POWER-HOUSE AND TAILRACE

The power house shall also be located on left bank of Tolung chu river in the upstream of confluence of Rahi chu & Tolungchu. Surface/Pit type power house has been proposed as good terrace of flatter slope is available. The tentative location of power house has been marked on layout plan. The overall size of power house have been tentatively fixed as 70 m X 18 m with unit spacing of 15m and service bay 17 m X 18 m of size. The power house shall house three vertical axis Pelton turbines of 8.33 MW each. Final decision for locating the power house shall be taken after detailed investigations and geology encountered. A short length of tail race channel will discharge the tail waters of Rahi Chu H.E. Project to Tolung chu river. It has not been possible to work out the layout of tail race due to limitation of survey data, which will be done during DPR stage.

CONSTRUCTION FACILITIES

Construction facilities like access road, construction camps, workshops, stores, installation of DG sets for construction power could be proposed on the river terraces on the left bank of the river near the power house area. The detailed infrastructure plan will be done during DPR stage.

HYDRO- MECHANICAL EQUIPMENT

DIVERSION TUNNEL GATES AND HOISTS

After the construction of the dam, for the purpose of plugging the diversion tunnel, one number fixed wheel type gate will be provided at the inlet of tunnel. The gate shall be operated by means of electrically operated rope drum hoist located on the hoist platform installed over the trestle above deck level. The gate is meant for one time closure, just before plugging of the tunnel. Gate is designed for operation against 20m water head.

SPILLWAY RADIAL GATES, HOISTS, EMERGENCY BULKHEAD GATE AND GANTRY CRANE

For flushing and to regulate the water level in the reservoir, three numbers submerged type spillway radial gates have been provided. Each gate shall be operated by means of suitable capacity hydraulic hoist from a power pack and two double acting cylinders (one on each end of the gate) having a provision of 25% pushing force. One trolley mounted mobile gasoline engine operated power pack capable of operating one gate at 25% of the normal rated speed is envisaged for emergency operation of spillway radial gates. One portable oil filter unit for filtration, dehydration & degasification of hydraulic oil is also being provided.

One number fixed wheel type bulkhead gate has been envisaged for the undersluice bay.

One number slide type stoplog gate has been envisaged to cater to the maintenance requirement of three nos. spillway radial gates. Another set of stoplog gate is also envisaged for maintenance of the undersluice gate.

TRASH RACK AND TRASH RACK CLEANING MACHINE

Upstream face of the intake shall be provided with the trash rack screen, which will be cleaned by means of a trash rack-cleaning machine.

INTAKE GATES, INTAKE BULKHEAD GATES AND HOISTS

One number fixed wheel type gates shall be provided at the intake. The intake gate is to be designed for self- lowering against upstream water level corresponding to FRL. The gate shall be operated by means of electrically operated rope drum hoist of suitable capacity. For maintenance and inspection of intake gates and embedded parts, one number vertical slide gate has been proposed on the upstream of the intake gate. The slide gate shall be operated by means of electrically operated rope drum hoist under balanced head condition.

DESILTING CHAMBER GATE & HOIST

One number slide type gate shall be provided at the outlet of desilting chamber for the maintenance requirement of two nos. desilting chambers. The gate shall be lowered / raised under balanced head condition by means of suitable capacity EOT Crane.

FLUSHING TUNNEL GATES & HOISTS

In two silt- flushing tunnels, each tunnel is provided with a set of two slide (Emergency & Service) gates for regulating the discharge through flushing tunnels. Both the (Emergency & Service) gates shall be operated by means of hydraulic hoists. The gate grooves are provided with bonnet structures embedded in the concrete and a watertight bonnet cover at the top of the groove.

SURGE SHAFT GATE AND HOIST

The intake of pressure shaft is provided with one number slide type gate. The gate shall be operated under balanced head condition by means of an electrically operated rope drum hoist.

