UPGRADATION OF DPR FOR SONG DAM DRINKING WATER PROJECT, DEHRADUN, UTTARAKHAND

DETAILED PROJECT REPORT

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VOL IA - MAIN REPORT

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REPORT
Rev 00

LIST OF VOLUMES

Volume No.	**Description**
Volume I A	**Main Report**
Volume I B	Main Report – Respective Annexures
Volume II	Project Geology
Volume III	Cost Estimate
Volume IV	Drawings

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DETAILED PROJECT REPORT

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Client : **IRRIGATION DEPARTMENT , UTTARAKHAND**

Project : **SONG DAM DRINKING WATER PROJECT, DEHRADUN**

Subject : **DETAILED PROJECT REPORT - VOLUME IA - MAIN REPORT**

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LOCATION	
State	Uttarakhand
District	Dehradun
River	Song
Location of Dam	Near village Sondana, 10 km. u/s of Maldeota
Nearest Airport & Railhead	Dehradun
Latitude	30°18’08”N
Longitude	78°11’30”E
HYDROLOGY	
Catchment area	85 sq.km
Snow catchment	0.00 sq.km
Annual average rainfall in the catchment	1942 - 2247 mm
RESERVOIR	
Reservoir Level (FRL/MWL)	EL. 980.0 m
Minimum Draw Down Level (MDDL)	EL. 923.0 m
Gross Storage at FRL/MWL	2640 Ha. m
Dead Storage	400 Ha. m
Live Storage	2240.0 Ha. m
River Diversion Pipe	
Number of Pipe	1 no.
Pipe size	2.0 m diameter steel pipe
Length of pipe	350 m (Approx.)
Inlet Invert Elevation	EL. 878.00 M
Proposed Longitudinal Slope	1:75
Outlet Invert EL	873.33
Coffer Dam	
Type of Material	Colcrete
Average Side Slopes, u/s & d/s	0.1H:1V & 0.5H:1V
Height	12.00 m
Length	75.45 m
Top Elevation	887.0 M
Base Width	12.2 m
Song Dam (RCC)	
Length at top	225m
Length at foundation (Deepest block)	30m
Height (From deepest foundation level)	130.6m
Width at Bottom	134.06m
Width at Top	12.5m
Slope U/s	0.3 H : 1 V
Slope D/s	0.8 H : 1 V
Bottom of Deepest Block of Dam	EL. 851.40 m
River Bed Level	EL. 874.75 m
New zero elevation after 100 years	EL. 910.366 m
Minimum Draw down Level	EL. 923.0 m

Top Level of Dam	982.0 m
SPILLWAYS - Main Orifice Spillway	
Gates	Radial and Stoplog Type
Sill elevation [m a.m.s.l.]	912.00
Stoplog gate size	7.0(w) x 7.525(h)
Number of openings	2
Width of opening (each) [m]	7.0
Height of opening (each) [m]	7.5
Energy dissipater	Trajectory Bucket
Invert Level of bucket [m a.s.l.]	890.00
Radius of Bucket [m]	25
SPILLWAYS - High Level Spillway	
Gates	Service and Stoplog Type
Crest Elevation	975.00
Sill elevation [m a.m.s.l.]	974.5 & 974.88
Stoplog gate size	5.0(w)x 5.12(h)
Service Gate Size	5,0(w) x 5.5 (h)
Number of openings	1
Width of opening (each) [m]	5.0
Height of opening (each) [m]	5.0
Intake	
Number of Intake	1 no.
Intake Trashrack Size	1.5 m (w) x 2.2 m (h)
Intake Gate size	1.5 m (w) x 1.5 m (h)
Intake Invert Elevation	EL. 918.00 M
Water Conductor System	
Total Length	14.7 km
Start Location	Dam Block No. 03
End Location	WTP Near Khalanga War Memorial
Diameter of the Pipeline	1.5m
Length along Song River	10.5 km
Length Along Baldi River	4.2 km
Water Demand	**150 MLD**
Project Cost	
Estimated Project Cost	1480.23 Crores

1. INTRODUCTION

1.1. Type of the Project

Dehradun is the capital city in the State of Uttarakhand and is on the Tourist map of the Country. The population of the city is 5,74,840 (2011) within the Municipal Corporation boundaries and it is continuously increasing. The tourists who visit Mussoorie and the pilgrims who visit the Shrines of Badrinath, Kedarnath, Gangotri and Yamunotri - halt at Dehradun. This has put a tremendous pressure for necessary amenities to be provided to the Public. Dehradun is already facing shortage of water supply and the situation becomes more grave during summers when the discharge at the sources of water supply reduces. There is a demand for Song storage reservoir to meet the drinking water requirement and ground/subsurface water source augmentation in the vicinity of Dehradun.

It is anticipated that this shortfall will go up continuously over the coming years. Keeping this in view, it is proposed to store surplus water during monsoon by constructing a dam across river song to solve the problem of domestic water requirement for the city of Dehradun and adjoining suburban areas.

Irrigation department, Uttarakhand has proposed a dam on river Song, to cater the domestic water demand of Dehradun city and its suburban areas. The project envisages construction of a dam 130.6 meters height.. The share for drinking water shall be released to proposed treatment plant near pacific Golf (Sahastradhara road) thereafter to distribution system. The project will be helpful in supplying the water through gravity and so the huge expenditure involved in pumping the water will be saved. By construction of the dam some of the water will seep into the ground and will supplement the ground water table which, in turn, will enhance the output of tube wells in the vicinity and Storage of water will help in recharging the ground water and augmentation of natural water sources in downstream. Rivers like Rispana, Bindal and other small streams may get recharged and ground water level in vicinity of Dehradun will also be increased. Tourism and Fisheries may also be developed.

1.2. Location the Project

The Song River is a major river in Dehradun district draining the central and eastern part of the Doon Valley, in the state of Uttarakhand, India. It is a tributary of Sooswa river, which in turn is a tributary of the Ganges. It originates as spring-fed stream in the southern slopes of the Mussoorie ridge of the Himalayan range and runs from Dhanaulti towards Narendranagar. Song is one of the largest rivers that drain the Doon Valley, and its tributaries includes, Kali Gad, Shahastradhara, Assan River and Rispana River.

The proposed site is located at the boundary of district Dehradun and Tehri Garhwal near village Sondhana at a distance of about 25 kilometers from Dehradun Railway Station. The coordinates of the dam site is as follows.

Longitude : 78°11’30”E, Latitude : 30°18’08”N, Bearing of Dam : N 300 W. Figure 1-1 shows the location of Song Dam Site.

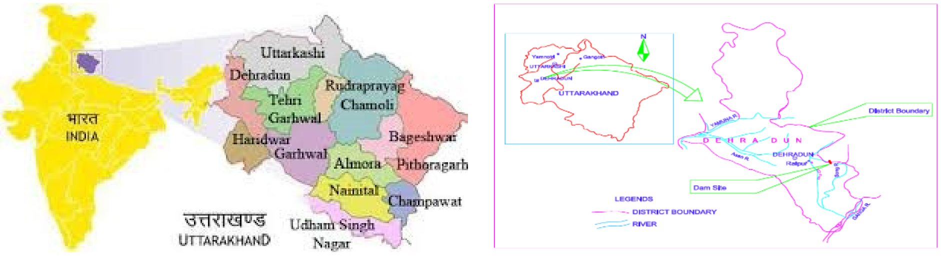


Figure 1-1: Location of Song Dam Site

1.3. Access to the Project

Dehradun City is located at a distance of around 236 km from national capital of New Delhi and can be easily accessed from major cities of India via all means of railways, airways as well as roadways.

Jolly Grant Airport is the nearest airport from Dehradun City- approximately 25 kms. Accessed through motorable roads. The city is well connected by rail and road routes as well. It lies on NH 72 easing the access to the city.

The proposed site is located at the boundary of district Dehradun and Tehri Garhwal near village Sondhana at a distance of about 25 kilometers from Dehradun Railway Station.

1.4. General Climatic Condition

Dehradun’s climate is a “humid subtropical” type being moderately hot in summers and very cold in winters. The temperature can soar up to 44°during summers (May-June) and dip between 1°to 20°during winter months. The Monsoon rainfall usually starts in late June and ends till September. The average annual and monsoon season rainfall is about 2247 mm and 1942 mm, respectively July and August being the rainiest months of the season.

1.5. Topography, Physiography & Geology of the project area

Adequate topographical surveys have been carried out by Irrigation Department, Dehradun, Uttarakhand to establish the selection and design of the most techno-economically viable alternative for the Song Dam Drinking Water Project. The scope and extent of the survey and investigations were finalized after extensive field reconnaissance of the project area by engineers and geologists.

Topographical survey of the left bank has been done up to a contour level of 1060 m while the right bank was surveyed up to a contour level of 1074 m.

The following topographical survey data has been used for preparing the DPR:

I. Survey of India Toposheet (Scale 1:50,000)

Survey of India Toposheet no. 53-J/3 which covers all the components of the project area. The dam site has a longitude of 78°11'18.63"E and latitude of 30°18'8.29"N.

II. Topographical Maps 1:3,000

Topographical survey covering the entire Dam Area, Reservoir area and approx. 1km downstream of the dam axis area on both the banks has been carried out at the scale of 1:3,000 with a contour interval of 2.0 m. The survey has been conducted up to 50m above the dam top level.

III. Cross-Sections of Song river

100 nos. of river cross sections at every 50.0m distance from the dam axis to 5035m in the upstream direction has been prepared.

Similarly, 30 nos. of river cross sections at every 50.0m distance from the dam axis to 1500m in the downstream direction has been prepared

Geology & Physiography

The Song river system is composed of a good number of tributaries of which the main are Bandal Nala, Chiphaldi nadi and some small streams from the south as well as north faces. Most of the streams are perennial and spring fed because there are no glaciers or snow covered mountains either at the source of the Song river or any of its tributaries. Most of the rain water goes as run off but some percentage gets in-filtered into the joints and crevases and comes out in the form of spring which form the bulk water of this river.

A large number of springs on the south hills of this river are located in the phyllite quartzite silt stone association of rocks which have been equated to Chandpur. Various lineaments / fractures in this formation which underlie the massive, hard, highly metamorphosed quartzite have mostly given rise to spring formation. Considerate amount of water is contributed to Song river from the northern hill slope having large number of tributaries with the water sources mainly from springs. The Song drainage basin at dam site has a total area of 85 sq.km. approximately. The width of the water bearing stream in the Song river is approximately 6.0 – 10.0 m wide with an average water depth of 0.6 m.

A series of ridge-lines intervened by valleys make up the landscape. The north facing slopes which also form the dip slopes are gentler and luxuriantly vegetated. Landslips and landslides occur mostly due to unstable slope conditions and old mining works in a few places. Numerous scarps, at times semi-amphitheatrical in shape, are present on both the banks of the Song. This region marks the youthful stage of the river. Cases of occasional braiding in the Song river also occur, forming channel bars which comprise of sand, gravel and boulders. In the upper reaches of Song, boulders are strewn all over.

1.6. Background of the project

According to the availability of water at the proposed site, the scheme can cater the domestic water demand of additional 15 lakh people at the rate of 135 lpcd for Dehradun city and suburban areas.

The preliminary investigations of this project were started in the year 2003 and detailed Geological studies are carried out by Geological Survey of India. Engineering and Environmental studies were carried out by IIT Roorkee as per requirement it is proposed to complete the project in five year time after the D.P.R. is approved by the Government.

The brief project background is summarized as under-

May, 1998- To fulfill the drinking water requirements of Dehradun city and suburban areas, A letter was sent to Irrigation department by Chairman Garhwal Jal Sansthan and Commissioner Garhwal.

June, 2004- A proposal was sanctioned by government for investigation and survey of site.

March, 2006- D.P.R. of Song River Drinking Water Project of estimated cost Rs 534 crore was submitted to Government.

March, 2013-Transactional Advisor (IL & FS) suggested to the govt. that existing ground water and subsurface water resources are enough to meet the drinking water requirement up to 2051.

Aug, 2017- Chief General Manager of Uttarakhand Jal Sansthan has written a letter to E-in-C Irrigation department in which he has recommended the construction of song dam to meet the drinking water requirement and ground/subsurface water source augmentation in the vicinity of Dehradun. Executive Summary of the project has been sent to the Secretary, MoWR, GoI by Principal Secretary, Irrigation, Uttarakhand on Aug 11, 2017

April, 2018- Administrative approval of the project has been accorded from government of uttarakhand.

July, 2018- Tractebel Engineering Private Limited was awarded the work of review and upgradation of DPR of Song Dam Drinking Water Project.

1.7. Organization of the Report

This document is the Detailed Project Report for Song Dam Drinking Water Project, Uttarakhand.

TE India has reviewed the previous DPR documents and had submitted an Inception Report on that basis.

Several geological studies were suggested to be carried out prior to submission of DPR for the project.

Water demand studies were conducted by TE-India and estimation of water demand on the basis of population projection and availability of surface and sub surface water till the year 2071 has been worked out and detailed in Chapter 2 of the report.

Rationale of the project discussing the various areas of impacts of the project are mentioned in Chapter 3. International/ interstate aspects upon the water distribution among affected states, if any are discussed in Chapter 4. Uttarakhand Irrigation Department has already conducted some topography and geological tests. However, upon review of earlier reports and site visits, some additional tests were finalized and were conducted on site. GSI is responsible for conducting the tests and report is prepared by them. The survey, Investigations and Project Geology has been discussed in Chapter 5. TE India has conducted a separate study on Hydrology of the dam Site. After several discussions with Irrigation Department and National Institute of Hydrology, Roorkee- a final concurrence was achieved and the Chapter was submitted to CWC for review. The same has been discussed in Chapter 6. Design of Civil structures and Hydro mechanical Equipment were carried out. For dam, the Design chapter was submitted to CWC for approval and for Water Conductor System, the design chapter has been submitted to IIT Roorkee for vetting purpose. The consolidated chapter is attached as Chapter 7. Reservoir planning for the project is discussed in Chapter 8. Following that, the Construction Program, Manpower, Plant Planning and Project Schedule are discussed in Chapter 9. EIA/EMP Studies has been conducted and the main aspects are discussed in Chapter 10. Thereafter, detailed project costing is mentioned in Chapter 11. Financial resources and allocation of funds are given in Chapter 12. The computation of revenues, Financial return and IRR for the project are mentioned in Chapter 13. Infrastructure Facilities are discussed in Chapter 14. Finally, the conclusion and recommendations of the study carried out by TE India for the project is discussed in Chapter 15.

2. WATER DEMAND, ANALYSIS AND PLANNING

2.1. Project Area

The project area encompasses source i.e from Song Dam situated on river song with is 25 km from Dehradun City. The water will be transmitted through cross country pipeline from Dam up to city limit.

The clear water transmission main of about 14.7 km run from Song dam up to proposed water reservoir near Khalanga War Memorial. A water treatment plant will be situated near Khalanga War Memorial and potable water will be supplied mainly by gravity to Dehradun city and adjoining suburban areas which is termed as service area of the project.

The project covers service area, which is Dehradun Municipal Corporation (DMC) area with its 6 wards, and peripheral areas limited by Dehradun Master Plan 2025. DMC area along with peripheral area has been considered for population projection and demand estimation.

Areas between Sahastradhara road and Rajpur road and sub urban areas such as Balawala and Nathuawala Jogiwala, Mothrowala, Jakhan etc. will be fed with supply of drinking water through this project.

The project area is shown in drawing in **Annexure 2.1**.

2.2. Summary of Past Population Projection and Water Demand

The previous DPR was reviewed and based on that following table and conclusions were drawn from that. The population project and demand assessment was furnished by Jal Sansthan for the drinking water requirement for year 2001 and expected future demand for year 2051.

Table 2-1: Summary Population and Demand by Jal Sansthan

Sl. No.	Description	Year 2001	Year 2011	Year 2021	Year 2031	Year 2041	Year 2051
A	**City Water Demand**						
1	Total population	6.35	8.38	10.83	12.08	12.63	13.19
2	Total water requirement MLD	142.00	187.60	241.60	271.60	287.60	303.80
3	Water being distributed MLD	66.77	85.91	85.91	85.91	85.91	85.91
4	**Short fall, MLD**	**75.23**	**101.69**	**155.69**	**185.69**	**201.69**	**217.89**
B	**Water Requirement surrounding rural area under MDDA limits**						
1	Population, lacs	1.19	1.60	2.17	2.93	3.95	5.34
2	Water requirement. MLD	13.09	17.60	23.87	32.23	43.45	58.74

Sl. No.	Description	Year 2001	Year 2011	Year 2021	Year 2031	Year 2041	Year 2051
i.	Available water, MLD	11.86	15.01	15.01	15.01	15.01	15.01
iv.	Short fall, MLD	1.23	2.59	8.86	17.22	28.44	43.73
	Total short fall / additional requirement MLD	**76.46**	**104.28**	**164.55**	**202.91**	**230.13**	**261.62**

The available water from existing source and expected ground water withdrawal was considered to arrive at shortfall water which needs to be fulfilled from proposed Song Dam.

Apart from fulfilling water requirement, power generation of 6 MW was also proposed. A water treatment plant was proposed at Kesarwala. After the implementation of the proposed dam, the ground water withdrawal is expected to remain constant on the present capacity in addition to the existing surface sources. The shortfall of water was proposed to be fulfilled by Song Dam.

2.3. Population Projection and Water Demand

2.3.1. Population Projection

The design year in past reports was considered up to year 2051 considering 50 years planning from year 2001. In this report, the future population and water demand has been calculated for 50 years planning considering year 2021 as base year. The proposed concept for various components is conceptualized for future demand for the ultimate year 2071 and provisions are made in the proposed system.

The population of Dehradun City for past decades is collected from Census of India and the same is projected for base year 2021, intermediate year 2051 and ultimate year 2071. The various methods are used for calculating population such as Arithmetic Increase method, Incremental Increase method and Geometrical increase method. Population projection has also been done using graphical techniques such as linear projection, logarithmic, exponential method. Projected population is also compared with the population projection by various available reports like, Master plan 2025, past reports and Census.

After analysing the growth trend, incremental increase method is selected for projecting Urban population and athematic increase method is found best suitable for projecting future population for rural areas,

The details of population projection are provided in **Annexure 2.2.**

Table 2-2: Projected Population

S. No	Description	Year 2011	Year 2018	Year 2021	Year 2031	Year 2041	Year 2051	Year 2061	Year 2071
I	**Population**								
1	Urban Area	706,124	789,262	829,552	984,045	1,169,601	1,386,221	1,633,904	1,912,652

2	Floating population	70,613	78,927	82,956	98,405	116,961	138,623	163,391	191,266
3	Rural Population	257,100	284,478	296,212	335,323	374,435	413,546	452,658	491,769
	Total Projected Population	**1,033,837**	**1,152,667**	**1,208,720**	**1,417,773**	**1,660,996**	**1,938,390**	**2,249,953**	**2,595,687**

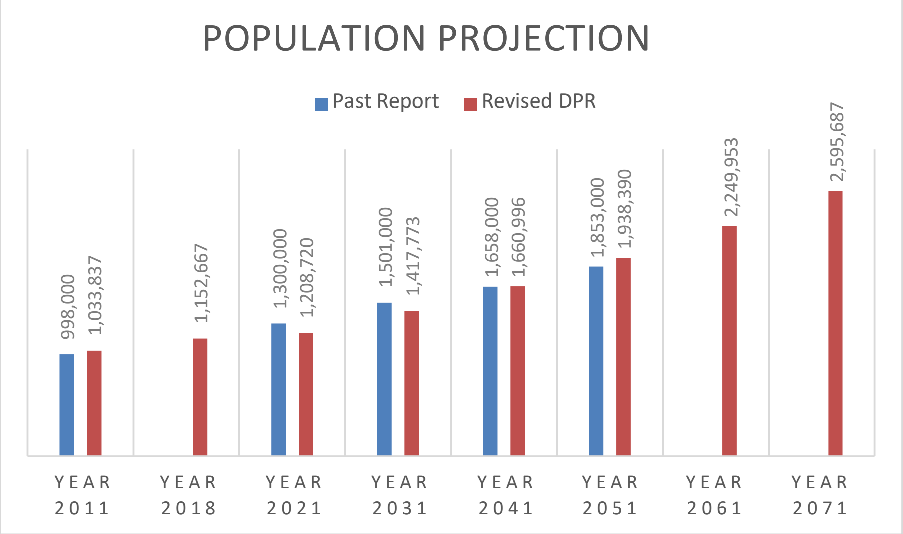


Figure 2-1: Population Bar Chart

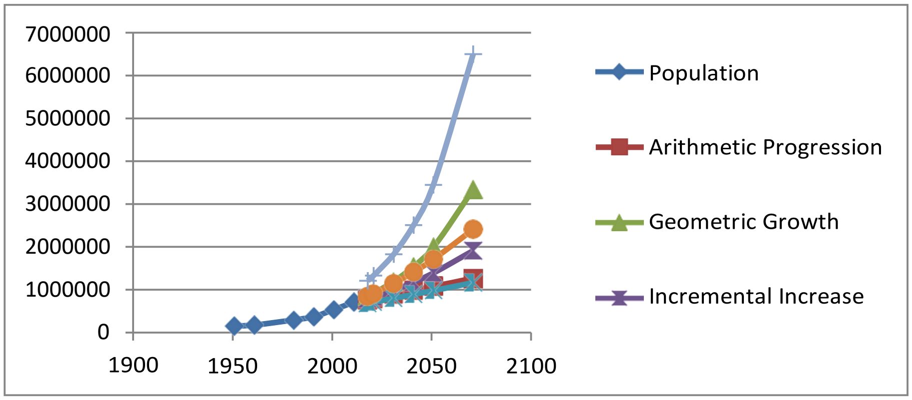


Figure 2-2: Population Projection – Dehradun UA

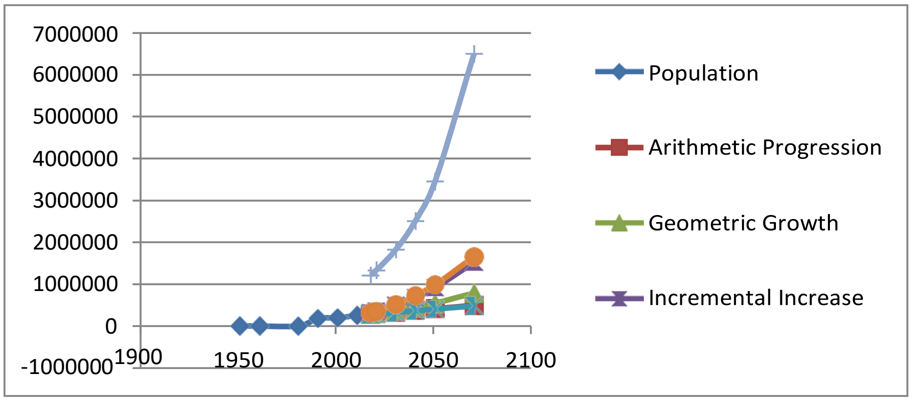


Figure 2-3: Population Projection – Rural Area

2.3.2. Existing Source of Water

The existing source of water is combination of surface water and sub surface source. The present source of supply is mainly form tube wells. The tube wells provide 80% of water supply of Dehradun town and its adjoining areas and 20% is from various surface resources.

2.3.2.1. GROUND WATER

The existing water supply mainly depends on ground water source. The water supply depends on 248 nos. tube wells yielding 165 MLD of ground water. For long term water security, it is recommended to shift on alternate source.

At present the ground water table in and around Dehradun city is continuously depleting, indicating the over exploitation of sub surface source at rate higher than the annual average recharge capacity.

The present ground water withdrawal rate is not sustainable and continuously depleting at 0.4 meter/year. The sustainable extraction of ground water for 150 Km^2 of project area is estimated at 150 MLD. It is recommended to restrict the ground water withdrawal at 150 MLD with sufficient ground water recharge arrangement.

The ground water extraction rate is calculated as below

Ground water depletion rate = 0.4 meter/year

Surface Area = 150 sqkm

Ground water Extraction Rate per year

= 150 x 0.4 x 10^6 m^3/year

= 60 MCM

= 164.39 MLD

For sustainable extraction of ground water, usage is restricted to 150 MLD

2.3.2.2. SURFACE WATER

The surface water sources comprise of rivers, mountain falls and canal. The capacity from different surface water sources are given in following Table 2-3.

Table 2-3: Capacity from different sources of water

S. No	Source	Present Drawl (in MLD)	Design Drawl (in MLD)	Water Treatment Plant	Capacity (installed/present)
1	Bandal River	8	10	Dilaram Bazaar WTP	20 MLD/16 MLD
2	Bijapur Canal	10	10		
3	Massi Fall &Shikhar Fall	8	12	Shehenshai Ashram WTP	14 MLD/10 MLD
4	Galogi	--	10	Pururkul Gram WTP	New treatment plant proposed in ADB project
5	Khalanga Canal	0.58	--		
	Total Capacity	**26.58**	**42**		

2.3.3. Water Demand

As recommended by CPHEEO manual, any city or town provided with piped water supply, where sewerage system is existing / contemplated, should supply at least 135 litres per capita per day of water. The water demand for nearby rural areas has been calculated considering the future growth and development. The nearby rural areas has seen a rapid urbanization in past years and same trend is expected to be continued in future also. The rapid urbanization will lead to an increase in per capita water demand. Initially per capita water demand of 100 LPCD is taken for rural population.

As the development happens, the per capita water requirement is increased from 100 LPCD to 135 LPCD in phase wise manner. At ultimate year equitable water at 135 LPCD will be supplied to all users in Dehradun area. The per capita water demand for floating population is take as 45 LPCD as per CPHEEO manual. The water supply is excluding UFW (Unaccounted for Water), which should be limited to 15%. Gross demand of the town is calculated considering 15% of UFW (10% in distribution and 5% in transmission).

The per capita water demand considered is given in the following Table 2-4.

Table 2-4: Per capita water demand

S. No	Year	Urban population	Rural/ Semi Urban Population	Floating Population
1	2021	135 LPCD	100 LPCD	45 LPCD
2	2031	135 LPCD	100 LPCD	45 LPCD
3	2041	135 LPCD	100 LPCD / 135 LPCD	45 LPCD
4	2051	135 LPCD	100 LPCD / 135 LPCD	45 LPCD
5	2061	135 LPCD	135 LPCD	45 LPCD

S. No	Year	Urban population	Rural/ Semi Urban Population	Floating Population
6	2071	135 LPCD	135 LPCD	45 LPCD

Based on this norms, total demand has been calculated for base year, intermediate and ultimate year. In addition to domestic demand, floating population, industrial and commercial demand is also considered.

The estimated water demand is given in the following Table 2-5.

Table 2-5: Estimated water demand

S. No	Description	Year 2011	Year 2018	Year 2021	Year 2031	Year 2041	Year 2051	Year 2061	Year 2071
I	**Population**								
1	Urban Area	706,124	789,262	829,552	984,045	1,169,601	1,386,221	1,633,904	1,912,652
2	Floating population	70,613	78,927	82,956	98,405	116,961	138,623	163,391	191,266
3	Rural Population	257,100	284,478	296,212	335,323	374,435	413,546	452,658	491,769
	Total Projected Population	**1,033,837**	**1,152,667**	**1,208,720**	**1,417,773**	**1,660,996**	**1,938,390**	**2,249,953**	**2,595,687**
II	**Water Computation**								
1	Water demand for Urban Area(in MLD) @ 135 LPCD	95.33	106.55	111.99	132.85	157.90	187.14	220.58	258.21
2	Water demand for floating population (in MLD) @ 45 LPCD	3.18	3.55	3.73	4.43	5.26	6.24	7.35	8.61
3	Water demand for Rural Area (in MLD)	25.71	28.45	29.62	33.53	44.00	52.21	61.11	66.39
4	Bulk Industrial Requirement in MLD	25.00	25.00	25.00	30.00	30.00	40.00	40.00	45.00
	Net Water demand in MLD	149.21	163.55	170.34	200.81	237.16	285.59	329.04	378.20
	Total Water Requirement in MLD @ 15% water loss	**175.55**	**192.41**	**200.40**	**236.24**	**279.01**	**335.99**	**387.10**	**444.95**
	Total water requirement in Cumec	2.03	2.23	2.32	2.73	3.23	3.89	4.48	5.15
	Total water requirement in MCM	64.07	70.23	3.15	86.23	101.84	122.63	141.29	162.41
III	**Water Supply**								
A	**Surface Sources**								

S. No	Description	Year 2011	Year 2018	Year 2021	Year 2031	Year 2041	Year 2051	Year 2061	Year 2071
1	Massi fall (Shahensai Ashram WTP)	10.00	10.00	12.00	12.00	12.00	12.00	12.00	12.00
2	Bandal river (Dilram Bazar WTP)	8.00	8.00	10.00	10.00	10.00	10.00	10.00	10.00
3	Bijapur canal (Dilram Bazar WTP)	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
4	Kolhu Khet	-	-	-	-	-	-	-	-
5	Khalanga Canal	-	-	-	-	-	-	-	-
6	Galogi (Purukul Gram WTP)	-	-	10.00	10.00	10.00	10.00	10.00	10.00
	Total Surface Water available for existing Source in MLD (A)	**28.00**	**28.00**	**42.00**	**42.00**	**42.00**	**42.00**	**42.00**	**42.00**
	Water losses @ 15%	4.20	4.20	6.30	6.30	6.30	6.30	6.30	6.30
	Net Surface Water Available from existing Source in MLD	23.80	23.80	35.70	35.70	35.70	35.70	35.70	35.70
B	**Song Dam**								
	Total water supply from song dam in cumec	-	-	1.74	1.74	1.74	1.74	1.74	1.74
	Total water supply in MCM	-	-	54.87	54.87	54.87	54.87	54.87	54.87
	Total water supply in MLD (B)	-	-	**150**	**150**	**150**	**150**	**150**	**150**
	Water Distribution losses @ 15%	-	-	22.55	22.55	22.55	22.55	22.55	22.55
	Net Water supply from Song Dam in MLD	-	-	127.79	127.79	127.79	127.79	127.79	127.79
	Total available surface water in MLD (A+B)	**28**	**28**	**192**	**192**	**192**	**192**	**192**	**192**
C	**Ground Water Sources**								
	Total available ground water in MLD	**150.00**	**165.00**	**150.00**	**150.00**	**150.00**	**150.00**	**150.00**	**150.00**
	Water Distribution losses @ 15%	22.50	24.75	22.50	22.50	22.50	22.50	22.50	22.50

S. No	Description	Year 2011	Year 2018	Year 2021	Year 2031	Year 2041	Year 2051	Year 2061	Year 2071
	Net water supply from Tube Wells in MLD	127.50	140.25	127.50	127.50	127.50	127.50	127.50	127.50
	Total water available to be supplied from surface and ground water	**178.00**	**193.00**	**342.34**	**342.34**	**342.34**	**342.34**	**342.34**	**342.34**
	Surplus / Deficit water demand in MLD	**2.45**	**0.59**	**141.93**	**106.09**	**63.33**	**6.35**	**(44.77)**	**(102.61)**

A detailed assessment of existing situation and future projection is carried out, which concludes that the available water resources including song dam is surplus to cater the increasing demand of Dehradun. The ground water source is restricted at a sustainable rate of 150 MLD up to year 2071. After restricting the ground water at 150 MLD, a combined shortfall of 102 MLD (8.4% of total demand) is expected after 50 years. Alternate source is proposed to be explored to supply the additional requirement at year 2071.

The water supply from available source will be a combination of surface and ground water depending on the location, treatment capacity, distribution network and cost economics. It is recommended to give priority to song dam and other available surface sources over ground water. The tube well will have higher operation and maintenance cost as compared to water supply from song dam. The water supply from song dam will be by gravity resulting is huge saving in power and O&M cost.

The present water production of 207 MLD (tube well 165 MLD and surface source 42 MLD), is sufficient to meet water demand of Dehradun till the year 2021.The water availability can be increased up to 2031 by improving the water management and rehabilitation of old and leaking distribution system. The existing NRW in distribution system is 60% which is higher that the MoUD guidelines of 15% losses.

2.3.4. Proposed Additional Source of Water – Song Dam

The proposed potential source for fulfilling the future drinking water demand of Dehradun City is from Song River. The Song Dam will prove to be lifeline for the growing city of Dehradun and help to reduce the pressure on ground water in addition to augmentation of sub surface flow. The proposed Dam will reduce the exploitation of subsurface water. This will not only increase the water table but also reduce the expenditure on operation and maintenance of bore wells. Even after 50 year, the sub surface source is restricted less than the current capacity.

3. RATIONALE OF THE PROJECT

3.1. General

Song Dam project is a drinking water scheme under Irrigation Department of Uttarakhand. The project envisages to cater to the growing demands of water in the area of Dehradun by building a 130.6m high dam at Song River and carrying water through about 14.7km long Water Conductor System via gravity to Water Treatment Plant located near Khalanga War Memorial. Thereafter, the water is treated and distributed- the distribution is taken up as a separate project. This shall lead to saving of huge expenses incurred in pumping water from Tube wells.

This chapter discusses the various areas of benefits of the project in the coming sections.

3.2. Water Supply In the Area

As discussed in detail in Chapter 2 of the project, the project has been conceptualised to cater to the needs of growing water demands in Dehradun district of Uttarakhand.

Water supply via gravity shall lead to significant saving on the cost incurred while pumping the water from tube wells.

3.3. Impact of the Project

The project has several positive impacts other than catering to the growing need of water in Dehradun District. They are discussed in following sections.

3.3.1. Ground water rejuvenation

Existing sources of surface and sub-surface water are being depleted at a higher rate. The tube wells provide 80% of water supply of Dehradun town and its adjoining areas and 20% is from various surface resources.

Presently, ground water being a major source of water in and around Dehradun City- with increase in demand and in absence of any alternate source, the ground water table is depleting at an alarming rate indicating over exploitation of sub surface source at rate higher than the annual average recharge capacity.

Storage of water in the reservoir thereafter shall help in recharging of sub surface sources-i.e. ground water. A calculation indicating the same is given in section 2.3.2.1.

3.3.2. Scope of Fisheries-Economic Boost

The project upon completion shall boost Fisheries in the area- thus creating some revenue. People in adjoin areas/ villages can explore it as a sustainable source of income.

3.3.3. Tourism Boost

The project will create a lake extending in a length of about 3.50 kms and will be a big attraction for the tourists. The submergence will involve about 73.583 hectares of forest and Benaap land and 10.332 hectare of agricultural land. The number of trees in submergence area is also very less and so the project is ideal with respect of environmental aspect. This reservoir can act as artificial lake and can be used to promote tourism in adjoin area.

3.4. Conclusion

The project shall serve as a water supply project and over and above, it shall be beneficial for tourism development, ground water recharge and economic development (boost in Fisheries) etc.

It is seen that upon completion, it shall be highly beneficial to Dehradun and adjoining areas in various aspects. It is found to be environment friendly as well.

4. INTERNATIONAL ASPECT/ INTER STATE ISSUES

The project is proposed on River Song – a right bank tributary of River Ganga. Streams namely Song, Rispana, Bindal, Suswa etc. flow in the Doon valley and form a part of Ganga basin in the upstream reach. Figure 4-1 shows schematically the various rivers flowing in the Doon Valley.

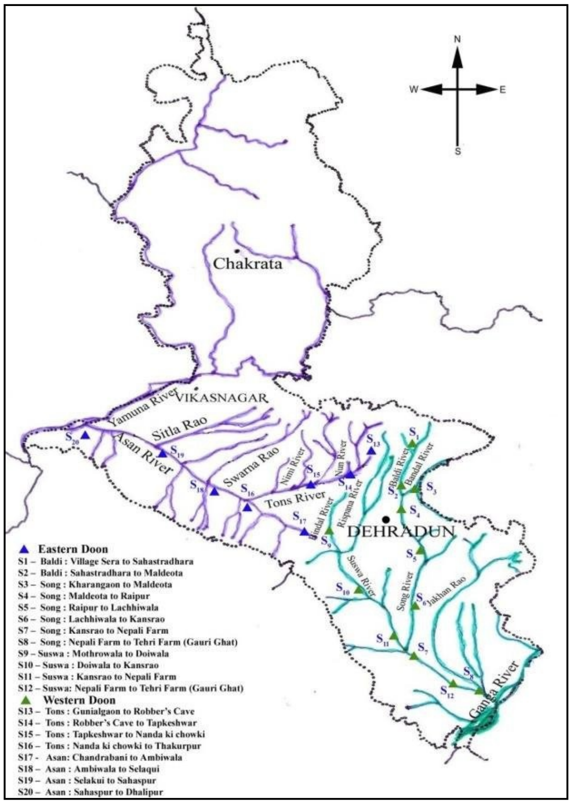


Image Courtesy: *https://www.researchgate.net/figure/Sampled-stations-and-distribution-of-rivers-in-Doon-valley_fig2_270577700*

Figure 4-1: Schematic View of Rivers in Doon Valley.

The site covers very small catchment area of 85 sq. km (around 0.36 % of catchment area at Haridwar) with a very small proportion of available water in river Ganga in plain).

As per water treaties for sharing of water amongst the Stakeholder states i.e. Uttarakhand and Uttar Pradesh, there should not be any obstruction in planning of the project – particularly for drinking water scheme for Dehradun City.

In concern to Interstate matter, necessary communications has been done with CWC so as to avoid future constrictions pertaining to water use of the river. Conclusively, the matter is looked into by FM Wing of DoWR. The FM Wing for International Clearance has seeked for some information about the project which has already been supplied. Hence clearance from international /JRC angle is obtained with no further comments.

The correspondences in relation to the Interstate/International aspects are reproduced below:

भारत सरकार
केंद्रीय जल आयोग
परियोजना मूल्यांकन (उत्तर) निदेशालय

No. 2/297/2018-PA(N)/380-82 dated: 30/01/2019

Sub: Song Dam Drinking Water Project Dehradun, Uttarakhand.....reg

Please find enclosed herewith a copy of letter dated 23.01.2019 received from Inter State Matters-2 Dte., CWC on above subject. In this context the following points may kindly be noted for compliance:

Comments:

1. Song river is a tributary of Ganga river which joins Ganga river just upstream of Haridwar. Since, Ganga being an inter-state river, the proposal needs to be examined from inter-State aspect.
2. There is no inter-state agreement on sharing of waters of river Ganga between basin states including Uttar Pradesh and Uttarakhand. Hence, water utilization including evaporation loss from the reservoir would be accounted against the State of Uttarakhand when any agreement for sharing of Ganga river water is reached among the basin States of UP and Uttarakhand. Accordingly, consumptive use from Song Dam including evaporation loss from the reservoir needs to be assessed and its details of calculation should be included in the DPR. Further, Govt. of Uttarakhand should certify that the proposed utilization would be accounted for whenever any inter-State agreement for sharing of Ganga river waters takes place between different States in future. A certificate in this regard may be submitted by Irrigation dept., Govt. of Uttarakhand.
3. Copy of the DPR needs to be sent to Uttar Pradesh for their comments, if any, and the same may be conveyed to CWC within a time bound manner for further examination w.r.t. inter-state aspect.
4. Further, as the project lies in the Ganga basin, international clearance from FM wing of MoWR, RD & GR needs to be obtained in view of the Indo-Bangladesh Ganga Water Treaty (1996). It is mentioned in the report that 150 mld withdrawal is proposed from the Song dam for drinking purposes which means that water would be withdrawn throughout the year. As per the provisions of Ganga Water Treaty, withdrawal is not permitted from Ganga basin during lean period (i.e. from 1st January to 31st May). Accordingly, the project authority needs to ensure that provisions are made for fulfilling the above.
5. No proper index map of the project has been provided in the DPR. A detailed and coloured index map, showing the details of upstream and downstream existing, proposed and ongoing projects with their various canal head points, and other relevant details of the project may be submitted for better appraisal of the project proposal in respect of its scope and benefits.

Encl: as above.

पीयूष रंजन
30/1/19
पीयूष रंजन
निदेशक

To,
SE, Project Circle, Irrigation Dept, Uttarakhand

Copy for kind information to:
1. Chief Engineer (PAO), CWC, New Delhi
2. Chief Engineer, Level1, Irrigation Dept., Uttarakhand.

7th Floor (South), Sewa Bhawan, R.K. Puram, New Delhi - 110066. Tel: 011-29583433/24 e-mail: panorth@nic.in

7 Floor (S)

Government of India
भारत सरकार
Central Water Commission
केन्द्रीय जल आयोग
Inter State Matters-2 Dte.

Fifth floor, Sewa Bhawan(S)
R.K.Puram, New Delhi-66
रामा कृष्ण पुरम, नई दिल्ली -६६
Telephone No: 011-29583207
Email: ism2dte@gmail.com

विषय: Proposal for construction of Song Drinking Water Project in Dehradun (Uttarakhand) – Reg.

संदर्भ: Letter no. 2/207/201`8-PA(N)/1959-69 dated 7.12.2018.

May kindly refer to letter under reference on the above subject received through email from Director, PA(N) Dte., CWC enclosing therewith proposal for construction of Song Drinking Water Project in Dehradun(Uttarakhand) and letter dated 6.12.2018 from Engineer-in-Chief, Irrigation Department, Uttarakhand requesting for 'In Principle" consent' of the project from CWC. The Project was examined from inter-state aspect and comments are as under:

Project Proposal:

Irrigation department, Uttarakhand has proposed a dam on river Song, to cater the domestic water demand of Dehradun city and its suburban areas. The Project envisages construction of a 130 meter high dam. Full Reservoir Level of the reservoir is at EL. 980.00 m and Max. Draw Down Level (MDDL) is at EL. 925.0.00 m. Live Storage is 26.4 MCM and Dead Storage at MDDL is 4.55 MCM. The drinking water shall be supplied through 1.5 m diameter M.S. Pipe to the proposed Water treatment Plant (WTP) at Village Kulhan, near pacific golf Dehradun after maintaining the minimum environmental flow, and thereafter it will be catered to consumers through distribution system. The total length of pipe from start location i.e. Dam Block No. 04 to end location i.e. WTP at Kulhan Man Singh would be 14.7 Km. The project will create a lake extending about 4 km from dam axis and the submergence area will be 83.85 ha. The storage capacity will be 2640 hact. m to meet the drinking water demand for the forecasted population.

Song River is a tributary of River Ganga, in the state of Uttarakhand. River Song originates from Dhanaulti at an elevation of about 2400m and joins River Ganga just upstream of Haridwar. The proposed site is located at the boundary of district Dehradun and Tehri Garhwal near village Sondhana at a distance of about 25 kilometers from Dehradun Railway Station. The coordinates of the dam site are: Longitude: 78^{0}11'30"E and Latitude: 30^{0}18'08"N.

As reported by Project Authority, "project is meant for drinking water purposes only and Government of Uttarakhand is interested in funding the project, it does not come under the purview of Advisory Committee of CWC as suggested by CWC in its letter dated 31.1.18. However, the dam being in a category of a high dam, its design needs to be vetted by CWC". The Dam shall meet a minimum extra demand of 150 MLD through surface water storage along with a sustainable ground water supply of 150 MLD more along with the existing surface sources of 42 MLD making a pool of 342 MLD in total for 100 years of its life. Here, future population and water demand has been considered for 50 years only from 2021 up to year 2071.

Comments:

1. Song river is a tributary of Ganga river which joins just upstream of Haridwar. Therefore, Ganga being an inter-State river, the proposal needs to be examined from inter-State aspect.

2. There is no inter-state agreement on sharing of waters river Ganga between basin states including Uttar Pradesh and Uttarakhand. Hence water utilization including evaporation loss from the reservoir would be accounted against the State

of Uttarakhand when any agreement for sharing of Ganga river water is reached among the basin States of UP and Uttarakhand. Accordingly, consumptive use from Song Dam including evaporation loss from the reservoir needs to be assessed and its details of calculation should be included in the DPR Further, Govt. of Uttarakhand should certify that the proposed utilization would be accounted for whenever any inter-State agreement for sharing of Ganga river waters takes place between different States in future.

3. Copy of the DPR may be sent to Uttar Pradesh for their comments, if any, and the same may be conveyed to this directorate within a time bound manner for further examination w.r.t. inter-state aspect.

4. Further, as the project lies in the Ganga basin, international clearance from FM wing of MoWR, RD & GR needs to be obtained in view of the Indo-Bangladesh Ganga Water Treaty (1996). It is mentioned in the report that 150 mld withdrawal is proposed from the Song dam for drinking purposes which means they would be withdraw water throughout the year. As per the provisions of Ganga Water Treaty, withdrawal is not permitted from Ganga basin during lean period (i.e. from 1st January to 31st May). Accordingly, the project authority needs to ensure that provisions are made for fulfilling the above.

5. No proper index map of the project has been provided in the DPR. A detailed and coloured index map, showing the details of upstream and downstream existing, proposed and ongoing projects with their various canal head points, and other relevant details of the project may be submitted for better appraisal of the project proposal in respect of its scope and benefits.

This issues with the approval of Member (WP&P), CWC.

राजेश कुमार

(Rajesh Kumar)
Director

Director, PA(N) Dte., CWC, Sewa Bhawan, R.K. Puram, New Delhi
CWC U.O. No. 2/6/ ISM-2/2017/23 Date: 23.01.2019

To,

The Director,
ISM-2 Dte.
CWC , New Delhi

Letter No. C-14 **CE level -1/ Dehradun/ Song Dam** **Date 13 March 2019**

Subject : Song Dam Drinking Water Project Dehradun, Uttarakhand.

Reference: CWC U.O. No. 2/6/ISM-2/2017/23

Sir,

With to your above mentioned letter, The Departmental reply regarding Inter State matter pertaining to Song Dam Drinking Water Project is being given as follows.

S.No.	Comments	Response
1	Song river is a tributary of Ganga river which joins Ganga river just up-streams of Haridwar, Since, Ganga being an inter-state river, the proposal needs to be examined from inter-state aspect.	The proposal notes submitted in CWC, New Delhi describes this aspect. Also, further clarification are being submitted in the following points.
2	There is no inter-state agreement on sharing of waters of river Ganga between basin states including Uttar Pradesh and Uttarakhand. Hence, water utilization including evaporation loss from the reservoir would be accounted against the state of Uttarakhand when any agreement for sharing of Ganga river water is reached among the basin states of UP and Uttarakhand. Accordingly, consumptive use from Song Dam including evaporation loss from the reservoir needs to be assessed and its details of calculation should be included in the DPR. Further, Govt. of Uttarakhand should certify that the proposed utilization would be accounted for whenever any inter-state agreement for sharing of Ganga river waters takes place between difference states in future. A certificate in this regard may be submitted by Irrigation Department, Government of Uttarakhand.	Assessment of water utilization including Drinking water demand of 150 MLD (with evaporation loss from the reservoir) as consumptive uses from Song Dam along with relevant details, has been included in the hydrology chapter of the DPR which has been submitted in CWC. The proposed drinking water utilization through the said Dam project is about 10.05 MCM only in non-monsoon season which will be made available from the stored water in reservoir from monsoon flow only. It has also been observed that Song river has very little discharge visible in a stretch beyond 1 km D/S of proposed project. Thus, it is evident that for this particular project, a very small quantum of water is proposed to be used compared to that available in Song River at Satynarayana (near confluence with Ganga in upstream of Haridwar) (about 2.75%). Further, catchment area at Bhimgoda barrage at Haridwar is 23365 SQ KM the proportion of above water use is conclusively negligible in area ratio proportion ie (635/23375X2.75) which comes out to be 0.0074 percent only . This proportion will reduce further as we move towards d/s places in Uttar Pradesh such as Kanpur and Varanasi. Therefore, the project will have a negligible effect on water availability in the stakeholder state of Uttar Pradesh. Thus there would not be any inter-state issue in utilization of water in far upstream end of Ganga basin especially for drinking water purpose.

		However, as desired by CWC a certificate in this regard is being attached **as Annexure-1.**
3	Copy of the DPR needs to be sent to U.P for their comments. if any, and the same may be conveyed to CWC within a time bound manner for further examination w.r.t. inter-state aspect.	The same has been submitted in CWC.
4	Further, as the project lies in the Ganga basin, international clearance from FM wing of MoWR, RD & GR needs to be obtained in view of the Indo-Bangladesh Ganga Water Treaty (1996). It is mentioned in the report that 150 MLD withdrawal is proposed from the Song Dam for drinking purposes which means that water would be withdrawn throughout the year. As per the provisions of Ganga Water Treaty, withdrawal is not permitted from Ganga basin during lean period (i.e. from 1st January to 31st May). Accordingly, the project authority needs to ensure that provisions are made for fulfilling the above.	As explained in (2) above, water utilization is 10.5 MCM only which is met through the proposed reservoir by storing water by flow in monsoon period only. So no international treaty is being violated here.
5	No proper index map of the project has been provided in the DPR. A detailed and coloured index map, showing the details of upstream and downstream existing, proposed and ongoing projects with their various canal head points, and other relevant details of the project may be submitted for better appraisal of the project proposal in respect of its scope and benefits.	The details including index map desired & other relevant details are attached here with as Annexure 2

Mukesh Mohan
Chief Engineer ,Dehradun
Irrigation Department Uttarakhand

Letter No. / Date

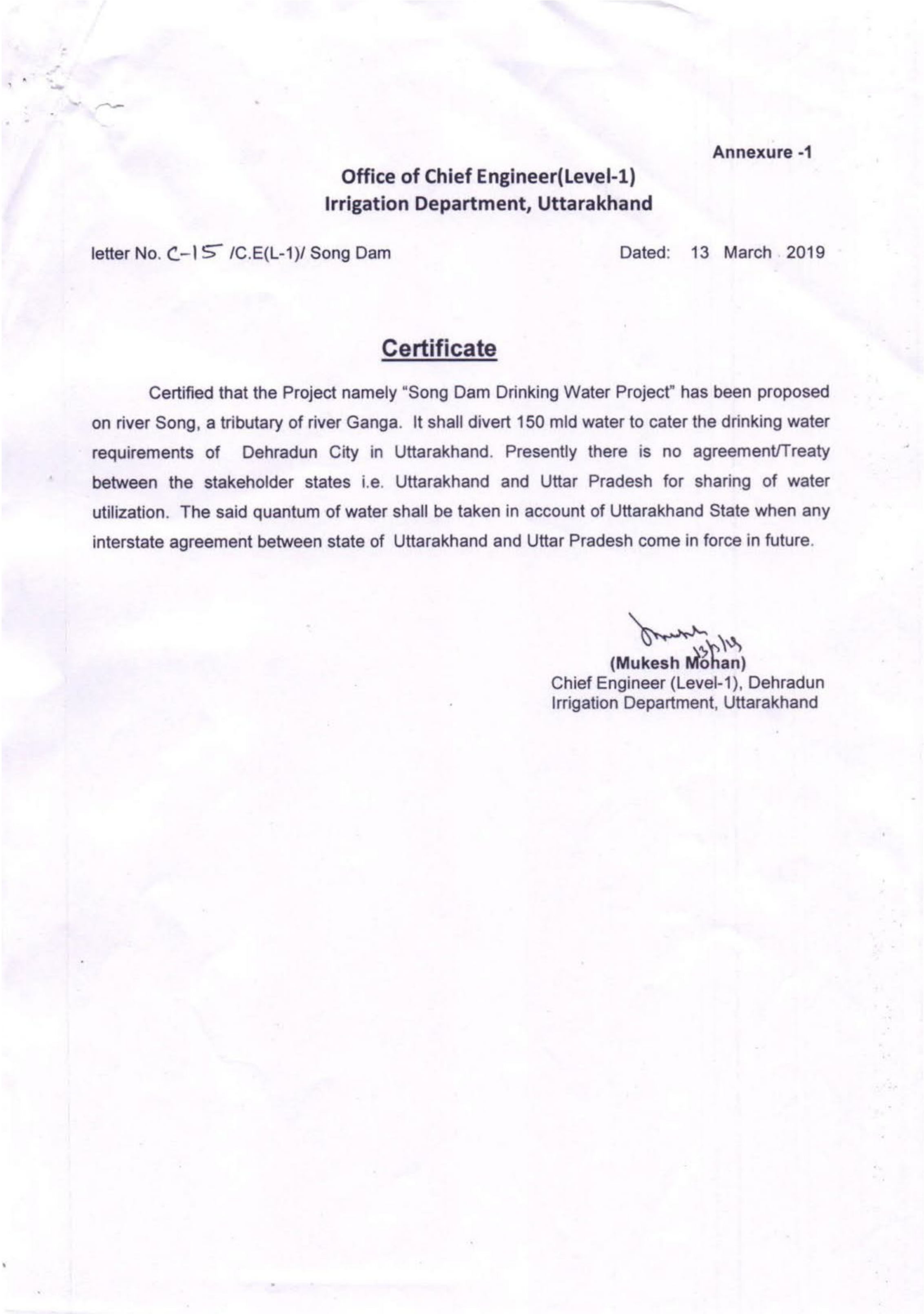
Copy to the Following for Information & necessary action
1. Engineer in Chief, Uttarakhand Irrigation Department.
2. Superintending Engineer , Project Circle , Dehradun

Mukesh Mohan
Chief Engineer ,Dehradun
Irrigation Department Uttarakhand

कार्यालय
अधीक्षण अभियन्ता
परियोजना मण्डल देहरादून

No. 1150 /PCD/ Song Dam / Dt. 16/3/19
Copy forwarded to Ex. En, I. & P. Division, Dehradun for Necessary Action pl.

अधीक्षण अभियन्ता
परियोजना मण्डल
देहरादून



Annexure -1

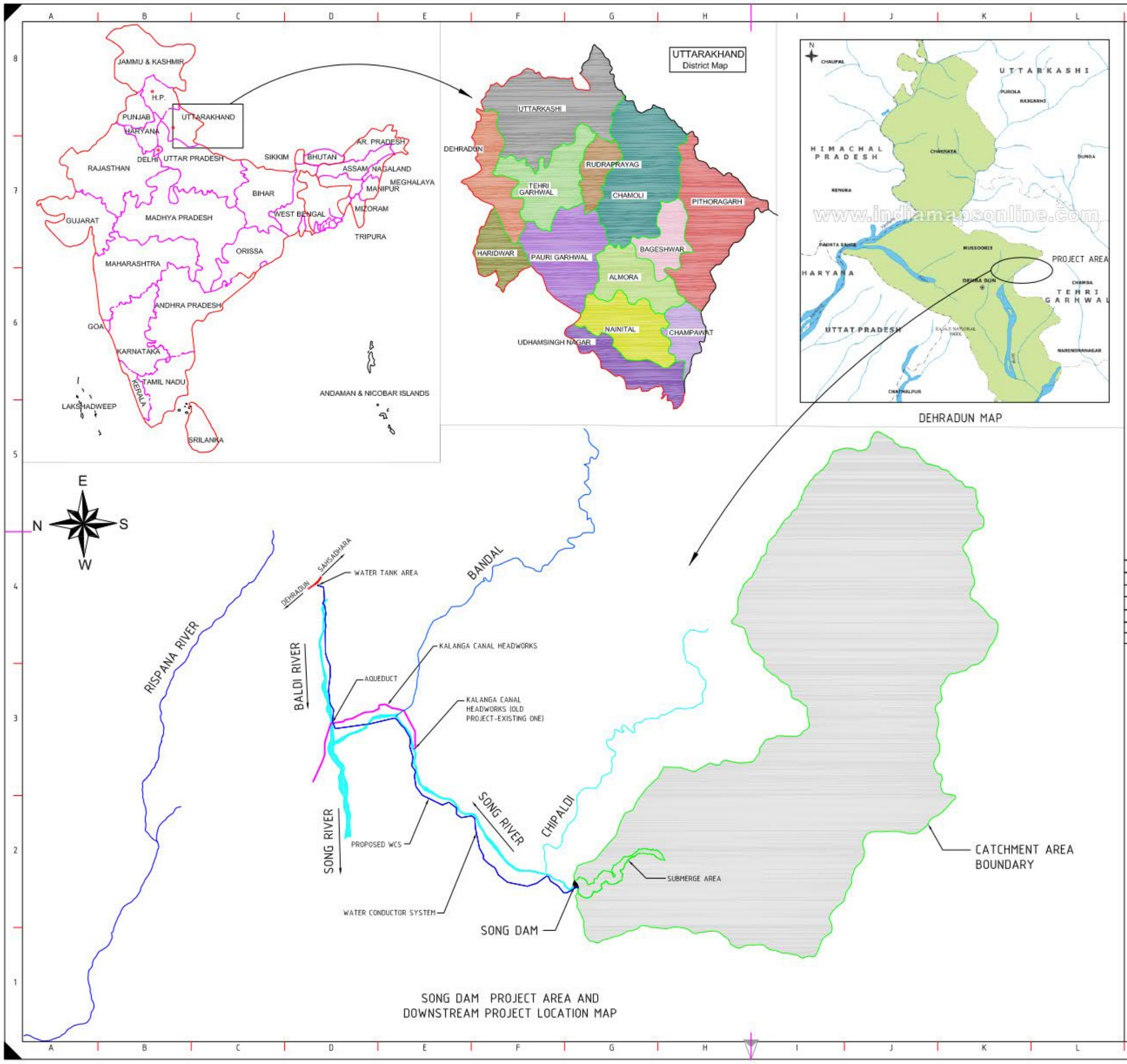
Office of Chief Engineer(Level-1)
Irrigation Department, Uttarakhand

letter No. C-15 /C.E(L-1)/ Song Dam   Dated: 13 March 2019

Certificate

Certified that the Project namely "Song Dam Drinking Water Project" has been proposed on river Song, a tributary of river Ganga. It shall divert 150 mld water to cater the drinking water requirements of Dehradun City in Uttarakhand. Presently there is no agreement/Treaty between the stakeholder states i.e. Uttarakhand and Uttar Pradesh for sharing of water utilization. The said quantum of water shall be taken in account of Uttarakhand State when any interstate agreement between state of Uttarakhand and Uttar Pradesh come in force in future.

13/3/19
(Mukesh Mohan)
Chief Engineer (Level-1), Dehradun
Irrigation Department, Uttarakhand



SONG DAM PROJECT AREA AND
DOWNSTREAM PROJECT LOCATION MAP

BASED ON DRAWING / DOCUMENTS

DRG./DOCUMENT NO.	SUBJECT

REFERENCE DRAWINGS

DRG. NO.	SUBJECT

Autocad release : 2008

THIS IS A DPR DRAWING NOT FOR CONSTRUCTION

REV. No.	DATE	STAGE	DESCRIPTION	CIVIL	HM	E&M
-	-	-	-	-	-	-
-	-	-	-	-	-	-
-	-	-	-	-	-	-
				CHECKED		

CLIENT

Uttarakhand Irrigation Department
सिंचाई विभाग उत्तराखण्ड

TRACTEBEL ENGINEERING PVT. LTD.
CONSULTING ENGINEERS, GURGAON

	NAME	SIGN
DRAWN BY	SK PANDEY	
DESIGN BY	MUKESH	
CHECKED BY	H GUPTA	
APPROVED BY	H GUPTA	
DATE:-	05-03-2019	
SHEET SIZE	SCALE	1:3000

PROJECT
SONG DAM DRINKING WATER PROJECT, DEHRADUN

DRAWING TITLE
INDEX MAP
GENRAL LAYOUT PLAN

DRG NO.	REV.	SHEET
P.012745.W.20301.00	A	1 OF 1

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन नदी विकास एवं गंगा संरक्षण विभाग
केंद्रीय जल आयोग
परियोजना मूल्यांकन (ऊ०) निदेशालय

सत्यमेव जयते

Government of India
Ministry of Jal Shakti
Dept. of Water Resources, RD&GR
Central Water Commission
Project Appraisal (North) Directorate

No. 2/297/2018-PA(N)/ 1117-19

dated: 30/07/2019

Sub: Song Dam Drinking Water Project Dehradun, Uttarakhand.....reg

Reference is invited to this office letter dated 24.06.2019 vide which the comments/observations of FE&SA Dte., CWC on foundation engineering and seismic aspects of above project were sent for compliance. The compliance is however still awaited. It is requested to submit the same at the earliest.

Also, please find enclosed herewith a copy of letter dated 07.03.2019 from FM Wing of DoWR, RD&GR. The Check-List has to be sent to FM Wing for International Clearance (Copy enclosed). It is requested to fill the same and submit to this office for further submission to FM Wing. The report on the water availability study of above project has already been sent vide this office letter dated 25.04.2019.

Encl: as above (02 page).

पीयूष रंजन
निदेशक

To,

SE, Project Circle, Irrigation Dept, Uttarakhand.

Copy for kind information to:

1. Engineer-in-Chief, Irrigation Dept., Uttarakhand.
2. Chief Engineer, Level1, Irrigation Dept., Uttarakhand.

सप्तम तल (दक्षिण), सेवा भवन
राम कृष्ण पुरम, नई दिल्ली -110066
दूरभाष: 011-29583424,
ई मेल: panorth@nic.in
♦जल संरक्षण-सुरक्षित भविष्य♦

7th Floor (South), Sewa Bhawan,
R.K. Puram, New Delhi-110066
Tel: 011-29583424,
E-mail: panorth@nic.in
♦Conserve Water- Save Life♦

CHECK LIST FOR PROJECT CLEARANCE FROM INTERNATIONAL/JRC ANGLE

1. Name of Project:
2. Name of State:
3. Name of river:
4. (a) Annual average water availability in the river:
   (b) Average water availability in the river in lean season (January –May).
5. (a) Annual average water availability in the Ganga basin:
   (b) Average water availability in lean season (January –May):
6. (a) Allocation of water for the co-basin State in the Ganga basin:
   (b) Existing consumptive water uses by the State in monsoon and non-monsoon periods:
   © Balance unutilized water share of the State in monsoon and non-monsoon periods:
7. How much water is supposed to be released by the project authority in downstream in lean season (January to May):
   (a) For Bangladesh share under Ganga Treaty:
   (b) For river eco-system and other downstream uses:
8. Whether the project would have any adverse impact on the inflows in lean season on Farakka or it would enhance the lean season flows:
9. Quantity of inflows likely to be decreased/ augmented at Farakka by the Project in each 10-day period from January-May:
10. Any other relevant information:

Signature and Name of the Director (PAO)
Central Water Commission

Countersigned by
Chief Engineer (PAO), CWC

From

Superintending Engineer
Project Circle
Uttarakhand Irrigation Department

To,

Chief Engineer
PAO, CWC New Delhi,

Letter No:-3078 /SE(PC)/ Song Dam **Dated** 6.08.2019

Subject: Song Dam Drinking Water Project, Uttarakhand

Ref: Your letter no 2/297/2018-PA(N)/1117-19 dated 30/07/2019

Sir,

With reference to your above cited letter regarding the observation by FM wing of DoWR, RD&GR, CWC regarding the international clearances, departmental reply is being attached below. Also, as mentioned in the aforesaid referred letter of CWC. It is stated that the reply to the observations regarding Geological aspects of the project on dated 24/06/2019 has already been sent to CWC by the department through its letter no:- 3014 /SE(PC)/ Song Dam, dated 02-08-2019.

Reply of the Check List for project clearance from international/JRC Angle.

1.	Name of Project:	Song Dam Drinking Water Project Dehradun, Uttarakhand.
2.	Name of State:	Uttarakhand
3.	Name of river:	Song River
4	a) Annual average water availability in the river:	137.58 MCM (as per the approved data series by CWC)
	b) Average water availability in the river in lean season (January-May):	30.46 MCM (as per the approved data series by CWC)
5	Annual average water availability in Ganga basin.	At Haridwar, the catchment area of Ganga basin is 23365 sq km whereas the catchment area at song dam site is only 85sqkm (0.36 percent of catchment at Haridwar). Average annual Water availability at Haridwar in catchment area proportion is about 37800 MCM.

	b) Average water availability in lean season (January-May)	Water availability at Haridwar in catchment area proportion in lean season is about 8300 MCM.
6	a) Allocation of water for the co-basin state in the Ganga basin.	Till Now, no agreement for sharing of water between Uttar Pradesh and Uttarakhand is in force.
	b) Existing consumptive water uses by the state in monsoon and non-monsoon periods.	Approx. 8000 MCM
	c) Balance unutilized water share of the state in monsoon and non-monsoon periods.	As explained in 6(a) above.
7	How much water is supposed to be released by the project authority in downstream in lean season (January to May)	Almost negligible, water is being utilized from non-monsoon flow. The total water utilization through the said dam is about 10.05 MCM only in non monsoon period which will be available from the stored water in reservoir from monsoon flow. Also mentioned in letter no C-14 /CE level 1/ Dehradun /Song dam/ dated 13 march 19 of Irrigation Department, in compliance to the observations of CWC regarding interstate issue.
	a) For Bangladesh share under Ganga Treaty	As mentioned above, site being situated in far upstream of Ganga Basin, Project has negligible effect on water availability at Farraka Barrage.
	b) For river eco-system and other downstream uses.	As per the *Gazette notification No. 4009 [S.O.5195(E)] dated 09 October 2018)"* Desired e-flow requirement has been taken into consideration.
8	Whether the project would have any adverse impact on the inflows in lean season on Farakka or it would enhance the lean season flow.	As explained in 7(a) above.
9	Quantity of inflows likely to be decreased/augmented at Farakka by the project in each 10- day period from January-May.	Negligible effect, as said above.
10	Any other relevant information.	The said project has been planned at the upstream end of Song river which is a

		tributary of Ganga basin with a very little catchment area of 85 sq km only, whereas catchment area of Farraka Barrage is 1008500 sq.km. Thus, considering the catchment area proportion it will have negligible effect at water availability at Farraka. Thereby, no violation of inter-national treaty.

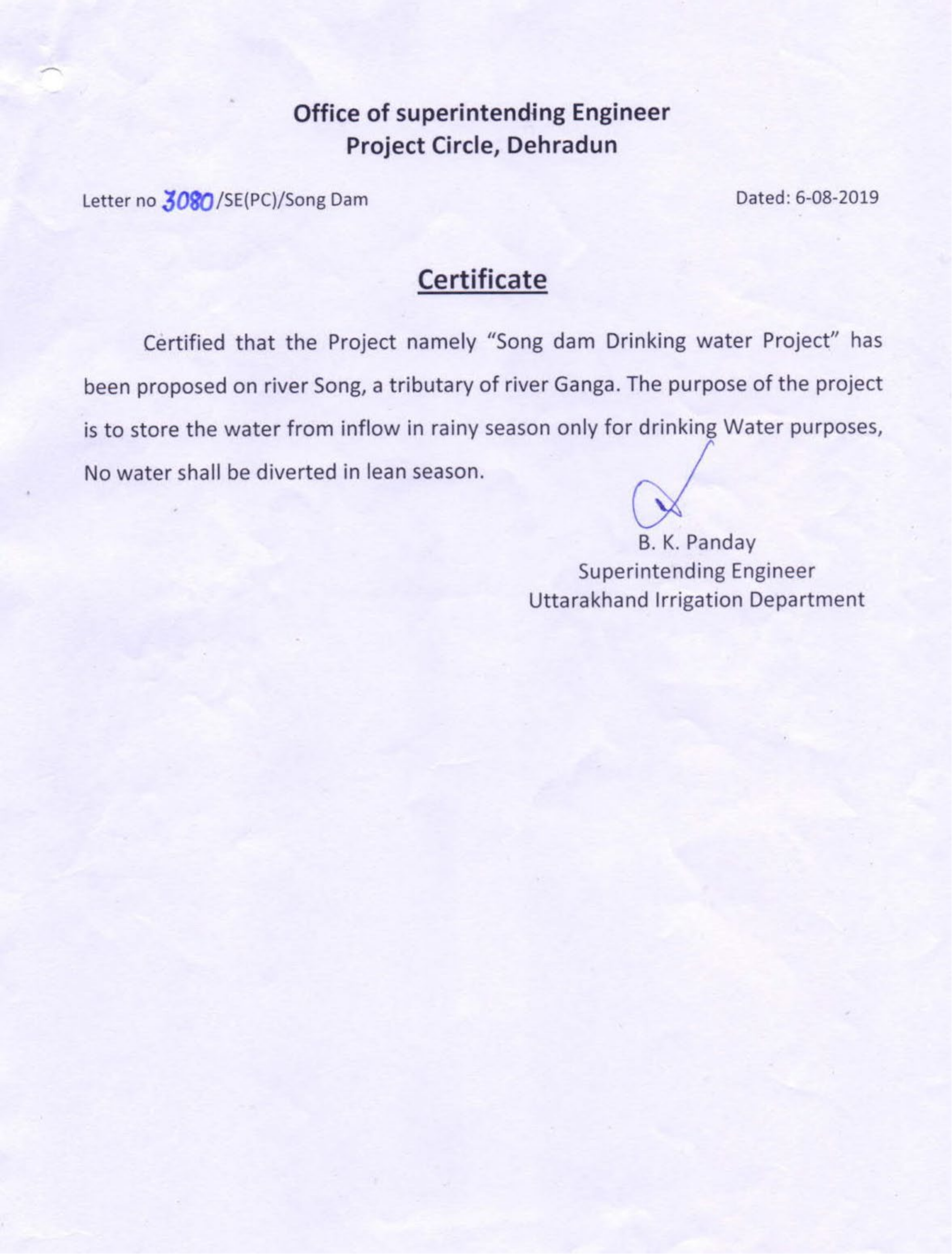
B.K Panday
Superintending Engineer
Uttarakhand Irrigation Department

Letter No:-3078/SE(PC)/ Song Dam

Copy to:-

1. Engineer-in-Chief, Uttarakhand Irrigation Department.
2. Chief Engineer (Level-01), Dehradun

B.K Panday
Superintending Engineer
Uttarakhand Irrigation Department



Office of superintending Engineer
Project Circle, Dehradun

Letter no 3080/SE(PC)/Song Dam Dated: 6-08-2019

Certificate

Certified that the Project namely "Song dam Drinking water Project" has been proposed on river Song, a tributary of river Ganga. The purpose of the project is to store the water from inflow in rainy season only for drinking Water purposes, No water shall be diverted in lean season.

B. K. Panday
Superintending Engineer
Uttarakhand Irrigation Department

File No.T-85013(16)/1/2019-ISM-2 DTE

Government of India
Central Water Commission
Irrigation Planning (North) Dte.

5th Floor, Sewa Bhawan(S)
R.K. Puram, New Delhi-66
Telephone No: 011-29583207
Email: ism2dte@gmail.com

विषय: Proposal for construction of Song Drinking Water Project in Dehradun (Uttarakhand)

Please refer to letter no. C-14 CElevel-1/Dehradun/Song Dam dated 13th March 2019 on the above subject from Chief Engineer, Dehradun Irrigation Department, Uttarakhand forwarding therewith compliance of comments of this office letter dated 23.01.2019 alongwith letter no. C-15/C.E(L-1_/Song Dam dated 13th March 2019 vide which certificate regarding the accounting of sharing of quantum of water utilization by Uttarakhand.

The compliance from the project Authority on the comments asked vide this office letter dated 23.01.2019 are as follows:

S.No.	Comments of ISM-2	Compliance
1	Song river is a tributary of Ganga river which joins Ganga river just upstream of Haridwar. Since, Ganga being an inter-state river, the proposal needs to be examined from inter-state aspect.	The proposal notes submitted in CWC, New Delhi describes this aspect. Also, further clarification is being submitted in the following points.
2	There is no inter-state agreement on sharing of waters of river Ganga between basin states including Uttar Pradesh and Uttarakhand. Hence, water utilization including evaporation loss from the reservoir would be accounted against the state of Uttarakhand when any agreement for sharing of Ganga river water is reached among the basin states of UP and Uttarakhand. Accordingly, consumptive use from Song Dam including evaporation loss from the reservoir needs to be assessed and its details of calculation should be included in the DPR. Further, Govt. of Uttarakhand should certify that the proposed utilization would be accounted for whenever any inter-State agreement for sharing of Ganga river waters takes place between different states in future. A certificate in this regard may be submitted by Irrigation Department, Government of Uttarakhand.	Assessment of water utilization including drinking water demand of 150 MLD (with evaporation loss from the reservoir) as consumptive uses from Song Dam along with relevant details has been included in the Hydrology chapter of DPR which has been submitted in CWC. The proposed drinking water utilization through the said Dam project is about 10.05 MCM only in non-monsoon season which will be made available from the stored water in the reservoir from monsoon flow only. It has also been observed that Song river has very little discharge visible in a stretch beyond 1km D/S of proposed project. Thus, it is evident that for this particular project, a very small quantum of water is proposed to be used compared to that available in Song River at Satyanarayana (near confluence with Ganga in upstream of Haridwar) (about 2.75%). Further, catchment area at Bhimgoda barrage at Haridwar is 23365 SQ KM the

		proportion of above water use is conclusively negligible in area ratio proportion ie(635/23375X2.75)which comes out to be 0.0074 percent only. This proportion will reduce further as we move towards d/s places in Uttar Pradesh such as Kanpur and Varanasi. Therefore, the project will have a negligible effect on water availability in the stakeholder state of Uttar Pradesh. Thus there would not be any inter-state issue in utilization of water in far upstream end of Ganga basin especially for drinking water purpose. However, as desired by CWC a certificate in this regard is being attached as **Anneexure-1**
3	Copy of the DPR needs to be sent to U.P for their comments. If any, and the same may be conveyed to CWC within a time bound manner for further examination w.r.t. inter-state aspect	The same has been submitted in CWC.
4	Further, as the project lies in the Ganga basin, international clearance from FM wing of MoWR, RD & GR needs to be obtained in view of the Indo-Bangladesh Ganga Water Treaty (1996). It is mentioned in the report that 150MLD withdrawal is proposed from Song Dam for drinking purposes which means that water would be withdrawn throughout the year. As per the provisions of Ganga Water Treaty, withdrawal is not permitted from Ganga basin during lean period (i.e. from 1st January to 31st May). Accordingly, the project Authority needs to ensure that provisions are made for fulfilling the above.	As explained in (2) above, water utilization is 10.5 MCM only which is met through the proposed reservoir by storing water by flow in monsoon period only. So no international treaty is being violated here
5	No proper index map of the project has been provided in the DPR. A detailed and coloured index map, showing the details of upstream and downstream existing, proposed and ongoing projects with their various canal head points, and other relevant details of the project may be submitted for better appraisal of the project proposal in respect of its scope and benefits	The details including index map desired & other relevant details are attached herewith as Annexure2

In view of the above following is submitted:

1. Since, as per the DPR the withdrawal of water for the project has been planned only during monsoon period, hence, this does not attracts the provision of Indo-Bangladesh Treaty 1996

on Farakka. However PAO, CWC may consider to send the proposal to FM Wing of MoWR, RD&GR , for taking formal international clearance.

2. In compliance to our earlier comment that , "there is no inter-state agreement on sharing of waters of river Ganga between basin states including Uttar Pradesh and Uttarakhand. Hence, water utilization including evaporation loss from the reservoir would be accounted against the state of Uttarakhand when any agreement for sharing of Ganga river water is reached among the basin states of UP and Uttarakhand. Accordingly, consumptive use from Song Dam including evaporation loss from the reservoir needs to be assessed and its details of calculation should be included in the DPR. Further, Govt. of Uttarakhand should certify that the proposed utilization would be accounted for whenever any inter-State agreement for sharing of Ganga river waters takes place between different states in future" a certificate to this effect has already been furnished by the State Govt. vide letter no.C-15/C.E (L-1)/Song Dam dated 13 March 2019(Copy enclosed) and further, it has been mentioned that water utilization including drinking water demand of 150 MLD (with evaporation loss from the reservoir) as consumptive uses from Song Dam along with relevant details has been included in the Hydrology chapter of DPR which has been submitted in CWC. Therefore, there is no comments to offer. However, copy of the proposal may be sent to the Govt. of U.P for information. There are no further comments to offer.

This issues with the approval of Chief Engineer (IMO), CWC.

(Rajesh Kumar)

Director

मुख्य अभियंता, पी.ए.ओ.(पीएओ), केन्द्रीय जल आयोग, सेवा भवन,रामा कृष्णा पुरम, नाई दिल्ली

केन्द्रीय जल आयोग पत्र संख्या 2/6/ISM2/2017/ 153 दिनांक: 30/04/2019

ignature Not Verified
gitally signed by RAJESH
JMAR
te: 2019.04.29 12:49:56 IST

Clearance of Song Dam Drinking Water project, Uttarakhand from International/JRC angle- Approvals from CWC

River Ganga concern with International/Inter-sate river and hence project should be planned/operated with satisfying the International Aspect / Interstate policy. Considering, Indo -Bangladesh water treaty, 1996 on Farakka, withdrawal is not permitted from Ganga basin during lean period (i.e. from 1st January to 31st May).

Besides above-mentioned correspondence, CWC has many observations on reservoir planning for fulfilling the International aspects. For getting approvals of Song Dam for International aspects, many correspondences and hence correction in reservoir planning have been takes place between Irrigation department, Govt. of Uttarakhand with CWC, New Delhi. All the correspondence and final approval regarding International Aspect /Interstate issue have been given as below:

- CWC-Draft Comment letter---.11.2019
- 10-12-2019 (from Uttrakhand Irrg. Dept.)
- 19-12-2019 (from CWC)
- 19-12-2019 (from Uttrakhand Irrg. Dept.)
- 27-12-2019 (from Uttrakhand Irrg. Dept.)
- 06-01-2020-inter state approval from CWC

केन्द्रीय जल आयोग
Central Water Commission
अंतरराज्यीय मामले निदेशालय-2
ISM-2 Directorate
5th Floor, Sewa Bhawan
R.K. Puram, New Delhi-66
Telephone No: 011-29583268
Email: ism2dte@gmail.com,
ism-2dte-cwc@nic.in

सत्यमेव जयते

विषय: DPR of Song Dam Drinking Water Project, Dehradun (Uttarakhand).

संदर्भ: i) Letter no. 2/297/2018-PA(N)/1299 dated 18.09.2019.
ii) Letter no. 1/Uttara/29/2006-Hyd(N)/148-149 dated 22.04.2019

May kindly refer to letter under reference on the above subject received from Director, PA(N) Dte., CWC enclosing therewith DPR of Song Dam Drinking Water Project, Dehradun (Uttarakhand) submitted by Superintending Engineer, Project Circle, Uttarakhand Irrigation Department, Dehradun, for examination from inter-state aspect. The Project was examined from inter-state aspect and comments are as under:

Project Proposal:

Irrigation department, Uttarakhand has proposed a dam on river Song, to cater the domestic water demand of Dehradun city and its suburban areas. The Project envisages construction of a 131.6 meter high dam. The Longitudes and Latitude of the dam site are 78°11'30"E and 30°18'08"N respectively. The proposed site is located at the boundary of the district Dehradun and Tehri Garhwal near village Sondhata at a distance of about 25 Km from Dehradun Railway Station. Full Reservoir Level of the reservoir is at EL. 980.00 m and Minimum Draw Down Level (MDDL) is at EL 925.00 m. Live Storage is 22.40 MCM and Dead Storage at MDDL is 4.00MCM. The water will be transmitted through cross country pipeline from Dam up to proposed water reservoir at village Khulan Mansingh. A Water Treatment Plant (WTP) will be situated at village Khulan Mansingh and potable water will be supplied mainly by gravity to Dehradun city, near pacific golf Dehradun and thereafter to distribution system. The total length of pipe from start location to WTP at Kulhan Man Singh would be 15 Km (Approx.). The total catchment area of Song river upto dam site is about 85.225 Sq. Km.

Song River is a tributary of Soowa river, which in turn is a tributary of River Ganga, in the state of Uttarakhand. River Song originates as spring fed stream in the southern slopes of Mussoorie ridge of Himalayan range and run from Dhanaulti at an elevation of 2400m and joins River Ganga near village Raiwala located between Rishikesh and Haridwar.

The demand of drinking water from Song Dam is 150.34 MLD (54.87 MCM), including water distribution losses @15% i.e. 22.55 MLD (8.23 MCM). As mentioned at page no. 42-43 of DPR, the total water utilization from the Song Dam is about 10.05 MCM.

The available water from existing source and expected ground water withdrawal was considered to arrive at shortfall water which needs to be fulfilled from proposed Song Dam.

As reported by Project Authority at page 105-107 of the DPR, the Song Dam shall meet a minimum extra demand of 150 MLD through surface water storage along with a sustainable ground water supply of 150 MLD more along with the existing surface sources of 42 MLD making a pool of 342 MLD in total. Here, future population and water demand has been considered for 50 years only from 2021 up to year 2071.

Earlier, the proposal for construction of Song Drinking Water Project in Dehradun (Uttarakhand) received in this office in December, 2018 was examined and accepted from inter-state aspects on 30.04.2019 subject to some conditions.

Comments:

1. Song river is a left bank tributary of Ganga river which joins just upstream of Haridwar. Therefore, Ganga being an inter-State river, the proposal needs to be examined from inter-State aspect.

2. There is no inter-state agreement on sharing of waters river Ganga between basin states including Uttar Pradesh and Uttarakhand. Hence, water utilization including evaporation and other loss from the reservoir would be accounted against the State of Uttarakhand when any agreement for sharing of Ganga river water is reached among the basin States of UP and Uttarakhand. Certificate in this regard has already been submitted by State Govt. vide letter C-15/C.E(L-1)/Song Dam dated 13.05.2019 at page 38 of DPR.

3. Water availability study of the project has been examined by Hydrology (N) Dte., CWC vide letter no. 1/Uttara/29/2006-Hyd(N)/148-149 dated 22.04.2019 and as per the above study, the availability of water at 50%, 75% and 90 % dependability is 135.03 MCM, 111.01 MCM and 98.60 MCM respectively.

4. At page 42-43 of DPR, State Govt. vide letter 3078/S.E(PC)/Song Dam dated 06.08.2019 has submitted that the withdrawal of water for the project has been planned only during monsoon period, hence, it does not attracts Indo-Bangladesh Water Treaty 1996 on Farakka. However, on examination of the DPR, under Chapter 8, Reservoir Planning, it has been found that Reservoir Planning aspect has been done and it is found that:

i) There is utilisation of lean flow of the river. In view Farakka water treaty, as per MoWR guidelines, it may be ensured that there should be no net utilisation from the river basin during the period from 1st January to 31st May.

ii) If, ground water utilization is envisaged in the project, it is suggested that views on availability of the same may be obtained from CGWB/State Ground Water Board.

iii) The Project Authorities have submitted reservoir balance analysis studies for the project for various scenarios. It may be mentioned here that the letter under reference (II) may be referred to, wherein the Hydrology Dte., CWC has prepared a report on Water Availability of proposed Song Dam Project. The same may be used while preparing water balance studies.

iv) The source from where the data for evaporation losses has been used in the DPR may also be mentioned.

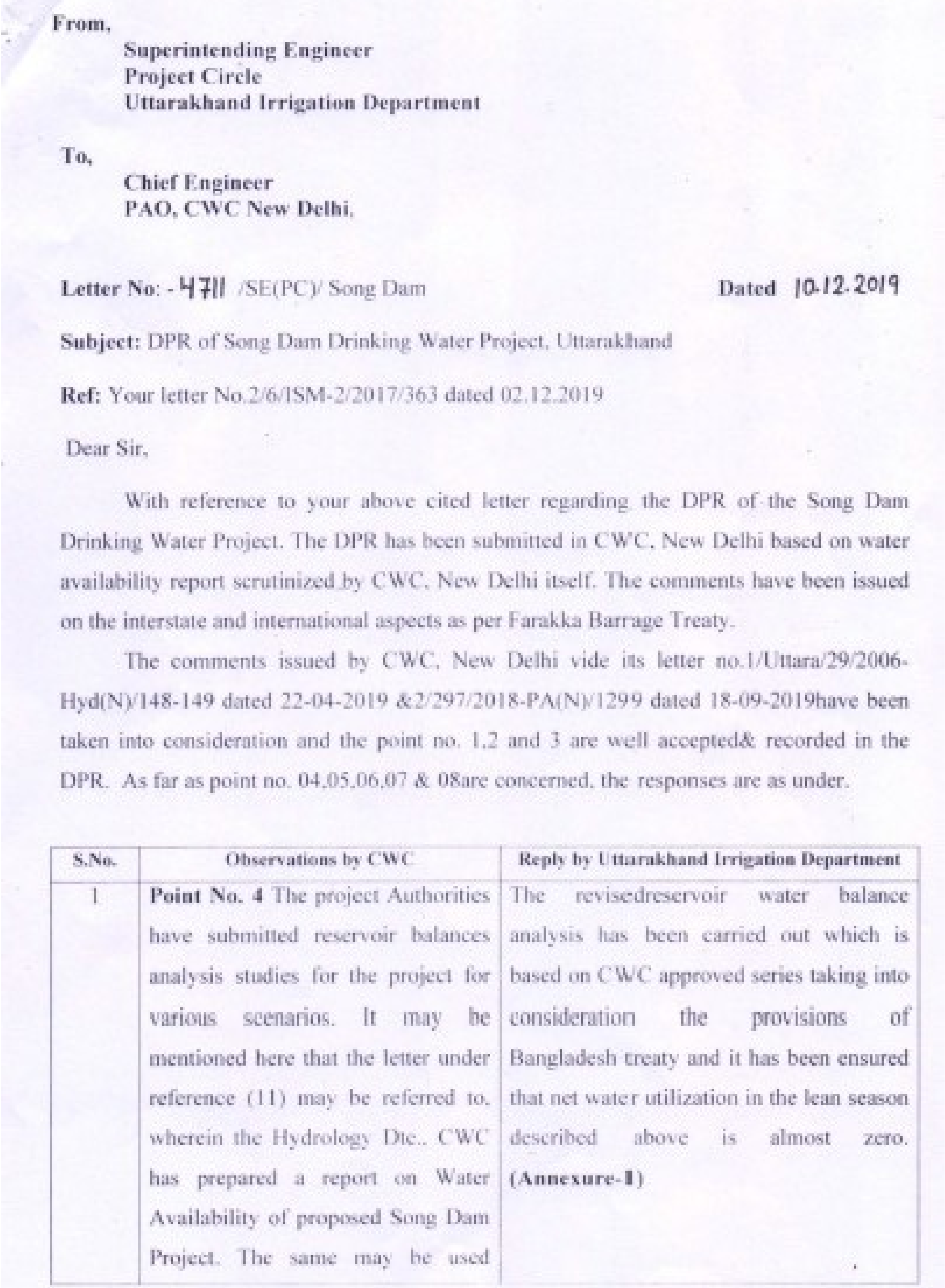
v) The seepage losses from the reservoir may also be appropriately considered by the Project Authorities.