TAIL RACE GATE AND HOIST

To isolate powerhouse units from the river during flood & also for maintenance, two number fixed wheel type tailrace gates have been envisaged. The gates shall be operated under balanced head conditions by suitable capacity electrically operated monorail hoist.

ADIT INSPECTION GATES

Two nos. adits shall be provided with manually operated hinged type gates in the concrete plug at the HRT to give access to the head race tunnel in the event of any inspection, repair and maintenance.

PRESSURE SHAFT STEEL LINER

One no. Pressure Shaft of dia. 2000 mm fully steel lined will take off from Surge Shaft to feed the turbines placed in the powerhouse. It comprises of horizontal & inclined ferrules, 2 nos. vertical bends, 2 nos. plan bends, 2 nos. bifurcations and branch pipes for feeding three nos. turbines. The material of Pressure Shaft liner shall conform to ASTM A537 Class -II. However, for bifurcation material shall conform to ASTM A517 Gr. F.

INSTRUMENT AND REMOTE CONTROL

Gates shall be provided with PLC based remote control system for Control and operation of gates and automatic control of the reservoir level.

DIESEL GENERATING SET

One diesel generating set complete with all accessories will be provided for emergency operation of gates and hoists.

POWER PLANT AND TRANSMISSION

GENERAL

Electro-Mechanical equipment will consist of turbine, generator, governor, oil pumping units, spherical valves, excitation system, battery & battery charger, step-up transformer, auxiliary transformer, DG set, cooling water system, station drainage & dewatering system, compressed air system, HVAC system, illumination etc. Brief description of above components has been given in relevant paragraphs below.

The power evacuation shall be through 132 KV transmission line and has been discussed in the relevant paragraph below.

TURBINE

Capacity

Rahi Chu HEP has a potential of producing 25 MW power against the available gross head of 438.7 m and discharge of 6.33 m3/s. To provide 25 MW of power, considering the availability of water discharge, ease of maintenance and to utilize the best operating conditions of machine (i.e, better average efficiency), three units of capacity 8.33 MW each has been selected.

Type of Turbine

The available head and size of machine mainly influence the selection criteria of type of the turbine. The available net head for the Rahi Chu HEP is 428.7 m and the suitable type of turbine for this head and capacity works out to be Pelton turbine. For turbine selection, the power output at turbine shaft has been considered as 8330 KW at rated head. For selection of speed, specific speed and turbine setting has been considered. Generally, for this capacity of machines with high heads, very high rpm machines are not advisable as the specific speed of the machine goes very high.

Based on preliminary analysis and considering the best techno-economical viability and ease for operation and maintenance of machine, a 428.6 rpm Vertical Shaft Twin Jet Pelton machine directly coupled to generator shaft is selected.

Parameters of hydraulic system

The details of the hydraulic system and the basic data for the design of the turbine are as follows:

- FRL : 1259 m
- MDDL : 1254 m
- Maximum TWL : 820 m
- Machine center line : 823.0 m
- Gross head : 438.7 m
- Rated net head : 428.7 m
- Rated discharge per unit : 2.11 m3/sec

MAIN INLET VALVE

Water from the penstock after trifurcation shall pass to turbine through main inlet valves. Valves are necessary for the closing as well as isolating the plant from the water conductor system. Considering the head of 428.7 m, Spherical Valves are best suited.

The main inlet valve for each generating unit shall be Spherical type. This will act as closure device. Valve shall have nominal diameter of 1350 mm and the design pressure of 65 kg/cm2. The Valve shall be operated by oil (hydraulic power pack) or by electric actuator and shall have the tendency of closing. Suitable bypass arrangement shall be provided for equalizing pressure on both side of valve so as to reduce torque during opening of valve.

GENERATOR

Type & description

The Generators shall be of Vertical shaft alternating current synchronous type suitable for coupling to the turbine described above. The generator specifications are:

- Rated output : 9.80 kVA
- Maximum output : 10.78 kVA
- Rated speed : 428.6 rpm
- Frequency : 50 Hz
- Power factor : 0.85 pf
- Rated terminal voltage b/w phases : 11 kV
- Qty : 3 Nos.