5. Further, the PAO, CWC may send the Project Report for international clearance from FM Wing of DoWR, RD&GR as the project involves withdrawal of water from Ganga basin.

This issues with the approval of Chief Engineer(IMO), CWC.

(राजेश कुमार)
निदेशक(ISM2)

मुख्य अभियन्ता, परियोजना मूल्यांकन संगठन (PAO), केंद्रीय जल आयोग, नई दिल्ली।
के.ज.आ. पत्र संख्या 2/6/ ISM-2/2017/ दिनांक: .11.2019



From,

Superintending Engineer
Project Circle
Uttarakhand Irrigation Department

To,

Chief Engineer
PAO, CWC New Delhi.

Letter No: - 4711 /SE(PC)/ Song Dam **Dated** 10.12.2019

Subject: DPR of Song Dam Drinking Water Project, Uttarakhand

Ref: Your letter No.2/6/ISM-2/2017/363 dated 02.12.2019

Dear Sir,

With reference to your above cited letter regarding the DPR of the Song Dam Drinking Water Project. The DPR has been submitted in CWC, New Delhi based on water availability report scrutinized by CWC, New Delhi itself. The comments have been issued on the interstate and international aspects as per Farakka Barrage Treaty.

The comments issued by CWC, New Delhi vide its letter no.1/Uttara/29/2006-Hyd(N)/148-149 dated 22-04-2019 &2/297/2018-PA(N)/1299 dated 18-09-2019have been taken into consideration and the point no. 1,2 and 3 are well accepted& recorded in the DPR. As far as point no. 04,05,06,07 & 08are concerned, the responses are as under.

S.No.	Observations by CWC	Reply by Uttarakhand Irrigation Department
1	**Point No. 4** The project Authorities have submitted reservoir balances analysis studies for the project for various scenarios. It may be mentioned here that the letter under reference (11) may be referred to, wherein the Hydrology Dte., CWC has prepared a report on Water Availability of proposed Song Dam Project. The same may be used	The revisedreservoir water balance analysis has been carried out which is based on CWC approved series taking into consideration the provisions of Bangladesh treaty and it has been ensured that net water utilization in the lean season described above is almost zero. **(Annexure-I)**

	while preparing water balance studies.	
2	**Point No. 5** The source from where the data for evaporation losses has been used in the DPR may also be mentioned.	Evaporation losses has been well discussed in the Chapter No. 6.4.3.1 of the DPR on the page no. 123. The report has been prepared by NIH, Roorkee and references have been well recorded. They have used measured pan evaporation data at FRI Dehradun.
3	**Point No. 6.** The seepage losses from the reservoir may also be appropriately considered by the Project Authorities.	Every effort has been made for minimizing the seepage losses by the provision of reservoir treatment. As demonstrated in the reservoir planning table, there is a scope of sufficient storage to cater the required demand from the proposed reservoir. Further, GSI has also not made any adverse comments in its report regarding the Seepage losses through the reservoir. However, seepage analysis assuming loamy type of soil in reservoirhaving a seepage value of 2.5mm/day/area has been carried out and the same has been calculated in column No. 8 of the revised reservoir planning annexed herewith. Overall total seepage through the reservoir is about 0.511 MCM which is almost negligible and not affecting the reservoir planning.
4	**Point No. 7** If, ground water utilization is envisaged in the	As detailed in DPR, the project envisages construction of a storage reservoir for a

	project, it is suggested that views on availability of the same may be obtained from CGWB/State Ground Water Board.	drinking water supply of 150 MLD which shall be met as per reservoir balance analysis. **(Annexure-1)** As far as ground water utilisation is concerned, present system utilising165 MLD of drinking water demand as detailed in Page no. 27 of DPR is totally based on sustainable ground water system which is as per availability ensured by CGWB to the agencies in state. Further, it is also being apprised that the proposed project is for the exploitation of surface water resources which will even reduce the ground water exploitation by providing 150 MLD of surface water, in terms of reduction in number of tube wells Hence, there is no need to elaborate the details here.
5	**Point No. 8** At Page 42-43 of DPR, State Govt. vide letter 3078/SE(PC)/Song Dam dated 06.08.2019 has certified that the withdrawal of water for the project has been planned only during monsoon period, hence, it does not attractIndo-Bangladesh Water Treaty1996 on Farakka. Since as per MoWR guidelines 2009, withdrawal is not permitted from Ganga Basin during lean period (i.e. from 1st January to 31stMay). Accordingly, the project authority may take the	As said in the reply of Point No.4 a revised reservoir balance analysis has been done as suggested and to ensure no net utilisation in lean period. A demand of 150 MLD is met easily by the proposed reservoir without having any net utilisation in lean period (i.e. from 1st January to 31stMay) (Please see the notes on Annexure 1). Hence there is no need of providing any additional proposals suggested in Point No. 8 (1 to 3) to meet the demand. Thus, the suggested measures may not be required. Also, the checklist included in letter

	suggested measures.	no.3078/SE(PC)/Song Dam dated 06.08.2019 of this office and the response of Chief Engineer PAO by letter no. 2/6/ISM2/2017/153 dated 30.04.2019 stands revised in view of aforesaid observations and is being annexed as **Annexure 2.**

In view of the above, you are kindly requested to send the report along with the annexure annexed here with for international clearances from FW Wing of DoWR, RD&GR, CWC.

With regards.

Enclosures: As above

B.K Panday
Superintending Engineer
Uttarakhand Irrigation Department

<u>Letter No:-4711/SE(PC)/ Song Dam</u>

Copy to:-

1. ✓Director, ISM-2,CWC, New Delhi.
2. Engineer-in-Chief, Uttarakhand Irrigation Department.
3. Chief Engineer (Level-01), Dehradun

B.K Panday
Superintending Engineer
Uttarakhand Irrigation Department

ANNEXURE - I

10-Daily Water Balance with Dam Storage (in MCM) for 97% dependable year 1987-88 (FRL 980 m)

Month		CWC approved Flow (MCM) at 97% Dependable year (say ~ 100%) of 1987-88	10-daily Drinking Water Demand (in MCM)	Environmental flow requirement (EFR) (As per GO 4009) (in MCM)	Evaporation losses (in MCM)	Reservoir Surface Area	seepage losses through Reservoir (loamy soil with 2.5 mm/day seepage loss is assumed)	10-Daily (Dam Inflow - Demand-EFR-Losses)	Part of Demand to be met from Dam Storage (MCM)	Reservoir Storage after meeting Demand (MCM)	Down stream release just in the D/S of the reservoir other than E flow	Net D/S outflow (E flow(col 9) + return flow to the system (80% of utilization, col8)+col 17)	Comments
								(C3-C4-C5-C6-C8)				0.80C4+C5+C12	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
							2.50 mm/day			26.400			
JANUARY	1	1.53	1.5	0.306	0.0049	64.8200	0.0162	-0.297	0.297	26.103	0.0000	1.5060	return flow(80 % of the utilization) is being released to the system in the D/s (I>= 0.8U+E(0.20) as per GO 4009 in the months of Jan to March) Thus U<=I i.e. D/s release required just in D/s of reservoir other than E flow is zero.
	2	1.49	1.5	0.298	0.0049	64.0000	0.0160	-0.329	0.329	25.774	0.0000	1.4980	
	3	1.56	1.65	0.312	0.0053	63.0000	0.0158	-0.423	0.423	25.351	0.0000	1.6320	
FEBRUARY	1	1.35	1.5	0.27	0.0075	62.6000	0.0157	-0.443	0.443	24.908	0.0000	1.4700	
	2	1.41	1.5	0.282	0.0072	62.0000	0.0155	-0.395	0.395	24.513	0.0000	1.4820	
	3	1.16	1.2	0.232	0.0057	61.0000	0.0153	-0.293	0.293	24.220	0.0000	1.1920	
MARCH	1	1.29	1.5	0.258	0.0138	60.4000	0.0151	-0.497	0.497	23.723	0.0000	1.4580	
	2	1.3	1.5	0.26	0.0135	59.2000	0.0149	-0.488	0.488	23.235	0.0000	1.4600	
	3	1.35	1.65	0.27	0.0146	58.3000	0.0146	-0.599	0.599	22.636	0.0000	1.5900	
APRIL	1	1.22	1.5	0.305	0.0214	57.5000	0.0144	-0.621	0.621	22.015	0.0454	1.5504	return flow (80 % of the utilization) is being released to the system in the D/s (I>= 0.8U+E(0.25) as per GO 4009 in the months of April to May) Thus U<=.93 x I i.e. D/s release required just in D/s of reservoir other than E flow is only 7 % of inflow as per treaty.
	2	1.12	1.5	0.28	0.0211	56.7000	0.0142	-0.695	0.695	21.320	0.0784	1.5584	
	3	1.07	1.5	0.2675	0.0206	55.3000	0.0138	-0.732	0.732	20.588	0.0789	1.5464	
MAY	1	1.05	1.5	0.2625	0.0280	54.0000	0.0135	-0.754	0.754	19.834	0.0735	1.5360	
	2	1	1.5	0.25	0.0271	52.3000	0.0131	-0.790	0.790	19.044	0.0700	1.5200	
	3	1.09	1.65	0.2725	0.0292	51.3000	0.0128	-0.874	0.874	18.169	0.0763	1.6688	
JUNE	1	1.71	1.5	0.5130	0.0208	49.0000	0.0123	-0.336	0.336	17.833			
	2	1.82	1.5	0.5460	0.0203	48.0000	0.0120	-0.258	0.258	17.575			
	3	1.51	1.5	0.4530	0.0199	47.0000	0.0118	-0.475	0.475	17.100			
JULY	1	1.51	1.5	0.4530	0.0100	46.3000	0.0116	-0.465	0.465	16.636			
	2	1.49	1.5	0.4470	0.0097	45.2000	0.0113	-0.478	0.478	16.158			
	3	1.73	1.65	0.5190	0.0096	44.4000	0.0111	-0.460	0.460	15.698			
AUGUST	1	1.43	1.5	0.4290	0.0082	44.0000	0.0110	-0.518	0.518	15.180			
	2	1.8	1.5	0.5400	0.0079	42.5000	0.0106	-0.259	0.259	14.921			
	3	4.19	1.5	1.2570	0.0085	41.8000	0.0105	1.414	0.000	16.335			
SEPTEMBER	1	13.14	1.5	3.9420	0.0088	45.7500	0.0114	7.678	0.000	24.013			
	2	5.02	1.5	1.5060	0.0113	59.0000	0.0148	1.988	0.000	26.001			
	3	2.51	1.5	0.7530	0.0124	64.8200	0.0162	0.228	0.000	26.229			
OCTOBER	1	1.96	1.5	0.4900	0.0119	64.8200	0.0162	-0.058	0.058	26.171			
	2	1.74	1.5	0.4350	0.0119	64.8200	0.0162	-0.223	0.223	25.948			
	3	1.89	1.65	0.4725	0.0118	64.8200	0.0162	-0.262	0.262	25.687			
NOVEMBER	1	1.64	1.5	0.3280	0.0069	64.8200	0.0162	-0.211	0.211	25.475			
	2	1.62	1.5	0.3240	0.0069	64.8200	0.0162	-0.227	0.227	25.248			
	3	1.63	1.5	0.3260	0.0069	64.8200	0.0162	-0.219	0.219	25.029			
DECEMBER	1	1.61	1.5	0.3220	0.0049	64.8200	0.0162	-0.233	0.233	24.796			
	2	1.61	1.5	0.3220	0.0049	64.8200	0.0162	-0.235	0.235	24.561			
	3	1.7	1.65	0.3400	0.0049	64.8200	0.0162	-0.311	0.311	24.252			
Total			54.60	18.843	0.4442		0.5108						

Total storage in Reservoir in MCM	26.4000
Total Annual Drinking Water Demand (MCM)	54.6000
Drinking water Demand in normal period (other than Lean Period) (MCM)	31.9500
Lean Period Drinking Water Demand	22.6500
Lean Period Water Use to Meet drinking water demand after construction. (MCM)	22.65-26.4= -3.75

Hence, Storage is sufficient to meet the lean period water requirement.

Notes:
1 Reservoir planning has been done based on 97% dependable year of 1987-88 as per CWC approved series
2 150 MLd water is being withdrawn for drinking water purposes throughout the year.
3 Column no 13 clearly shows that the net water release in the d/S in the lean period is even more than inflow in the river, taking into account the contribution of water utilization in the form of waste water disposal which becomes the part of stream in D/S.
4 Reference for the seepage loss "http://www.fao.org/tempref/FI/CDrom/FAO_Training/FAO_Training/General/x6705e/x6705e02.htm"
5 Reference for Return Flow being equal to 80% of utilization - "Page 136 of SP 35 of BIS"

ANNEXURE-02

Check List for project clearance from international/JRC Angle.

1.	Name of Project:	Song Dam Drinking Water Project Dehradun, Uttarakhand.
2.	Name of State:	Uttarakhand
3.	Name of river:	Song River
4	a) Annual average water availability in the river:	137.58 MCM (as per the approved data series by CWC)
	b) Average water availability in the river in lean season (January-May):	30.46 MCM (as per the approved data series by CWC)
5	Annual average water availability in Ganga basin.	At Haridwar, the catchment area of Ganga basin is 23365 sq km whereas the catchment area at song dam site is only 85sqkm (0.36 percent of catchment at Haridwar). Average annual Water availability at Haridwar in catchment area proportion is about 37800 MCM.
	b) Average water availability in lean season (January-May)	Water availability at Haridwar in catchment area proportion in lean season is about 8300 MCM.
6	a) Allocation of water for the co-basin state in the Ganga basin.	Till Now, no agreement for sharing of water between Uttar Pradesh and Uttarakhand is in force.
	b) Existing consumptive water uses by the state in monsoon and non-monsoon periods.	Approx. 8000 MCM
	c) Balance unutilized water share of the state in monsoon and non-monsoon periods.	As explained in 6(a) above.
7	**How much water is supposed to be released by the project authority in downstream in lean season (January to May)**	**The total water utilization through the said dam is about 22.65 MCM only in lean period which will be available from the stored water in reservoir before the start of lean period (January to May). Therefore, net utilization of river flow in lean period**

		is zero.
	a) For Bangladesh share under Ganga Treaty	As mentioned above, site being situated in far upstream of Ganga Basin, Project has negligible effect on water availability at Farraka Barrage.
	b) For river eco-system and other downstream uses.	As per the *Gazette notification No. 4009 [S.O.5195(E)] dated 09 October 2018)"* Desired e-flow requirement has been taken into consideration.
8	Whether the project would have any adverse impact on the inflows in lean season on Farakka or it would enhance the lean season flow.	As explained in 7(a) above.
9	Quantity of inflows likely to be decreased/augmented at Farakka by the project in each 10- day period from January-May.	Negligible effect, as said above.
10	Any other relevant information.	The said project has been planned at the upstream end of Song river which is a tributary of Ganga basin with a very little catchment area of 85 sq km only, whereas catchment area of Farraka Barrage is 1008500 sq.km. Thus, considering the catchment area proportion it will have negligible effect at water availability at Farraka. Thereby, no violation of inter-national treaty.

Government of India
Ministry of Jal Shakti
Department of Water Resources, RD & GR
(Flood Management Wing)
***

Block-11, 8th Floor,
CGO Complex, Lodhi Road,
New Delhi-110003

Sub: **Clearance of "Song Dam Drinking Water Project", Uttarakhand from International/JRC Angle- reg.**

Ref: **CWC ID No. 2/297/2018-PA(N)/1388-89 dated 10.10.2019**

Kind reference is invited to PA(N), Directorate, Central Water Commission ID No 2/297/2018-PA(N)/1388-89 dated 10.10.2019 vide which the 'Check List' in respect of 'Song Dam Drinking Water Project' of Uttarakhand has been furnished duly vetted by Chief Engineer (PAO), CWC for clearance from International/ JRC angle.

It is observed from the 'Check List' which duly vetted by CWC that *"the total water utilization through the said dam is about 10.05 MCM only in the non monsoon period which will be available from the stored water in reservoir from monsoon flow. The site being situated far upstream of Ganga Basin, Project has negligible effect on water availability at Farakka Barrage"*. Further, Project Authority has certified in the DPR that the purpose of this project is to store the water from inflow in rainy season only for drinking water purposes, no water shall be diverted in lean season.

In view of the above, the undersigned is directed to convey 'No Objection' from International /JRC angle in respect of Ganga Water Sharing Treaty-1996 to "Song Dam Drinking Water Project", Uttarakhand subject to following conditions:

1. Government of Uttarakhand shall ensure that storage provided in the reservoir of this dam is sufficient to meet the envisaged water requirement of the project during lean season (1st January to 31st May).
2. Necessary provisions will be made by Government of Uttarakhand / Project Authority during and post execution of this project to ensure continuous unaffected lean season flow (1st January to 31st May) in Ganga River.
3. All conditions as imposed by National Mission for Clean Ganga shall be duly complied with by the Project Authority.

19-12-2019
(R.R. Sambharia)
Sr. Joint Commissioner-I (FM)

Director, PA(N), Central Water Commission, Sewa Bhawan, R.K Puram, New Delhi
Z-23011/1/2019-O/o SJC-I (FM) 4105-06 dated 19 December, 2019

Copy for information to:
Chief Engineer (PAO), Central Water Commission, R.K Puram, New Delhi

From,
Superintending Engineer
Project Circle
Uttarakhand Irrigation Department

To,
Chief Engineer
PAO, CWC New Delhi.

Letter No: - 4882 /SE(PC)/ Song Dam **Dated** 19.12.2019

Subject: DPR of Song Dam Drinking Water Project, Uttarakhand.
(Corrigendum to letter no. 4711/SE(PC)/ Song Dam dated 10-12-19 of this office)

Ref: Your letter No.2/6/ISM-2/2017/363 dated 02.12.2019.

Dear Sir,

With reference to your above cited letter regarding the DPR of the Song Dam Drinking Water Project, the response has already been given in aforesaid letter dated 10.12.19 of this office but reservoir balance analysis has been **suitably revised to ensure the demand that can be met through the proposed reservoir in lean period when net utilization is zero and also to further ensure that the hydrological cycle repeats in the next year** The contents of the aforesaid letter are again being quoted as under in revised fashion

The DPR has been submitted in CWC, New Delhi based on water availability report scrutinized by CWC, New Delhi itself. The comments have been issued on the interstate and international aspects as per Farakka Barrage Treaty.

The comments issued by CWC, New Delhi vide its letter no.1/Uttara/29/2006-Hyd(N)/148-149 dated 22-04-2019 &2/297/2018-PA(N)/1299 dated 18-09-2019 have been taken into consideration and the point no. 1,2 and 3 are well accepted & recorded in the DPR. As far as point no. 04,05,06,07 & 08 are concerned, the responses are as under.

Observations by CWC	Reply by Uttarakhand Irrigation Department
Point No. 4 The project Authorities have submitted reservoir balances analysis studies for the project for various scenarios. It may be mentioned	The revised reservoir water balance analysis has been carried out which is based on CWC approved series taking into consideration the provisions of Bangladesh treaty and it has been

here that the letter under reference (11) may be referred to, wherein the Hydrology Dte., CWC has prepared a report on Water Availability of proposed Song Dam Project. The same may be used while preparing water balance studies.	ensured that net water utilization in the lean season described above is negligible. **(Revised Annexure-1)**
Point No. 5 The source from where the data for evaporation losses has been used in the DPR may also be mentioned.	Evaporation losses has been well discussed in the Chapter No. 6.4.3.1 of the DPR on the page no. 127. The report has been prepared by NIH, Roorkee and references have been well recorded. They have used measured pan evaporation data at FRI Dehradun.
Point No. 6. The seepage losses from the reservoir may also be appropriately considered by the Project Authorities.	Every effort has been made for minimizing the seepage losses by the provision of reservoir treatment. As demonstrated in the reservoir planning (Revised annexure 1), there is a scope of sufficient storage to cater the required demand from the proposed reservoir. Further, GSI has also not made any adverse comments in its report regarding the Seepage losses through the reservoir. However, seepage analysis assuming loamy type of soil in reservoir having a seepage value of 2.5mm/day/area has been carried out and the same has been calculated in column No. 8 of the revised reservoir planning annexed herewith. Overall seepage through the reservoir is about 0.511 MCM which is almost negligible and not affecting the reservoir planning.
Point No. 7 If, ground water utilization is envisaged in the project, it is	The project has been conceptualized to reduce the ground water exploitation by construction

suggested that views on availability of the same may be obtained from CGWB/State Ground Water Board.	of a storage reservoir. 150 MLD of water demand shall be met through the project except in the month of Oct (130 MLD), November (130 MLD) & December (120 MLD). Present system utilising 165 MLD of drinking water demand as detailed in Page no. 27 of DPR is totally based on sustainable ground water system which is as per availability ensured by CGWB to the agencies in state. Clearly, a little shortage in aforesaid month shall be met through existing surface & ground water sources which are sufficient enough to meet the present demand of 193 MLD (165 MLD from ground water & 28 MLD of existing surface water resources) as mentioned in Table 2.5 on page no. 29 of DPR. Please also see the reply of point no. 04.
Point No. 8 At Page 42-43 of DPR, State Govt. vide letter 3078/SE(PC)/Song Dam dated 06.08.2019 has certified that the withdrawal of water for the project has been planned only during monsoon period, hence, it does not attract Indo-Bangladesh Water Treaty 1996 on Farakka. Since as per MoWR guidelines 2009, withdrawal is not permitted from Ganga Basin during lean period (i.e. from 1^{st} January to 31^{st}May). Accordingly, the project authority may take the suggested measures.	As said in the reply of Point No.4 a revised reservoir balance analysis has been done as suggested and to ensure no net utilisation in lean period. A demand of 150 MLD is easily met by the proposed reservoir throughout the year except in month of October, November & December, without having any net utilisation in lean period (i.e. from 1^{st} January to 31^{st}May). (Please see the notes & column 13 on Revised Annexure 1). The shortage in these months shall be met with the existing Surface & Ground water sources which are sufficient to meet the present demand of 193 MLD as mentioned in Table 2.5 on page no. 29 of DPR and is in accordance with the suggestions

	provided in point no 8(1). Also, the checklist included in letter no.3078/SE(PC)/Song Dam dated 06.08.2019 of this office and the response of Chief Engineer PAO by letter no. 2/6/ISM2/2017/153 dated 30.04.2019 stands revised in view of aforesaid observations and is being annexed as **Revised Annexure 2.**

In view of the above, you are kindly requested to send the report along with the annexure annexed here with for international clearances from FW Wing of DoWR, RD&GR, CWC.

With regards,

Enclosures: As above

B.K Panday
Superintending Engineer
Uttarakhand Irrigation Department

Letter No:-4832/SE(PC)/ Song Dam

Copy to:-

1. Director, ISM-2,CWC, New Delhi.
2. Engineer-in-Chief, Uttarakhand Irrigation Department.
3. Chief Engineer (Level-01), Dehradun

B.K Panday
Superintending Engineer
Uttarakhand Irrigation Department

REVISED ANNEXURE-1

10-Daily Water Balance with Dam Storage (in MCM) for 97% dependable year 1987-88 (FRL 988 m)

Month		CWC approved Flow (MCM) at 97% Dependable year (i.e. ~ (80%) of 1987-88	10-daily Drinking Water Demand (in MCM)	Environmental Flow requirement (EFR) (As per GO 4009) (in MCM)	Evaporation losses (in MCM)	Reservoir Surface Area	Seepage losses through Reservoir (loamy soil with 2.5 mm/day seepage loss is assumed)	10-Daily (Dam Inflow - Demand-EFR-Losses)	Part of Demand to be met from Dam Storage (MCM)	Reservoir Storage after meeting Demand (MCM)	Down stream release just in the D/S of the reservoir other than E flow	Net D/S outflow (E flow(col5) + return flow to the system (80% of utilisation, col4)(col 12))	Comments
								(C3-C4-C5-C6-C8)				0.8XC4+C5+C12	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
							2.50 mm/day			26.400			
JANUARY	1	1.53	1.5	0.306	0.0049	64.8200	0.0163	-0.297	0.297	26.103	0.0000	1.5060	
	2	1.49	1.5	0.298	0.0049	64.0000	0.0160	-0.329	0.329	25.774	0.0000	1.4980	
	3	1.56	1.65	0.312	0.0058	63.0000	0.0158	-0.422	0.422	25.351	0.0000	1.6320	1. Return flow(80 % of the utilisation) is being released to the system in the D/s (i => 0.8(4)+EFR). 2. EFR = 0.20 I in the months of Jan to March as per Gazette notification no. 4009 (S.O.5195(E)) dated 09 October 2018. 3. Net D/s Release (Col 13) is Greater than or Equal to inflow (Col 3)
FEBRUARY	1	1.35	1.5	0.27	0.0075	62.5000	0.0157	-0.443	0.443	24.908	0.0000	1.4700	
	2	1.41	1.5	0.282	0.0072	62.0000	0.0155	-0.395	0.395	24.513	0.0000	1.4820	
	3	1.16	1.2	0.232	0.0057	61.0000	0.0153	-0.293	0.293	24.220	0.0000	1.1920	
MARCH	1	1.29	1.5	0.258	0.0138	60.4000	0.0151	-0.497	0.497	23.723	0.0000	1.4580	
	2	1.3	1.5	0.26	0.0135	59.2000	0.0148	-0.488	0.488	23.235	0.0000	1.4600	
	3	1.35	1.65	0.27	0.0166	58.3000	0.0146	-0.599	0.599	22.636	0.0000	1.5900	
APRIL	1	1.22	1.5	0.305	0.0216	57.5000	0.0144	-0.621	0.621	22.015	0.0854	1.5904	1. Return flow (80 % of the utilisation) is being released to the system in the D/s (i => 0.8(4)+EFR). 2. EFR = 0.25 I in the months of April to May as per Gazette notification no. 4009 (S.O.5195(E)) dated 09 October 2018. 3. Net D/s Release (Col 13) is Greater than or Equal to inflow (Col 3)
	2	1.12	1.5	0.28	0.0211	56.7000	0.0142	-0.695	0.695	21.320	0.0784	1.5584	
	3	1.07	1.5	0.2675	0.0206	55.2500	0.0138	-0.732	0.732	20.588	0.0749	1.5424	
MAY	1	1.05	1.5	0.2625	0.0280	54.0000	0.0135	-0.754	0.754	19.834	0.0735	1.5360	
	2	1	1.5	0.25	0.0271	52.2000	0.0131	-0.790	0.790	19.044	0.0700	1.5200	
	3	1.09	1.65	0.2725	0.0292	51.1200	0.0128	-0.874	0.874	18.169	0.0763	1.6688	
JUNE	1	1.71	1.5	0.5130	0.0208	49.0000	0.0123	-0.336	0.336	17.833			
	2	1.82	1.5	0.5460	0.0205	48.0000	0.0120	-0.258	0.258	17.575			
	3	1.51	1.5	0.4530	0.0199	47.0000	0.0118	-0.475	0.475	17.100			
JULY	1	1.51	1.5	0.4530	0.0200	46.5000	0.0116	-0.465	0.465	16.636			
	2	1.49	1.5	0.4470	0.0197	45.2000	0.0113	-0.478	0.478	16.158			
	3	1.75	1.65	0.5250	0.0196	44.4000	0.0111	-0.460	0.460	15.698			
AUGUST	1	1.45	1.5	0.4350	0.0192	44.0000	0.0110	-0.518	0.518	15.180			
	2	1.6	1.5	0.3480	0.0179	43.5000	0.0109	-0.259	0.259	14.921			
	3	4.19	1.5	1.2570	0.0085	41.8000	0.0105	1.414	0.000	16.335			
SEPTEMBER	1	11.14	1.5	3.3420	0.0088	45.7500	0.0114	7.678	0.000	24.013			
	2	5.02	1.5	1.5060	0.0113	59.0000	0.0148	1.988	0.000	26.001			
	3	2.51	1.5	0.7530	0.0126	64.8200	0.0163	0.228	0.000	26.229			
OCTOBER	1	1.96	1.3	0.4900	0.0119	64.8200	0.0163	0.142	0.000	26.371			
	2	1.74	1.3	0.4350	0.0119	64.8200	0.0163	-0.023	0.023	26.348			
	3	1.89	1.43	0.4725	0.0130	64.8200	0.0163	-0.042	0.042	26.307			
NOVEMBER	1	1.44	1.3	0.1280	0.0069	64.8200	0.0163	-0.011	0.011	26.295			
	2	1.42	1.3	0.1240	0.0069	64.8200	0.0163	-0.027	0.027	26.268			
	3	1.43	1.3	0.1260	0.0069	64.8200	0.0163	-0.019	0.019	26.249			
DECEMBER	1	1.41	1.2	0.1220	0.0049	64.8200	0.0163	0.067	0.000	26.316			
	2	1.41	1.2	0.1220	0.0049	64.8200	0.0163	0.067	0.000	26.383			
	3	1.7	1.32	0.1480	0.0049	64.8200	0.0163	0.211	0.000	26.400			
Total			53.45	18.843	0.4442		0.5108						

Total storage in Reservoir in MCM (S)	26.40
Total Annual Drinking Water Demand (MCM)	52.45
Drinking water Demand in normal period (other than Lean Period) (MCM) (D1)	39.80
Lean Period Drinking Water Demand (D2)	12.65

Since D2 < S, so Lean Period Demand is Met through Dam Storage only.

Notes:

1 Reservoir planning has been done based on 97% dependable year of 1987-88 as per CWC approved series.

2 The project has been conceptualized to reduce the ground water exploitation by construction of a storage reservoir. 150 MLD of water demand shall be met through the project except in the month of Oct (130 MLD), November (130 MLD) & December (120 MLD). Clearly,A little Shortage in these month shall be met through existing surface & ground water sources which are sufficient enough to meet the present demand of 193 MLD as mentioned in Table 2.3 on page no. 29 of DPR. Please see the reply of point no. 04 detailed in letter attached.

3 Column no 13 clearly shows that the net water release in the D/S in the lean period is even more than inflow in the river, taking into account the contribution of Return flow which becomes the part of stream in D/S .

4 Reference for the seepage loss "http://www.fao.org/tempref/FI/CDrom/FAO_Training/FAO_Training/General/x6708e/x6708e02.htm"

5 Reference for Return Flow being equal to 80% of utilisation - "Page 136, SP 35 of BIS"

Page 1 of 2

Reservior filling after commissioning of project

		CWC approved (MCM) at 97% Dependability (say ~ 100%)	Cumulative Inflow to dam (MCM)	Effective Storage in Dam
1	2	3	4	
MONTH	**10-DAILY**	**1987-88**		
SEPTEMBER	1	**13.14**	13.140	13.140
	2	**5.02**	18.160	18.160
	3	**2.51**	20.670	20.670
OCTOBER	1	**1.96**	22.630	22.630
	2	**1.74**	24.370	24.370
	3	**1.89**	26.260	26.260
NOVEMBER	1	**1.64**	27.900	26.400
	2	**1.62**	29.520	26.400
	3	**1.63**	31.150	26.400
DECEMBER	1	**1.61**	32.760	26.400
	2	**1.61**	34.370	26.400
	3	**1.7**	36.070	26.400

Hence, Reservior is full before the start of lean season.

REVISED ANNEXURE-02

Check List for project clearance from international/JRC Angle.

1.	Name of Project:	Song Dam Drinking Water Project Dehradun, Uttarakhand.
2.	Name of State:	Uttarakhand
3.	Name of river:	Song River
4	a) Annual average water availability in the river:	137.58 MCM (as per the approved data series by CWC)
	b) Average water availability in the river in lean season (January-May):	30.46 MCM (as per the approved data series by CWC)
5	Annual average water availability in Ganga basin.	At Haridwar, the catchment area of Ganga basin is 23365 sq km whereas the catchment area at song dam site is only 85sqkm (0.36 percent of catchment at Haridwar). Average annual Water availability at Haridwar in catchment area proportion is about 37800 MCM.
	b) Average water availability in lean season (January-May)	Water availability at Haridwar in catchment area proportion in lean season is about 8300 MCM.
6	a) Allocation of water for the co-basin state in the Ganga basin.	Till Now, no agreement for sharing of water between Uttar Pradesh and Uttarakhand is in force.
	b) Existing consumptive water uses by the state in monsoon and non-monsoon periods.	Approx. 8000 MCM
	c) Balance unutilized water share of the state in monsoon and non-monsoon periods.	As explained in 6(a) above.
7	**How much water is supposed to be released by the project authority in downstream in lean season (January to May)**	**The total water utilization through the said dam is about 22.65 MCM only in lean period which will be available from the stored water in reservoir before the start of lean period (January to May). Therefore, net utilization of river flow in lean period is zero.**

	a) For Bangladesh share under Ganga Treaty	As mentioned above, site being situated in far upstream of Ganga Basin, Project has negligible effect on water availability at Farraka Barrage.
	b) For river eco-system and other downstream uses.	As per the *Gazette notification No. 4009 [S.O.5195(E)] dated 09 October 2018)"* Desired e-flow requirement has been taken into consideration.
8	Whether the project would have any adverse impact on the inflows in lean season on Farakka or it would enhance the lean season flow.	As explained in 7(a) above.
9	Quantity of inflows likely to be decreased/augmented at Farakka by the project in each 10- day period from January-May.	Negligible effect, as said above.
10	Any other relevant information.	The said project has been planned at the upstream end of Song river which is a tributary of Ganga basin with a very little catchment area of 85 sq km only, whereas catchment area of Farraka Barrage is 1008500 sq.km. Thus, considering the catchment area proportion it will have negligible effect at water availability at Farraka. Thereby, no violation of inter-national treaty.

From

Superintending Engineer
Project Circle
Uttarakhand Irrigation Department

To,

Chief Engineer
PAO, CWC New Delhi.

Letter No:- 4920 /SE(PC)/ Song Dam **Dated** 27.12.2019

Subject: DPR of Song Dam Drinking Water Project, Uttarakhand

Ref: Letter No. 2/6/ISM-2/2017/363 dated 02-12-2019 of ISM-2 Directorate addressed to you.

Dear Sir,

With kind reference to the above said subject and Inter-state concern of ISM-2 Directorate, point wise replies of the observations laid in aforesaid letter are as under.

Observations by CWC	Reply by Uttarakhand Irrigation Department
Point No. 1 Song river is a left bank tributary of Ganga river which joins just upstream of Haridwar. Therefore, Ganga being an inter-state river, the proposal needs to be examined from inter-state aspect.	Agreed.
Point No. 2 There is no inter-state agreement on sharing of water river Ganga between basin states including Uttar Pradesh and Uttarakhand. Hence, water utilization including evaporation and other loss from the reservoir would be accounted against the state of Uttarakhand when any agreement for sharing of Ganga river water is reached among the basin states of UP and Uttarakhand. Certificate in this regard has already been submitted by State Govt. vide letter C-15/C.E(L-1)/Song Dam dated 13-03-2019 at page 38 of DPR.	No Comments
Point No. 3 Water availability study of the project has been examined by Hydrology (N) Dte.., CWC vide letter no. 1/Uttara/29/2006-Hyd(N)/148-149	No Comments.

dated 22-04-2019 and as per the above study, the availability of water at 50%, 75% and 90% dependability is 135.03 MCM, 111.01 MCM and 98.60 MCM respectively.	
Point No. 4 The project authorities have submitted reservoir balance analysis studies for the project for various scenarios. It may be mentioned here that the letter under reference (11) may be referred to, wherein the Hydrology Dte., CWC has prepared a report on Water Availability of proposed Song Dam Project. The same may be used while preparing water balance studies.	The revised reservoir balance analysis has been carried out, which is based on CWC approved series, taking into consideration the provisions of Bangladesh treaty (**Annexed here with**). It is evident that net out flow in the lean period (1st Jan-31st May) is more than inflow.
Point No. 5 The source from where the data for evaporation losses has been used in the DPR may also be mentioned.	Evaporation losses have been well discussed in the Chapter No. 6.4.3.1 (page no. 127) of the DPR. The report has been prepared by NIH, Roorkee and references have been well recorded. Detailed calculation for evaporation losses has been carried out in Modified reservoir analysis (**Annexed here with**). NIH, Roorkee has used measured pan evaporation data at FRI Dehradun.
Point No. 6. The seepage losses from the reservoir may also be appropriately considered by the Project Authorities.	It has been carried out in detail in the modified reservoir analysis. Overall seepage through the reservoir is about 0.511 MCM which is almost negligible and is not affecting the reservoir planning.
Point No. 7 If, ground water utilization is envisaged in the project, it is suggested that views on availability of the same may be obtained from CGWB/State Ground Water Board.	Present system utilising 165 MLD of drinking water demand, as detailed in Page no. 27 of DPR, is totally based on sustainable ground water system which is as per availability ensured by CGWB to the agencies in state. Please see the aforesaid reservoir balance analysis for details.
Point No. 8 At Page 42-43 of DPR, State Govt. vide letter 3078/SE(PC)/Song Dam dated 06.08.2019 has certified that the withdrawal of water for the project has been planned only during monsoon period, hence, it does not attract Indo-	Please refer to the Final Reservoir Balance analysis (**Annexed here with**) as a reply to the observation raised. Further, it is inferred from the attached annexure that net outflow in the lean period is more than inflow. Thus, it does not attract Indo-Bangladesh treaty. Also, it is submitted that the international clearance has

Bangladesh Water Treaty 1996 on Farakka. Since as per MoWR guidelines 2009, withdrawal is not permitted from Ganga Basin during lean period (i.e. from 1st January to 31stMay). Accordingly, the project authority may take the suggested measures.	already accorded by CWC vide its letter no. Z-23011/1/2019-O/o SJC-1(FM) 4105-06 dated 19-12-2019.

In view of the above, you are requested to accord the interstate clearance for the project.