The generator shall be salient pole type. The class of insulation shall be F and temperature rise shall be limited to class B under maximum operating condition of 10% overload and cooling water temperature of 20 deg C and ambient temperature of 30 deg C. The generator shall be water cooled.

Each Generator shall be star connected. Three main & three neutral leads shall be brought out of the stator frame for mounting of the current & potential transformers for control, metering & protection. The Surge protection Cubicle shall be connected on line side complete with Lightning arrestors & capacitors. The generator neutral shall be grounded through a Grounding Transformer. The generator shall be complete with all equipment & devices for control, instrumentation and safety. Further Generator LAVT Cubicle and Neutral Grounding Cubicle separate for each unit shall be provided. Dial type thermometer, RTD's shall be mounted in Generator and will be connected to indication & recording instruments on the panels.

Excitation System

The excitation cum automatic voltage regulation system shall be of static type. The voltage regulation system shall be both manual as well as automatic control. The automatic voltage regulation shall be with digital control. The system shall be capable enough to maintain the output terminal voltage constant within the regulation limits.

PROTECTION & CONTROL SYSTEM

Unit Control Panel

PLC based Unit Control board shall be provided with microprocessor based data logging system, which shall control all functions of the generating units, transformers and lines etc., both in auto & manual mode. A separate Unit Control Board shall be provided for each unit and shall comprise of recorder, push buttons, indicators, suitable alarm and trip circuits for indicating abnormal conditions like high bearing temperature, low oil pressure, over speed relay etc., as per the system requirement.

Protection and Metering Panel

The protection equipment will comprise voltage controlled over current relay, over voltage relay, under voltage relay, reverse power relay and differential protection relay. In addition suitable alarm/trip circuits shall be provided for indicating for above. Further, ammeter, voltmeter, power factor meter, kWh meter, kVAR meter, frequency meter, trivector meter shall also be provided. The trivector energy meters shall also be provided of 0.2 accuracy class for measurement of import & export of energy for the system.

For power transformer, Bucholz protection and temperature alarm/trip circuit shall be provided. The protection system is designed for 220V DC operation.

In addition to above, there will be mechanical protection of instrument and various bearings.

All Control and Protection system shall be integrated with SCADA and centralized control, data acquisition and storage shall be provided at the Central Control Room.

MECHANICAL AUXILIARIES

EOT Crane for Power house

65/15 T EOT Crane, Double Girder, Cabin operated shall be provided to meet the requirement of the erection & maintenance activities of the Powerhouse equipment.

Cooling Water System

Cooling water for generating stations and transformers and other purposes would be tapped from the turbine discharge water (tailrace).

Compressed Air System

Compressed air requirements have been envisaged for governor pressure oil system, the turbine inlet valve pressure oil system, generator brakes and station service. Two high-pressure compressors with an air receiver tank meeting the requirements of both the units have been proposed. Low-pressure air required for generator brakes and station service is tapped off from the main high-pressure air header with a pressure reducing valve and a low-pressure air receiver.

Ventilation & Air Conditioning System

Forced Ventilation & Air Conditioning System shall be provided. The Control room, shift engineer and officer's rooms shall be air conditioned with suitable package type air conditioning units. For rest of the power house suitable forced Ventilation System shall be provided.

Fire Protection

The generators shall be provided with mist type of fire protection system. Transformers shall be provided with high velocity water spray system. Other relevant locations of the power house and the switchyard shall be protected with hydrant type of fire protection system. In addition to above, portable extinguishers will be positioned at suitable locations in the plant for use against local fire.

Power house drainage system

The seepage water & other leakage water in the Powerhouse shall be collected in the drainage trench provided all around the power house walls. The trench shall be connected to a common drainage sump. The water thus collected shall be suitably routed to discharge into the tailrace.