With regards,

B.K Panday
Superintending Engineer
Uttarakhand Irrigation Department
O/c

Letter No:-4970/SE(PC)/ Song Dam

Copy to:-

1. Engineer-in-Chief, Uttarakhand Irrigation Department.

B.K Panday
Superintending Engineer
Uttarakhand Irrigation Department
O/c

ANNEXURE - 1

10-Daily Water Balance with Dam Storage (in MCM) for 97% dependable year 1987-88 (FRL 988 m)

Month		CWC approved Flow (MCM) at 97% Dependable year (i.e. ~ 100%) of 1987-88	10-daily Drinking Water Demand (in MCM)	Environmental flow requirement (EFR) (As per GO 4009) (in MCM)	Evaporation losses (in MCM)	Reservoir Surface Area	Seepage losses through Reservoir (Sandy soil with 2.5 mm/day seepage loss is assumed)	10-Daily (Dam Inflow - Demand) (Diff.-Losses)	Part of Demand to be met from Dam Storage (MCM)	Reservoir Storage after meeting Demand (MCM)	Down stream release just in the D/S of the reservoir other than E flow	Net D/S outflow (E flow(Col 5) + return flow to the system (80% of utilization, col(4)+col 12)	Comments
								(C3-C4-C5-C6-C8)				0.8XC4+C5+C12	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
							2.50 mm/day			26.400			
JANUARY	1	1.53	1.5	0.306	0.0049	64.8200	0.0162	-0.297	0.297	26.103	0.0000	1.5060	1. Return flow(80 % of the utilization) is being released to the system in the D/s [I <= 0.8U+EFR]. 2. EFR = 0.20 I in the months of Jan to March as per Gazette notification no. 4009 [S.O.5209(E)] dated 09 October 2018. 3. Net D/s Release [Col 13] is Greater than or Equal to inflow [Col 3]
	2	1.49	1.5	0.298	0.0049	64.0000	0.0160	-0.329	0.329	25.774	0.0000	1.4980	
	3	1.56	1.65	0.312	0.0053	63.6000	0.0159	-0.421	0.421	25.353	0.0000	1.6320	
FEBRUARY	1	1.35	1.5	0.27	0.0073	62.6000	0.0157	-0.443	0.443	24.909	0.0000	1.4700	
	2	1.41	1.5	0.282	0.0071	62.0000	0.0155	-0.395	0.395	24.513	0.0000	1.4820	
	3	1.16	1.2	0.232	0.0057	61.0000	0.0153	-0.293	0.293	24.220	0.0000	1.1920	
MARCH	1	1.29	1.5	0.258	0.0132	60.6000	0.0151	-0.497	0.497	23.723	0.0000	1.4580	
	2	1.3	1.5	0.26	0.0131	59.2000	0.0149	-0.488	0.488	23.235	0.0000	1.4600	
	3	1.35	1.65	0.27	0.0146	58.0000	0.0146	-0.599	0.599	22.636	0.0000	1.5900	
APRIL	1	1.22	1.5	0.305	0.0214	57.5600	0.0144	-0.621	0.621	22.015	0.2854	1.5054	1. Return flow (80 % of the utilizations) is being released to the system in the D/s [I <= 0.8U+EFR]. 2. EFR = 0.25 I in the months of April to May as per Gazette notification no. 4009 [S.O.5209(E)] dated 09 October 2018. 3. Net D/s Release [Col 13] is Greater than or Equal to inflow [Col 3]
	2	1.12	1.5	0.28	0.0211	56.7600	0.0142	-0.695	0.695	21.320	0.0784	1.5584	
	3	0.75	1.5	0.1875	0.0206	56.2000	0.0138	-0.732	0.732	20.588	0.0749	1.4624	
MAY	1	1.05	1.5	0.2625	0.0280	54.8000	0.0135	-0.754	0.754	19.834	0.0725	1.5350	
	2	1	1.5	0.25	0.0271	53.2000	0.0131	-0.790	0.790	19.044	0.0780	1.5280	
	3	0.69	1.65	0.1725	0.0283	52.1000	0.0129	-0.879	0.879	18.165	0.0763	1.5688	
JUNE	1	1.71	1.5	0.5130	0.0288	49.8000	0.0123	-0.332	0.332	17.833			
	2	1.82	1.5	0.5460	0.0283	48.8000	0.0120	-0.258	0.258	17.575			
	3	1.51	1.5	0.4530	0.0195	47.6000	0.0118	-0.475	0.475	17.100			
JULY	1	1.51	1.5	0.4530	0.0180	46.3000	0.0116	-0.465	0.465	16.635			
	2	1.39	1.5	0.4170	0.0097	45.2000	0.0113	-0.478	0.478	16.156			
	3	1.06	1.65	0.3180	0.0096	44.4000	0.0111	-0.460	0.460	15.698			
AUGUST	1	1.43	1.5	0.4290	0.0081	44.0000	0.0110	-0.518	0.518	15.180			
	2	1.8	1.5	0.5400	0.0075	42.5600	0.0106	-0.259	0.259	14.921			
	3	4.49	1.5	1.3470	0.0085	41.8000	0.0105	1.414	0.000	16.335			
SEPTEMBER	1	10.14	1.5	3.0420	0.0088	45.7500	0.0114	7.578	0.000	23.913			
	2	6.63	1.5	1.9890	0.0113	55.0000	0.0148	1.988	0.000	26.051			
	3	2.51	1.5	0.7530	0.0124	64.8200	0.0162	0.328	0.000	26.229			
OCTOBER	1	1.98	1.3	0.4950	0.0119	64.8200	0.0162	0.142	0.000	26.371			
	2	1.74	1.3	0.4350	0.0119	64.8200	0.0162	-0.023	0.023	26.348			
	3	1.88	1.43	0.4720	0.0130	64.8200	0.0162	-0.041	0.041	26.307			
NOVEMBER	1	1.64	1.2	0.3280	0.0069	64.8200	0.0162	-0.011	0.011	26.296			
	2	1.63	1.2	0.3260	0.0069	64.8200	0.0162	-0.027	0.027	26.269			
	3	1.63	1.2	0.3260	0.0069	64.8200	0.0162	-0.019	0.019	26.249			
DECEMBER	1	1.61	1.2	0.3220	0.0049	64.8200	0.0162	0.067	0.000	26.316			
	2	1.61	1.2	0.3220	0.0049	64.8200	0.0162	0.067	0.000	26.383			
	3	1.7	1.32	0.3400	0.0049	64.8200	0.0162	0.019	0.000	26.400			
Total			51.45	18.820	0.4641		0.5109						

Total Storage in Reservoir in MCM (S)	26.40
Total Annual Drinking Water Demand(MCM)	51.45
Drinking water Demand in normal period (other than Lean Period)(MCM) (D1)	29.40
Lean Period Drinking Water Demand (D2)	22.05

Since D2 < S, so Lean Period Demand is Met through Dam Storage only.

Notes:
1 Reservoir planning has been done based on 97% dependable year of 1987-88 as per CWC approved series.
2 The project has been conceptualized to reduce the ground water exploitation by construction of a storage reservoir. 150 MLD of water demand shall be met through the project except in the month of Oct (130 MLD), November (120 MLD) & December (120 MLD). Clearly,A little Shortage in these month shall be met through existing surface & ground water sources which are sufficient enough to meet the present demand of 150 MLD as mentioned in Table 1.5 on page no. 20 of DPR. Please see the reply of point no. 04 detailed in letter attached.
3 Column no 13 clearly shows that the net water release in the D/S in the lean period is even more than inflow in the river, taking into account the contribution of Return flow which becomes the part of stream in D/S.
4 Reference for the seepage loss: "http://www.fao.org/tempref/FI/CDrom/FAO_Training/FAO_Training/General/x6705e/x6705e02.htm"
5 Reference for Return Flow being equal to 80% of utilization - "Page 136 , SP 33 of BIS"

केन्द्रीय जल आयोग
Central Water Commission
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ISM-2 Directorate
5th Floor, Sewa Bhawan
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सत्यमेव जयते

विषय: DPR of Song Dam Drinking Water Project, Dehradun (Uttarakhand).

संदर्भ: Letter no. 4920/SE(PC)/Song Dam dated 27.12.2019.

May kindly refer to letters under reference on the above subject received from Superintending Engineer, Project Circle, Uttarakhand Irrigation Department, Dehradun, submitted compliance to the comments of this office asked vide letter no. 2/6/ISM-2/2017/363 dated 02.12.2019 for examination from inter-state aspect. The same was examined and further comments on the compliance are as under:

Comments:

SI. No.	Observation of ISM-2, CWC	Reply by Uttarakhand Irrigation Deptt.	Further comments of ISM-2 Dte., CWC
1	**Point No. 1:** Song river is a left bank tributary of Ganga river which joins just upstream of Haridwar. Therefore, Ganga being an inter-State river, the proposal needs to be examined from inter-State aspect.	**Agreed**	**No comments**
2	**Point No. 2:** There is no inter-state agreement on sharing of waters river Ganga between basin states including Uttar Pradesh and Uttarakhand. Hence, water utilization including evaporation and other loss from the reservoir would be accounted against the State of Uttarakhand when any agreement for sharing of Ganga river water is reached among the basin States of UP and Uttarakhand. Certificate in this regard has already	**No Comments**	**No further comments**

	been submitted by State Govt. vide letter C-15/C.E(L-1)/Song Dam dated 13.03.2019 at page 38 of DPR.		
3	**Point No. 3:** Water availability study of the project has been examined by Hydrology (N) Dte., CWC vide letter no. 1/Uttara/29/ 2006-Hyd(N)/ 148-149 dated 22.04.2019 and as per the above study, the availability of water at 50%, 75% and 90 % dependability is 135.03 MCM, 111.01 MCM and 98.60 MCM respectively.	**No Comments**	**No further comments**
4	**Point No. 4:** The Project Authorities have submitted reservoir balance analysis studies for the project for various scenarios. It may be mentioned here that the letter under reference (ii) may be referred to, wherein the Hydrology Dte., CWC has prepared a report on Water Availability of proposed Song Dam Project. The same may be used while preparing water balance studies.	The revised reservoir water balance analysis has been carried out which is based on CWC approved series taking into consideration the provisions of Bangladesh treaty(Annexed herewith) is evident that net out flow in the lean period (1st Jan-31st May) is more than inflow.	As per revised reservoir water balance analysis, CWC approved flow from January to May is 18.99 MCM and net D/s out flow (E flow+return flow from + d/s release other than E Flow) from Jan. to May is 22.704 MCM. The reservoir storage after meeting demand at the end of December is 26.40 MCM and drinking water demand from Jan. to May is 22.65 MCM. As per Revised Annexure-I, out flow is more than inflow during Jan. to May. Hence, the lean period drinking water demand from Song Dam will be met from the Dam storage not from the Song river. Hence, it does not attract international treaty of Farakka.
5	**Point No. 5:** The source from where the data for evaporation losses has been used in the DPR may also be mentioned.	Evaporation losses have been well discussed in the Chapter no. 6.4.3.1(page no. 127) of the DPR. The report has been prepared by NIH, Roorkee and references have been well recorded. Detailed calculation for evaporation losses has been carried out in Modified reservoir analysis (Annexed herewith). NIH,	In the water balance analysis, the Evaporation loss during the year has been given as 0.4442 MCM, hence, no further comments to offer.

		Roorkee has used measured pan Evaporation data at FRI Dehradun.	
	Point No. 6: The seepage losses from the reservoir may also be appropriately considered by the Project Authorities.	It has been carried out in detail in the modified reservoir analysis. Overall seepage through the reservoir is about 0.511 MCM which is almost negligible and is not affecting the reservoir planning.	In the water balance analysis, the Seepage loss during the year has been given as about 0.511 MCM, hence, no comments to offer.
7	**Point No. 7:** If, ground water utilization is envisaged in the project, it is suggested that views on availability of the same may be obtained from CGWB/State Ground Water Board.	Present system utilizing 165 MLD of drinking water demand, as detailed in page 27 of DPR, is totally based on sustainable ground water system which is as per availability ensured by CGWB to the agencies in state. Please see the aforesaid reservoir balance analysis for details.	No further comments to offer
8	**Point No. 8:** At page 42-43 of DPR, State Govt. vide letter 3078/S.E(PC)/Song Dam dated 06.08.2019 has certified that the withdrawal of water for the project has been planned only during monsoon period, hence, it does not attracts Indo-Bangladesh Water Treaty 1996 on Farakka. Since, as per MoWR guidelines 2009, withdrawal is not permitted from Ganga basin during lean period (i.e. from 1st January to 31st May). Accordingly, the project authority may take the following measures.	Please refer the Final Reservoir Analysis (Annexed herewith) as a reply to the observation raised. Further, it is inferred from the attached annexure that net outflow in the lean period is more than inflow. Thus, it does not attract Indo-Bangladesh treaty. Also it is submitted that the international clearance has already accorded by CWC vide letter no. Z-23011/1/2019-O/o SJC-I(FM)4105-06 dated 19.12.2019.	As per water balance analysis, CWC approved flow from January to May is 18.99 MCM and net D/s out flow (E flow+return flow from + d/s release other than E Flow) from Jan. to May is 22.704 MCM and the reservoir storage after meeting demand at the end of December is 26.40 MCM and drinking water demand from Jan. to May is 22.65 MCM. Hence, the lean period drinking water demand from Song Dam will be met from the Dam storage. As replied, the shortage in months of October, November & December, shall be met with the existing surface and ground water sources which are sufficient to meet the present demand of 193 MLD as mentioned in Table 2.5 of DPR

As per the revised Annexure –I received from the State Govt., under Reservoir Balance Analysis-column 4, total drinking water annual demand from the Song Dam is 52.45 MCM and 80% of the domestic demand has been considered being released back to the river system as return flow. Hence, net water utilization including evaporation and seepage loss from the reservoir worked out by the State Govt. as detailed below would be accounted against the State of Uttarakhand when any agreement for sharing of Ganga river water is reached among the basin States.

i) Total Annual Demand from the Song Dam = 52.45 MCM

ii) Less 80% return flow=52.45-41.96 =10.49 MCM

iii) Evaporation loss = 0.4442 MCM

iv) Seepage Loss = 0.511 MCM

v) Total annual utilization =(ii)+(iii)+(iv)=11.4452 MCM

There is no inter-state agreement on sharing of waters river Ganga between basin states including Uttar Pradesh and Uttarakhand. Hence water utilization including evaporation loss, seepage loss from the reservoir would be accounted against the State of Uttarakhand as and when any agreement for sharing of Ganga river water is reached among the basin States. Certificate in this regard has already been submitted by the State Government.

In view of the above, it may be conveyed that there is no objection to the withdrawal of water for the Song Dam Drinking Water Project from inter-State aspect and subject to fulfilling of conditions mentioned in international Clearance furnished by Sr. Joint Commissioner-I(FM), DoWR, RD & GR vide letter No. Z-23011/1/2019-O/o SJC-I (FM) dated 19.12.2019. However, this may not be taken as approval of the CWC for allocation of 52.45 MCM of water for domestic water use.

This issues with the approval of Member (WP&P), CWC.

06/1/2020

(राजेश कुमार)
निदेशक(ISM2)

मुख्य अभियन्ता, परियोजना मूल्यांकन संगठन (PAO), केंद्रीय जल आयोग, नई दिल्ली।

के. ज.आ. पत्र संख्या 2/6/ ISM-2/2017/ 535 दिनांक: 06.01.2020

ANNEXURE - 1

10-Daily Water Balance with Dam Storage (in MCM) for 57% dependable year 1987-88 (FRL 988 m)

Month		CWC approved Flow (MCM) at 57% Dependable year (i.e. ~100%) of 1987-88	10-daily Drinking Water Demand (in MCM)	Environmental flow requirement (EFR) (As per GO 4009) (in MCM)	Evaporation losses (in MCM)	Reservoir Surface Area	Seepage losses through Reservoir (Seepage loss with 2.5 mm/day seepage loss is assumed)	10-Daily (Dam Inflow - Demand (EFR+Losses))	Part of Demand to be met from Dam Storage (MCM)	Reservoir Storage after meeting Demand (MCM)	Down stream release put in the D/S of the reservoir other than E flow	Net D/S outflow (E flow(Col 5) + return flow to the system (80% of utilization, col4)+col 12)	Comments
								(C3-C4-C5-C6-C8)				0.8XC4+C5+C12	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
							2.50 mm/day			26.400			
JANUARY	1	1.50	1.5	0.306	0.0549	64.8350	0.0162	-0.297	0.297	26.103	0.0000	1.5060	
	2	1.48	1.5	0.298	0.0545	64.0000	0.0160	-0.326	0.326	25.776	0.0000	1.4980	
	3	1.66	1.65	0.312	0.0053	63.6000	0.0159	-0.323	0.323	25.253	0.0000	1.6320	1. Return flow(80 % of the utilization) is being released to the system in the D/s [I = 0.8U+EFR]. 2. EFR = 0.20 I in the months of Jan to March as per Gazette notification no. 4009 [S.O.3089(E)] dated 09 October 2018. 3. Net D/s Release (Col 13) is Greater than or Equal to inflow (Col 3)
FEBRUARY	1	1.26	1.5	0.27	0.0073	62.6000	0.0157	-0.442	0.443	24.908	0.0000	1.4700	
	2	1.41	1.5	0.282	0.0071	62.0000	0.0155	-0.395	0.393	24.513	0.0000	1.4820	
	3	1.16	1.2	0.232	0.0057	61.0000	0.0153	-0.293	0.293	24.220	0.0000	1.1920	
MARCH	1	1.26	1.5	0.258	0.0134	60.4000	0.0151	-0.497	0.497	23.723	0.0000	1.4580	
	2	1.3	1.5	0.26	0.0131	59.2000	0.0148	-0.488	0.488	23.235	0.0000	1.4600	
	3	1.35	1.65	0.27	0.0146	58.2000	0.0146	-0.599	0.599	22.636	0.0000	1.5900	
APRIL	1	1.02	1.5	0.505	0.0214	57.5000	0.0144	-0.621	0.621	22.015	0.0054	1.5054	1. Return flow (80 % of the utilization) is being released to the system in the D/s [I = 0.8U+EFR]. 2. EFR = 0.25 I in the months of April to May as per Gazette notification no. 4009 [S.O.3089(E)] dated 09 October 2018. 3. Net D/s Release (Col 13) is Greater than or Equal to inflow (Col 3)
	2	1.42	1.5	0.26	0.0211	56.7000	0.0142	-0.695	0.695	21.320	0.0284	1.5284	
	3	1.07	1.6	0.1875	0.0206	55.2000	0.0138	-0.732	0.732	20.588	0.0749	1.5624	
MAY	1	1.06	1.5	0.2625	0.0280	54.0000	0.0135	-0.754	0.754	19.834	0.0725	1.5000	
	2	1	1.5	0.25	0.0271	53.2000	0.0131	-0.790	0.790	19.044	0.0780	1.5000	
	3	1.09	1.65	0.1725	0.0283	51.1000	0.0128	-0.874	0.874	18.169	0.0763	1.6683	
JUNE	1	1.71	1.5	0.1130	0.0209	49.8000	0.0123	-0.336	0.336	17.833			
	2	1.82	1.5	0.2460	0.0201	48.8000	0.0120	-0.258	0.258	17.575			
	3	1.61	1.5	0.4530	0.0159	47.0000	0.0118	-0.475	0.475	17.100			
JULY	1	1.61	1.5	0.4530	0.0100	46.2000	0.0116	-0.465	0.461	16.635			
	2	1.49	1.5	0.4470	0.0097	45.2000	0.0113	-0.478	0.478	16.158			
	3	1.73	1.65	0.1130	0.0096	44.4000	0.0111	-0.460	0.460	15.698			
AUGUST	1	1.43	1.5	0.4290	0.0082	44.0000	0.0110	-0.518	0.518	15.180			
	2	1.8	1.5	0.5400	0.0079	42.5000	0.0106	-0.259	0.259	14.921			
	3	4.99	1.5	1.2570	0.0085	41.8000	0.0105	1.414	0.000	16.335			
SEPTEMBER	1	10.14	1.5	1.9420	0.0086	45.7500	0.0114	7.678	0.000	24.013			
	2	6.02	1.5	1.3060	0.0111	59.0000	0.0148	1.888	0.000	25.901			
	3	2.61	1.5	0.7530	0.0124	64.8300	0.0162	0.338	0.000	26.239			
OCTOBER	1	1.96	1.5	0.4900	0.0119	64.8350	0.0162	0.142	0.000	26.371			
	2	1.74	1.5	0.4350	0.0119	64.8350	0.0162	-0.023	0.023	26.348			
	3	1.89	1.65	0.4725	0.0130	64.8300	0.0162	-0.041	0.041	26.307			
NOVEMBER	1	1.64	1.5	0.1280	0.0065	64.8350	0.0162	-0.011	0.011	26.295			
	2	1.63	1.5	0.1260	0.0069	64.8300	0.0162	-0.027	0.027	26.268			
	3	1.63	1.5	0.1260	0.0069	64.8350	0.0162	-0.019	0.019	26.249			
DECEMBER	1	1.61	1.5	0.1220	0.0049	64.8300	0.0162	0.067	0.000	26.316			
	2	1.61	1.5	0.1220	0.0049	64.8300	0.0162	0.067	0.000	26.383			
	3	1.7	1.32	0.1400	0.0045	64.8300	0.0162	0.019	0.000	26.400			
Total			52.45	18.xxx	0.5611		0.5339						

Total Storage in Reservoir in MCM (S)	26.40
Total Annual Drinking Water Demand(MCM)	52.45
Drinking water Demand in normal period (other than Lean Period)(MCM) (D1)	30.40
Lean Period Drinking Water Demand (D2)	22.05

Since D2 < S, so Lean Period Demand is Met through Dam Storage only.

Notes:

1. Reservoir planning has been done based on 57% dependable year of 1987-88 as per CWC approved series.
2. The project has been conceptualized to reduce the ground water exploitation by construction of a storage reservoir. 150 MLD of water demand shall be met through the project except in the month of Oct (138 MLD), November (130 MLD) & December (120 MLD). Clearly,A little Shortage in these month shall be met through existing surface & ground water sources which are sufficient enough to meet the present demand of 193 MLD as mentioned in Table 3.5 on page no. 20 of DPR. Please see the reply of point no. 44 detailed in letter attached.
3. Column no 13 clearly shows that the net water release in the D/S in the lean period is even more than inflow in the river, taking into account the contribution of Return flow which becomes the part of stream in D/S.
4. Reference for the seepage loss: "http://www.fao.org/tempref/FI/CDrom/FAO_Training/FAO_Training/General/x6705e/x6705e02.htm"
5. Reference for Return Flow being equal to 80% of utilization - "Page 138 , SP 35 of BIS"

5 SURVEY, INVESTIGATIONS & PROJECT GEOLOGY

Survey and geological investigation data along with various test results are essential for planning and design of a Drinking water scheme. They form the basis for identification of project alternatives, selection of sites and optimization of project components. The type and extent of survey & investigation is also decided on the size of development and level of information already available.

Adequate topographical surveys & Geological investigations have been carried out by Irrigation Department, Dehradun, Uttarakhand to establish the selection and design of the most techno-economically viable alternative for the Song Dam Drinking Water Project. The scope and extent of the survey and investigations were finalized after extensive field reconnaissance of the project area by engineers and geologists. These survey and investigations are described in the subsequent sections respectively.

5.1 Topographical Surveys

After a series of site visits and reconnaissance of the project area, various information was gathered to decide the type, extent and magnitude of structures so that a reasonable/agreeable project layout could be developed. The obvious choice is a 130.00m high RCC dam as a storage structure.

Topographical survey of the left bank has been done up to a contour level of 1060 m while the right bank was surveyed up to a contour level of 1074 m.

The following topographical survey data has been used for preparing the DPR:

IV. Survey of India Toposheet (Scale 1:50,000)

Survey of India Toposheet no. 53-J/3 which covers all the components of the project area. The dam site has a longitude of 78°11'18.63"E and latitude of 30°18'8.29"N.

V. Topographical Maps 1:3,000

Topographical survey covering the entire Dam Area, Reservoir area and approx. 1km downstream of the dam axis area on both the banks has been carried out at the scale of 1:3,000 with a contour interval of 2.0 m. The survey has been conducted up to 50m above the dam top level.

VI. Cross-Sections of Song river

100 nos. of river cross sections at every 50.0m distance from the dam axis to 5035m in the upstream direction has been prepared.

Similarly, 30 nos. of river cross sections at every 50.0m distance from the dam axis to 1500m in the downstream direction has been prepared.

5.2 Other Surveys

Various types of surveys are carried out for a project to confirm the suitability of the scheme. These survey depends on the type, magnitude and importance of the project. For the present Song Dam project various surveys and studies have been carried out which are described below under different headings.

5.2.1 Archaeological Survey

The proposed Song Dam Project is a large scheme on river Song at about 10 km away from Maldeota Temple in Dehradun. Since the proposed project envisages construction of high Dam and the FRL has been chosen to head-up a water column more than 100m, there will be a submergence in the reservoir area upto a distance of 4.0km, as this is a storage scheme. In spite of huge magnitude of dam and the reservoir, no place of archaeological importance has been found in the nearby area which is going to be submerged and therefore no archaeological survey is required in the reservoir area.

5.2.2 Mineral survey

The catchment area of river Song at Dam site is about 85 sq.km. A mineral survey is advisable in light of the fact that Song Dam is located at a distance of approximately 20 km from the 2 nos. of abandoned Rock Phosphate PPCL mines at Maldeota and Durmala. These mines are under operation up to late 80’s but since then these are closed and declared abandoned by Indian Bureau of Mines.

In addition to this, limestone is occurring in the reservoir area but its grade and quality is not known at present.

5.2.3 Right of way survey

Presently the villages in the reservoir area are accessible by means of the only road which passes through the Dam axis at the river bed level at EL. ± 875m. hence, to provide access to the villages after the construction of the Dam and filling of the reservoir, the proposed alternative access road to the villages have been planned using the Survey of India (SoI) toposheet and 1:3,000 topographical map surveyed as part of this study. This road has been planned in such a way that they will pass through the government and private land and the forest area is avoided to the best possible extent. Other infrastructure facilities like dumping area, batching & crushing plant etc. are planned on the government land as well as private land. The details have been worked out in subsequent Chapter 10.

5.2.4 Communication survey

Distance from Maldeota to Song dam site is approximately 10.0 km and two places are connected by an un-metalled seasonal motorable road. Maldeota, is very well connected to Dehradun and other important parts of the state. The broad gauge railhead at Dehradun is about 25 km from the Dam site. All bridges on the way are already constructed and do not need any specific improvement. The connectivity within the project area is not adequate and shall require improvement by construction of new roads or improvement of the existing roads by means of metalling and widening.

In addition to this, the telecommunication services in and around the project area are in a poor condition and needs improvement. Some special operators like BSNL provides little or small coverage in the area while other operators are not playing in the area due to low population. Hence, it is advised that while and after construction of the project, the authorities may have to develop their own communication system.

5.2.5 EIA/EMP study

As the height of dam is quiet high and there is a considerable submergence of the land due to impoundment of the water. Environmental Impact Assessment (EIA) study has already been carried out by STEP, I.I.T, Roorkee. The scope of the study includes cross – sectional characterization of the existing environment in an area of 10 Km radius from the Dam site of the project as well as regional background status for environmental components viz. air, noise, water, land, biological and socio–economic.

Water of song river is quiet nutritious in nature and supports many types of flora and fauna. Many types of small and large fishes along with other species are found in the water. In addition to this many types of algae is also found in the waters of Song.

5.3 Topography & Physiography

The project area nestles in the outer Himalaya and is located northeast of the linear geomorphic depression- "Dun", whose northern and eastern limits are marked by structural and denudational hills of Mussoorie range (Outer Himalaya), which display a rugged and dissected topography. The hills abruptly attain great height (1478m) with drainage network showing deep incision forming narrow and deep valleys.

The river song, a perennial river, transversely cuts across the NW-SE trending range and flows in a narrow tight valley traversing in NE-SW direction. Near Sondana, where the valley is open, the river changes its course attaining a braided pattern and follows the regional trend of the rocks with northwesterly direction. After joining the river Bandal at Kumalda it takes a sharp southerly turn and flows in SE direction. Song sub-basin constitutes a part of the Ganga Basin. The river Song drains through the eastern part of Dun Surface and join the river Ganga near Khadri. The important tributaries of Song are Chipaldi nadi, Bandal nadi, Baldi Nadi, Jakhan Rao and Suswa Nadi. All of these contribute their discharge downstream of the project area. However, the water of Chipaldi nadi, downstream of the proposed dam site, would be utilised for supply to Dehradun through the existing Kalanga weir of Irrigation Department, Uttaranchal.

The Song river system is composed of a good number of tributaries of which the main are Bandal Nala, Chiphaldi nadi and some small streams from the south as well as north faces. Most of the streams are perennial and spring fed because there are no glaciers or snow covered mountains either at the source of the Song river or any of its tributaries. Most of the rain water goes as run off but some percentage gets in-filtered into the joints and crevases and comes out in the form of spring which form the bulk water of this river.

A large number of springs on the south hills of this river are located in the phyllite quartzite silt stone association of rocks which have been equated to Chandpur. Various lineaments / fractures in this formation which underlie the massive, hard, highly metamorphosed quartzite have mostly given rise to spring formation. Considerate amount of water is contributed to Song river from the northern hill slope having large number of tributaries with the water sources mainly from springs. The Song drainage basin at dam site has a total area of 85 sq.km. approximately. The width of the water bearing stream in the Song river is approximately 6.0 – 10.0 m wide with an average water depth of 0.6 m.

A series of ridge-lines intervened by valleys make up the landscape. The north facing slopes which also form the dip slopes are gentler and luxuriantly vegetated. Landslips and landslides occur mostly due to unstable slope conditions and old mining works in a few places. Numerous scarps, at times semi-amphitheatrical in shape, are present on both the banks of the Song. This region marks the youthful stage of the river. Cases of occasional braiding in the Song river also occur, forming channel bars which comprise of sand, gravel and boulders. In the upper reaches of Song, boulders are strewn all over.

5.4 Seismotectonic Aspects of the Project Area

The project area lies in the **Seismic zone 'IV'** of India as incorporated in the Indian **Standard Criteria for Earthquake Resistant Design of Structures (IS: 1893 Part 1-2002)**. According to "**Seismotectonic Atlas of India and its Environ (SEISET-6)**" the project area lies in the Older cover sequence folded during Himalayan fold-trust movement and is very close to the thrust area (unknown). Thus, the overall seismicity level in the project area is high.

Study for determination of site specific design earthquake parameters for the Song dam has been completed by Department of Earthquake Engineering, Indian Institute of Technology, Roorkee in 2018. The studies related to Site Specific Design Earthquake Parameters were taken up using the probabilistic and deterministic approaches of estimation of seismic hazard.

The report from IIT, Roorkee is appended as **Annexure 1.6 of Volume II Project Geology (Site Specific Design Earthquake Parameters for Song H. E. Project Site, Uttarakhand)**

The site specific design earthquake parameters for MCE and DBE conditions are recommended as 0.495g and 0.278g for horizontal and 0.330g MCE and 0.185g DBE for the vertical ground motions. The design seismic coefficient for dam (primary structure) is evaluated as α**h = 0.18** and α**v = 0.12**.

Clearance from NCSDP (National Committee on Seismic Design Parameters) has been obtained at 34th meeting held on 26th February 2019 at New Delhi. The clearance letter from NCSDP committee is appended in **Annexure 1.6 of Volume II Project Geology**.

The Seismic Zone Map of India showing the project location is appended as **Drawing No. P.012745.W-20390-003** and the Seismotectonic map around the project area is appended as **Drawing No. P.012745.W-20390-004.**

5.5 Regional Geology

The area falls in the southern fringe of the Mussoorie Syncline. Rocks of the Nagthat Formation, Blaini Formation, Infra Krol Formation and Krol Group cover the dam site and reservoir area of the project. The general geological succession in the area is as follows.

The area lies in the lesser Himalaya belt and forms the northern faulted limb of the Doon Syncline, where Pre-Tertiary rocks of Pre-Cambrian and Palaeozoic age (?) have thrusted over the younger Upper Tertiary rocks and quaternary sediments along Main Boundary Thrust/Fault. The Main Boundary Fault (MBF) is the main tectonic element in the area. The exposed formations in the area north of Main Boundary Thrust strike in a Northwest-Southeast trend. These formations dip in the northeast and form the southern limb of the Mussoorie Syncline (the syncline axis falls north of the mapped area). Mainly four groups of rocks striking NW-SE and dipping 30°to 66°due northeast are exposed along Song valley.

The oldest group of rock is the association of thin-banded quartzite, Phyllite, slates and siltstone with dark brown to greenish colour possessing laminations are recognised as equivalents of Chandpur Group. These are overlain by pink to white occasionally grey quartzite with massive bedding and irregular vein quartz. This quartzite are equivalent to Nagthat Formation.

Two sets of joints one parallel to the bedding plane and other at right angles are present in this rock. A thin patch of Blaini boulder bed is also encountered overlying Nagthat quartzite. The limestone belonging to the Krol formations occurs at Ghursalgaon, a village near Ghuttu overlying the massive quartzite. Limestone forming massive scarp are dark grey in colour. Calcite veins and two joint sets are observed in this rock.

The general stratigraphy and lithology of the various formation in the area is as tabulated below in Table 5-1**.**

Regional Geological map of the project area is appended as **Drawing No. P.012745.W-20390-005**.

Table 5-1: Stratigraphic Succession of the Project Area

Formation		Group
Dun Gravels		Dun Gravels
Upper Middle and Lower Siwalik		Siwalik Group
E	Krol	Mussoorie Group
D		
C		
B		
A		
Infra Krol		
Blaini Boulder Bed		
Nagthat		
Chandpur		Jaunsar Group

5.5.1 Chandpur Formation

It is characterised by rhythmic, thinly banded quartzite and phyllite. The quartzite at places grades to sheany schistose phyllite. The quartzite occasionally show ripple marks and current bedding. There is presence of abundant green beds. Thin interbeds of tuffaceous chloritic phyllite/slate and quartzite are the main rocks of the Chandpur Formation. Occasionally, amygdaloidal basic lavas and coarse-grained doleritic dykes are also present in the Chandpur Formation.

Its lower part is represented by grey to dark grey phyllite, which are generally intensely folded. The upper part is characterised by purple reddish brown and greenish phyllite with occasional quartzite bands.

The rocks of Chandpur Formation show a low grade of metamorphism and are highly folded.

5.5.2 Nagthat Formation

This conformably overlies the Chandpur Formation. It is characterised dominantly by greenish grey to off-white, purple, medium to Coarse grained, quartzite which is profusely ripple marked and current bedded. Locally it is interbedded with maroon, green and grey phyllites/slates. The upper part is more coarser i.e. granular and conglomeratic.

5.5.3 Blaini Formation

Blaini Formation overlies the Nagthat Formation with a marked unconformity and at places has a faulted contact. It is sub divided as follows:

- Transitional Zone, Pink limestone and Calcareous slates
- Upper boulder bed (diamictite)
- Banded and bleached shales/slates
- Lower Blaini boulder bed. (diamictite)

The lower Blaini boulder bed (diamicite) marks its first appearance east of Maldeota and eastward extension is exposed south of Kumalda, on the left bank of Song river. It has argillaceous and arenaceous matrix. It is polymictic and the clasts are composed of slate, quartzite, limestone and vein quartz.

5.5.4 Banded and bleached slates

These are grey to dark grey and at places carbonaceous with interbands of thin quartzite. At places, the slate changes to shale and phyllite. The thin interbands of quartzite are medium grained, light brownish to light greyish in colour. The banded and bleached slates/shales are exposed around Sripur and Kumalda area.

5.5.5 Upper boulder bed

The upper boulder bed is generally, grey to light grey in colour with clasts of slate, quartzite, limestone and vein quartz. The clasts vary in size from pebble to cobble and rarely to boulder. The matrix is arenaceous or gritty. It appears in Song river 2.5 km upstream of Jaintwalgon in the reservoir area.

5.5.6 Infral Krol Formation

The Infra Krol Formation characterised by slate and sandstone occupy a portion between the underlying Blaini and the overlying Krol Formation without any structural disturbance. These are generally grey to dark grey coloured, occasionally carbonaceous, pyritous shales/slates and frequently present a bleached surface with concentric or semicircular or oval rings of ferruginous stains. These shales/slates are interbedded with thin quartzite bands. The rocks of Infra Krol Formation are intensely folded and faulted.

5.5.7 Krol Group

The rocks of Krol Group are mainly calcareous, which overlie the Infra Krol slates with limestone or red shales. The following is the generallised sequence

- Krol C,D & E (Kauriala Formation) - Upper Krol
- Krol B (Jarashi Formation) - Middle Krol
- Krol A (Mahi Formation) - Lower Krol

(after Ravi Shankar et.al.1993)

The Lower Krol (Krol A) is characterised by alternately banded limestone and shale and grey to green or grey slate. The limestone is light grey to dark grey and contain crystalline calcite and black chert veins.

The Middle part (Krol B) consist of soft and laminated green shale with minor lenses of limestone. The gypsum deposits of the Krol Group are confined to this formation.

The Upper Krol (Krol C, D and E) is represented by dark grey dolomitic limestone and limestone (bluish in colour), interbedded with calcareous shale and siltstone. The limestone contains veins, pockets and fracture fillings of gypsum and calcite.

5.5.8 Tal Group

The rocks of Tal Group overlie the rocks of Krol Group and are characterised by black chert, argillaceous and arenaceous rocks with calcareous bands. The following is the generalised sequence:

Dhaulagiri Formation	E	Quartz arenite, shale, silt stone
	D	Algal lime stone and silt stone
	C	Arkosic arenite
	B	Shale and thin arenite
	A	Quartz arenite

Deo-ka-Tibba Formation	Calcareous Member
	Arenaceous Member
	Argillaceous Member
	Chert Member

5.6 Project Geology

For the proper geological and geotechnical assessment of the geology of the project structures, surface geological mapping of the dam area has been carried out by GSI in year 2002-03, 2003-04, 2004-05 & 2018-19 respectively.

However, geological mapping completed so far does not cover the reservoir area and proposed water Pipeline alignment. Hence, GSI is carrying out fresh mapping of the entire project area which is in progress.

The project components will be geologically mapped over the desired scale as given below:

- Reservoir area shall be mapped on 1:10000 scale with 2m contour interval.
- Water Pipeline alignment shall be mapped on 1:10000 scale with 2m contour interval.

The findings of the geological mapping and investigations conducted are detailed in the further discussions under different headings.

Surface geological plan of the dam area on 1:750 scale is appended as **P.012745.W-20390-006.**

5.6.1 Dam Site

Song dam axis is aligned in N330°& is located at about 1.25 km upstream of Chiphaldi Nadi. At dam site, bed rock is very well exposed on both the abutments up to hill top and in the upstream of dam axis i.e. in the reservoir area. Slopes of both the abutments are steep in order of 60°-70°. Bedrock belongs to Nagthat Formation characterized by greenish grey to reddish brown/purple, banded to massive, medium to fine grained quartzite. The hills on either bank rise from R.L. 880 to more than R.L. 1000 m on. Nagthat quartzites are dipping in the upstream direction.

At dam site, the Song river flows in N240°direction. The total width of river at river bed level is about 45m - 60m.

The surface geological map of the dam site (as per the GSI FS 2018-19) is appended as **Drawing No. P.012745.W-20390-006** while the geological cross section of the dam axis is appended as Drawing No. **P.012745.W-20390-007**.

5.6.2 Dam Axis - Right Abutment

Right abutment of the dam axis has good rock exposures with scarce vegetation cover over it. The rocks exposed belongs to the Nagthat Formation characterised by greenish grey, off-white, reddish brown, banded to massive, medium to coarse-grained quartzite. The bands are up to 1.5m thick. The general strike of the beds varies from N35º to 55º W to S35º-55ºE with 35º-45º dip in NE direction. i.e. upstream dipping. The sedimentary structures such as lamination, cross lamination, convolute bedding etc. have been observed in the fine grained bands of quartzites. The quartzites on this abutments give rise to very steep slopes/cliffs. Downstream of the proposed dam axis, the right abutment shows a thin veneer of scree material covering the basal part of the slope. Right abutment of dam is strong in nature to host the dam structure.

To establish the suitability of the right abutment, it has been explored by three drifts i.e. R-1, R-2 & R-3 at bottom of dam (river bed level), mid and top level respectively. Out of three drift, drift at base level (R-1) close to river bed was completed during GSI FS 2004-05 while other two drifts i.e. R-2 at mid level and R-3 at the top level of Dam has been completed in 2018-2019. The results of the drifts completed on the right bank confirms the stripping limit of the abutment within 5.0 to 6.0m. Figure 5-1 below shows the location of all the three drifts excavated on the right abutment of the dam axis.

Discontinuities observed in the bedrock along right bank are tabulated under Table 5-2.

Table 5-2: Details of Discontinuities at Right Bank of Dam Axis

S. No	Joint Name	Dip Direction/Amount	Persistence	Spacing	Remarks
1	Foliation (F)-J1	N 030-050º/30-45º	>6m	2cm-1.25m	Slickenside surface, staining on surface, upstream dipping, bedding parallel
2	J2	N 185-210º/40-55º	>5m	2cm-1.5m	-
3	J3	N 140-160º/40-50º	1.5m	2-20cm	Dipping into the hill
4	J4	N 230-265º/60-75º	1-3m	5-70cm	Dipping into the valley
5	J5	N 115-135º/75-80º	1.5m	2-20cm	Dipping into the hill

Geological section of the dam axis showing the conditions on the right abutment with three drifts and stripping line/limit is appended as **Drawing No. P.012745.W-20390-007.**

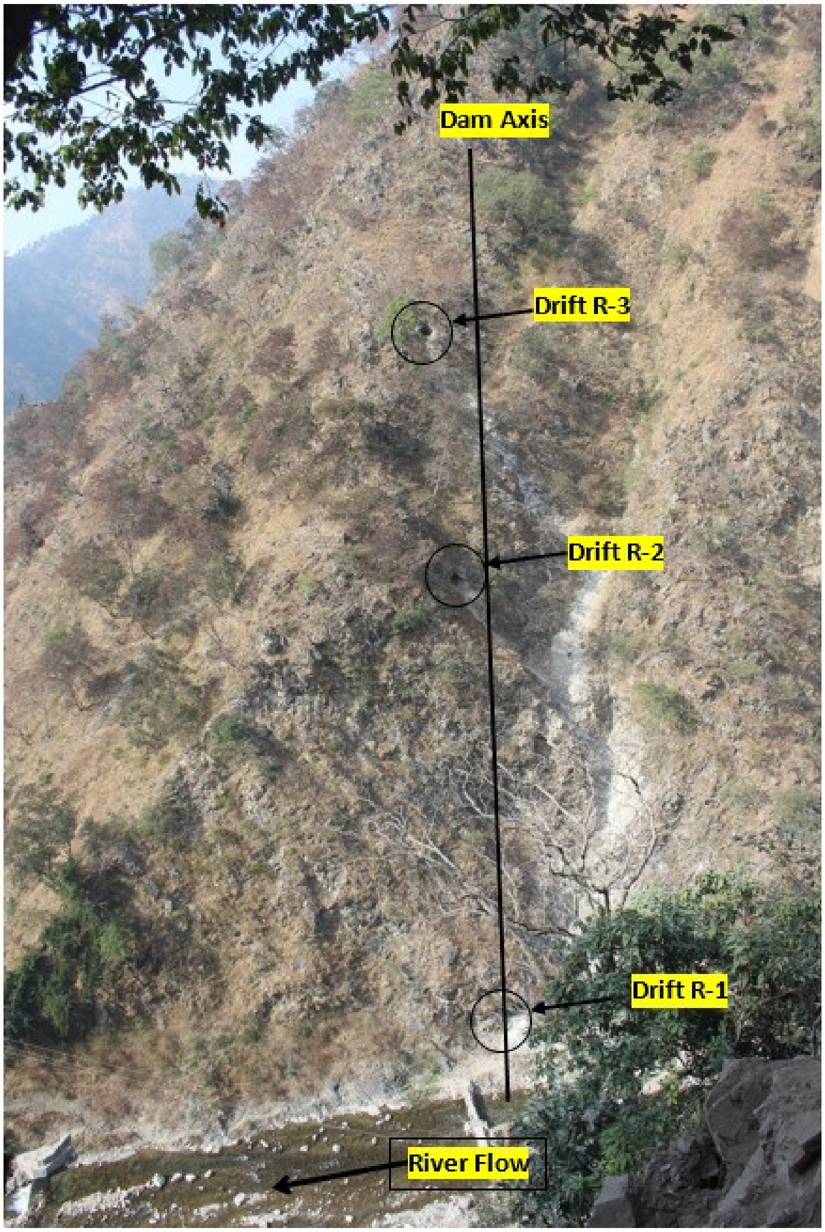


Figure 5-1 : Generalized View of three Drifts (R-1, R-2 & R-3) on right bank of Dam axis (as observed from Left bank)

5.6.3 Dam Axis - Left Abutment

Like right abutment, left abutment of the dam is also quiet strong and bedrock is too exposed on this abutment. The bedrock is dipping upstream with a dip ranging in between 45°-55°. Foliation/ joints are free of infilling. Joint spacing is ranging in between 0.50m – 1.00m giving a blocky structure. The bedding joints are the most prominent one, which are persistent on this abutment and show slickensided surfaces. The other joint set, which has steeper dips than bedding joint but with attitude in same direction also shows slickensided surface. Bedding plane parallel shears (up to 10cm thick), characterised by pulverized rock have also been observed.

Left abutment is in shape of a spur. The spur, which forms the left abutment of the dam at the dam axis, is composed of jointed quartzite with thin cover of debris at the top. The spur is narrow (about 6m at 995m level and about 8m at 1000m level) and has a curvilinear trend in southwesterly direction. About 500-600m upstream of the dam axis, a landslide is present. However the slide would be submerged under water once the full reservoir level is achieved. The landslide falls on the upstream slope of the spur of the left abutment. In this zone the slope is consequent in nature (dip slope). The cause of the landslide is the intersection of other joints with bedding plane parallel joint set.

Like Right abutment, left abutment of the Dam has also been explored through three drift (L-1, L-2 & L-3) at bottom of dam (river bed level), mid and top level respectively. Out of three drifts, drift at base level (L-1) close to river bed was completed during GSI FS 2004-05 while other two drifts i.e. R-2 at mid level and R-3 at the top level of Dam has been completed in 2018-2019 (Figure 5-2). The results of the drifts completed on the right bank confirms the stripping limit of the abutment within 5.0 to 11.0m. Geological cross section of dam axis showing the conditions on the left bank/abutment is appended as **Drawing No. P.012745.W-20390-007**.

Discontinuities observed on the bedrock along right bank are tabulated under Table 5-3.

Table 5-3: Details of Discontinuities at Left Bank of Dam Axis

S. No	Joint Name	Dip Direction/Amount	Persistence	Spacing	Remarks
1	Foliation (F)-J1	N 015-045º/40-55º	>6m	2cm-1.25m	Slickenside surface, staining on surface, upstream dipping, bedding parallel
2	J2	N 195-210º/50-65º	5m	2cm-1.5m	
3	J3	N 120-140º/65-70º	1.5m	2-20cm	Dipping into the hill
4	J4	N 240-260º/50-55º	1-3m	5-70cm	Dipping into the valley
5	J5	N 310-330º/70-75º	1m	20cm-2.5m	Upstream dipping

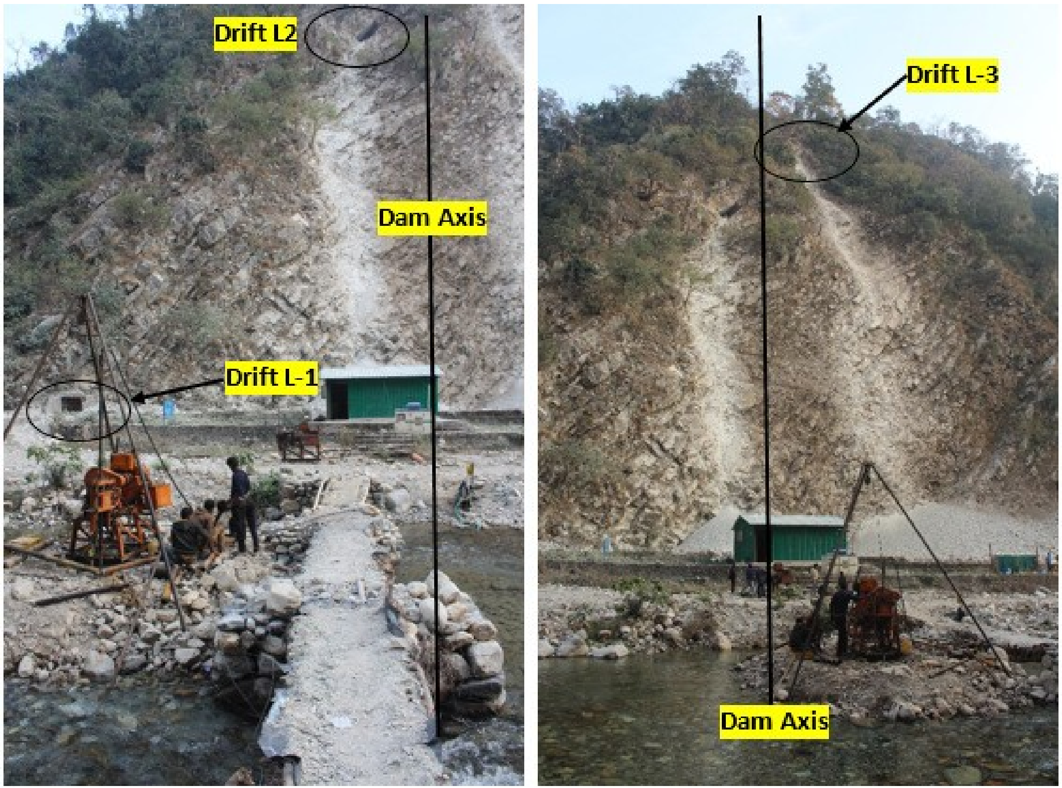


Figure 5-2: Generalized View of three Drifts (L-1, L-2 & L-3) on Left bank of Dam axis (as observed from right bank)

5.6.4 Dam Axis - River Bed

River bed of the Song river in and around dam axis is occupied by River Borne Material (RBM) comprising of boulders, cobbles, pebbles and gravels of various rock types embedded in the sandy matrix. The size of the boulders in the river bed varies up to 1m in size. Bank to bank river width is about 36m. On the basis of site geology, geomorphology and sub-surface exploration, it has been inferred that the depth of river borne material (RBM) in the river bed may vary up to 28m or little more.

Geological cross section of dam axis showing the conditions on the river bed is appended as **Drawing No. P.012745.W-20390-007** while Geological longitudinal section of the dam axis showing the conditions on the river bed along the river centreline from upstream to downstream is appended as **Drawing No. P.012745.W-20390-009**.

5.6.5 Plunge Pool Area

Plunge Pool area is approximately 250m downstream of the dam axis. River bed of the Song river in and around this area is occupied by River Borne Material (RBM) comprising of boulders, cobbles, pebbles and gravels of various rock types embedded in the sandy matrix. The size of the boulders in the river bed varies up to 1.5m in size. On the basis of site geology, geomorphology and sub-surface exploration, it has been inferred that the depth of river borne material (RBM) in the river bed may vary up to 30m or little more.

Geological section of the river showing the conditions on the river bed along the river centreline from upstream to downstream covering the Dam and Plunge Pool is appended as **Drawing No. P.012745.W-20390-009** while Geological cross section of Plunge Pool from right bank to left bank showing the conditions on the river bed is appended as **Drawing No. P.012745.W-20390-016.**

5.7 Investigations for the Project Components

Project area has been explored through intensive surface and sub-surface geological investigation. Following means of investigations has been completed for various components of the project.

- Drilling – 1526m of drilling
- Drifting – 294.43m of drifting
- Geophysical Tests
- Laboratory & In-situ testing

Investigations for the project completed is mentioned in Table 5-4. The location of all the holes and drifts is shown in **Drawing No. P.012745.W-20390-002** titled **Investigation plan for the Project area**.

Table 5-4: Summary of Completed Investigations

Type of Investigation	Quantity/Nos	Remarks
Drilling at Dam site	30 nos	20 nos before 2018-19 (DH series) 10 nos during 2018-19 (NDH series)
Laboratory Testing on Core samples	Under Progress	Under Progress
Drifting at Dam Axis	3 drifts on left abutment (L-1, L-2 & 3) 3 drifts on right abutment (R-1, R-2 & R-3)	L-1 & R-1 completed before L-2018-19. L-2, L-3, R-2 & R-3 completed during 2018-19.
In situ Tests inside Drifts	Done in four drifts i.e. in L-1, R-1, L-2 and R-2	Completed
Geophysical Tests	7 nos. of Vertical Resistivity (by GSI) 6 nos. of Seismic profiles (by GSI) 6 profiles of Seismic tests (by Parsons) 10 profiles of Electrical Resistivity tests (by Parsons)	
Surface Geological mapping of Dam Area	Completed by GSI in 2002-03, 03-04, 04-05 & 18-19	
Geological mapping of Reservoir area	--	In progress
Geological mapping of Water Pipeline alignment and Water Treatment Plant area	--	In progress

Type of Investigation	Quantity/Nos	Remarks
Auger Drilling along Water Pipeline	--	In progress
Test Pits along water Pipeline alignment	--	In progress
Plate Load Test (PLT) along Water Pipeline alignment	---	Location yet to be assigned based on geological mapping
Laboratory testing for Disturbed and Undisturbed samples (DS & UDS) along water pipeline alignment	---	Location yet to be assigned based on geological mapping

All the investigations completed are explained in the subsequent sections below. The investigation plan for the entire project area showing the location of the investigations carried out is appended as **Drawing No. P.012745.W-20390-002** and is also shown below in Figure 5-3 Drill hole locations & Figure 5-4 Drift Locations.

5.7.1 Exploratory Drilling

Project area has been investigated by thirty three (30) number of drill holes having a cumulative length of 1526.00m. Out of 30 drill holes,

- 6 drill holes (DH-1, 3, 4, 10, 11 & 15) has been completed in the upstream area of the dam axis
- 19 drill holes (DH-2, 5, 6, 7, 8, 9, 12, 13, 14, 16, 17, 22, 23, 24, NDH-4, 5, 6, 7 & 8) has been drilled in the dam body area including both the abutments and spillway area.
- 3 drill holes (NDH-1, 2 & 3) has been drilled on the left abutment of the dam axis.
- 2 drill holes (NDH-12 & 13) has been drilled at Plunge Pool area.

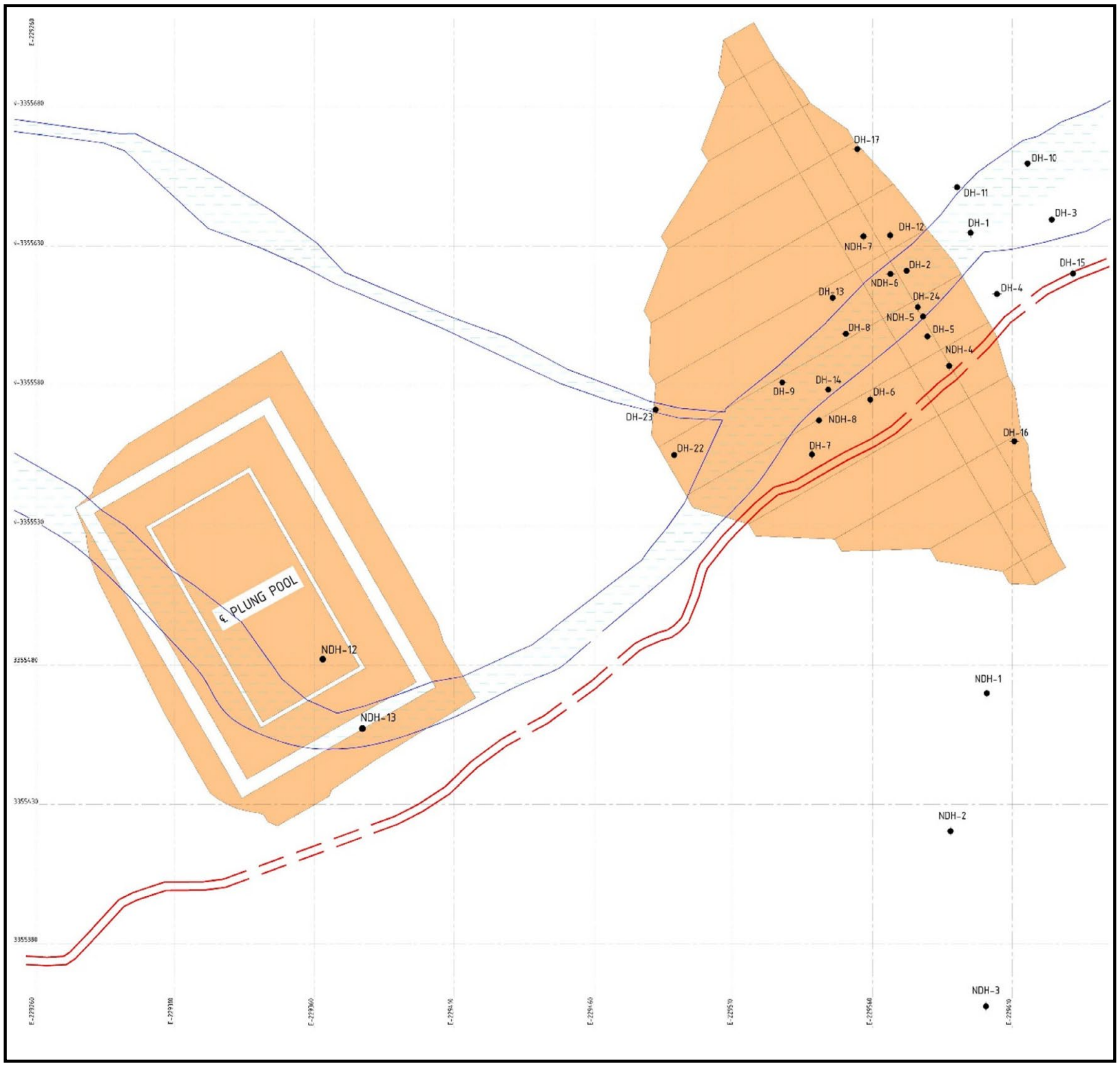


Figure 5-3 : Location of Drill holes

Investigation plan for the entire project area showing the location of drill holes is appended as **Drawing No. P.012745.W-20390-002**. Summarized drill holes are tabulated under Table 5-5.

Table 5-5: Details of Drill Holes Completed for the Project

Sr. No.	Drill Hole No.	Location	Ground/ Coller El. (m)	Co-ordinate	Total Depth (m)	Overburden Depth (m)	Rock Type
1	DH-01	River Centre 30m US of dam Axis	881.48	E229595.063, N3355634.873	60	22.50	Quartzite
2	DH-02	River Centre Dam Axis	878.70	E229572.085, N3355621.270	31	16.75	Quartzite
3	DH-03	Left Bank 60m US of Dam Axis	879.20	E229624.085, N3355639.622	35	14.76	Quartzite
4	DH-04	Left Bank of Dam Axis	879.09	E229604.457, N3355612.919	105.00	21.50	Quartzite

Sr. No.	Drill Hole No.	Location	Ground/ Coller El. (m)	Co-ordinate	Total Depth (m)	Overburden Depth (m)	Rock Type
5	DH-05	Left Bank of Dam Axis	877.58	E229579.603, N3355597.734	100.10	23.00	Quartzite
6	DH-06	Left Bank, 60m Downstream of Dam Axis	877.00	E229559.083, N3355575.058	35.10	26.80	Quartzite
7	DH-07	Left Bank, 45m Downstream of Dam Axis	876.34	E229538.174, N3355555.418	35.10	25.80	Quartzite
8	DH-08	Left Bank, 60m Downstream of Dam Axis, River Bed	875.24	E229550.355, N3355598.680	100.20	6.06	Quartzite
9	DH-09	90m Downstream of Axis	874.74	E229527.538, N3355581.225	100.10	8.35	Quartzite
10	DH-10	Upstream of Dam Axis	876.68	E229615.457, N3355659.643	30.20	11.25	Quartzite
11	DH-11	Right Bank at Dam Axis	876.68	E229590.228, N3355651.163	30.60	7.40	Quartzite
12	DH-12	Right Bank of Dam Axis	876.16	E229566.245, N3355633.951	25.10	3.50	Quartzite
13	DH-13	Right Bank, 60m Downstream of Dam Axis	875.17	E229545.634, N3355611.591	25.10	2.55	Quartzite
14	DH-14	45m downstream of Dam Axis	875.14	E229544.046, N3355578.633	28.10	17.50	Quartzite
15	DH-15	30m Upstream of Dam Axis	878.50	E229631.760, E N355620.273	25.10	9.00	Quartzite
16	DH-16	Left Abutment (Dam Axis) (horizontal hole)	933.60	E229610.758, N3355560.166	25.05	0.00	Quartzite
17	DH-17	Right abutment (Dam Axis) (horizontal hole)	933.00	E229553.913, N3355665.478	35.30	0.00	Quartzite
18	DH-22	Dam Site (Plunge Pool area)	873.51	E229488.803, N3355555.214	35.50	28.00	Quartzite
19	DH-23	Dam Site (Plunge Pool area)	873.14	E229482.173, N3355571.492	35.00	23.75	Quartzite
20	DH-24	Dam Axis, Left Bank	876.50	E229576.105, N3355608.232	150.00	22.50	Quartzite
21	NDH-1	Left bank/ abutment top	996.830	E229600.860, N3355469.810	33.00	0.00	Quartzite

Sr. No.	Drill Hole No.	Location	Ground/ Coller El. (m)	Co-ordinate	Total Depth (m)	Overburden Depth (m)	Rock Type
22	NDH-2	Left bank/ abutment top	1003.305	E229587.812, N3355420.385,	50.00	1.50	Quartzite
23	NDH-3	Left bank/ abutment top	1014.701	E 229600.58, N3355357.565	50.00	1.50	Quartzite
24	NDH-4	Dam Axis-Left bank- River section-T1 Terrace	877.396	E 229587.34, N3355587.17	35.00	18.00	Quartzite
25	NDH-5	Dam Axis- left bank- river bed level	875.361	E 229578.04, N3355604.863	40.00	25.50	Quartzite
26	NDH-6	Dam Axis- Centre of River	875.148	E 229566.332, N3355620.129	35.50	15.00	Quartzite
27	NDH-7	Dam Axis-Right Bank, river bed level	875.476	E 229556.606, N3355633.617	35.00	0.00	Quartzite
28	NDH-8	Dam body area- 50m Downstream of dam axis	875.201	E229540.652, N3355567.63	123.00	28.69	Quartzite
29	NDH-12	Plunge Pool Area	868.98	E229362.98 N33582.019	40.00	30.00	Quartzite
30	NDH-13	Plunge Pool Area	868.50	E-229377.124 N33554572.153	40.00	27.00	Quartzite
			Total Depth (m)		**1526.00**		

The description of all completed drill holes is given below.

DH-1 (EL.881.48m)

Drill hole DH-1 is located in the centre of the river at about 30m upstream of the dam axis. The drill hole has been drilled to a depth of 60.00m. The drill hole has proved the 22.50m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is fine to medium grained greyish to greenish grey quartzite with quartz veins at places. The core recovery varies from 0.00 to 100% while the RQD% ranges from 0.00 to 87.00% in the bed rock. The hole shows the acceptable foundation grade rock at 23.10m depth.

The cyclic water percolation tests carried out indicates the permeability value ranges from 1.37 to 11.44 litre/min/m.

The log of drill hole and permeability data is appended as **Annexure1.3 of Volume II Project Geology.**

DH-2 (EL.878.70m)

Drill hole DH-2 is located in the centre of the river over the dam axis. The drill hole has been drilled to a depth of 31.00m. The drill hole has proved the 16.75m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is fine to medium grained grey quartzite with minor silicificaiton. The core recovery varies from 44.00 to 93.00% while the RQD% ranges from 10.00 to 74.00% in the bed rock. The hole shows the acceptable foundation grade rock at 18.50m depth.

The cyclic water percolation tests carried out indicates the permeability value ranges from 17.33 to 70.22 litre/min/m.

The log of drill hole and permeability data is appended as **Annexure 1.3 of Volume II Project Geology.**

DH-3 (EL.879.20m)

Drill hole DH-3 is located on the left bank of the river about 60m upstream of the dam axis. The drill hole has been drilled to a depth of 35.00m. The drill hole has proved the 14.76m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is white to greyish white medium grained quartzite with leached mineral, pyrites and chalcopyrite crystals. The core recovery varies from 24 to 70% while the RQD% ranges from 24 to 38% in the bed rock. The hole shows the acceptable foundation grade rock at 25.50m depth.

The cyclic water percolation tests carried out indicates the permeability value ranges from 1.9 to 18.22 litre/min/m.

The log of drill hole and permeability data is appended as **Annexure 1.3 of Volume II Project Geology.**

DH-4 (EL.879.09m)

Drill hole DH-4 is located on the left bank of the dam axis. The drill hole has been drilled to a depth of 105.00m. The drill hole has proved the 21.50m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is fine grained, fresh and greenish grey to purplish quartzite. From 69.50 to 71.00m the bed rock is phyllitic in nature. The core shows a high frequency of joints. The RQD% ranges from 0.00 to 91.33% in the bed rock.

The cyclic water percolation tests were carried out in 41 test sections (with a length of 1.5m each) in rock. The permeability value ranges from 2.71 lugeon to 40.11 lugeon.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology.**

DH-5 (EL.877.58m)

Drill hole DH-5 is located on the left bank of the river. The drill hole has been drilled to a depth of 100.10m. The drill hole has proved the 23.00m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is fine grained, greenish grey pinkish white banded quartzite. Core recovery in the drill hole varies from 26.80 to 100% while the RQD% ranges from 0.00 to 90% in the bed rock. Phyllitic bands has also been observed at 29.00 to 30.00m and at 38.30 to 39.50m depths respectively.

The cyclic water percolation tests were carried out in 51 test sections (with a length of 1.5m each) in rock. The permeability value ranges from 7.48 lugeon to 26.61 lugeon.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology**.

DH-6 (EL.877.00m)

Drill hole DH-6 is located on the left bank of the river. The drill hole has been drilled to a depth of 35.10m. The drill hole has proved the 26.80m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is fine to medium grained, greenish grey and pinkish white banded quartzite. The rock surface below the overburden is characterized by pot holes (28.30m to 30.00m). Core recovery in the drill hole varies from 28.66 to 80% while the RQD% ranges from 0.00 to 64.54% in the bed rock.

The cyclic water percolation tests were carried out in 5 test sections (with a length of 1.5m each) in rock. The permeability value ranges from 14.33 lugeon to 22.89 lugeon.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology**.

DH-7 (EL.876.34m)

Drill hole DH-7 is located on the left bank of the river about 30m downstream of the DH-6. The drill hole has been drilled to a depth of 35.10m. The drill hole has proved the 25.80m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is fresh, medium to coarse grained, reddish brown/maroon and greenish grey banded quartzite. Core recovery in the drill hole varies from 72 to 84.61% while the RQD% ranges from 17.00 to 54.00% in the bed rock.

The cyclic water percolation tests were carried out in 6 test sections (with a length of 1.5m each) in rock. The permeability value ranges from 16.57 lugeon to 27.28 lugeon.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology**.

DH-8 (EL.875.24m)

Drill hole DH-8 is located on the right bank of the river about 30m downstream of the dam axis. The drill hole has been drilled to a depth of 100.20m. The drill hole has proved the 6.06m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is hard, compact, jointed, greenish grey and purplish grey, banded, medium to fine grained quartzite. Core recovery in the drill hole varies from 10 to 100% while the RQD% ranges from 0.00 to 96.15% in the bed rock.

The cyclic water percolation tests were carried out in 50 test sections (with a length of 1.5m each) in rock. The permeability value ranges from 4.40 lugeon to 22.62 lugeon.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology.**

DH-9 (EL.874.74m)

Drill hole DH-9 is located in the river channel about 60m downstream of the dam axis. The drill hole has been drilled to a depth of 100.10m. The drill hole has proved the 8.35m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is medium grained quartzite which is weathered and shows pot holes /cavities. This weathering zone is only for initial 1.00m stretch after which the bed rock is fresh. The bed rock also contains interbands of phyllitic quartzite and gravely quartzite.

The cyclic water percolation tests were carried out in 54 test sections (with a length of 1.5m each) in rock. The permeability value ranges from 8.58 lugeon to 20.95 lugeon.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology.**

DH-10 (EL.876.68m)

Drill hole DH-10 is located on the right bank of the river about 30m upstream of the dam axis. The drill hole has been drilled to a depth of 30.20m. The drill hole has proved the 11.25m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is weathered, medium to coarse grained, greenish grey, jointed quartzite having staining along the joints up to 15.00m depth after which it is fresh. Core recovery in the drill hole varies from 46.66 to 98% while the RQD% ranges from 0.00 to 15.71% in the bed rock.

The cyclic water percolation tests were carried out in 12 test sections (with a length of 1.5m each) in rock. The permeability value ranges from 2.32 lugeon to 12.82 lugeon.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology.**

DH-11 (EL.876.68m)

Drill hole DH-11 is located on the right bank of river at the dam axis. The drill hole has been drilled to a depth of 30.60m. The drill hole has proved the 7.40m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is medium to coarse grained, greenish grey quartzite having staining along the joints upto 9.50m depth after which it is fresh. Core recovery in the drill hole varies from 56 to 100% while the RQD% ranges from 0.00 to 87% in the bed rock.

The cyclic water percolation tests were carried out in 13 test sections (with a length of 1.5m each) in rock. The permeability value ranges from 15.60 lugeon to 28.90 lugeon.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology**.

DH-12 (EL.876.16m)

Drill hole DH-12 is located on the right bank of river at the dam axis. The drill hole has been drilled to a depth of 25.10m. The drill hole has proved the 3.50m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is banded, laminated, purplish/pinkish, greenish grey, medium to fine grained quartzite having pyrites specks. Core recovery in the drill hole varies from 44 to 97%.

The cyclic water percolation tests were carried out in 13 test sections (with a length of 1.5m each) in rock. The permeability value ranges from 19.21 lugeon to 42.65 lugeon.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology**.

DH-13 (EL.875.17m)

Drill hole DH-13 is located on the right bank of river at 30m in downstream of the dam axis. The drill hole has been drilled to a depth of 25.10m. The drill hole has proved the 2.55m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is medium to fine grained, greenish to pinkish grey, banded quartzite. Core recovery in the drill hole varies from 63 to 100% while the RQD% ranges from 10.00 to 98% in the bed rock.

The cyclic water percolation tests were carried out in 14 test sections (with a length of 1.5m each) in rock. The permeability value ranges from 13.40 lugeon to 38.48 lugeon.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology**.

DH-14 (EL.875.14m)

Drill hole DH-14 is located on the left bank of river at 45m in downstream of the dam axis on the edge of the river channel. The drill hole has been drilled to a depth of 28.10m. The drill hole has proved the 17.50m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is fresh, hard, jointed, medium to fine grained, greenish to purplish grey banded quartzite. Core recovery in the drill hole varies from 60 to 94.44% while the RQD% ranges from 18.57 to 94.44% in the bed rock.

The cyclic water percolation tests were carried out in 7 test sections (with a length of 1.5m each) in rock. The permeability value ranges from 12.05 lugeon to 35.01 lugeon.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology**.

DH-15 (EL.878.50m)

Drill hole DH-15 is located on the left bank of river at 30m upstream of the dam axis. The drill hole has been drilled to a depth of 25.10m. The drill hole has proved the 9.00m thick overburden material (RBM) after which bed rock is encountered in the drill hole. The bed rock met in the drill hole is off white to greenish grey, medium to fine grained at places coarse grained quartzite. Core recovery in the drill hole varies from 30 to 91.81% while the RQD% ranges from 0.00 to 66.00% in the bed rock.

The cyclic water percolation tests were carried out in 5 test sections (with a length of 1.5m each) in rock. The permeability value ranges from 18.34 lugeon to 54.04 lugeon.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology**.

DH-16 (Horizontal hole) (EL.933.60m)

Drill hole DH-16 has been drilled over the Dam axis on the left abutment. The drill hole has been drilled horizontally to the length of 25.50m. The drill hole has been started from the bed rock and has encountered medium to fine grained, off-white to light grey, jointed quartzite. The weathering and opening of the joints is observed up to 5m depth. A fractured zone has been observed between 17.23 to 17.45m. The core recovery ranges from 50% to 86% whereas the RQD% varies from nil to 60%.

The cyclic water percolation tests were carried out in 15 test sections (with a length of 1.5m each) in rock. The permeability value ranges from 12.65 lugeon to 69.67 lugeon. The high permeability values may be attributed to the direction of the hole i.e. horizontal, which is parallel or sub-parallel to the strike direction of the bedding (bedding joint).

This hole has indicated that the stripping limit of the abutment for tying up of the dam around this elevation (± 933m) can be limited to 5m.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology.**

DH-17 (Horizontal hole)

Drill hole DH-17 has been drilled over the Dam axis on the right abutment. The drill hole has been drilled horizontally to the length of 35.50m. The drill hole has been started from the bed rock and has encountered medium to coarse grained, off-white to greenish grey quartzite with quartz veins (up to 1cm.thick). The weathering and opening of the joints is observed up to 7.75 depth. A major shear zone has been recorded from 16.85m to 20.26m, characterized by shattered and pulverised rock and rock flour. The core recovery varies from 44% to 100% whereas RQD ranges from nil to 86%.

The cyclic water percolation tests were conducted in 20 test sections (with test length of 1.5m each) in rock. The permeability value ranges from 13.94 lugeon to 48.24 lugeon. However, based upon the permeability values in the rock the grout curtain has to be extended up to sound rock on the right abutment.

The weathering and opening of joints indicate that limit of stripping around 935m elevation is 7.75 m which is subject to variation and would be decided finally at the time of excavation.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology**.

DH-22 (EL.873.51m)

This exploratory hole was drilled in the plunge pool area (110m downstream of old axis), towards the left bank in the river channel, to prove the thickness of overburden material. The total depth of the hole is 35.50m. It has proved 28.00m of overburden material. Below the overburden the bed rock encountered is fresh, medium to fine grained, greenish grey, banded, re-crystallized, quartzite. The core recovery varies from 70% to 95% whereas RQD varies from nil to 47%.

The cyclic water percolation tests carried out in 5 test sections (with test length of 1.5m each) in rock. The permeability value ranges from 28.94 lugeon to 51.17 lugeon. The pattern of lugeon values in 80 % sections show void filling (28.94 lugeon – 38.03 lugeon), whereas 20% show turbulent type (43.49 lugeon).

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology**.

DH-23 (EL.873.14m)

This hole was drilled 110m downstream of old dam axis towards right bank in the river channel, in the plunge pool area of the proposed dam, to prove the thickness of the overburden. The total depth of the hole is 35.00m. It has proved 23.75m thick overburden material. The rock encountered below the overburden material is fine-grained greenish grey, pinkish, purplish, recrystallized banded quartzite, traversed by quartz veins (.5cm thick). The rock is highly jointed from 30.77m till 35.00m. Sheared rock, rock flour and mylonitised surface have been observed from 30.77m to 31.50m. Intercalated phyllite (maroon in colour) and quartzite – have been observed from 31.90m to 32.95m. The core recovery varies from 33% to 90% whereas RQD percentage ranges from nil to 64%.

The cyclic water percolation tests carried out in 7 test sections (with length of 1.5m each) in rock. The permeability value ranges from 15.50 lugeon to 77.53 lugeon.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology**.

DH-24 (EL.876.50m)

Drill hole DH-24 has been drilled vertically over the Dam axis on the left bank of Song river at dam axis. The drill hole has been drilled to a depth of 150.00m. It has proved 22.50m thick of overburden (river borne material). In the initial stretch rock shows pothole and cavities and is generally fresh with low grade of weathering. The rock encountered is medium to fine-grained, off-white, greenish grey and purplish, banded quartzite with thin interbands (2cm thick) of phyllite at places. Quartzite is phyllitic from 50.60 to 54.15m and 137.00m to 143.00m. Minor shears have also been observed at 29.50m and at 30.78m. Highly fractured rock has been observed from 74.80m to 75.00m.

Core recovery varies from nil to 100% where as RQD ranges from nil to 90%. Poor to nil recovery zones have been observed (with almost nil core recovery and RQD) from 72.00m to 81.50m and 120.00m to 135.00m.

The cyclic water percolation tests carried out in 81 (with test length of 1.5 m each) test sections in rock. The permeability value ranges from 5.14 lugeon to 22.65 lugeon. The values show a decline towards deeper levels i.e. after 58.50m depth and particularly below 88.50m depth. This points towards the competent nature of the rock at deeper levels.

The log of drill hole is appended as **Annexure 1.3 of Volume II Project Geology**.

NDH-1 (EL.996.83m)

Drill hole NDH-1 has been drilled vertically over the Left abutment (42m away from dam axis towards downstream side). The drill hole has been drilled to a depth of 33.00m. The main purpose of this drill hole is to ascertain the subsurface geological conditions of the left abutment of the dam. This drill hole has been started from the bed rock i.e. without overburden.

The rock encountered is fresh to slightly weathered (W0-W1 grade), coarse to medium grained, Greenish quartzite and Green Quartzite with purple patch. The core recovery varies from 24% to 86.6% whereas RQD ranges from 8% to 15.6%. Nil RQD is observed in run from 1.5 to 3m, 7.5 to 9m, 10.5 to 12m, 15 to 16.5m, 16.5 to 18m, 18 to 19.5m, 19.5 to 21m, 21 to 22.5m, 22.5 to 24m, 25.5 to 27m, 27 to 28.5m, 28.5 to 30m, 30 to 31.5m and 31.5 to 33m. The joint sets recorded are dipping 20º-30º, 300-450, 500-600 and 900 with reference to shorter axis of the core.

The log of drill hole is appended in **Annexure 1.1 of Volume II Project Geology** - Note on Dpr Stage Geological/ Geotechnical Investigation of Song Dam Drinking Water Project, District Dehradun, Uttarakhand (FSP ID: M4EEG/C/NR/SU- UK/2018/15812), (Field Season 2018 - 2019).

NDH-2 (EL. 1003.305m)

Drill hole NDH-2 has been drilled vertically over the Left abutment (94m away from dam axis towards downstream side). The drill hole has been drilled to a depth of 50.00m. The main purpose of this drill hole is to ascertain the subsurface geological conditions of the left abutment of the dam.

This drill hole has proved 1.50m thick overburden after which bedrock is present. The rock encountered is fresh to slightly weathered (W0-W1 grade), light green, off white and purple colored, coarse to medium grained quartzite. The core recovery varies from 14.6% to 43.3% from 1.5 to 15m depth and from 36 to 50m however between 15 to 36m core recovery is good and varies from 66.6 to 96% whereas RQD ranges from 7.3% to 54%. Nil RQD is observed in run from 1.5 to 3m, 4.5 to 6m, 6 to 7.5m, 7.5 to 9m, 9 to 10.5m, 10.5 to 12m, 13.5 to 15m, 25.5 to 27m, 27 to 28.5m, 30 to 31.5m, 31.5 to 33m, 33 to 34.5m, 34.5 to 36m, 36 to 37.5m, 37.5 to 39m, 39 to 40.5m, 40.5 to 42m, 42 to 43.5m, 43.5 to 45m, 45 to 46.5m, 46.5 to 48m, 48 to 49.5and 49.5 to 50m. The joint sets recorded are dipping 200-300, 400-450, 500-600 and 900 with reference to shorter axis of the core. Cyclic WPT conducted in NDH-2 indicates permeability values ranging from 50.73 to 67.95Lu (high permeability).

The log of drill hole is appended in **Annexure 1.1 of Volume II Project Geology** - Note on Dpr Stage Geological/ Geotechnical Investigation of Song Dam Drinking Water Project, District Dehradun, Uttarakhand (FSP ID: M4EEG/C/NR/SU- UK/2018/15812), (Field Season 2018 - 2019).

NDH-3 (EL. 1014.701m)

Drill hole NDH-3 has been drilled vertically over the Left abutment (152m away from dam axis towards downstream side). The drill hole has been drilled to a depth of 50.00m. The main purpose of this drill hole is to ascertain the subsurface geological conditions of the left abutment of the dam.

The drilling has proved 1.5m of overburden material comprising irregular rubbles of green and purple coloured, coarse to medium grained quartzite. Below this, fresh to slightly weathered (W0-W1 grade), light green, off white and purple colored, coarse to medium grained quartzite is encountered. At the initial depth from 1.5 to 30m, the core recovery in bed rock is poor and it varies from 12% to 25.3% however, below 30m till the termination of the bore hole (50m) core recovery improves and varies from 55.3 to 92.6%. The RQD ranges from 7% to 37.3%. Nil RQD is observed in runs from 1.5 to 3m, 3 to 4.5m, 4.5 to 6m, 6 to 7.5m, 7.5 to 9m, 9 to 10.5m, 10.5 to 12m, 13.5 to 15m, 15 to 16.5m, 16.5 to 18m, 18 to 19.5m, 19.5 to 21m, 24 to 25.5m, 25.5 to 27m, 27 to 28.5, 28.5 to 30m, 31.5 to 33m, 34.5 to 36m, 45 to 46.5m, 46.5 to 48m, 48 to 49.5and 49.5 to 50m. The joint sets recorded are dipping 200, 400, 500-600, 700 and 900 with reference to shorter axis of the core. Cyclic WPT conducted in NDH-3 indicates permeability values ranging from 22.70 to 75.48 Lu (Medium to high permeability).

The log of drill hole is appended in **Annexure 1.1 of Volume II Project Geology** - Note on Dpr Stage Geological/ Geotechnical Investigation of Song Dam Drinking Water Project, District Dehradun, Uttarakhand (FSP ID: M4EEG/C/NR/SU- UK/2018/15812), (Field Season 2018 - 2019).

NDH-4 (EL. 877.396m)

Drill hole NDH-4 has been drilled vertically over the dam axis in the river section on the left bank of river over the river Terrace T-1. The drill hole has been drilled to a depth of 35.00m. The main purpose of this drill hole is to ascertain the thickness of river borne material in the river section at the dam axis. This drill hole has proved 18.00m thick overburden material containing river borne material after which bed rock has encountered.

The rock encountered below overburden, is fresh (W0 grade), medium grained, greenish grey to purple quartzite. The core recovery varies from 88 to 100% in bed rock whereas RQD ranges from 21% to 95%. Nil RQD is observed in run from 29 to 30m and 30 to 31m. The joint sets recorded are dipping 300-450, 500-600, 700-750 and 800-900 with reference to shorter axis of the core. Cyclic WPT conducted in NDH-4 indicates permeability values ranging from 2.11 to 3.61 Lu (low permeability). The competent foundation grade rock will be available at 18m bgl.

The log of drill hole is appended in **Annexure 1.1 of Volume II Project Geology** - Note on Dpr Stage Geological/ Geotechnical Investigation of Song Dam Drinking Water Project, District Dehradun, Uttarakhand (FSP ID: M4EEG/C/NR/SU- UK/2018/15812), (Field Season 2018 - 2019).

NDH-5 (EL. 875.361m)

Drill hole NDH-5 has been drilled vertically over the dam axis at river bed level/ active river channel near center of river. The drill hole has been drilled to a depth of 40.00m. The main purpose of this drill hole is to ascertain the thickness of river borne material in the river section at the dam axis. This drill hole has proved 25.50m thick overburden material containing river borne material after which bed rock has encountered.

the rock encountered is fresh, greenish grey, white and purple colored, medium grained quartzite. The core recovery varies from 82 to 98% in bed rock whereas RQD ranges from 8.6% to 50%. Nil RQD is observed in run from 27 to 28.5m and 39 to 40m. The joint sets recorded are dipping 300-450, 500-600, 700 and 800-900 with reference to shorter axis of the core. Cyclic WPT conducted in NDH-5 indicates permeability values ranging from 3.36 to 5.98 Lu (low to moderate permeability). The competent foundation grade rock will be available at 25.5m bgl.

The log of drill hole is appended in **Annexure 1.1 of Volume II Project Geology** - Note on Dpr Stage Geological/ Geotechnical Investigation of Song Dam Drinking Water Project, District Dehradun, Uttarakhand (FSP ID: M4EEG/C/NR/SU- UK/2018/15812), (Field Season 2018 - 2019).

NDH-6 (EL. 875.148m)

Drill hole NDH-6 has been drilled vertically over the dam axis at the centre of river at river bed level/active river channel. The drill hole has been drilled to a depth of 35.50m. The main purpose of this drill hole is to ascertain the thickness of river borne material in the river section at the dam axis. This drill hole has proved 15.00m thick overburden material containing river borne material after which bed rock has encountered.

The rock is fresh (W0 grade), greenish grey to purple, coarse to medium grained quartzite is encountered. The core recovery varies from 76 to 94% in bed rock whereas RQD ranges from 6.6% to 42%. Nil RQD is observed in run from 24 to 25.5m, 25.5 to 27m, 33 to 34.5 and 34.5 to 35.5m. The joint sets recorded are dipping 300-450, 500-650, 700-750 and 850-900 with reference to shorter axis of the core. Cyclic WPT conducted in NDH-6 indicates permeability values ranging from 3.59 to 6.88 Lu (low to moderate permeability). The competent foundation grade rock will be available at 15m bgl.

The log of drill hole is appended in **Annexure 1.1 of Volume II Project Geology** - Note on Dpr Stage Geological/ Geotechnical Investigation of Song Dam Drinking Water Project, District Dehradun, Uttarakhand (FSP ID: M4EEG/C/NR/SU- UK/2018/15812), (Field Season 2018 - 2019).

NDH-7 (EL. 875.476m)

Drill hole NDH-7 has been drilled vertically over the dam axis, right bank of the river, near to active river channel. The drill hole has been drilled to a depth of 35.00m. The main purpose of this drill hole is to ascertain the thickness of river borne material in the river section at the dam axis. This drill hole has started from bed rock i.e. without overburden material.

The rock encountered is fresh to slightly weathered (W0-W1 grade), coarse to medium grained, light green quartzite with purple patches. The core recovery varies from 77.3 to 96.6% in general except in runs between 0 to1.5m and 13.5 to 15m where it is 41.3% and 66.6% respectively. The RQD ranges from 7.3% to 62.6%. Nil RQD is observed between 15 and 16.5m and from 25.5 to 27m. The joint sets recorded are dipping 200-400, 500-600, 70º-750 and 900 with reference to shorter axis of the core. Cyclic WPT conducted in NDH-7 indicates permeability values ranging from 3.13 to 7.37 Lu (low to moderate permeability). The competent foundation grade rock will be available on the ground surface i.e. 0m depth.

The log of drill hole is appended in **Annexure 1.1 of Volume II Project Geology** - Note on Dpr Stage Geological/ Geotechnical Investigation of Song Dam Drinking Water Project, District Dehradun, Uttarakhand (FSP ID: M4EEG/C/NR/SU- UK/2018/15812), (Field Season 2018 - 2019).