Workshop Equipment

For local repair of equipment and proper maintenance of plant a complete set of tools and tackles are proposed. Local technician and supervisor shall be able to carry out all the minor repair and maintenance work of the plant. Due to space constraint, the tools and tackles shall be housed in the service bay itself. The major tools and tackles shall be: Electric welding sets, diesel generator welding sets, cutting sets, drill machines, grinders, hand tools and accessories etc.,

ELECTRICAL AUXILIARIES

Main Transformer

Individual Step-up transformers of 12 MVA, 11 /132 kV, 3 phase, Delta/Star, ONAF cooling with normal protective devices such as restricted earth fault, etc will be installed. Lighting arresters shall be provided to protect lines and transformer from surges. Step-up transformer will be connected to 132 kV bus-bar of switchyard through 132 kV, SF6 Circuit Breaker.

Auxiliary transformers

One no. 11 kV/433V, 500 kVA capacity Unit Auxiliary transformer (UAT - Oil filled type) each for individual units shall be provided to meet unit auxiliary loads and for feeding the station service boards in case of station supply failure.

Two nos. Station Service Transformers (SST - Dry type) of 500 KVA capacity shall be provided for feeding the station auxiliaries of the powerhouse, switchyard, general lighting, compressors, crane, ventilation and other misc. loads. The station supply shall be drawn from some nearby substation.

415 V Switchgear

A sectionalized station service switchboard for operation at 415V, 3 phase, 4 wire, 50Hz supply shall be provided. The panel shall comprise of 415V, incomer ACBs, single phase single core current transformers, potential transformers, AC voltmeters, kWH meters, fuses etc., outgoing feeders with MCCB mainly for station lighting, Ventilation & AC, Crane, Air compressors etc. This board shall be fed from the SSTs.

Individual unit auxiliary switchboards shall be provided for feeding the unit auxiliary loads. These shall be fed from the UATs.

Battery & Battery charger

220 V DC supply of suitable capacity required for the control equipment will be provided by a chargeable power pack unit complete with batteries, battery charging equipment and DC distribution board with protective system.

Emergency Diesel Generator set

An emergency diesel Generator set of suitable capacity 415V, 50Hz, 3 phase 4 wire of electric start, radiator cooled, four stroke multi cylinder of suitable rpm shall be provided. The DG set shall be with AMF panel and shall start automatically with the help of AMF panel when the supply on the 415V Panel fails.

Grounding System

The powerhouse will be provided with a grounding mesh of 75mm X 6mm (or equivalent as per earthing design calculation) MS Flats. All non-current carrying parts of the various equipments will be connected to the grounding system. Earthing will be done by 50 mm x 6 mm MS flats. Size of earthing rod shall be 22 mm dia, 3 m long rods buried in ground at a depth of 0.75 m, as laid in IS code 3043 -1987 and Indian Electricity Rules, 1956. Number of electrodes should be such as to limit the current carried by each rod as per the standards.

Illumination of Powerhouse

Power supply for the illumination scheme and convenient outlets shall be obtained by feeders taken from station service board located at LT room in the powerhouse. The outgoing feeders from lighting panel shall be suitably controlled by MCBs. There shall be separate lighting panels as per requirement for various areas, which are connected to Main Lighting Distribution Board. The power circuit and lighting circuits shall be separate.

The emergency AC lighting system shall be supplied through an inverter connected to the DC distribution board.

132 KV SWITCHYARD

The switchyard shall be open type located nearby the power house. It will have a double bus bar arrangement with a Bus Coupler Bay. Bus PTs shall be provided for metering and synchronizing purpose. All three generators shall be synchronized to this bus-bar. The 132 kV switchyard shall be provided with all protection and metering equipment. Switchyard equipment includes SF6 Circuit Breaker, Lightning arrestors, multi-core CTs, Isolators with Earth switch, multi core PT etc. Bus post insulator is provided for supporting the conductor wherever necessary. Fencing will be provided for security reasons and as required by the safety rules.