NDH-8 (EL. 875.201m)

Drill hole NDH-8 has been drilled vertically in the dam body area, 50m Downstream of dam axis on the left bank of the river, near to active river channel. The drill hole has been drilled to a depth of 123.00m. The main purpose of this drill hole is to ascertain the thickness of river borne material in the river section at the dam axis. This drill hole has proved 28.69m thick overburden material containing river borne material after which bed rock has encountered.

the rock encountered is fresh to slightly weathered (W0-W1 grade), greenish grey, green, purple, medium grained quartzite. The core recovery in bed rock in general varies from 74 to 98% except in the run from 93.5 to 94.5m where it is 62.6%. The RQD ranges from 6.6% to 57.3%. Nil RQD is observed in run from 28.5 to 30m, 58 to 59.5m, 64 to 65.5m, 65.5 to 67m, 67 to 68.5m, 70 to 71.5m, 79 to 80.5m, 86.5 to 88m, 93.5 to 94.5m, 95.5 to 96.5m, 96.5 to 97.5m, 97.5 to 98.5m, 98.5 to 99.5m, 99.5 to 100.5m, 100.5 to 101.5m, 101.5 to 102.5m, 102.5 to 103.5m, 104.5 to 105.5, 105.5 to 106.5m, 106.5 to 107.5m, 107.5 to 108.5m, 108.5 to 109.5m, 110.5 to 111.5m, 111.5 to 112.5m, 112.5 to 113.5m, 114.5 to 115.5m, 115.5 to 116.6m, 116.5 to 117.5m, 117.5 to 118.5m, 118.5 to 119.5m, 119.5 to 120.5m, 120.5 to 121.5m, 121.5 to 122.5m and 122.5 to 123m. The joint sets recorded are dipping 300-450, 500-600, 70º-750 and 800-900 with reference to shorter axis of the core. Cyclic WPT conducted in NDH-8 indicates permeability values ranging from 2.14 to 11.54 Lu (low to moderate permeability).

The log of drill hole is appended in **Annexure 1.1 of Volume II Project Geology** - Note on Dpr Stage Geological/ Geotechnical Investigation of Song Dam Drinking Water Project, District Dehradun, Uttarakhand (FSP ID: M4EEG/C/NR/SU- UK/2018/15812), (Field Season 2018 - 2019).

NDH-12 (EL. 868.98m)

Drill hole NDH-12 has been drilled vertically in the Plunge pool area, 250m Downstream of dam axis on the left bank of the river, near to active river channel. The drill hole has been drilled to a depth of 40.00m. The main purpose of this drill hole is to ascertain the thickness of river borne material in the river section at the dam axis. This drill hole has proved 30.00m thick overburden material containing river borne material after which bed rock has encountered.

The rock encountered is fresh to slightly weathered (W0 grade), greenish grey, medium grained quartzite with some purple bands. The core recovery in bed rock in general varies from 80 to 97%.

The log of drill hole is appended in **Annexure 1.1 of Volume II Project Geology** - Note on Dpr Stage Geological/ Geotechnical Investigation of Song Dam Drinking Water Project, District Dehradun, Uttarakhand (FSP ID: M4EEG/C/NR/SU- UK/2018/15812), (Field Season 2018 - 2019).

NDH-13 (EL. 868.50m)

Drill hole NDH-13 has been drilled vertically in the Plunge pool area near to NDH-12, 250m Downstream of dam axis on the left bank of the river, near to active river channel. The drill hole has been drilled to a depth of 40.00m. The main purpose of this drill hole is to ascertain the thickness of river borne material in the river section at the dam axis. This drill hole has proved 27.00m thick overburden material containing river borne material after which bed rock has encountered.

The rock encountered is fresh to slightly weathered (W0 grade), greenish grey, medium grained quartzite with purple bands. The core recovery in bed rock in general varies from 59.3 to 90%.

The log of drill hole is appended in **Annexure 1.1 of Volume II Project Geology** - Note on Dpr Stage Geological/ Geotechnical Investigation of Song Dam Drinking Water Project, District Dehradun, Uttarakhand (FSP ID: M4EEG/C/NR/SU- UK/2018/15812), (Field Season 2018 - 2019).

5.7.2 Exploratory Drifts

Six exploratory drifts having a cumulative length of **294.43m** has been excavated on both the abutments of the dam axis to access the rock mass condition and to ascertain the stripping limit at the dam axis to ascertain the suitability of the abutments. Out of six drifts, three are on the right abutment at different levels while three are on left abutment at different levels. All the drifts has cross cuts in both upstream and downstream direction. 3D logging of all the six drifts has been completed by GSI. Location of the drifts in comparison to the Dam body is shown below in Figure 5-4 while the details of all drifts is given in Table 5-6.

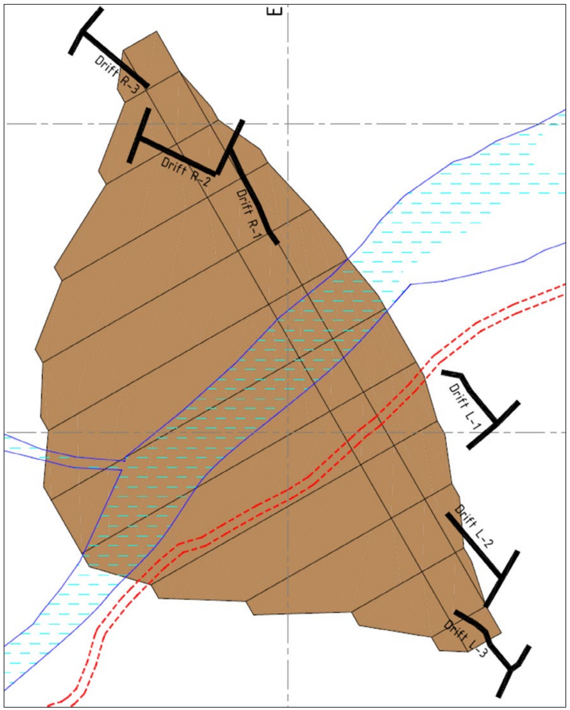


Figure 5-4 : Location of Drifts

Table 5-6: Details of Drift

Sr. no.	Drift No.	Location	Co-ordinate	Elevation (m)	Length (m)	Status
1	R-1	Right Abutment	N3355633.617 E229557.975	878.197	54.60	Completed
2	R-2		N3355663.504 E229536.604	935.360	47.00	Completed
3	R-3		N3355692.030 E229514.724	976.732	46.50	Completed
4	L-1	Left Abutment	N3355599.392 E229609.474	877.958	48.50	Completed
5	L-2		N3355553.690 E229611.518	931.928	50.83	Completed
6	L-3		N3355521.793 E229614.003	964.955	47.00	Completed
				Total	**294.43**	

The summary of all the drifts excavated on both the abutments of the dam axis is summarized below in Table 5-7.

Table 5-7: Summary of the Drifts on Dam Axis

S. No	Drift No	Location	Elevation (m)	Excavated Length (m)	Rock Type	Stripping Limit
1.	R-1	Dam Axis right abutment	878.197	54.60	medium to fine grained, off-white to greenish grey, dark brown or maroon, banded and laminated quartzite	5.00m
2.	R-2		935.360	47.00		5.50m
3	R-3		976.732	46.50		6.00m
4.	L-1		877.958	48.50		6.00m
5.	L-2		931.928	50.83		4.50m

S. No	Drift No	Location	Elevation (m)	Excavated Length (m)	Rock Type	Stripping Limit
6.	L-3	Dam Axis Left abutment	964.955	47.00	medium to fine grained, off-white to greenish gray, purplish, maroon banded, at places, laminated quartzite	11.00m
			Total	**294.43**		

The detailed investigation plan of the dam site showing location of drifts is appended as **Drawing No. P.012745.W-20390-002** while the geological cross section of the dam axis showing the drifts is appended as **Drawing No. P.012745.W-20390-007.** The finding of the drifts on both the abutments is summarized as below:

A. Right Bank Drifts

1. Drift R-1 (EL.878.197m) –Bottom level drift

This drift has been excavated to explore the right abutment conditions and to assess the limit of stripping and rock-mass condition vis-à-vis geological discontinuities.

The drift is located on the right bank at dam axis. Total length of the drift R-1 at the bottom level is 54.60m including cross-cuts. The total length of the main drift is 35m with two cross cuts both in upstream and downstream direction with 10m and 9.60m length respectively. Front R.D. 0.00 to 5.00m the drift is excavated in N35°W direction, thereafter from R.D. 5.0m to 14.00 m in N22°W and from R.D.14.00m to 25.00m in N28°W direction. After R.D.25.00m it is driven in N25°W direction till R.D. 35.00m where two cross cuts in upstream and downstream direction are excavated in N25°E and S25°W direction respectively.

3D logging is completed by GSI. 3D log reveals dripping condition at Rd. 33.90 m. Bedrock is fined grained, off white to greenish grey to maroon coloured, banded and laminated quartzite. In-situ test viz. shear parameter and Plate Load Test (PLT) has been completed in this drift. Intermittent sheared patches are expected, as inferred from 3D log of excavated drift.

The rock exposed along the drift and in crosscuts is medium to fine grained, off-white to greenish grey, dark brown or maroon, banded and laminated quartzite. At R.D. 25.00m quartzite shows disseminations of pyrite. In the main drift at R.D. 3.00m over break (up to 1m), at crown level, has been observed due to wedge failure along two sets of joints. In the main drift the limit of weathering extends to 5m as reflected by the open joints filled with soil material and plant root penetration. Based on these observations the stripping limit has been kept at 5m. The entire drift is self-supporting.

The most prominent joint set observed is bedding plane parallel joint, which is dipping 35-50° in N40-50°E direction. It shows undulatory nature due to folding. An open fold was observed at R.D. 26.40m on the left wall, at floor level. At R.D. 13.30m reddish brown or maroon, medium to fine grained quartzite bands have been observed.

Minor shears varying in thickness from 5-10cm, characterized by sheared rock, rock flour and at places, clay gouge, have been recorded at crown level at R.D.12.50m, 16.00m, 25.00m, and 31.00m, and 27.50m at right spring level. Thin quartz veins (1-2cm thick) have also been observed.

In the cross cut (Downstream) with bearing in S25°W direction, a shear has been observed at RD 7.5m (at crown level). Other shears, at RD 2.20m with attitude of 40° in N10°E direction (right wall at floor level) and at RD 9.10m at crown level have been observed in the Upstream cross cut with bearing in N25°E direction. The most prominent set of shears is parallel to bedding plane.

The different shears recorded in the main drift and in cross cuts are given in Table 5-8 and joints recorded within the drift and cross cuts are given in Table 5-9. 3-D geological log of the drift (logged by GSI) is appended as **Drawing No. P.012745.W-20390-010.**

Table 5-8: Drift R-1 - Details of Shears Recorded in Drift and Cross Cuts

S. No.	Dip.	Direction	Remarks
Sz1	40-45°	N35-45°E	Bedding plane parallel, affected zone 8-10cm, sheared rock, rock flour, up to 1cm thick clay gauge.
Sz 2	50°	N10°E	Sheared rock, rock flour, affected zone, 8 to15 cm.
Sz 3	80°	West	Affected zone 6cm, rock flour.
Sz 4	75°	NE	Affected zone 10-15cm, clay gauge 1cm, rock flour, sheared rock, slickensided surface, pinching and swelling character.
Sz 5	40°	N55°E	Affected zone 10cm,clay gauge 2-3cm,crushed rock, and rock flour.
Sz 6	50°	N10°E	Clay gauge 2cm, affected zone 6cm, fractured rock, rock flour.
Sz 7	40°	N10°E	Wet, water dripping, clay gauge 2-4cm, affected zone 6cm, sheared rock, rock flour.

The joints recorded in the drifts and in cross cuts are summarised in Table 5-9**.**

Table 5-9: Drift R-1 - Details of Joints in Drift and Cross Cuts

S.No.	Dip.	Direction	Spacing (in cm.)	Remarks
J1	35-50°	N35-55°E	1- 30	Rough to moderately smooth, undulatory, bedding plane parallel, continuity +4m, tight, slickensided surface.
J2	60-80°	N80-85°W to West	1- 30	Rough, undulatory, fresh or ferruginous stained surface, tight, continuity +2m.
J3	45-55°	S5-20°W	2- 40	Rough to moderately smooth, fresh, flat/planar, tight, continuity +2m.
J4	40-65°	N10E to North	4- 50	Rough, planar to undulatory, continuity +2m.
J5	60-80°	S85°W	5- 40	Rough, undulatory, ferruginous stained surface, continuity 2 to 3m.
J6	50°	N10°W	5-20	Rough, planar to undulatory, continuity +2m.

2. Drift R-2 (EL.935.360m) – Mid level drift

This drift has been excavated to explore the right abutment conditions and to assess the limit of stripping and rock-mass condition. The drift is located on the right abutment of the dam axis at mid level of the dam height. Total length of the drift R-2 is 47.00m including cross-cuts. The total length of the main drift is 28m with two cross cuts both in upstream and downstream direction with 10m and 9.00m length respectively. The main drift i.e. from 0.00m to 28.00m the drift is excavated in N296° direction while the two cross cuts in upstream and downstream direction are excavated in N020° and N200°direction respectively. Based on these observations the stripping limit has been kept at 5.50m. The entire drift is self-supporting.

3D logging is completed by GSI. 3D log reveals Root penetration up to chainage 5.5m. The drift has been excavated through medium to fine grained, off-white to greenish grey, at places pyrite bearing, banded and laminated quartzite. The rock in general is W0 to W2 grade however; along shear zones W3 grade of rock has also been noticed. Pyrite and iron staining is seen on the rock surface. Five sets of joints including two random joints have been recorded. The general strike of the bedding is NW-SE with 35°-45°dips towards NE. Shears (mainly bedding parallel) varying in thickness from 2-15cm with opening filled with sheared rock, rock flour and clay gouge have been recorded. Wedge and planar failure have been noticed between Ch 0 to 2m. The drift is generally dry, but dampness has been observed at few locations in the crown portion. Dripping condition at crown has been observed at chainage 4m, 6m and 8m in the upstream cross cut. The Q-value calculated ranges from 3.04 to 5.0 indicating poor to fair category of rock.

Based on the extent of weathering, open joints and root penetration the stripping limit has been deciphered at 5.5m.

The joints recorded in the main drift are given in Table 5-10, while Shears recorded in the main drift is tabulated in Table 5-11. Shears recorded in the downstream crosscut are tabulated in Table 5-12, while shears recorded in the Upstream crosscut are tabulated in Table 5-13. The 3-D geological log of the drift (logged by GSI) is appended as **Drawing No. P.012745.W-20390-011.**

Table 5-10: Drift R-2 - Details of joint sets recorded in Main Drift

SL. No.	Joint No.	Attitude		Characteristics				
		Dip Amount	Dip Direction	Spacing (in cm)	Continuity / Persistence	Aperture/ Opening	Condition	Remarks
1.	J_1	35^0-45^0	N35^0-45^0	4-45	>5m	Tight, at places open (2 mm)	MSP to RU	Slickenside surface, bedding parallel
2.	J_2	60^0-75^0	N275^0-280^0	2-17	1m	Tight at places open (1 mm)	RU	Staining on surface
3.	J_3	45^0-52^0	N185^0-210^0	2-40	1.5m	Tight	Rough to MSP	
4.	J_{4a}	40^0-60^0	N140^0-160^0	5-40	1m	Tight to open up to 1mm	RU to RP	
	J_{4b}	25^0	N150^0-160^0	4-40	1m	Tight to open up to 1mm	RU to RP	Random
5.	J_{5a}	40^0-45^0	N300^0-350^0	4-50	1m	Tight	RU	
	J_{5b}	25^0	N340^0-350^0	3-50	1m	Tight	RU	Random

(Remarks: RU: Rough Undulatory, MSP: Moderately Smooth Planar, RP: Rough Planar)

Table 5-11: Drift R-2 - Details of shears recorded in the Main Drift

Shear no.	Dip Amount	Dip Direction	Remarks
SZ1	55^0	N200-210^0	Affected zone: 3-8cm, filled with crushed rock and minor clay, tree roots noted
SZ2	55^0	N210^0	Affected zone: 2-10cm, filled with crushed rock and minor clay, tree roots noted
SZ3	50^0	N20^0	Bedding parallel, Affected zone: 3-8cm, filled with crushed rock and clay
SZ4	52^0	N210^0	Affected zone: 2-10cm, filled with crushed rock and minor clay, tree roots noted
SZ5	40^0	N45^0	Bedding parallel, Affected zone: 2-7cm, filled with crushed rock and minor clay
SZ6	50^0	N40^0	Bedding parallel, Affected zone: 3-10cm, filled with crushed rock, rock powder and minor clay
SZ7	45^0	N50^0	Bedding parallel, Affected zone: 1-8cm, filled with crushed rock and clay
SZ8	40^0	N60^0	Bedding parallel, Affected zone: 2-12cm, filled with crushed rock and clay
SZ9	80^0	N100^0	Affected zone: 3-10cm, filled with crushed rock and clay
SZ10	70^0	N160^0	Affected zone: 1-5cm, filled with crushed rock and clay
SZ11	55^0	N50^0	Affected zone: 1-17cm, filled with crushed rock and clay
SZ12	75^0	N120^0	Affected zone: 1-5cm, filled with crushed rock and clay
SZ13	40^0	N60^0	Affected zone: 5-15cm, filled with crushed rock and clay
SZ14	70^0	N120^0	Affected zone: 2-10cm, filled with crushed rock and clay

Table 5-12: Drift R-2 - Details of shears recorded in Downstream cross cut

Shear no.	Dip Amount	Dip Direction	Remarks
SZ1	45^0	N50^0	Bedding parallel, stained, Affected zone: 2-12cm, filled with crushed rock and clay
SZ2	40^0	N40^0	Bedding parallel, Affected zone: 2-5cm, filled with crushed rock and clay
SZ3	30^0	N30^0	Bedding parallel, Affected zone: 2-6cm, filled with crushed rock and minor clay
SZ4	40^0	N45^0	Bedding parallel, stained, Affected zone: 5-15cm, filled with crushed rock and minor clay
SZ5	35^0	N10^0	Affected zone: 2-5cm, filled with crushed rock and minor clay
SZ6	60^0	N30^0	Bedding parallel, Affected zone: 2-15cm, filled with crushed rock (phyllite), and clay gauge
SZ7	42^0	N40^0	Bedding parallel, yellow staining, Affected zone: 5-12cm, filled with crushed rock and clay

Table 5-13: Drift R-2 - Details of shears recorded in Upstream cross cut

Shear no.	Dip Amount	Dip Direction	Remarks
SZ1	20^0	N45^0	Bedding parallel, Affected zone: 5-15cm, filled with crushed rock and clay
SZ2	45^0	N45^0	Bedding parallel, Affected zone: 2-10cm, filled with crushed rock and minor clay
SZ3	40^0	N40^0	Bedding parallel, Affected zone: 2-5cm, filled with crushed rock and minor clay
SZ4	35^0	N30^0	Bedding parallel, Affected zone: 2-12cm, filled with crushed rock (phyllite) and clay gauge
SZ5	50^0	N50^0	Bedding parallel, Affected zone: 2-8cm, filled with crushed rock (phyllite), crushed quartz vein and clay gauge
SZ6	40^0	N40^0	Bedding parallel, Affected zone: 2-10cm, filled with crushed rock and clay

3. Drift R-3 (EL. 976.732m) – Top level drift

This drift has been excavated to explore the right abutment conditions and to assess the limit of stripping and rock-mass condition. The drift is located on the right abutment of the dam axis at near top level of the dam height. Total length of the drift R-3 is 46.50m including cross-cuts. The total length of the main drift is 28m with two cross cuts both in upstream and downstream direction with 10m and 8.50m length respectively. The main drift i.e. from 0.00m to 28.00m the drift is excavated in N310° direction while the two cross cuts in upstream and downstream direction are excavated in N040° and N208°direction respectively. Based on these observations the stripping limit has been kept at 6.0m. The entire drift is self-supporting.

3D logging is completed by GSI. 3D log reveals the rock encountered is medium to fine grained, off-white to greenish grey, at places pyrite bearing and laminated quartzite. The rock in general is W0 to W2 grade however along shear zones W2-W3 grade of rock has also been noticed. Five sets of joints have been recorded. The general strike of the bedding is NW-SE with 45°-55° dips towards NE. Shears (mainly bedding parallel) varying in thickness from 2-15cm filled with crushed rock, rock flour and minor clay gouge have been recorded. Closely spaced joints have been noticed between Ch 2.0m to 7.0m. The drift is generally dry but dampness has been observed at few locations between Ch. 2m to 6m in the crown portion.

Based on the extent of weathering, open joints and root penetration the stripping limit has been deciphered at 6m.

The joints recorded in the main drift are given in Table 5-14**,** while Shears recorded in the main drift is tabulated in Table 5-15. Shears recorded in the Downstream crosscut are tabulated in Table 5-16**,** while shears recorded in the Upstream crosscut are tabulated in Table 5-17. The 3-D geological log of the drift (logged by GSI) is appended as **Drawing No. P.012745.W-20390-012.**

Table 5-14: Drift R-3 - Details of joint sets recorded in Main Drift

SL. No.	Joint No.	Attitude		Characteristics				
		Dip Amount	Dip Direction	Spacing (in cm)	Continuity/ Persistence	Aperture/ Opening	Condition	Remarks
1.	J$_1$	45^0-55^0	N40^0-50^0	2-50	>6m	Tight, at places open (1cm, opening filled with crushed rock)	MSP to RU	Slickenside surface, bedding parallel, staining on surface
2.	J$_2$	60^0-75^0	N290^0-310^0	4-17	1m	Tight, at places open (1 mm)	MSP to RU	-
3.	J$_3$	38^0-50^0	N210^0-260^0	1-60	>5m	Tight to opening in few mm	MSP	Staining on surface
4.	J$_4$	58^0-70^0	N100^0-130^0	1-30	3m	Tight to open up to 1mm	SP to MRU	-
5.	J$_5$	40^0-48^0	N185^0-200^0	2-40	2m	Tight	RU to MSP	-

(**Remarks:** RU: Rough Undulatory, MSP: Moderately Smooth Planar, SP: Smooth Planar, MRU: Moderately Rough Undulatory).

Table 5-15: Drift R-3 - Details of shears recorded in the Main Drift

Shear no.	Dip Amount	Dip Direction	Remarks
SZ1	45^0	N60^0	Bedding parallel, Affected zone: 2-4cm, filled with crushed rock and minor clay
SZ2	42^0	N60^0	Bedding parallel, Affected zone: 1-4cm, filled with crushed rock and minor clay
SZ3	65^0	N120^0	Affected zone: 4-10cm, filled with crushed rock and rock powder
SZ4	45^0	N50^0	Bedding parallel, Affected zone: 1-5cm, filled with crushed rock, rock powder and minor clay
SZ5	45^0	N50^0	Bedding parallel, Affected zone: 1-5cm, filled with crushed rock, rock powder and minor clay
SZ6	60^0	N30^0	Affected zone: 1-10cm, filled with crushed rock, rock powder and minor clay
SZ7	55^0	N50^0	Bedding parallel, Affected zone: 5-10cm, filled with crushed rock and rock powder
SZ8	52^0	N50^0	Bedding parallel, Affected zone: 2-4cm, filled with crushed rock and rock powder
SH	45^0	N60^0	Bedding parallel, Hair line

Table 5-16: Drift R-3 - Details of shears recorded in Downstream cross cut

Shear no.	Dip Amount	Dip Direction	Remarks
SZ1	44^0	N48^0	Bedding parallel, Affected zone: 2-5.5cm, filled with crushed rock and rock powder
SZ2	50^0	N40^0	Bedding parallel, Affected zone: 1-3cm, filled with crushed rock and rock powder
SZ3	50^0	N45^0	Bedding parallel, Affected zone: 3-7cm, filled with crushed rock and rock powder
SZ4	50^0	N45^0	Bedding parallel, Affected zone: 1-3cm, filled with crushed rock and rock powder
SZ5	48^0	N46^0	Bedding parallel, Affected zone: 1-3cm, filled with crushed rock and rock powder
SZ6	28^0	N30^0	Affected zone: 1-3.5cm, filled with crushed rock and rock powder
SZ7	48^0	N50^0	Bedding parallel, Affected zone: 2-4.5cm, filled with crushed rock and rock powder
SZ8	45^0	N50^0	Bedding parallel, Affected zone: 1-3cm, filled with crushed rock and rock powder
SZ9	46^0	N45^0	Bedding parallel, Affected zone: 1-3cm, filled with crushed rock and rock powder

Table 5-17: Drift R-3 - Details of shears recorded in Upstream cross cut

Shear no.	Dip Amount	Dip Direction	Remarks
SZ1	60^0	N45^0	Bedding parallel, Affected zone: 1-5cm, filled with crushed rock and rock powder
SZ2	58^0	N45^0	Bedding parallel, Affected zone: 1-2.5cm, filled with crushed rock and rock powder
SZ3	45^0	N50^0	Bedding parallel, Affected zone: 1-3cm, filled with crushed rock and rock powder
SZ4	42^0	N50^0	Bedding parallel, Affected zone: 1-3cm, filled with crushed rock and rock powder
SZ5	44^0	N45^0	Bedding parallel, Affected zone: 3-6cm, filled with crushed rock, rock powder and minor clay
SZ6	42^0	N35^0	Affected zone: 3-5cm, filled with crushed rock and rock powder
SZ7	50^0	N220^0	Affected zone: 1-2.5cm, filled with crushed rock and rock powder
SZ8	34^0	N220^0	Bedding parallel, Affected zone: 1-3cm, filled with crushed rock and rock powder

B. Left Bank Drifts

1. Drift L-1 (EL.877.958m) – Bottom level drift

The drift is located on the left abutment of the dam axis. This drift has been completed 25m upstream of the dam axis. The length of the total drift is 48.50m including cross cuts. The length of the main drift is 26.00m while that of cross cuts is 10.00m and 12.50m in upstream direction and downstream direction respectively.

3D log confirms the stripping limit of 6m. Overall drift reveals the dry condition except between Rd. 11.90m-14.40m where moist and seepage conditions are observed. Dripping condition has been observed at Rd. 26m in Main drift and at Rd. 10m in upstream cross-cut. Bedrock is medium to coarse grained, greenish grey quartzite till Rd. 18m whereas medium to fine grained, off white to greenish grey, Maroon banded & laminated quartzite encountered from Rd. 18 onwards till end of the drift and in cross-cuts.

From 0.00m to R.D. 6.50m the bearing of the drift is S80°E and the rock encountered is medium to coarse grained, massive but jointed quartzite of greenish grey colour. From R.D. 6.5 m to R.D. 12.00m the bearing of the drift is S30° E whereas from R.D. 12.00m to 18.50m, it is excavated in S 40°E direction. The drift is excavated in S 40°E direction from R.D. 18.00m to 26.00m and was logged along with cross cuts measuring 10m and 12.50m in N45°E and S50°W direction respectively

Throughout its length in the main drift and in cross cuts, as well, the drift stands unsupported. It is excavated through medium to fine grained, off-white to greenish gray, purplish, maroon banded, at places, laminated quartzite. The general strike of bedding is NW- SE with 40-45° dips towards NE. The bedding planes show undulatory nature due to folding.

In the cross cut in upstream direction i.e. N45°E, at R.D.7.00m (from the main drift) over break at crown level (up to 1.00m) due to failure of wedge by two intersecting joints has been observed. The drift is generally dry but it is moist and dripping at R.D. 26.00m and at R.D.10.00m in upstream cross cut (with N45°E direction) and at RD-5.00m in downstream cross cut (S45°W).

The joints recorded in the drift are given in Table 5-18**,** while the 3-D geological log of the drift (logged by GSI) is appended as **Drawing No. P.012745.W-20390-013.**

Table 5-18: Drift L-1 - Details of Joints in Drift

S. No.	Dip.	Direction	Spacing	Remarks
J1	40-45°	N40-50°E	2–40cm	Smooth to rough, tight, contumely 2-3m, fresh.
J2	40-60°	S30-50°E	2-25cm	Rough, undulatory, continuity 2m.
J3	65-80°	S55-70°W	2-30cm	Moderately smooth, planar, tight, continually +2m, ferruginous stains.
J4	50-60°	S5 -15°E	1-40cm	Continuity +2m, moderately smooth, undulatory, tight.
J5	50-60°	N20°E	2-40cm	Moderately smooth to rough, undulatory fresh, tight, continuity +2m
J6	80-85°	N65-80°W	3-30cm	Rough, undulatory, at places moderately smooth, tight, continently 1 to 3m.

2. Drift L-2 (EL.931.928m) – Mid level drift

This drift has been excavated to explore the left abutment conditions and to assess the limit of stripping and rock-mass condition. The drift is located on the right abutment of the dam axis at mid level of the dam height. Total length of the drift L-2 is 50.83m including cross-cuts. The total length of the main drift is 27.70m with two cross cuts both in upstream and downstream direction with 10.43m and 10.70m length respectively. The main drift i.e. from 0.00m to 27.70m the drift is excavated in N140° direction while the two cross cuts in upstream and downstream direction are excavated in N030° and N210° direction respectively. Based on these observations the stripping limit has been kept at 4.50m. The entire drift is self-supporting.

3D logging is completed by GSI. 3D log reveals that the drift is self supporting. Opening in joints and root penetration has been observed upto chainage 4.5m. Medium to fine grained, off-white to greenish grey quartzite is predominant lithology encountered in the drift. However, at places specs of pyrite in quartzite is also observed. The rock in general exhibits W0 to W1 grade of weathering. However, along shear seams W2-W3 grade of weathering has also been noticed. Oxidation/ Pyrite staining is seen on the rock surface. Six sets of joints have been recorded including three random joints. The general strike of the bedding is NW-SE with 40°-45° dips towards NE. Shears (mainly bedding parallel) varying in thickness from 2-12cm with opening filled with crushed rock, rock flour and minor clay gouge have been recorded. Wedge and planar failure have been noticed between Ch 0 to 4m, at Ch 7.0m, Ch. 13 to 15m, Ch. 17 to 19 and at places it is leading to over breaks. The drift is generally dry but it is wet at crown at Ch 14.0m. Along shears the drift is wet at Ch-8.0m (upstream cross cut) and Ch-4.0m in downstream crosscut. The Q-value ranges from 2.8 to 5.4 indicating poor to fair category of rock.

Based on the extent of weathering, joints opening and root penetration the stripping limit has been deciphered at 4.5m.

The joints recorded in the main drift are given in Table 5-19**,** while Shears recorded in the main drift is tabulated in Table 5-20. Shears recorded in the Upstream crosscut are tabulated in Table 5-21**,** while shears recorded in the downstream crosscut are tabulated in Table 5-22. The 3-D geological log of the drift (logged by GSI) is appended as **Drawing No. P.012745.W-20390-014.**

Table 5-19: Drift L-2 - Details of Joints joint sets recorded in Main Drift

SL. No.	Joint No.	Attitude		Characteristics				
		Dip Amount	Dip Direction	Spacing (in cm)	Continuity / Persistence	Aperture/ Opening	Condition	Remarks
1.	J_1	35^0-50^0	N35^0-50^0	2.5-70	>4m	Tight, at places open (2 mm)	MSP to SU	Slickenside surface, bedding parallel
2.	J_2	45^0-55^0	N215^0-240^0	1-70	50cm to 1m	Tight	SP to RU	Staining on surface
3.	J_3	50^0-65^0	N120^0-140^0	2-10	2m	Tight to open up to 1mm	SP-RU	-
4	J_4	45^0-50^0	N195^0-200^0	8-14	1 to 1.5m	Tight to open up to 2mm	SP-RU	-
5	J_{5a}	75^0-80^0	N130^0-160^0	10-18	1m	Tight to open up to 2mm	SP	-
	J_{5b}	30^0-35^0	N130^0-160^0	2-3	1m	Tight to open up to 5mm	SP-RU	Random

6	J_{6a}	70^0-75^0	N320^0-340^0	3-40	2m	Tight	MSP-RU	-
	J_{6b}	45^0-50^0	N320^0-340^0	8-14	1m	Tight	MSP-RU	Random
7	J_R	45^0-50^0	N195^0-200^0	2-4	1m	Tight	SP-RU	Random

(Remarks: RU: Rough Undulatory, MSP: Moderately Smooth Planar, SP: Smooth Planar)

Table 5-20: Drift L-2 - Details of shears recorded in the Main Drift

Shear no.	**Dip Amount**	**Dip Direction**	**Remarks**
SZ1	40^0	N40^0	Bedding parallel, Affected zone: 10-16cm, filled with crushed rock and minor clay
SZ2	80^0	N145^0	Bedding parallel, Affected zone: 2-10cm, filled with crushed rock and minor clay
SZ3	40^0	N45^0	Bedding parallel, Affected zone: 2-10cm, filled with crushed rock and clay
SZ4	42^0	N45^0	Bedding parallel, Affected zone: 2-5cm, filled with crushed rock and minor clay
SZ5	45^0	N45^0	Bedding parallel, Affected zone: 2-6cm, filled with crushed rock and minor clay
SZ6	70^0	N120^0-150^0	Affected zone: 8-15cm, filled with crushed rock, rock powder and minor clay
SZ7	40^0	N40^0	Bedding parallel, Affected zone: 3-5cm, filled with crushed rock and rock powder
SZ8	55^0	N30^0	Bedding parallel, Affected zone: 3-15cm, filled with crushed rock and clay
SZ9	40^0	N50^0	Bedding parallel, Affected zone: 5-15cm, filled with crushed rock and clay
SZ10	50^0	N30^0	Bedding parallel, Affected zone: 2-5cm, filled with crushed rock and clay
SZ11	65^0	N140^0	Affected zone: 2-10cm, filled with crushed rock and clay
SZ12	45^0	N40^0	Bedding parallel, Affected zone: 4-20cm, filled with crushed rock and clay
SZ13	40^0	N45^0	Bedding parallel, Affected zone: 2-6cm, filled with crushed rock and clay

Table 5-21: Drift L-2 - Details of shears recorded in Upstream Cross cut

Shear no.	**Dip Amount**	**Dip Direction**	**Remarks**
SZ1	50^0	N40^0	Bedding parallel, Affected zone: 2-6cm, filled with crushed rock, rock powder and minor clay
SZ2	55^0	N60^0	Bedding parallel, Affected zone: 1-6cm, filled with crushed rock, rock powder and minor clay
SZ3	38^0	N40^0	Bedding parallel, Affected zone: 2-12cm, filled with crushed rock, rock powder and minor clay
SZ4	40^0	N30^0	Bedding parallel, Affected zone: 4-12cm, filled with crushed rock, rock powder and minor clay
SZ5	40^0	N50^0	Bedding parallel, Affected zone: 4-10cm, filled with crushed rock, rock powder and minor clay
SZ6	25^0	N40^0	Bedding parallel, Affected zone: 3-14cm, filled with crushed rock, rock powder and minor clay
SZ7	25^0	N35^0	Bedding parallel, Affected zone: 2-8cm, filled with crushed rock, rock powder and minor clay

Table 5-22: Drift L-2 - Details of shears recorded in Downstream Cross cut

Shear no.	**Dip Amount**	**Dip Direction**	**Remarks**
SZ1	35^0	N40^0	Bedding parallel, Affected zone: 2-6cm, filled with crushed rock, rock powder and minor clay
SZ2	30^0	N40^0	Bedding parallel, Affected zone: 2-10cm, filled with crushed rock, rock powder and minor clay

SZ3	40^0	N40^0	Bedding parallel, Affected zone: 2-12cm, filled with crushed rock, rock powder and minor clay
SZ4	50^0	N40^0	Bedding parallel, hair line, filled with crushed rock, rock powder and minor clay
SZ5	15^0	N330^0	Affected zone: 2-6cm, filled with crushed rock, rock powder and minor clay
SZ6	45^0	N40^0	Bedding parallel, Affected zone: 2-10cm, filled with crushed rock and minor clay
SZ7	35^0	N40^0	Bedding parallel, Affected zone: 2-6cm, filled with crushed rock and minor clay

3. Drift L-3 (EL.964.955m) – Top level drift

This drift has been excavated to explore the left abutment conditions and to assess the limit of stripping and rock-mass condition. The drift is located on the right abutment of the dam axis at near top level of the dam height. Total length of the drift L-3 is 47.00m including cross-cuts. The total length of the main drift is 27.00m with two cross cuts both in upstream and downstream direction with 10.00m and 10.00m length respectively. The main drift i.e. from 0.00m to 8.00m the drift is excavated in N120° direction, from 8.00m to 12.00m the drift is excavated in N130° direction, from 12.00m to 16.50m the drift is excavated in N160°direction & from 16.50m to 27.00m the drift is excavated in N140° direction. While the two cross cuts in upstream and downstream direction are excavated in N030° and N205° direction respectively. Based on these observations the stripping limit has been kept at 11.00m. The entire drift is self-supporting.

3D logging is completed by GSI. 3D log reveals root penetration up to chainage11m. The rock encountered is medium to fine grained, off-white to greenish grey quartzite, however at places specs of pyrite in quartzite, banded and laminated quartzite is also encountered. The rock in general is W0 to W1 grade however along shear zones W2-W3 grade of rock has also been noticed. Pyrite and iron staining is seen on the rock surface. Six sets of joints including two random joints have been noted. Highly jointed and distressed rock has been noticed between Ch. 5 and 6m on left wall. Highly jointed rock has been noticed between Ch 13 and 17, from Ch 22 to 24m on right wall. Wedge and planar failures leading to over breaks, have also been noticed. Shears (mainly bedding parallel) varying in thickness from 2-15cm with opening filled with sheared rock, rock flour and clay gouge have been recorded at various chainages. The drift is generally dry. The Q-value calculated ranges from 2.82 to 5.68 indicating poor to fair category of rock.

Based on the extent of weathering, open joints and root penetration the stripping limit has been deciphered at 11m.

The joints recorded in the main drift are given in Table 5-23, while Shears recorded in the main drift is tabulated in Table 5-24. Shears recorded in the Upstream crosscut are tabulated in Table 5-25, while shears recorded in the downstream crosscut are tabulated in Table 5-26. The 3-D geological log of the drift (logged by GSI) is appended as **Drawing No. P.012745.W-20390-015.**

Table 5-23: Drift L-3 - Details of joint sets recorded in Main Drift

SL. No.	**Joint No.**	**Attitude**		**Characteristics**				
		Dip Amount	**Dip Direction**	**Spacing (in cm)**	**Continuity/ Persistence**	**Aperture/ Opening**	**Condition**	**Remarks**
1.	J_1	35^0-50^0	N35^0-50^0	4-80	>5m	Tight, at places open (5 mm)	SP to SU	Slickenside surface,

								bedding parallel
2.	J$_2$	50^0-55^0	N210^0-245^0	12-37	60cm to 1.5m	Tight open up to 2mm	SP to RU	
3.	J$_3$	50^0-65^0	N120^0-140^0	3-25	1.5m	Tight to open up to 5mm	MSP-RU	
4	J$_4$	45^0-50^0	N195^0-200^0	8-14	1 to 1.5m	Tight to open up to 2mm	SP-RU	
5	J$_{5a}$	75^0-80^0	N130^0-160^0	3-25	1.5m	Tight	SP-RU	
	J$_{5b}$	30^0-35^0	N130^0-160^0	2-3	1m	Tight to open up to 5mm	SP-RU	Random
6	J$_{6a}$	70^0-80^0	N310^0-320^0	8-60	90cm	Tight to open up to 2cm	MSP-RU	
	J$_{6b}$	40^0-50^0	N310^0-320^0	1-8	1.4m	Tight to open up to few mm	MSP-RU	Random

(**Remarks:** RU: Rough Undulatory, MSP: Moderately Smooth Planar, SP: Smooth Planar)

Table 5-24: Drift L-3 - Details of shears recorded in the Main Drift

Shear no.	**Dip Amount**	**Dip Direction**	**Remarks**
SZ1	55^0	N200°-210^0	Affected zone: 3-8cm, filled with crushed rock and minor clay, tree roots noted
SZ2	55^0	N210^0	Affected zone: 2-10cm, filled with crushed rock and minor clay, tree roots noted
SZ3	50^0	N20^0	Bedding parallel, Affected zone: 3-8cm, filled with crushed rock and clay
SZ4	52^0	N210^0	Affected zone: 2-10cm, filled with crushed rock and minor clay, tree roots noted
SZ5	40^0	N45^0	Bedding parallel, Affected zone: 2-7cm, filled with crushed rock and minor clay
SZ6	50^0	N40^0	Bedding parallel, Affected zone: 3-10cm, filled with crushed rock, rock powder and minor clay
SZ7	45^0	N50^0	Bedding parallel, Affected zone: 1-8cm, filled with crushed rock and clay
SZ8	40^0	N60^0	Bedding parallel, Affected zone: 2-12cm, filled with crushed rock and clay
SZ9	80^0	N100^0	Affected zone: 3-10cm, filled with crushed rock and clay
SZ10	70^0	N160^0	Affected zone: 1-5cm, filled with crushed rock and clay
SZ11	55^0	N50^0	Affected zone: 1-17cm, filled with crushed rock and clay
SZ12	75^0	N120^0	Affected zone: 1-5cm, filled with crushed rock and clay
SZ13	40^0	N60^0	Affected zone: 5-15cm, filled with crushed rock and clay
SZ14	70^0	N120^0	Affected zone: 2-10cm, filled with crushed rock and clay

Table 5-25: Drift L-3 - Details of shears recorded in Upstream cross cut

Shear no.	**Dip Amount**	**Dip Direction**	**Remarks**
SZ1	30^0	N35^0	Bedding parallel, Affected zone: 2-6cm, filled with crushed rock and minor clay
SZ2	38^0	N40^0	Bedding parallel, Affected zone: 1-7cm, filled with crushed rock and minor clay
SZ3	32^0	N30^0	Bedding parallel, Affected zone: 2-11cm, filled with crushed rock, rock powder and minor clay
SZ4	50^0	N60^0	Affected zone: 2-3cm, filled with crushed rock, rock powder and minor clay
SZ5	45^0	N35^0	Bedding parallel, Affected zone: 9-11cm, filled with crushed rock, rock powder and minor clay
SZ6	42^0	N35^0	Bedding parallel, Affected zone: 8-10cm, filled with crushed rock, rock powder and minor clay
SZ7	45^0	N35^0	Bedding parallel, Affected zone: 2-4cm, filled with crushed rock, rock powder and minor clay

SZ8	40^0	N30^0	Bedding parallel, Affected zone: 2-4cm, filled with crushed rock, rock powder and minor clay

Table 5-26: Drift L-3 - Details of shears recorded in Downstream cross cut

Shear no.	Dip Amount	Dip Direction	Remarks
SZ1	38^0	N35^0	Bedding parallel, Affected zone: 3-8cm, filled with crushed rock and minor clay
SZ2	40^0	N30^0	Bedding parallel, Affected zone: 3-12cm, filled with crushed rock and minor clay
SZ3	38^0	N40^0	Bedding parallel, Affected zone: 2-6cm, filled with crushed rock, rock powder and minor clay
SZ4	42^0	N35^0	Bedding parallel, Affected zone: 2-4cm, filled with crushed rock and minor clay
SZ5	35^0	N30^0	Bedding parallel, hairline, filled with crushed rock and minor clay
SZ6	60^0	N35^0	Bedding parallel, Affected zone: 2-3cm, filled with crushed rock and clay
SZ7	44^0	N55^0	Bedding parallel, Affected zone: 2-6cm, filled with crushed rock and minor clay
SZ8	32^0	N40^0	Bedding parallel, Affected zone: 2-7cm, filled with crushed rock and minor clay
SZ9	35^0	N20^0	Affected zone: 2-8cm, filled with crushed rock and minor clay

5.7.3 Geophysical Investigations

River bed area at dam site has also been explored through geophysical survey to confirm the sub-surface geological conditions. The geophysical exploration involves – Seismic Refraction Test (SRT) & Electrical Resistivity Test (ERT).