POWER EVACUATION

Power will be transmitted through 132 kV S/C Transmission line from Rahi Chu HEP to the nearest Pooling Station proposed at Mangan (Teesta III HEP) which is approximately 2 Km from Rahi Chu HEP.

FURTHER STUDIES

DESIGN STUDIES

1. Hydraulic design of various structures like spillway, power intake, desilting chambers, transient studies of surge shaft shall be required for firming up the dimensions.
2. Stability analysis of non-overflow and overflow sections shall have to be done taking into account the approved seismic parameters.
3. Hydraulic model studies for reservoir and Dam spillway shall be required for the confirmation of design parameters.
4. Sedimentation analysis for working out the post sedimentation storage capacity of the reservoir.
5. Alternative studies for location, type and layout of main components based on detailed topographical and geological studies.
6. Alternative studies for diversion structure i.e. possibility of other types of diversion structures.

COST ESTIMATE

The cost of the project has been worked out on the basis of preliminary designs and drawings. Costs of equipment and materials have been taken on the basis of similar projects in nearby area. Unit prices have been derived for major works based on preliminary survey and assumptions.

PRICE LEVEL

The cost estimate has been made at the price level of Mar'2011. All costs have been first estimated on a per unit basis for each of the components. These have been added to obtain the entire project cost. Lump sum costs have been allocated for components where a detailed breakdown of costs is not available or worthwhile.

RATE ANALYSIS

Unit rates of major items of civil works have been derived on the basis of preliminary market surveys and available data. While analyzing the rates, recommendations made in the "Report of the Committee on Cost Control for River Valley Projects" by CWC have been followed wherever relevant.

COST OF PROJECT

As discussed above for development of the Project, following civil/electrical works are involved.

- A diversion structure
- Intake and desilting chambers
- 3.0m meter dia head race tunnel
- Surge Shaft
- H&M including Gates and Penstocks
- Power House
- Electro-Mechanical Equipment, Pelton turbines, generators, auxiliary system, transformers etc.
- Transmission Line

The cost estimate has been done on the basis of current market rates and working out preliminary sizes of various project components. An installed capacity of 25MW has been considered. The present day cost assessed based on CWC broad guidelines for framing River Valley Projects works out to Rs.144.76 Crs. The abstract of cost is placed as under:

Description	**Amount (in Rs Crs.)**
CIVIL WORKS	
DIRECT CHARGES	
I – Works	
A – Preliminary	0.50
B – Land	1.00
C – Works	43.00
J - Power Plant Civil Works	36.60
K – Buildings	2.00
M – Plantation	0.25
O – Miscellaneous	1.33
P – Maintenance	1.50
Q - Spl. Tools & Plants	1.00
R – Communication	3.00
X - Environment & Ecology	1.00
Y - Losses on Stocks	0.50
Total of I-Works	**91.68**
II - Establishment @ 8% of cost of I-Works (less B-Land)	7.334
III - Tools and Plants @ 1% of cost of I-Works	0.91
IV – Suspense	
V - Receipt & Recoveries (-)	0.00
TOTAL DIRECT CHARGES	99.92
INDIRECT CHARGES	
Capitalised Value of Abatement of Land Revenue	0.10
Audit and Account Charges @ 1% of cost of I-Works	1.0
TOTAL INDIRECT CHARGES	1.10
TOTAL DIRECT & INDIRECT CHARGES	101.02
Electrical Works	**43.74**
TOTAL COST	**144.76**

FINANCIAL EVALUATION

Preliminary financial analysis for the Rahi Chu Hydro Electric Project has been carried out to ascertain the financial viability of the scheme.

PROJECT COST

Base Cost

Cost of the project is taken as estimated and discussed in Chapter under cost estimation. The cost is estimated at MAR-2011 price level.

IDC

Interest during construction is worked out based on the disbursement of cash flow. The interest rate is taken as 12.0% p.a.

Escalation in cost

Escalation of 6% p.a. over civil works cost and 4.5% p.a. over E&M cost has been considered for working out completed cost of the project.