Earlier during 2004-05, Geophysical division of GSI has completed the 07 nos. of Vertical Resistivity Sounding (VES) and 06 profiles of Seismic Refraction Survey (SRS). The results confirm the depth of overburden in range of 12m-27m.

The report from executing agency (GSI) is appended as **Annexure 1.4A of Volume II Project Geology (A report on the Geophysical** Investigation **for the Delineation of Bed Rock Topography at Song Dam Site)**

During year 2018, geophysical investigation has also been completed by Parsons. It includes Seismic refraction (SRT) along 06 profiles having total length of 690m and Electrical Resistivity Imaging (ERT/ERI) along 10 profiles having total profile length of 2950m.

Draft report from executing agency (Parsons) is appended as **Annexure 1.4 of Volume II Project Geology (Ground Geophysical Investigations of Proposed Song Dam Drinking Water Project on Song River, Dehradun, Uttarakhand)**

5.7.4 Petrological Studies

6 rock samples from the dam seat area were collected and were tested at Petrology Division, Geological Survey of India, Northern Region, Lucknow for petrographic studies. The study has revealed tourmaline, and mica bearing quartzite. In general mineral assemblages shows Quartz-70-85%, Plagioclase 3-5%, Microcline feldspar 2-3%, Sericite Muscovite and Chlorite 3-10%, tourmaline and Biotite around 1% each.

The report from executing agency (GSI) is appended as **Annexure 1.7 of Volume II Project Geology.**

5.7.5 Geo-Technical Tests

A. Laboratory Testing of samples from Drilling

Representative core samples recovered from the exploratory drilling has been tested in the laboratory for engineering properties of the rock mass, especially Uniaxial Compression Test (UCS). The laboratory tests were conducted by IRI, Roorkee.

Test completed so far includes mechanical property test (Porosity, Water Absorption, Sp. Gravity, Crushing/ compressive Strength, Modulus of Elasticity, Poisson's Ratio& Shear parameter) and Uniaxial compressive strength test. The test results obtained are summarized under Table 5-27, Table 5-28, Table 5-29, Table 5-30**,** Table 5-31 and Table 5-32.

The laboratory test report consisting the details of all the tests conducted is appended as **Annexure 1.5 of Volume II Project Geology**.

Table 5-27: Summary of Uniaxial Compressive Strength Test Result

Sr. No.	Drill Hole No.	Location	Chainage	Sl. No.	Compressive Strength (kg/cm2)	Average Compressive Strength (kg/cm2)
1	DH-2	Dam Axis	20.57 – 21.35	2/1	821.67	1049.36
				2/2	1187.95	
				2/3	1138.45	
2	DH-5	Dam Axis	33.54 – 34.36	5/1	1880.93	1359.55
				5/2	910.76	
				5/3	1286.95	
3	DH-6	Dam Seat Area	34.48 – 35.10	6/1	2276.91	1356.25
				6/2	989.96	
				6/3	801.87	
4	DH-8	Dam Seat Area	27.07 – 27.81	8/1	752.37	989.96
				8/2	1227.55	
				8/3	989.96	
5	DH-9	Dam Seat Area	17.84 – 19.81	9/1	890.96	877.77
				9/2	752.37	
				9/3	989.96	
6	DH-12	Dam Axis	9.04 – 10.36	12/1	1346.35	1336.45
				12/2	1316.65	
				12/3	1346.35	
7	DH-13	Dam Seat Area	6.50 – 7.50	13/1	1603.74	864.57
				13/2	554.38	
				13/3	435.58	
8	DH-14	Dam Seat Area	21.70 – 23.53	14/1	1346.35	1300.15
				14/2	1049.36	
				14/3	1504.74	

Table 5-28: Value of Porosity, Water Absorption and Specific Gravity

Sr. No.	Sample No.	Specific Gravity	Water Absorption (%)	Porosity (%)
1	DH-2	2.634	0.174	0.700
2	DH-5	2.641	0.205	0.400
3	DH-6	2.638	0.213	0.607
4	DH-8	2.625	0.200	0.860
5	DH-9	2.642	0.201	0.893
6	DH-12	2.641	0.196	0.776
7	DH-13	2.643	0.220	0.773
8	DH-14	2.641	0.230	0.903

Table 5-29: Crushing/ Compressive Strength

Sr. No.	Drill Hole No.	Location	Lab. Mark	compressive Strength (kg/cm2)	Average compressive Strength (kg/cm2)
1	DH-8	Dam Seat Area	D.H. 8-1	1682.9	1385.90
			D.H. 8-2	950.4	
			D.H. 8-3	1524.5	
2	DH-9	Dam Seat Area	D.H. 9-1	989.96	1102.15
			D.H. 9-2	1128.55	
			D.H. 9-3	1187.95	
3	DH-20	Reservoir Area	1/20 – 5/20	---	744.44
4	DH-20	Reservoir Area	1/21 – 5/21	---	1227.54

Table 5-30: Modulus of Elasticity

Sr. No.	Drill Hole No.	Location	Load stress (kg/cm2)	Modulus of Elasticity (kg/cm2)
1	DH-8	Dam Seat Area	297.0	5.06 x 105 & 6.19 x 105

Table 5-31: Poisson's Ratio Test

Sr. No.	Drill Hole No.	Location	Load stress (kg/cm2)	Modulus of Elasticity (kg/cm2)
1	DH-8	Dam Seat Area	297.0	0.204 & 0.208

Table 5-32: Shear Parameter Test

Sr. No.	Drill Hole No.	Location	Core Depth (m)	Cohesion (C) (kg/cm2)	Angle of Internal Friction (ϕ) (0)
1	DH-9	Dam Seat Area	40.23 – 41.87	172.9	38.9

B. Rock Mechanic Tests Inside the Drifts

Six nos of exploratory drifts has been excavated on both the abutments of the dam i.e. 3 drift on each abutment. Rock mechanic tests to know the engineering properties of rock has been conducted in four drifts i.e. in R1, R2, L1 and L2 respectively. These drifts are on lower level i.e. near to river bed level R1 and L1 and mid levels R2 and L2.

The testing inside the drifts has been conducted by Irrigation Research Institute, Roorkee. The tests includes:

1. Rock to Concrete
2. Rock to rock Block Shear test
3. Plate Load tests

1. Tests in Lower Level Drifts (L1 and R1):

Four No's. Block Shear Tests were conducted at Left Bank and Right Bank drift of Song Dam Project, Dehradun. On the basis of test results of Left and Right Bank drift, the value of Cohesion 'C' and Angle of Internal Friction 'ø' at Peak and Residual Strength are as follows:-

Left Bank Drift (L1)

1. Rock to Concrete
    - Peak Shear Strength ‘C’ = 4.05 kg/cm² and Ø = 53º
    - Residual Shear Strength ‘C’ = 0.0 kg/cm² and Ø = 48º
2. Rock to Rock
    - Peak Shear Strength ‘C’ = 6.7 kg/cm² and Ø =56º
    - Residual Shear Strength ‘C’ = 0.0 kg/cm² and Ø = 52.5º

Right Bank Drift (R1)

1. Rock to Concrete
    - Peak Shear Strength ‘C’ = 4.1 kg/cm² and Ø =52º
    - Residual Shear Strength ‘C’ = 0.0 kg/cm² and Ø = 50º
2. Rock to Rock
    - Peak Shear Strength ‘C’ = 6.9 kg/cm² and Ø =55º
    - Residual Shear Strength ‘C’ = 0.0 kg/cm² and Ø = 53º

Two No’s Plate Load Tests were conducted at T-point of Left Bank drift and Right Bank drift of dam site.

At Left Bank drift the Settlement was found 2.16 mm corresponding to Maximum Applied Stress 56.79 kg/cm² and at Right Bank drift the Settlement was found 2.33 mm corresponding to maximum Applied Stress 50.37 kg/cm².

The test report consisting the details of all the tests conducted inside the drift is appended as **Annexure 1.8 of Volume II Project Geology**.

2. Tests in Middle Level Drifts (L2 and R2):

Four No’s. Block Shear Tests were conducted at Left Bank Middle Drift (L2) and Right Bank Middle Drift (R2) of Song Dam Project, Dehradun . On the basis of test results of Left Bank Middle Drift (L2) and Right Bank Middle Drift (R2), the value of Cohesion ‘C’ and Angle of Internal Friction ‘ø’ at Peak and Residual Strength are as follows :-

Left Bank Middle Drift (L2)

1. Rock to Concrete
    - Peak Shear Strength ‘C’ = 3.2 kg/cm² and ‘ø’ = 52º
    - Residual Shear Strength ‘C’ = 0.0 kg/cm² and ‘ø’ = 49º
2. Rock to Rock
    - Peak Shear Strength ‘C’ = 4.1 kg/cm² and ‘ø’ = 55.5º
    - Residual Shear Strength ‘C’ = 0.0 kg/cm² and ‘ø’ = 53º

Right Bank Middle Drift (R2)

1. Rock to Concrete
    - Peak Shear Strength ‘C’ = 3.4 kg/cm² and ‘ø’ = 51.5º
    - Residual Shear Strength ‘C’ = 0.0 kg/cm² and ‘ø’ = 50º
2. Rock to Rock
    - Peak Shear Strength ‘C’ = 4.3 kg/cm² and ‘ø’ = 54º
    - Residual Shear Strength ‘C’ = 0.0 kg/cm² and ‘ø’ = 52.5º

Two No’s Plate Load Tests were conducted at T-point of Left Bank Middle Drift (L2) and Right Bank Middle Drift (R2) of dam site. At Left Bank Middle Drift (L2) the Settlement was found 2.29 mm corresponding to Maximum Applied Stress 61.73 kg/cm² and at Right Bank Middle Drift (R2) the Settlement was found 2.55 mm corresponding to maximum Applied Stress 55.80 kg/cm².

The test report consisting the details of all the tests conducted inside the drift is appended as **Annexure 1.8 of Volume II Project Geology**.

5.8 Geotechnical Assessment of the Structures

The project structures are to be dealt with two types of strata i.e. overburden and bed rock. In the project area the overburden strata comprise of the two types of strata i.e.

1. **River Borne Material:** Occupies the mainstream and adjacent area i.e. area along the river bed and river channel. It mainly consists of rounded/sorted cobbles, pebbles boulders of various rock types intermixed with river sandy matrix. The source of material is the catchment of the river. Material is quiet compacted, hard and strong enough.
2. **Scree/ Slopewash material:** Occupies majorly the hill slopes and comprises of detached rock fragments including small to large size of rock mass intermixed with humus.

The bed rock comprises of Nagthat Formation characterised by greenish grey, off white, reddish brown/ purple, banded to massive, medium to fine grained, at places coarse grained quartzite which is hard and competent in nature.

5.8.1 Dam Foundation & Abutments

Slopes on both the banks of dam axis has exposed bed rock with scarce vegetation cover. However, at places they are occupied by thin cover of overburden material comprising of scree/ slopewash material. Bedrock is exposed on both the banks from river bed level up to the higher elevations and comprises of slightly weathered to fresh, foliated, jointed, hard and compact Quartzite.

Logging of the drill holes reveals that the acceptable foundation grade rock would be available within 2-3m below the overburden material. The thickness of overburden varies upto a maximum depth of 28.96m (NDH-8) in the dam body. Bedrock is competent enough and is acceptable as foundation grade rock for placing the high dam structure. The UCS values are fairly high (average 1248.45 Kg Cm^2) in dam seat area to bear the load of the giant structure.

3-D logging of the expoloratory dirfts on both the abutments revelas that the limit of stripping is nominal on right bank which is within a limit of 5-6m while on the left bank the limit of stripping is slighlty more and varies from 5.0m to 11.0m(at top level). The top area of the left bank is almost flat for some extent (approx. 50-70m length) and has a width of 2-4 m at top.

As far as the treatment of foundation by grouting is concerned, it would be decided once test grouting will be completed in foundation grade rock isexposed.

Permeability values of the bedrock in & around the dam area have been found low to moderately high i.e. ranging from 4.40 lugeon to 42.65 lugeon. Hence, the foundation rock will have to be sealed with grouting till attaining the permeability values below 1 lugeon. Based on the permeability values in the rock the grout curtain has to be extended to sound rock. Proposed test grouting will guide the spacing and pattern of the grout holes.

The river bed and nearby adjacent areas are occupied by river borne material comprises of boulders, cobbles, pebbles, gravels intermixed with sandy matrix.

Earlier (before 2018), the dam area has been investigated by 20 no of drill holes out of which 6 drill holes namely DH-16, DH-5, DH-24, DH-2, DH-12 and DH-17 has been drilled along the dam axis while other drill holes are drilled in the upstream, downstream and other associated areas. The depth of overburden material in the river bed as proved by drill hole DH-5 and DH-24 is 23.00m and 22.50m respectively and the foundation grade rock is after stripping of 7m-8m of bed rock. Based on completed drill hole it has been observed that the foundation of the dam in the river bed and on the abutments is likely to be laid upon sound rockmass.

In addition to this 8 new drill holes (NDH-1, 2, 3, 4, 5, 6, 7 & 8) has been completed recently (2018-19) covering the dam & left abutment of the dam body area. The results of these drill holes are almost similar to that of the earlier drill holes. The maximum depth of overburden in the dam body area is noticed in NDH-8 which is 28.96m. Other parameters of the rocks are almost common.

One horizontal drill hole each on either abutment namely DH-16 (Left abutment) and DH 17 (Right abutment) respectively has been completed. DH-16 & DH-17 has been drilled at an higher elevation at about 933.60m and 933.00m respectively with respective length of about 25.05m and 35.30m. Drill hole proves the foundation grade rock at about 5m-7m length in both drill holes.

Due to existence of number of joints with close spacing, wedge failure due to foliation and J1 joint along the Left abutment and due to J2 and J3 joint along the right abutment is expected towards the valley (refer **Drawing No. P.012745.W-20390-007**). Remedial for adequate support in the form of rock bolting and wire mesh is advisable during excavation of either abutment.

5.8.2 Plunge Pool area

Presently, Plunge Pool area is occupied by thick cover of overburden material comprising of river borne material, boulders, cobbles, pebbles, gravels intermixed with sandy matrix.

Logging of the drill holes drilled in this area reveals that the thickness of overburden varies upto a maximum depth of 30.00 (NDH-12) and acceptable foundation grade rock would be available within 2-3m below the overburden material. Bedrock is competent enough and is acceptable as foundation grade rock for placing the structure.

The geolgical sections based on the drill holes NDH-12 and NDH-13 along and across the Plunge Pool is appended as **Drawing No. P.012745.W-20390-009 & Drawing No. P.012745.W-20390-016 respectively**

5.9 Construction Materials

Availability of construction material and its suitability for use is always a challenge. For implementation of Song Dam Project three rock quarries has been identified to fullfill the requirement of construction material for the project. Out of these three quarries two quarries are 1.0km in the upstream of the dam i.e. in the reservoir area, one on left bank and one on right bank while the third one is 1.5km downstream of the dam site on the right bank of river. The third quarry will act as potential quarry which will fulfill the requirement of material when there is scarcity.

The samples from identified quarries were collected and are being tested at laboratory for various engineering properties and parameters for their suitability as usable construction purpose.

Coarse and Fine aggregate to be used in the construction of the dam is planned to be extracted by quarrying the hill slopes on both the banks of the river about 1.0km in the upstream of the dam area. The extraction of the materials from these quarries will also add volume to the reservoir.

The material which is to be extracted from the quarries in the upstream of dam axis will have to be carried to the crushing plant (approx 2.0km in downstream side). After cursing the aggregates (coarse and fine) again has to be transported to batching plant.

The location plan of the identified quarries for coarse and fine material is appended as **Drawing No. P.012745.W-20390-001.**

The identified quarry hillock chiefly consists of quartzite, scarcely covered with vegetation cover and shall be used as a construction material (to be confirmed after lab tests). Also, the river borne material consisting of boulders/pebbles/ cobbles etc. which is deposited in the river bed shall also be a substitute for coarse aggregates.

The key construction materials required for construction of the project are:

- Coarse aggregate and fine aggregate
- Fly Ash
- Cement
- Steel
- Explosives
- Oil and Lubricants

Transported river borne materials in the downstream of dam site constitute good quantity and quality of construction materials viz. coarse and fine aggregates based on visual observation (refer **Annexure 1.2 of Volume II Project Geology**).

5.9.1 Requirement of Construction Materials

The detail of concrete quantity required has been worked out and shown in Table 5-33 as below.

Table 5-33: Detail of Concrete Quantity (RCC) Required

Sl. No.	Components	Concrete Grade	Quantities
1	Dam	Roller Compacted Concrete	10,00,000 m^3

2	Dam And Other Appurtenant Structures	Conventional Concrete	2,00,000 m^3

As per the mix design for RCC (normal Practices), the Quantity of different materials required to prepare the concrete is as per details given below in Table 5-34.

Table 5-34: Categorization of Concrete Material

S.No	**Material**	**Required Quantity / m^3 of Concrete**	**Total Required Quantity (m^3)**
1	Coarse Aggregate	0.85 m^3	10,20,000 m^3
2	Fine Aggregate	0.47 m^3	5,64,000 m^3
3	Fly Ash	110 kg	1,10,000 MT
4	Portland Cement	110 kg for RCC and 320 kg for Conventional Concrete	1,74,000 MT
5	Water	0.5 WC Ratio	142,000 m^3
6	Admixture	2.2 kg for RCC and 1.6 kg for Conventional Concrete	2520 MT

*may subject to change

All above mentioned percentage (%) mixed shall depend upon Concrete Mix Design which is based on Compressive and Tensile Strength of Concrete.

5.9.2 Investigation for Aggregates

Drill hole and laboratory testing are proposed for confirming the suitability of identified quarry material.

- Drilling: 03 drill holes (NDH- 14, 15 & 16)
- Laboratory Tests on Core Samples: Samples yet to be recovered.

5.9.3 Availability of Construction Materials

A. Coarse Aggregate

Coarse aggregates forms a major part of the RCC dam. For the fulfilment of the requirement of coarse aggregate for the dam and allied structures, two primary quarries 1.0km in the upstream of the dam axis has been identified while a third potential quarry has been identified 1.5km downstream of dam axis on the right bank of river Song.

It is estimated that approximately 37716m2 area may be utilized for extraction of material and the total quantity which can be extracted from this site may be 2348000m3. Out of 2348000m3 of material extracted, 80% may be used for production of aggregates while rest of the 20% shall not be used or shall be used for other purposes.

To establish the suitability of the Horizontal drilling in the said hill to assess the stripping limit, quality and quantity is under progress (Figure 5-5).

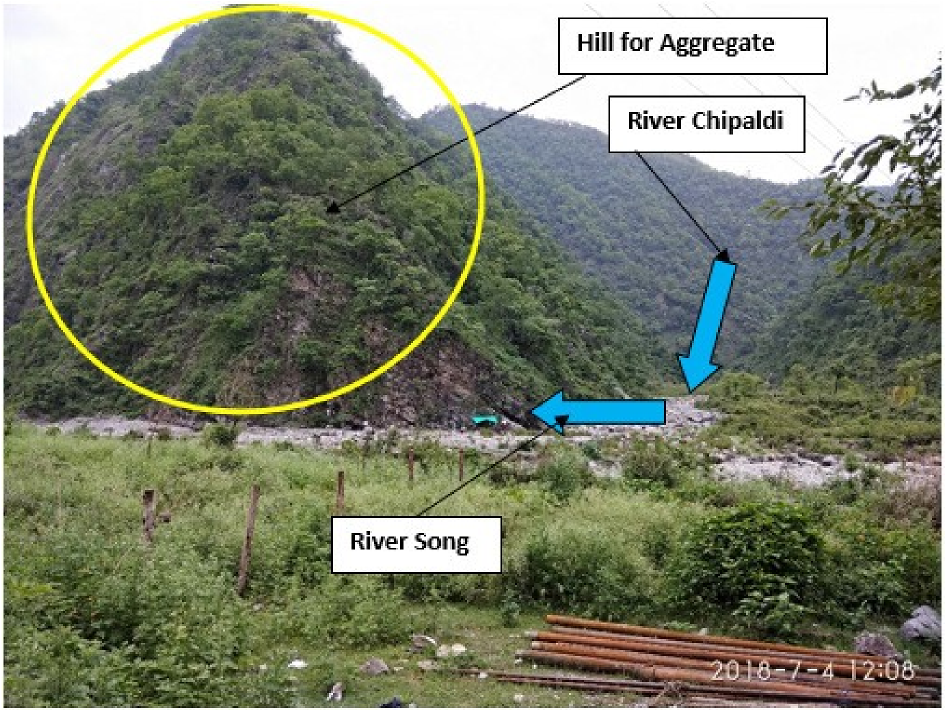


Figure 5-5: Hillock Proposed for Aggregates Quarry

B. Fine Aggregate

Like coarse aggregates, fine aggregates also forms a large part of the RCC Dam. Fine aggregates shall be prepared by cursing of the coarse aggregates. The quarry identified for coarse aggregates may fulfil the requirement of the fine aggregates too.

C. Fly Ash

Fly Ash, an industrial waste product, is an integral part of RCC and is increasingly being used. It acts as a pozzolanic substitute for cement. However, it is used for not only saving cement cost, but also for enhancing strength and durability. The latest trend in RCC dam construction is the adoption of high paste RCC dam with cement and low lime fly ash. Replacement level of fly ash, primarily class F (**Class F** fly ash contain at least 70% pozzolanic compounds (silica oxide, alumina oxide, and iron oxide)), ranges from 30-75% of total cementitious material.

Requirement of Fly ash for the Song dam construction shall be ascertained from the Table 5-35 mentioned Thermal Power Plants (TPP), nearest to the project area.

Table 5-35: List of Thermal Power Plant with Distance to Song Project Site

Name of Power Plant	**Distance from Project site (Km)**
Deenbandhu Chhotu Ram Thermal Power Plant, Yamuna Nagar, Haryana	112
Guru Gobind Singh Super Thermal Power Plant, Ganauli, Roopnagar, Punjab	230

Name of Power Plant	**Distance from Project site (Km)**
Badarpur Thermal Power Station, Badarpur, NCT Delhi	252

D. Cement

Cement is an important construction material apart from aggregates to be used in RCC dam. Based on the requirement of cement for proposed RCC dam in Song Dam project, Table 5-36 shows the list of cement plant location based on distance to Song dam project area.

Table 5-36: List of Cement Plant with Distance to Song Project Site

Name of Plant and State	**Distance (Km)**
ACC, Gagal Cement Works-I, Barmana, Himachal Pradesh.	330
Ambuja Cements Ltd (Unit: Darlaghat), Himachal Pradesh	240
Ambuja Cements Ltd (Unit: Nalagarh), Himachal Pradesh	204
Asian Concretes Cement Ltd, Himachal Pradesh	250
Cement Corporation of India Ltd- Rajban, Himachal Pradesh	65
Ultra Tech Cement Ltd.-Jhajjar, Haryana	305
UltraTech- Dadri Cement Works, Uttar Pradesh	250

E. Steel

Steel is also an important part of construction. Directly or indirectly it is used in many components of the Project. However, in Song Dam it may be used in less quantities.

Steel can be procured directly from the open market by dealers of various production units like Jindal Steels, Tata Steels, Rathi Steels, Sail etc.

6. HYDROLOGICAL & SEDIMENTATION STUDIES

6.1. Introduction

Tractebel Engineering Private Limited had carried out an independent study for determining the hydrological parameters of the project. The study was thereby discussed with National Institute of Hydrology, Roorkee and finally a report was submitted to CWC by NIH, Roorkee.

The study for water availability, design flood and sedimentation was entrusted to NIH, Roorkee and a detailed report prepared by NIH was submitted to CWC through Irrigation department. In its scrutiny, CWC raised observations regarding the Water availability and other hydrological issues related to Song dam and the same was replied in due course. The observation of CWC and subsequent conclusions that have been laid in the appraisal reports of CWC is being summarized as under.

6.2. General

The study of hydrological aspects plays vital role in the planning, assessment and operation of any water resources development projects. It is important in assessment and measurement of available water resources at a specific location and in a given point of time. Hydrological inputs provide an irreplaceable historical insight support to decision making in the planning, execution and operation of any water resources development project. Hydrological inputs include the assessment of quantities of available water and its variation with time, requirements of storage capacity, estimation of design flood for diversion and spillway, assessment of sedimentation, assessment of risk related to hydrologic extremes etc. Accordingly, this study was planned and conducted to assess above hydrological inputs for the suitable planning of proposed Song Dam Drinking Water Project, Dehradun Uttarakhand.

A roller compacted concrete gravity dam is proposed to be constructed on Song river to store surplus water for drinking water purpose for the city of Dehradun and adjoining areas. The Irrigation Department, Government of Uttarakhand, Dehradun, engaged National Institute of Hydrology (NIH), Roorkee vide letter no. 3140/P.C.DDN/Song dated 28th June 2018 to carry out the consultancy study entitled “Study of Hydrological Aspects of Proposed Song Drinking Water Dam Project”. A Memorandum of Understanding (MOU) was signed between NIH, Roorkee and the Department of Irrigation, Government of Uttarakhand Dehradun on 28th June 2018 in respect of the said study. The purpose of the above MOU is limited to this scientific study for assessment of water availability in Song River for drinking water purposes, design flood estimation and assessment of reservoir sedimentation including checking and vetting of relevant sections of DPR prepared by Irrigation Department, Govt. of Uttarakhand. In view of the above, a team of scientists of NIH conducted detailed study under consultancy services and this report has been prepared and submitted to Irrigation Department, Govt. of Uttarakhand.

6.2.1. Objectives and Scope of the Study

The primary objective was to conduct study of hydrological aspects of proposed Song Dam Drinking Water Project to assess and ascertain water availability, design flood estimation at the Song dam site and assessment of reservoir sedimentation. The details of scope of work for the study was as follows.

1. Annual and monsoon season water availability at various reliability levels.
2. Estimation of Design flood at Song Dam Site.
3. Flood routing to check the capacity of spillway proposed in the dam.
4. Assessment of reservoir sedimentation in the proposed Song-Dam project
5. To check the DPR for the Song project, prepared by the Irrigation Department, Govt. of Uttarakhand with respect to the four objectives as mentioned above.

6.2.2. Brief Description of Proposed Song Dam Drinking Water Project

The Song Dam is planned to create one of the primary amenities of drinking water supply for city of Dehradun and adjoining areas considering present and future water demands. Dehradun is facing shortage of water supply and the situation becomes grave during summers when the discharge of rivers diminishes. Therefore, it is proposed to create Song Dam with suitable storage capacity to store excess runoff from Song River catchment during monsoon season to augment the drinking water supply for Dehradun. The Song Dam is proposed to be constructed across River Song at Latitude: 30°18’08” N and Longitude: 78°11’30” E near village Sondhana P.O. Maldevata, district Dehradun (Uttarakhand) at an elevation of about 875 m.The dam site is located about 25 km from Dehradun (GhantaGhar) and 9 Km in u/s of Maldevata. According to Guidelines of Bureau of Indian Standard (IS: 11223-1985) any dam having hydraulic head greater than 30 m may be classified as large dam. Since the proposed height of Song Dam is about 130.6m from the deepest foundation level, therefore, it is to be a large dam. The catchment area of Song River is hilly and largely forested and covered with green vegetation up to the dam site. Song is one of the left bank tributaries of River Ganga. It originates from Dhanaulti at an elevation of about 2400 m and joins River Ganga near village Raiwala located between Rishikesh and Haridwar (Uttarakhand). It is proposed to meet the current and projected future drinking water demands for the Dehradun and adjoining areas.

The steps of approach to adopted in the present study include consistency check of rainfall data at FRI and IMD stations Dehradun with that of corresponding period at Song Dam Site data, dependability analysis of long-term rainfall to identify dry years at different dependability levels, development of long-term flow series using a suitable rainfall-runoff model and observed rainfall-runoff records, water availability assessment and reservoir water balancing, estimation of design flood, and estimation of sediment rate in to the song Dam using suitable modelling techniques. The methodology, analysis and results on above components of study are presented in respective chapters.

6.3. THE STUDY AREA AND DATA USED IN THE STUDY

6.3.1. The Song Dam Catchment Area

The study area is Song River catchment up to Dam Site. Song River is one of the large rivers that drains the Doon valley and is a left bank tributary of Ganga River. The major tributaries of Song River are Kali Gad, Sahastradhara, Assan River and Rispana River. The river Song originates from Surkanda Devi temple in District Tehri- Garhwal at an elevation of about 2700 m above msl. It joins River Ganga at near Raiwala between Haridwar and Rishikesh at an elevation of about 315 m. The project area lies in the Survey of India (SoI) Toposheet No 53J/3. The catchment area up to Dam site has mountainous physical geography and dominantly covered with forest and green vegetation. The climate of the area is moderately hot in summers and very cold in winters. During the summer months (May & June), the temperature ranges between 36◦C and 16.7◦C. The winter months are colder with the maximum and minimum temperatures touching 23.4°C and 5.2°C, respectively. The Monsoon rainfall starts in late June to and ends till September. The average annual and monsoon season rainfall is about 2247 mm and 1942 mm, respectively July and August being the rainiest months of the season.

Uttrakhand Irrigation Department has proposed a roller compacted concrete (RCC) gravity dam of a maximum height of 130.6 metres from deepest foundation level across the river song near village Sondhana, P.O. Maldeota, Distt. Dehradun to meet the water demand of Dehradun city. The project is situated in the district of Dehradunlocated about 9 km U/S of Maldeota village. Proposed Dam Site on River Song is located at Latitude 30°18'08" North and Longitude 78°11'30" East about 9 km U/S of Maldeota village.

The total catchment area of Song River up to the dam site is about 85.225 sq km consisting mainly of hilly terrain with about 90% of the area falling in a slope range of 20-100%. The catchment is dominated by forests (80%). The range lands and agricultural lands occupy nearly 10% and 8% of the catchment respectively. The soils in the catchment area are chiefly loamy soils. The map of Song River drainage network and the catchment Digital Elevation Model up to dam site is shown in Figure 6-1. The major part of the catchment area (about 85%) is covered by excessively drained, loamy and loamy-skeletal soils with moderately shallow to very shallow soil-depth. The loamy surface on steep slopes have erosion problem. Moderately deep, well drained, coarse loamy soils mixed with fine loamy soils on moderate slopes have slight erosion.

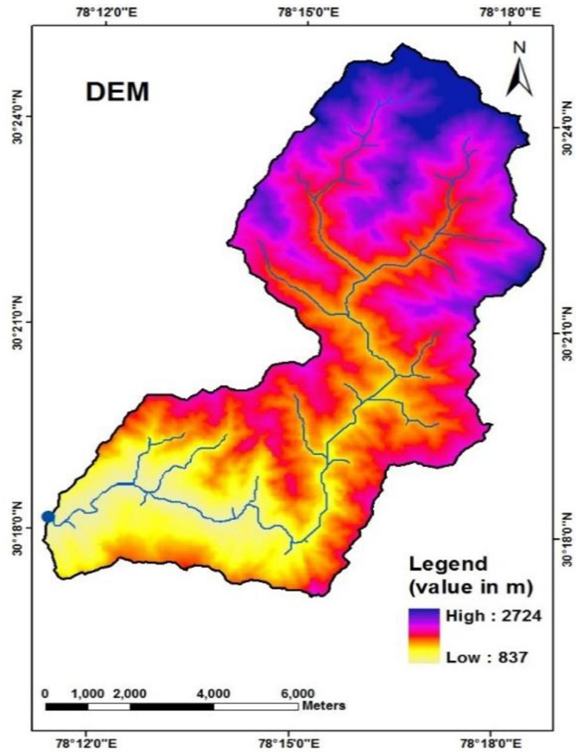


Figure 6-1: The map of drainage network and Digital Elevation Model of catchment up to Dam Site of Song River

6.3.2. Rainfall Data

The Irrigation Department, Govt. of Uttarakhand started an observation site at the proposed Song Dam and started measurement daily rainfall and other meteorological data (temperature, humidity, wind speed sunshine hours etc.) at the Dam site for the period from 2003-2005. The long-term daily rainfall data Dhanaulti and Dehradun stations was procured from India Meteorological Department (IMD) for the period from 1985 to 2017. In case of Dhanaulti station rainfall data records for some of the years was missing but the length of remaining available records was reasonably good. The Dhanaulti Rainfall station is located within the catchment in the upstream of dam site near the origin of the Song River. The Dehradun station is also located in the Song river catchment at about 14 kms in the downstream of proposed dam site. The daily rainfall data for the period 1974 to 2016 was also obtained for a nearby rain gauge station within song catchment at Forest Research Institute (FRI) Dehradun. The details of rainfall used in the study are presented in Table 6-1.

Table 6-1 : Details of rainfall data used in the study

Sl No	Data Type	Name of Stations/Site	Period	Remarks
1	Daily Rainfall / FRI	Forest research Institute (FRI)	1971-2015	Provided by Irrigation Department, Govt. of Uttarakhand
2	Daily Rainfall IMD	IMD Dehradun	1971-2004	Procured from IMD Note: Some of the data was found missing in the rainfall records for Dhanaulti and Mussoorie stations.
		Dhanaulti	1989-91, 1996-99 & 2011-2015	
		Mussoorie	1985-86 & 2011-2017	
3	Daily Rainfall Dam Site	Dam Site	Feb 2003-Dec 2005	Provided by Irrigation Department, Govt. of Uttarakhand

6.3.3. Observed Discharge Data

The Irrigation Department, Govt. of Uttarakhand started an observation site at the proposed Song Dam and started measurement of discharge and sediment in the year 2001 and continued till 2005. Also, the daily rainfall and other meteorological data (temperature, humidity, wind speed sunshine hours etc.) were recorded at the Dam site for the period from 2003-2005. The Song River discharge data of Central Water Commission (CWC) discharge measurement at Satyanarayana site was available for the period from 1971-2004. This discharge measurement site on the Song River at Satyanarayana is located downstream of proposed Dam site at a distance of about 50 kms. The catchment area of Song River up to Satyanarayan site is about 635 km^2. The catchment area of Song River up to of proposed Dam site is about 85.225 km^2. The details of observed discharge used in the study are presented in Table 6-2.

Table 6-2: Details of rainfall and observed discharge data used in the study

Sl No.	Data Type	Name of Stations/ Site	Period	Remarks
1	Daily Stream Flow Data	Dam Site	Mar. 2001- Dec 2005	Provided by Irrigation Department, Govt. of Uttarakhand
2	Daily Stream Flow Data	Satyanarayana Site	1971-2004	Provided by Irrigation Department, Govt. of Uttarakhand

For analysis purpose the daily flow records have been converted in to average 10-daily data series. Each month has been divided in to three 10-daily steps as follows:

1st 10-daily period of a month	1st -10th day

2nd 10-daily period of a month	11th -20th day
3rd 10-daily period of a month	21st - Last day of month (i.e. 30th or 31st or 28th day or 29th day in case of leap year as the case may be)

6.3.4. Evaporation Data

The pan evaporation data measured at FRI station for the period from 1975-1993 and 2004-2016 has been used to estimate potential evapotranspiration (PET) and the evaporation from reservoir. The details of measured pan evaporation data used is presented in Table 6-3**.**

Table 6-3: Details of measured pan evaporation data used

Sl No.	**Data Type**	**Name of Stations/ Site**	**Period**	**Remarks**
1	Evaporation data FRI	Forest research Institute (FRI)	1971-2016	Provided by Irrigation Department, Govt. of Uttarakhand

The potential evapotranspiration (PET) varies with time of seasons depending mainly onair temperature, humidity, sunshine hours and wind speed. For the very good vegetation conditions the conversion coefficient for pan evaporation to PET values have been estimated more than one during the year in the north of 22° latitudes in India (Ramdas, 1957; NIH, 1995 & Ramasastri, 1987). The pan evaporation has been converted to PET for good vegetation condition using coefficient ranging between 1.02 to 1.16 in different months as shown in Table 6-4.

Table 6-4: Monthly average values of Pan to PET conversion coefficients

Month	**Jan.**	**Feb.**	**Mar.**	**Apr.**	**May**	**Jun.**	**Jul.**	**Aug.**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Pan to Lake Coefficient	1.16	1.10	1.04	1.03	1.02	1.02	1.02	1.02	1.04	1.07	1.12	1.14

However, the evaporation from the lakes/reservoirs or water body depends on the temperature difference between the air and the water in the water body (Ramasastri 1987). Rate of evaporation from pan is greater than that from large water bodies (Kohlar 1959). Therefore, suitable coefficient is used to adjust the pan evaporation to get estimated values of evaporation from the lake/reservoirs (Kohlar 1967 & NIH 1997). Ramasastri (1987) suggested following coefficient (Table 6-5) to estimate evaporation from water bodies using measured Pan Evaporation.

Table 6-5 : Monthly average values of Pan to reservoir evaporation conversion coefficients

	Location	**Pan to Lake/ Reservoir adjustment Coefficient**		
		0.6	**0.7**	**0.8**
I	North of 22° latitude	Nov.- Feb	Mar.-April & Sept.- Oct.	May-Aug
II	South of 22° latitude	Dec.- Jan.	Feb.- March & Sept.- Nov.	April-Aug

Using above values of conversion coefficients in Table 6-4 & Table 6-5, the pan evaporation values measured at FRI station for the period from 1975-1993 and 2004-2016, the monthly average PET values for the Song River catchment area up to Dam site and monthly average evaporation from Song Dam reservoir have been estimated as given in Table 6-6.

Table 6-6: Estimated average monthly values of PET and evaporation from reservoir body of Song Dam.

Month	**Measured value of average Pan evaporation mm/day**	**Pan to PET conversion Coefficient**	**Estimated average PET from Song Dam catchment mm/day**	**Pan to lake evaporation conversion Coefficient**	**Evaporation from water reservoir body. mm/day**
Jan.	1.27	1.16	**1.47**	0.6	**0.762**
Feb.	1.94	1.10	**2.13**	0.6	**1.164**
Mar.	3.26	1.04	**3.39**	0.7	**2.282**
Apr.	5.32	1.03	**5.48**	0.7	**3.724**
May	6.49	1.02	**6.62**	0.8	**5.192**
Jun.	5.30	1.02	**5.41**	0.8	**4.240**
Jul.	2.70	1.02	**2.75**	0.8	**2.160**
Aug.	2.32	1.02	**2.37**	0.8	**1.856**
Sep.	2.74	1.04	**2.85**	0.7	**1.918**
Oct.	2.61	1.07	**2.79**	0.7	**1.827**
Nov.	1.78	1.12	**1.99**	0.6	**1.068**
Dec.	1.26	1.14	**1.44**	0.6	**0.756**

6.3.5. Elevation-Area-Capacity Curve of Proposed Song Dam

The Elevation-Area-Capacity based on the recently conducted topographical surveys (2018) of the Song Dam reservoir area is presented in Table 6-7 and Figure 6-2.

Table 6-7: Elevation-Area-Volume of the Song Reservoir

SI No	**Elevation (m)**	**Submerge Area (Ha)**	**Capacity (Ham)**	**Capacity (Mm^3)**

1	875	0	0.0	0.000
2	880	1.5495	2.2	0.022
3	885	3.1415	10.2	0.102
4	890	4.7638	25.0	0.250
5	895	6.274	48.0	0.480
6	900	7.7475	81.0	0.810
7	905	9.776	127.0	1.270
8	910	11.69	185.0	1.850
9	915	13.8	257.0	2.570
10	920	15.694	341.0	3.410
11	925	17.89	439.0	4.390
12	930	21.062	551.0	5.510
13	935	24.054	676.0	6.760
14	940	27.118	817.0	8.170
15	945	30.335	977.0	9.770
16	950	33.75	1156.0	11.560
17	955	38.776	1356.0	13.560
18	960	43.699	1575.0	15.750
19	965	48.813	1813.0	18.130
20	970	54.029	2060.0	20.600
21	975	58.878	2331.0	23.310
22	**980 (FRL)**	**64.829**	**2640.0**	**26.400**
23	985	70.64	2980.0	29.800
24	990	76.651	3352.0	33.520
25	995	82.475	3754.0	37.540
26	1000	88.635	4187.0	41.870

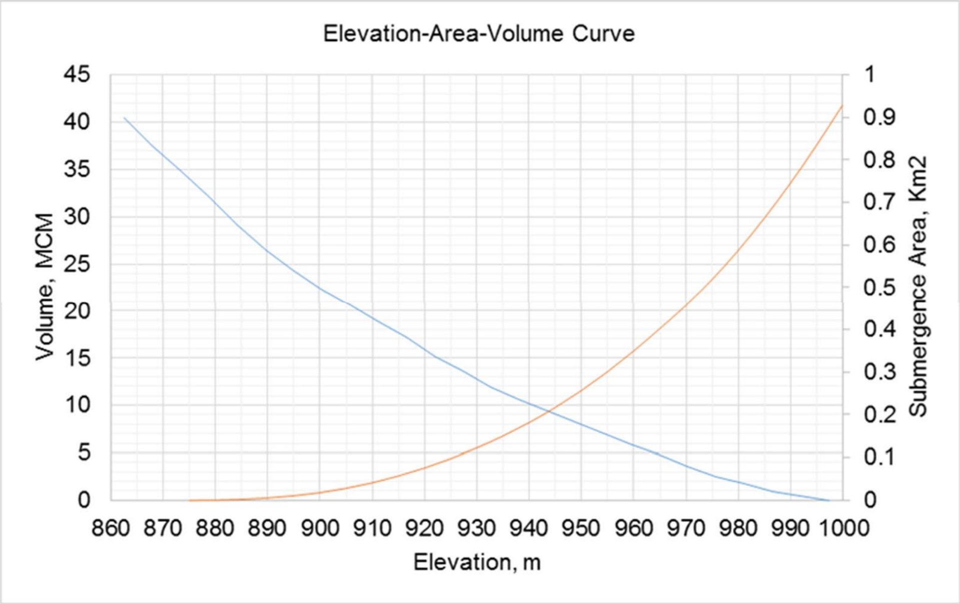


Figure 6-2 : Elevation-Area-Volume Curve of Song Dam

Important observation from above table are as below:

Gross Storage up to FRL (EL 980):	2640.0Ham (26.40 MCM)
Dead Storage up to MDDL (EL 923):	400.0 Ham (4.00 MCM)
Live Storage (FRL-MDDL):	2240.0 Ham (22.40 MCM)

6.3.6. Drinking Water Demand

The estimated drinking water demand for the present and projected population of Dehradun and the existing water supply provisions have been obtained from Department of Irrigation, Govt. of Uttarakhand. The water demand estimations have been carried out for demand the of 150 MLD at 980 m FRL. The detailed calculations of water demand from Song Dam is given in **Annexure 6.1.** A summary of water demand calculations for above options are presented in Table 6-8.