Phasing

Capital cost for the project will be disbursed during the project construction period. Quaterly phasing of expenses is done for the purpose of analysis.

Financing

It is assumed that the project shall be financed at the rate of interest of 12.0% p.a. 70% of capital cost is considered as debt and balance is equity. The debt shall be payable in 12 years after COD.

ENERGY SALE PRICE

The energy tariff has been worked out as per practice with 15.5% return on equity. The same has been used for sale of the energy.

ANNUAL COSTS

Annual operation and maintenance expenses including insurance have been taken as 2.0% of the capital cost, which shall be escalated by 5.72% annually.

DEPRECIATION

The depreciation is calculated according to Straight line Method (SLM). Accelerated depreciator has been allowed for 12 years wef COD as per CERC norms. The balance cost is depreciated over the remaining period of project life.

OTHERS

Economic life of the project has been taken as 35 years,

Discount rate is taken as 10.19%.

ECONOMIC EVALUATION:

The following basic parameters are used to determine sale rate of generation per unit.

Basic Parameters:

Debt Equity :	70:30
Construction period :	3.5 years
Plant Useful Life :	40 years
Loan Repayment Period :	12 Years from COD
Moratorium on loan repayment	12 months from COD
Interest rate on Term Loan :	12%
Interest charges on working capital :	12%
Return on equity :	15.5%
O & M charges :	2%
O & M Escalation rate :	5.72% per year

Auxiliary consumption : 0.5% of total energy production
Transformation Losses : 0.5% of total energy production
Free power to state : 12% of total energy production
Rate of income tax : As per existing norms
Accelerated Depreciation: considered for a period of 12 years

MAJOR FINANCIAL RESULTS

The major financial results are as under:

Financial Analysis of Rahi Chu H.E. Project (3 x 8.33 MW)

Assumptions			
Energy	:	**Design Energy**	**121.07 MU**
Debt: Equity	:		70% :30%
Escalation Factor	:		3.80%
Basic Cost of project	:		144.76 crs.
Escalation and Contingency during construction	:		Rs. 23.74 Crs.
Interest During Construction	:		Rs. 23.6 Crs.
Total Capitalised Cost	:		**Rs. 192.1 Crs.**
Cost/ MW installation	:		Rs. 7.68 Crs.
Contingencies considered	:		5%
Period of Construction	:		3.5 years
Rate of term loan interest	:		**12%**
Loan Repayment Period	:		**12 years**
Sale Rate of Power	:		**Rs. 4.37/Unit**
Escalation in Sale Rate of Power	:	Annually	1%
Discount Factor	:		10.19%

Results		
Cost of power as per CERC (1st year tariff)	:	Rs. 4.60/Unit
Cost of power as per CERC (levellised tariff)	:	Rs. 3.91/Unit
Sale Rate of Power		Rs.4.37 /Unit
Project IRR	:	14.83%
Equity IRR	:	17.83%
Average DSCR	:	1.55
Minimum DSCR	:	1.19

CONCLUSION

On the basis of inputs and assumptions as given, the project demonstrates attractive tariff and as per the preliminary financial evaluation, the project is considered as techno-economically viable project and recommended for further detailed, surveys, investigations and preparation of Detailed Project Report.

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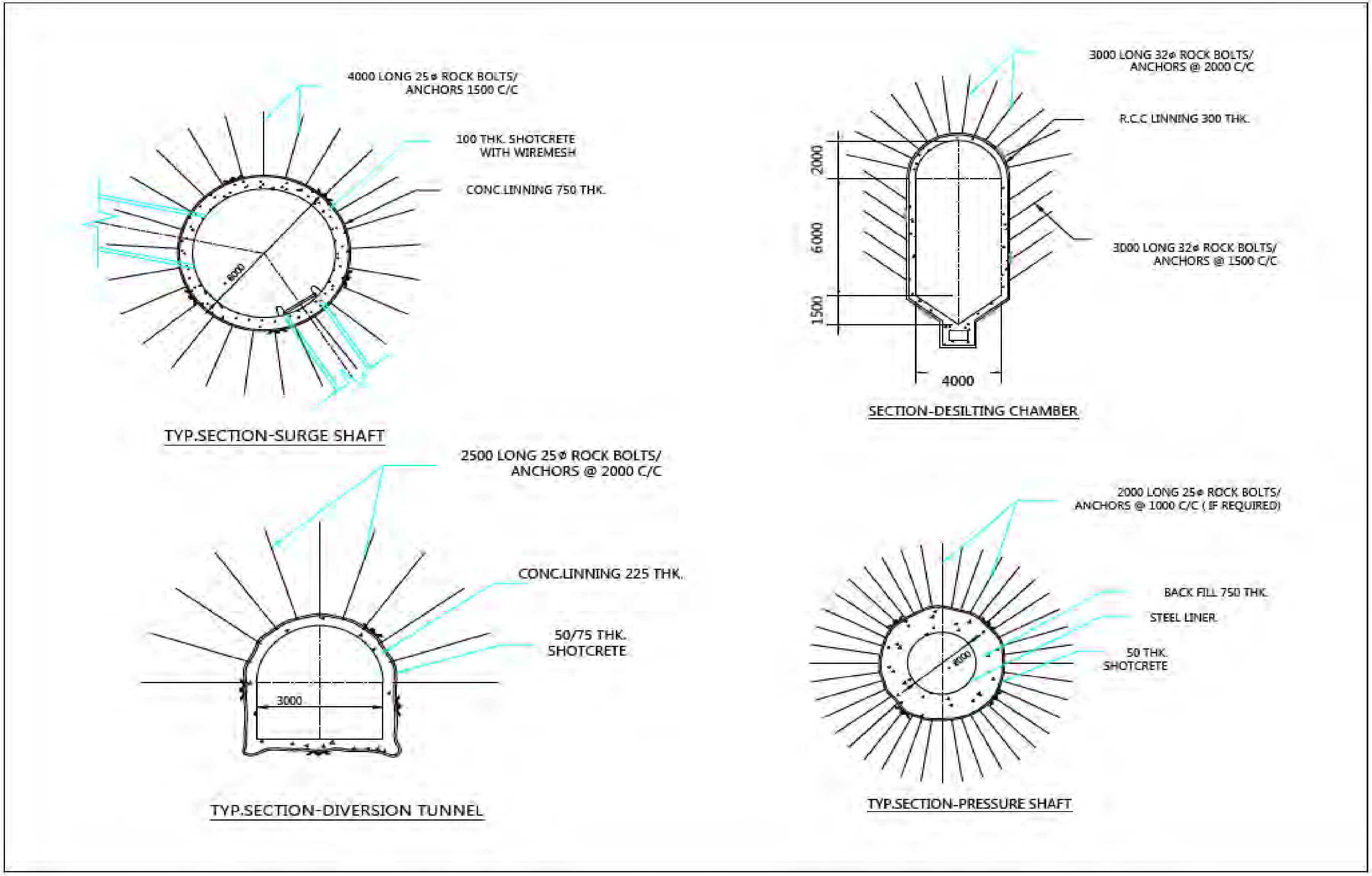
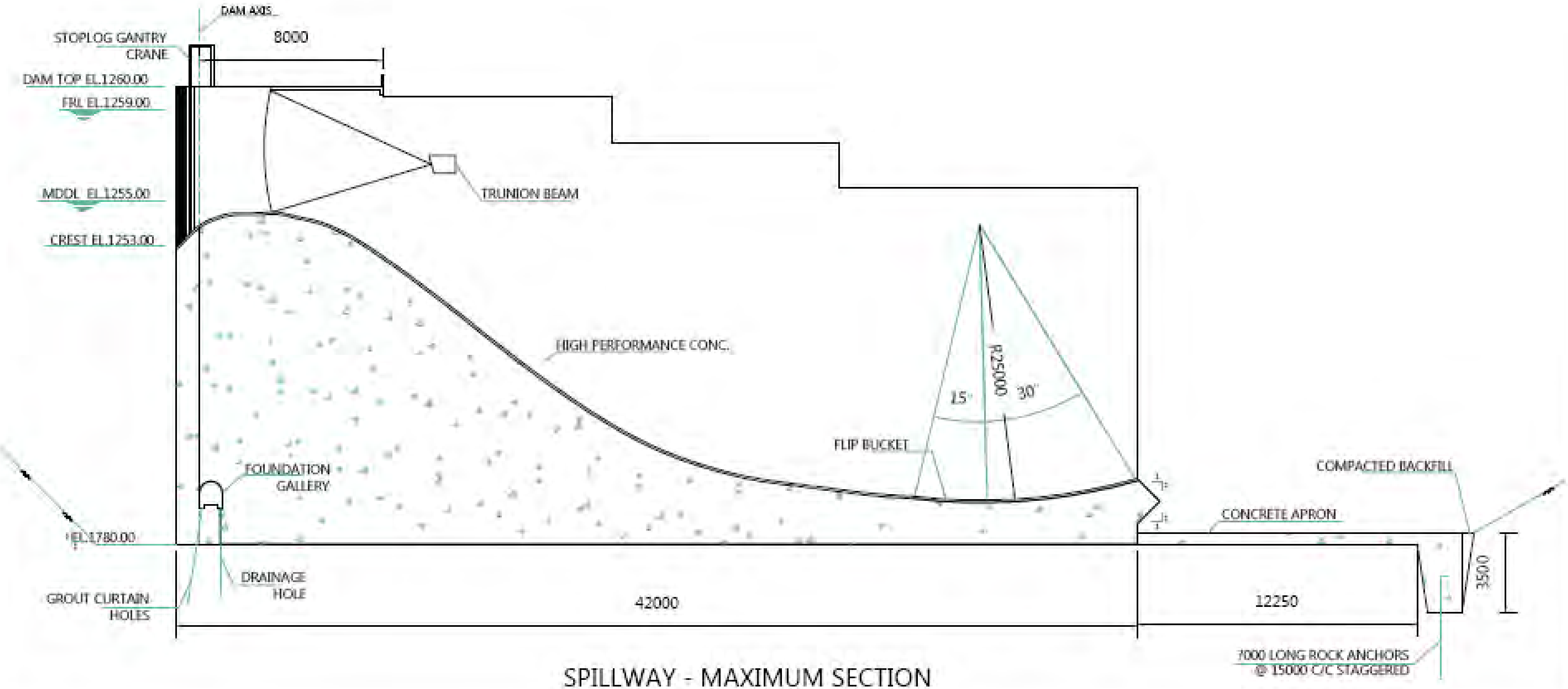

4000 LONG 25ø ROCK BOLTS/
ANCHORS 1500 C/C
100 THK. SHOTCRETE
WITH WIREMESH
CONC.LINNING 750 THK.
8000
TYP.SECTION-SURGE SHAFT
3000 LONG 32ø ROCK BOLTS/
ANCHORS @ 2000 C/C
R.C.C LINNING 300 THK.
3000 LONG 32ø ROCK BOLTS/
ANCHORS @ 1500 C/C
2000
6000
1500
4000
SECTION-DESILTING CHAMBER
2500 LONG 25ø ROCK BOLTS/
ANCHORS @ 2000 C/C
CONC.LINNING 225 THK.
50/75 THK.
SHOTCRETE
3000
TYP.SECTION-DIVERSION TUNNEL
2000 LONG 25ø ROCK BOLTS/
ANCHORS @ 1000 C/C (IF REQUIRED)
BACK FILL 750 THK.
STEEL LINER.
50 THK.
SHOTCRETE
TYP.SECTION-PRESSURE SHAFT



SPILLWAY - MAXIMUM SECTION