Table 6-8: Water Demand Calculation for 150 MLD at 980 m FRL

Sl No	**Description**	**Year 2011**	**Year 2018**	**Year 2021**	**Year 2031**	**Year 2041**	**Year 2051**	**Year 2061**	**Year 2071**	**Remarks**

I	Population {Total Projected Urban + Floating + Rural)	1033837	1152667	1208720	1417773	1660996	1938390	2249953	2595687	Census data & population projection
II	Total Estimated Water Requirement in MLD including @ 15% water loss in supply	175.55	192.41	200.40	236.24	279.01	335.99	387.10	444.95	As per CPHEEO Manual for water supply
III	**Water Supply**									
	Surface Water Sources									
	Total Surface Water available for existing Source in MLD (A)	28	28	42	42	42	42	42	42	
	Proposed water supply from Song Dam in MLD (B)	--	--	**150**	**150**	**150**	**150**	**150**	**150**	
	Total available surface water in MLD (A+B)	28.00	28.00	192.34	192.34	192.34	192.34	192.34	192.34	
	Ground Water Sources									
	Total available ground water in MLD	150.00	165.00	150.00	150.00	150.00	150.00	150.00	150.00	
	Total water available to be supplied from surface and ground water	178.00	193.00	342.34	342.34	342.34	342.34	342.34	342.34	
	Surplus / Deficit water demand in MLD	2.45	0.59	141.93	106.09	63.33	6.35	--	--	

6.4. Estimation of water availibilty

6.4.1. Consistency Check of Rainfall and Observes Discharge Data

6.4.1.1. CONSISTENCY CHECK OF RAINFALL DATA

Hydrological studies require long term hydro-meteorology data to carryout water availability assessment. For the Song Dam Site rainfall records are available for the period from Feb 2003 to Dec 2005 only. The long-term daily rainfall recorded for rain gauge stations at India Meteorological Department (IMD) Dehradun and at Forest Research Station (FRI) Dehradun are available for the period from 1989-2017 and 1975 -2016, respectively. The consistency check of rainfall at Song Dam Site has been carried out with the rainfall at IMD station and FRI station monthly rainfall data for concurrent period (i.e. Feb 2003 to Dec 2005).

Double mass curve analysis has been carried out using monthly rainfall at FRI station and IMD station with that of Song Dam Site as given in Table 6-9**.** The monthly cumulative rainfall for 35 months at Song dam site and at FRI station Dehradun has been plotted to obtain double mass curve as shown in Figure 6-3. The analysis shows that the data at the above two stations are consistent and have very good correlation close to unity (R^2 =0.9955). Similarly, the double mass curve for monthly cumulative rainfall at Song dam site and at IMD station Dehradun for concurrent period (i.e. Feb 2003 to Dec 2005) has been presented in Figure 6-4. It can be seen from Figure 6-4 that the rainfall at Song dam site and at IMD station Dehradun also consistent with further better correlation coefficient value R^2 equal to 0.997 and it is relatively more close to unity. This indicates that the long-term rainfall record at IMD station Dehradun very closely represent the rainfall at the dam site.

The double mass curve analysis of long-term annual and seasonal rainfall between IMD station Dehradun and FRI station is also plotted and it is analogous with values of R^2 equal to 0.9998 and 0.9999 as it can be seen in **Annexure 6.2**.

This reveals that the rainfall data recoded at IMD Dehradun station can be used for flow simulation to develop long-term flow series at Dam site and other hydrological analysis for Song Dam catchment.

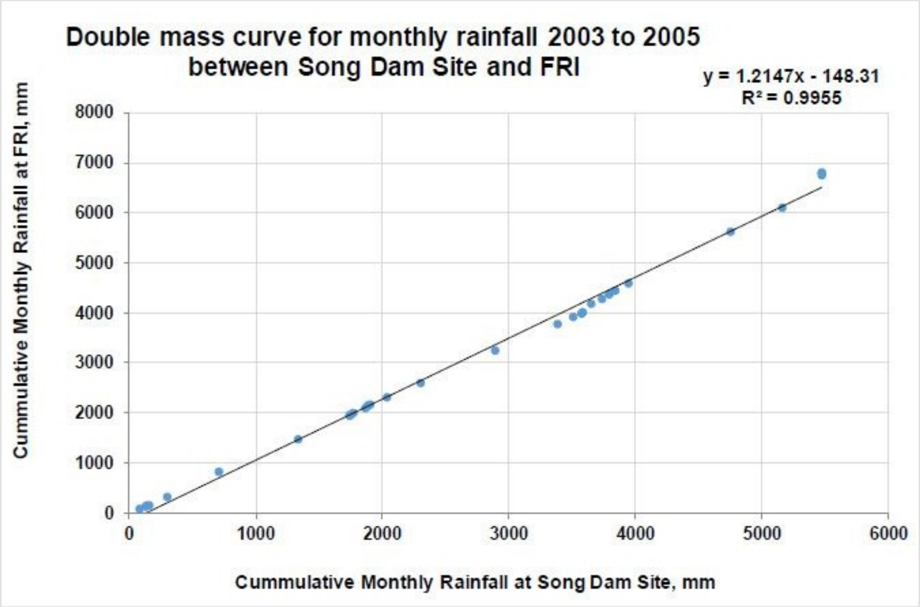


Figure 6-3: Double mass curve for monthly rainfall 2003 to 2005 between Song Dam Site and FRI

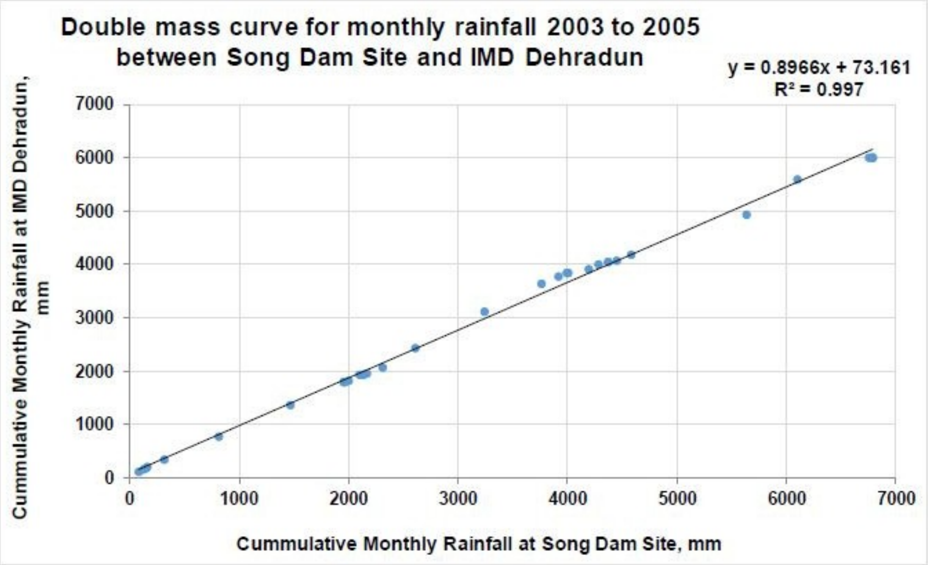


Figure 6-4: Double mass curve for monthly rainfall 2003 to 2005 between Song Dam Site and IMD Station Dehradun.

Table 6-9: Analysis of consistency check of rainfall at FRI and IMD station Dehradun with rainfall at Dam Site.

Year	Month	Monthly rainfall in mm			Cumulative Monthly rainfall at FRI Dehradun in mm	Cumulative Monthly rainfall at Dam Site in mm	Cumulative Monthly rainfall at IMD Dehradun in mm
		FRI	Dam Site	IMD Dehradun	FRI	Dam Site	IMD Dehradun
2003	Feb.	79.8	85.1	98.9	79.8	85.1	98.9
	Mar.	52.0	47.9	49.6	131.8	133.0	148.5
	Apr.	10.6	12.9	13.8	142.4	145.9	162.3
	May	19.9	18.7	31.2	162.3	164.6	193.5
	Jun.	140.8	151.2	138.5	303.1	315.8	332.0
	Jul.	410.2	199.3	424.7	713.3	815.1	756.7
	Aug.	625.0	650.7	601.3	1338.3	1465.8	1358
	Sep.	403.7	488.7	436.1	1742.0	1954.5	1794.1
	Oct.	0.0	0.0	0.0	1742.0	1954.5	1794.1
	Nov.	6.4	9.1	6.6	1748.4	1963.6	1800.7
	Dec.	20.6	40.3	21.8	1769	2003.9	1822.5
2004	Jan.	97.5	101.2	94.6	1866.5	2105.1	1917.1
	Feb.	24.4	30.0	21.8	1890.9	2135.1	1938.9
	Mar.	0.0	0.0	0.0	1890.9	2135.1	1938.9
	Apr.	18.6	33.7	21.4	1909.5	2168.8	1960.
	May	124.5	142.4	99.8	2034.0	2311.2	2060.1
	Jun.	267.7	299.9	359.3	2301.7	2611.1	2419.4
	Jul.	587.5	629.4	694.8	2889.2	3240.5	3114.2
	Aug.	498.9	527.4	517.3	3388.1	3767.9	3631.5
	Sep.	122.9	148.4	147.4	3511	3916.3	3778.9
	Oct.	66.7	79.4	62.7	3577.7	3995.7	3841.6
	Nov.	0.0	0.0	0.0	3577.7	3995.7	3841.6

	Dec.	6.9	10.0	7.7	3584.6	4005.7	3849.3
2005	**Jan.**	69.2	186.2	62.4	3653.8	4191.9	3911.7
	Feb.	80.9	96.9	82.1	3734.7	4288.8	3993.8
	Mar.	63.6	87.7	61.6	3798.3	4376.5	4055.4
	Apr.	0.2	1.0	0.3	3798.5	4377.5	4055.7
	May	42.2	69.2	22.5	3840.7	4446.7	4078.2
	Jun.	104.8	140.8	98.7	3945.5	4587.5	4176.9
	Jul.	810.1	1045.7	767.7	4755.6	5633.2	4944.6
	Aug.	410	471.3	655.5	5165.6	6104.5	5600.1
	Sep.	311.7	645.5	412.6	5477.3	6750.0	6012.7
	Oct.	0.9	37.3	5.2	5478.2	6787.3	6017.9
	Nov.	0.0	0.0	0.0	5478.2	6787.3	6017.9
	Dec.	0.2	0.22	0.6	5478.4	6787.52	6018.5

6.4.1.2. CONSISTENCY CHECK OF RAINFALL AND FLOW DATA

To check consistency of observed flow records with rainfall the double mass curve of monthly rainfall and estimated flow depth from observed flow at the Dam site (for 2003-2005) has been prepared as shown in Figure 6-5 below. The value of R^2 is about 0.9876 indicating that the observed flows at dam site have genuine consistency with the rainfall for the corresponding period. It, also, verifies that the flow measurements at Dam Site have been taken appropriately.

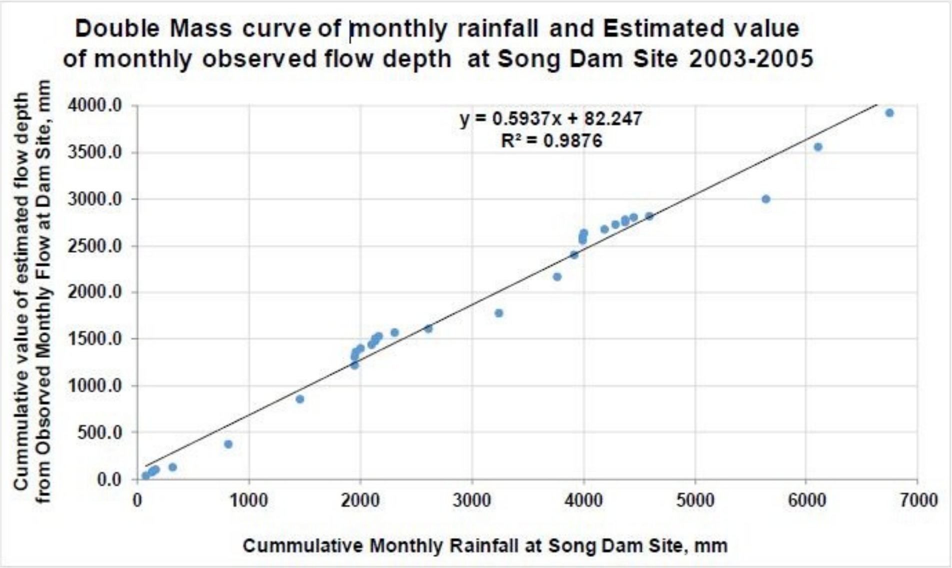


Figure 6-5: Consistency Check of monthly rainfall and estimated value of monthly observed flow depth at Song Dam Site 2003-2005

In view of the above consistency analysis, it is decided to use the observed flow data at the Dam Site and long-term rainfall at the IMD station at Dehradun to develop long term flow series for the water availability analysis.

6.4.2. Water Availability Assessment

For water availability assessment it is implicit that the year in which the rainfall in the catchment area of a river is less, consequently, the flows in the river will be less. Accordingly, the dependability analysis of long-term annual rainfall records has been carried out to identify the year of rainfall at different dependability level.

6.4.2.1. DEPENDABILITY ANALYSIS OF LONG-TERM RAINFALL

The long-term rainfall records of IMD rain gauge station at Dehradun for the period from 1989-90 to 2016-17 have been used to identify the dry years at different dependability level in the Song river catchment. The in identify probability of exceedance (i.e., dependability level) for seasonal (June- sept.) and annual rainfall for hydrologic year (starting from June to May of next year) have been estimated from Weibull's formula (Weibull 1939) to determine dependable rainfall years at different dependability level.

The seasonal and annual rainfall records were arranged in descending order and the rainfall values are ranked from 1 to 29. The highest value of rainfall is ranked as 1, the second highest as 2 and so on. The lowest value is ranked as 29. Using Weibull's formula, the percentage probability of exceedance (P) is calculated as P= 100*R/(N+1). The plot of dependability level of annual and seasonal rainfall is shown in the Figure 6-6.

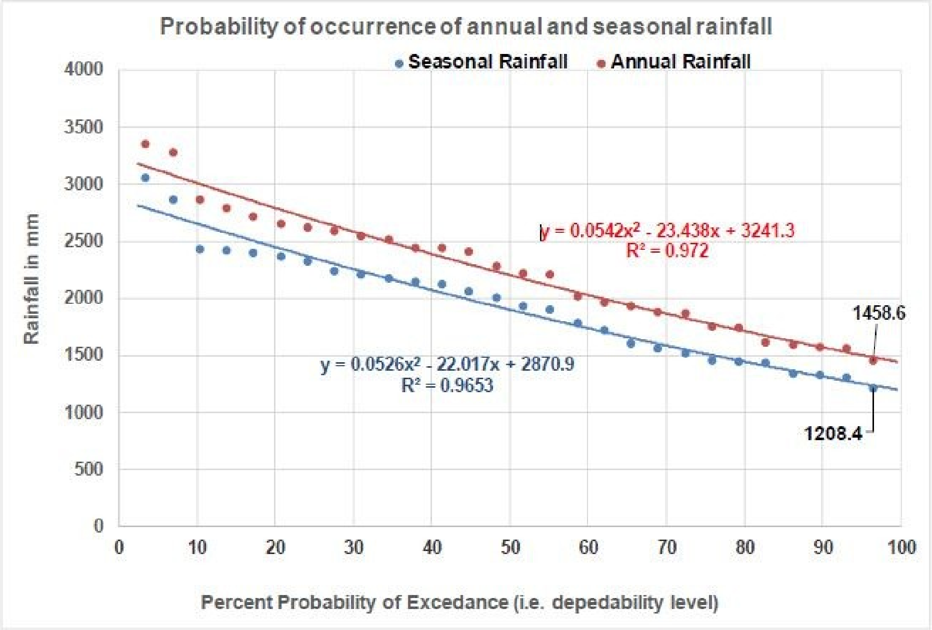


Figure 6-6 : Plot of percent probability of occurrence of annual and seasonal rainfall at IMD station Dehradun

The dependable rainfall years at different probability level (i.e. 86%, 90%, 93% 97%) are given in Table 6-10. The detailed analysis for determination of dependable years is shown in Table 6-11. The analysis indicated that out of 29 years of records the lowest monsoon season rainfall (1208.4) and annual rainfall (1459.6 mm) had occurred during 2002-03 and it has been estimated as 97% dependable year both for seasonal as well as annual rainfall.

Table 6-10: Dependability level of dry years Seasonal (June-Sept.) and Annual rainfall

Dependability Level	**Seasonal Rainfall (June- Sept.)**			**Annual Rainfall (Hydrologic Year)**		**Remarks**
	Year	**RF, mm**		**Year**	**RF, mm**	
86%	1991-92	1341.4		2015-16	1590.0	
90%	2016-17	1328.4		2009-10	1575.8	
93%	2009-10	1304.0		1991-92	1560.4	
97%	2002-03	1208.4		2002-03	1458.6	2002-03 is Lowest Rainfall year in record

Fortunately, the observed flow records at Dam site are available for the period from 2001-2005. Therefore, the flow records of year 2002-03, which corresponds lowest rainfall year (i.e., 97 % dependable year) based on both seasonal and annual rainfall in the area, can be used in the assessment of water availability for proposed Song Dam.

Table 6-11: Dependability analysis of annual and Seasonal rainfall (June-Sept.) for period from 1989-90 to 2016-17

Year	Seasonal Rainfall mm	Annual Rainfall mm	Year	Seasonal Rainfall in Descending Order. Mm	Year	Annual Rainfall Descending Order, mm	Rank	% Prob. Of Exceedance
2016-17	1328.4	1614	2010-11	3057.8	2010-11	3358.9	1	3
2015-16	1443.1	1590	2013-14	2865.2	2013-14	3286	2	7
2014-15	1438.4	1881.5	1990-91	2435	1999-2000	2866.6	3	10
2013-14	2865.2	3286	2011-12	2425.7	1990-91	2791.2	4	14
2012-13	2144.2	2517.1	1999-2000	2400.6	1997-98	2717.8	5	17
2011-12	2425.7	2593.5	2007-08	2367	1998-99	2652.8	6	21
2010-11	3057.8	3358.9	1998-99	2330.6	1996-97	2624.5	7	24
2009-10	1304	1575.8	2008-09	2240.5	2011-12	2593.5	8	28
2008-09	2240.5	2439.9	1996-97	2204.2	2007-08	2549.2	9	31
2007-08	2367	2549.2	2000-01	2182.3	2012-13	2517.1	10	34
2006-07	1458.5	1750.1	2012-13	2144.2	2000-01	2441.1	11	38
2005-06	1934.5	2279.5	1997-98	2127.3	2008-09	2439.9	12	41
2004-05	1718.8	2018.1	2001-02	2056.2	2001-02	2408.5	13	45
2003-04	1600.6	1866.6	1993-94	2007.4	2005-06	2279.5	14	48
2002-03	1208.4	1458.6	2005-06	1934.5	1992-93	2217	15	52
2001-02	2056.2	2408.5	1992-93	1898.9	1993-94	2212.4	16	55
2000-01	2182.3	2441.1	1994-95	1783.8	2004-05	2018.1	17	59
1999-2000	2400.6	2866.6	2004-05	1718.8	1994-95	1967.8	18	62
1998-99	2330.6	2652.8	2003-04	1600.6	1989-90	1931.6	19	66
1997-98	2127.3	2717.8	1989-90	1561.5	2014-15	1881.5	20	69
1996-97	2204.2	2624.5	1995-96	1518.4	2003-04	1866.6	21	72
1995-96	1518.4	1745.8	2006-07	1458.5	2006-07	1750.1	22	76
1994-95	1783.8	1967.8	2015-16	1443.1	1995-96	1745.8	23	79
1993-94	2007.4	2212.4	2014-15	1438.4	2016-17	1614	24	83
1992-93	1898.9	2217	1991-92	1341.1	2015-16	1590	25	86
1991-92	1341.1	1560.4	2016-17	1328.4	2009-10	1575.8	26	90
1990-91	2435	2791.2	2009-10	1304	1991-92	1560.4	27	93
1989-90	1561.5	1931.6	2002-03	1208.4	2002-03	1458.6	28	97

Observation on dependability analysis by CWC

After a thorough discussion and scrutiny of the analysis made above, CWC has deduced a data series based on discharge record at Satyanarayana Gauge site during year 1971-72 to 2004-05 and the extended data series for period 2004-05 to 2012-13. The physiographic parameters of the river catchment at Satyanarayana site/song dam site have been estimated by GIS processing of STRM DEM. The catchment area of Satyanarayana site comes out to be 963. 7km^2 (revised one) whereas catchment area up to proposed Song dam site is 85.225km^2.

The discharge data at Song dam site is available for 4 around years and yield during 2001-02 to 2004-05 is as under.

Year	Yield at Song Dam Site (mm)		Rainfall at IMD Dehradun Station (mm)	
	Jun-Sep	Annual	Jun-Sep	Annual
2001-02	1337	2063	2056	2408
2002-03	774	1126	1208	1458
2003-04	1124	1464	1600	1866
2004-05	836	1238	1718	2018

Using the annual yield values the dependable yield has been estimated. Accordingly, the estimated minimum yield is 72.26MCM and the 75% and 90% dependable yields are 111.01 and 98.60MCM respectively as tabulated below, E-flows, if any as per statutory norms, may also be maintained.

Song Dam-Dependable yields

S, No	Year	Annual Yield (MCM)	Dependability
1	2010-11	246.75	2.33
2	1978-79	245.45	4.65
3	2008-09	189.22	6.98
4	2011-12	180.62	9.30
5	2000-01	171.39	11.63
6	1990-91	167.82	13.96
7	1985-86	165-86	16.28
8	1977-78	165.46	18.60
9	1912-13	165.22	20.93
10	2005-06	162.51	23.26
11	1986-87	153.59	25.58
12	1973-74	153.26	27.91
13	1999-00	150.96	30.23
14	1995-96	150.87	32.56
15	1993-94	150.77	34.88
16	1971-72	147.45	37.21
17	1980-81	144.67	39.53
18	2007-08	142.65	41.86

19	1984-85	142.60	44.19
20	1981-82	140.80	46.51
21	1975-76	138.40	48.84
22	1998-99	131.65	51.16
23	1974-75	128.66	53.49
24	1994-95	128.40	55.81
25	1989-90	127.61	58.14
26	2001-02	125.49	60.47
27	1992-93	125.32	62.79
28	2003-04	124.63	65.12
29	1996-97	120.41	67.44
30	1983-84	116.86	69.77
31	2002-03	112.94	72.09
32	1988-89	111.94	74.42
33	1997-98	108.57	76.74
34	1979-80	105.68	79.07
35	1972-73	104.55	81.40
36	1976-77	102.16	83.72
37	1991-92	101.48	86.05
38	2009-10	99.73	88.37
39	2004-05	98.60	90.70
40	2006-07	95.37	93.02
41	1982-83	83.28	95.35
42	1987-88	77.26	97.67
		135.03	50%
		111.01	75%
		98.60	90%
		72.26	Minimum

6.4.2.2. ESTIMATION OF LONG-TERM FLOW SERIES

The observed daily flow in Song River at Dam site is available only for the period from February 2001 to December 2005 (**Annexure 6.3**). However, in the downstream of Song dam, the Central Water Commission (CWC) conducted discharge measurements on river Song at Satyanarayana Site for the period from 1971 to 2004. This site at Satyanarayana has been closed by CWC in July 2005. According to reports of CWC the catchment area of Song river up to Satyanarayana discharge measurement site is about 963.7km^2 and it is located at downstream of proposed Dam site at a distance of about 50 kms at an elevation of about 316 m above mean sea level (msl). On the other hand, the catchment area of Song River up to Dam site is about 85.225 Km^2 and it is located at an elevation of about 875 m above msl. Further, the catchment area up to Satyanarayana site is much larger than that of Song Dam catchment. It is almost 11.3 times of Song Dam catchment area. Hence, there was opinion of some of the experts that the estimation of flow at Dam site using measured discharge at Satyanarayana site may or may not be correct representative of actual flows at Dam site. Therefore, this matter was thoroughly discussed with various experts and learned field engineers of Uttarakhand Irrigation Department and it was decided to develop a long-term rainfall runoff series using a suitable rainfall-runoff modelling technique to simulate flow series at the Dam site using available long –term rainfall records (1989-90 to 2016-17) and evapotranspiration etc. Subsequently, the estimated flow series for Dam site from observed flow series at Satyanarayana and simulated flow series at Dam Site have been used for further analysis and to assess water availability at Dam site.

Estimation of flow series from observes flow at Satyanarayana.

The long term 10 daily average flow series for Dam site has been estimated using catchment area ratio and 10 daily average observed flow series at Satyanarayana ($Q_{Obs\text{-}Satya}$). The catchment area of Song River at Satyanarayana site (CA_{Satya}) has been taken as 963.7 km^2 and it is about 85.225 km^2 up to Dam site ($CA_{Dam\text{-}site}$). Thus, the flow series at Dam-Site has been estimated as follows:

$$Q_{Est-Dam\ site} = Q_{obs-Satya}\ X\ \frac{CA_{Dam\text{-}Site}}{CA_{Satya}}$$

The estimated 10-daily flow series at Dam Site is presented in **Annexure 6.4**

Simulation of flow series using rainfall- runoff modelling.

Water resources development and management in the river basin can be planned by making use of appropriate hydrological model. The hydrologic response of catchment to rainfall, estimates of catchment yield, and runoff data are of vital importance for hydrological analysis for the purpose of water resources planning, hydrograph simulation, pollution control and many other applications (Shamsudin and Hashim, 2002). Most of river catchments in India are ungauged and generally the limited discharge data are available with the concern state and central agencies. Under such circumstances rainfall-runoff model can be developed to simulate the natural hydrological processes to estimate the runoff from the catchment. The Rainfall- runoff models describe hydrological complex processes in a catchment as it is influenced by a number of implicit and explicit factors such as precipitation distribution, evaporation, transpiration, abstraction, and topography and soil types. Hydrologic models especially simple rainfall-runoff models are widely used in understanding and quantifying the impacts of land use changes and to provide information that can be used in decision making for water resources planning (Shoemaker et al., 1997).

Application of Mike-Basin-NAM Model (Mike by DHI) for Rainfall-Runoff modelling:

The Mike-Basin NAM model (MIKE by DHI) has been used for rainfall-runoff modelling in the Song catchment up to Dam site. The model was developed at the Technical University of Denmark. The model is also part of DHI Mike-Hydro model. It is a deterministic, conceptual, continuous and lumped rainfall- runoff model. This model is one of the professional models, particularly used for water resources planning. The NAM model has been applied to a number of catchments around the world, representing many different hydrological regimes and climatic conditions (Fleming, 1975; Kjelstrom and Moffat, 1981; Kjelstrom, 1998; Arcelus, 2001;Shamsudin and Hashim, 2002) etc.Inassociation with DHI-Dekmarkthe National Institute of Hydrology has applied Mike Basin NAM model for rainfall-runoff modelling for the Development of Decision Support System (DSS) for water resources planning in the 9-states in India under the World Bank Funded Hydrology Project phase-2 (HP-2, 2006-2012). These are some of the ready examples of applicability of NAM-Model in water resources planning studies.

The NAM model (NedbørAffstrømnings Model) has simple representation for surface, root zone and groundwater representations. Storages are conceptualized as one or more linear reservoirs. Flow from these storages are assumed to be surface flow, interflow and groundwater flow. Surface zone storage represents interception, surface depression and upper few centimetres of the soil. Lower zone storage represents root zone from where transpiration takes place. Various thresholds of root zone saturation levels are specified for initiation of overland flow, interflow and groundwater flows. Excess precipitation is divided into infiltration and overland flow components using runoff coefficient. Storages available in excess of defined thresholds for flow categories are routed to catchment outlet using linear reservoir time constants. For interflow and groundwater flow single linear reservoir is conceptualized and for overland flow one or two linear reservoir may be adopted. Upper storage limit for upper and lower zones also need to be set. All hydrologic models require specifying initial state of various storages and flows. Changes in storages and flows takes place due to external forcing and hydrologic processes. In NAM, initial values of the upper and lower zone storages and overland flow, interflow and groundwater flows are specified in the model setup. The model allows auto-calibration of parameters using multiple- objective optimization in SCE algorithm. Available objective functions are overall, peak and low flow RMSE and overall water balance. The parameters which can be calibrated are upper and lower zone storages, overland flow runoff coefficient, time constants and lower zone storage thresholds for flows routing. Various parameters lower and upper bounds are also needed in parameter optimization. Description of parameters is given in Table 6-12**.**

The Input data

The basic input data requirements for the NAM model are daily rainfall time series, potential evapotranspiration time series and observed discharge data at Dam site. On this basis, the model produces a time series of catchment runoff, a time series of subsurface flow contributions to the channel, and information about other elements of the land phase of the hydrological cycle, such as soil moisture content and groundwater recharge. The input used in the study are given below.

(i) **Rainfall**: The daily rainfall data of IMD station Dehradun for the period of five years i.e. from 01-01-1989 – 31-12-1997.

(ii) **Runoff**: The observed discharge data at proposed Song Dam site for the period of five years i.e. 06-03-2001 to 31-12-2005.

(iii) **Potential evapotranspiration (PET)**: The estimated average PET values have been given in Table 6-6 in Section 6.3.

The model was set up for Song catchment. In the model setup, one catchment and one stream channel are defined. Catchment area was set equal 85.22 sq. km. Basin module, namely rainfall- runoff was selected. For calibration of the model, calibration period of 1.6.2002 to 31.122005 was selected. Model was simulated for daily time step. Input time series of mean monthly PET rates (as given in Table 6-6, Section 6.3), daily observed discharge) (period 6.3.2001 to 31.12.2005) at the catchment outlet and daily rainfall at Dehradun (period 1.1.1989 to 30.8.2017 were specified (Figure 6-7 and Figure 6-8). All model parameters except CKBF (time constant for routing groundwater flow) were selected for calibration. CKBF was assigned a value to 1200 hr. The calibrated values of the parameters are given in Table 6-12. Initial fraction of upper and lower zone storages was assumed to be equal to 0.5. Initial value of base flow was assumed to be equal to 1 cumec. Overall RMSE in calibration was 0.69 and water balance was 0.03% (observed 1452.3 mm/year and calibrated 1451.9 mm/year). Simulated and observed discharge and accumulated water balance for calibration are given in Figure 6-9 and Figure 6-10, respectively. The comparison of observed and simulated period for the calibration period showed in very good agreement. Thus, the daily flow series for Song Dam site has been simulated for the period from Jan 1, 1989 to Dec. 31, 2017. Simulated daily discharge using calibrated model parameter is given in Figure 6-11**.** In the model calibration, moderate value in overall RMSE was achieved 10-daily simulated discharge series from 1989-90 to 2016-17 is given in **Annexure 6.5.**

Table 6-12: Model parameters and their calibrated/ selected values, minimum and maximum recommended values

Parameter	Unit	Description	Calibrated	Calibrated value	Minimum	Maximum	Effect
U_{max}	mm	Maximum water content in surface storage	True	10.234	10	20	Overland flow, infiltration, evapotranspiration, interflow
L_{max}	mm	Maximum water content in lower zone/root storage	True	100.99	100	300	Overland flow, infiltration, evapotranspiration, base flow
C_{QOF}	hrs	Overland flow coefficient	True	0.12534	0.1	1	Volume of overland flow and infiltration
C_{KIF}	hrs	Interflow drainage constant	True	47.133	40	1000	Drainage of surface storage as interflow
T_{OF}		Overland flow threshold	True	38.496	10	50	Soil moisture demand that must be satisfied for overland flow to occur
T_{IF}	hrs	Interflow threshold	True	10	10	50	Soil moisture demand that must be satisfied for interflow to occur
T_G		Groundwater recharge threshold	True	0.25905	0	0.99	Soil moisture demand that must be satisfied for groundwater recharge to occur
$C_{K1,2}$	hrs	Timing constant for overland flow	True	0.037853	0	0.99	Routing overland flow along catchment slopes and channels
C_{K2}	hrs	Timing constant for interflow	True	0.0036688	0	0.99	Routing interflow along catchment slopes

C_{KBF}	hrs	Timing constant for base flow	False	1200	500	4000	Routing recharge through linear groundwater Recharge

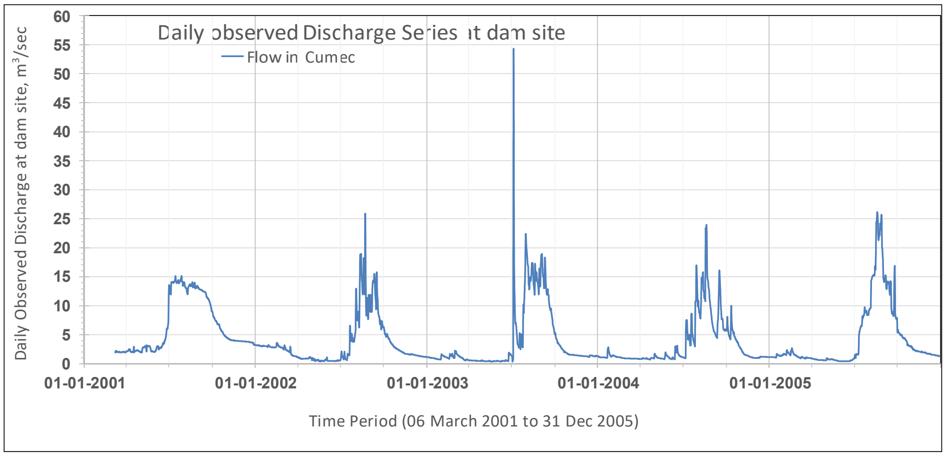


Figure 6-7: Observed discharge (in m^3/sec) at project outlet (i.e. Dam Site)

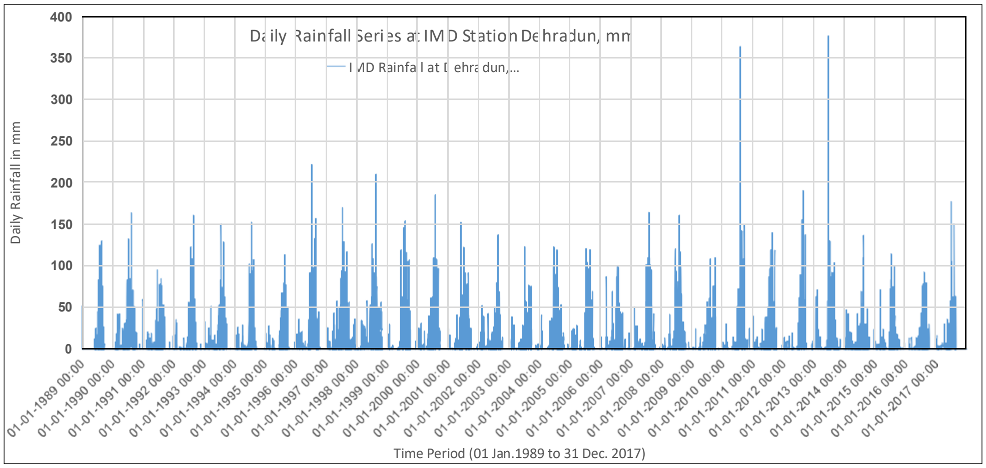


Figure 6-8: Rainfall at IMD Station Dehradun, mm

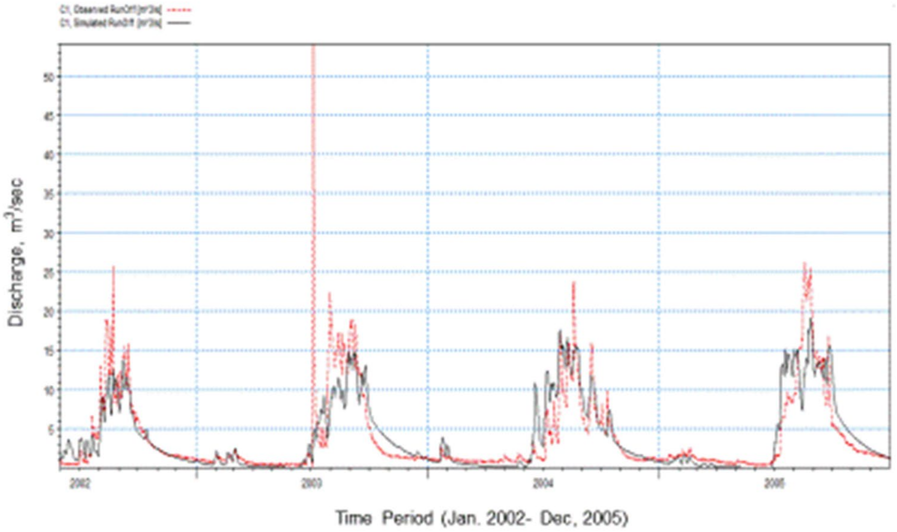


Figure 6-9: Simulated and observed discharge in model calibration

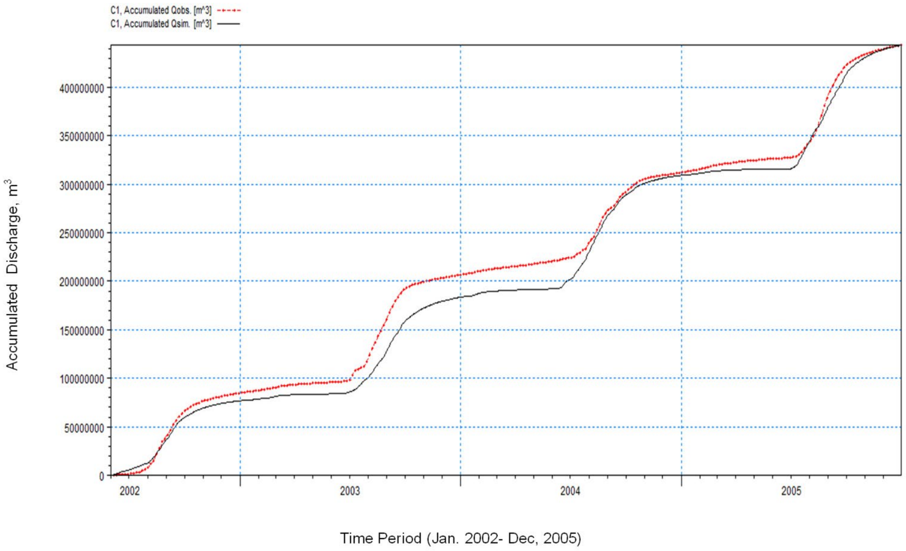


Figure 6-10: Accumulated water balance in model calibration

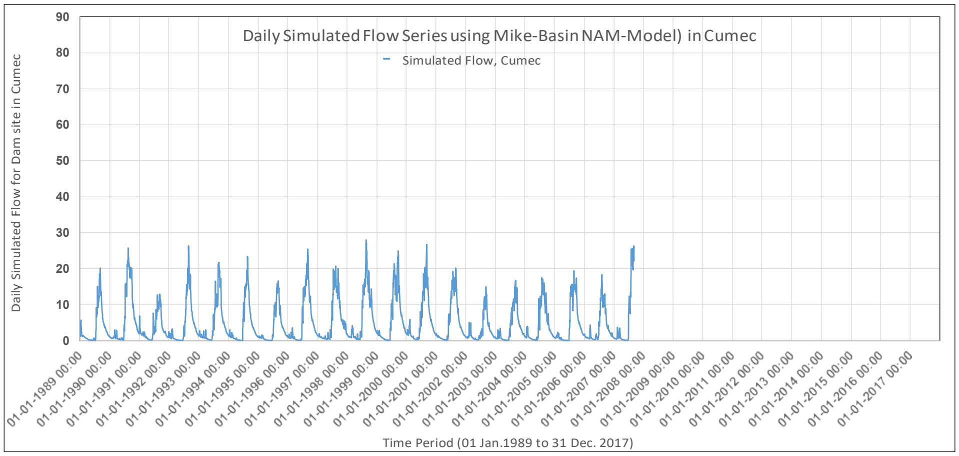


Figure 6-11: Simulated discharge from the Dam catchment

Further, a comparison of simulated flow series at Dam site and the estimated flow series for Dam site using observed flow at Satyanarayana have been compared and found consistent.

Thus, the following three flow series for the lowest rainfall year 2002-03 (97% dependable year) have been used for further analysis (as presented in Table 6-13) to assess water availability at Dam site using inflow and reservoir storage balancing.

Table 6-13: Assessment of water availability in 97% dependable year (2002-03)

Sl. No.	**Flow Series**	**Available flow in 97% dependable year (2002-03)**		
		Total annual flow in MCM	**Monsoon season flow in MCM**	**Non-Monsoon season flow in MCM**
1	Simulated flow at Dam site	85.485	57.682	27.903
2	Estimate flow for Dam site using observed flow series at Satyanarayana.	74.859	40.080	34.779
3	Actual observed flow series at Dam site	95.999	66.006	29.993

The simulated flow values in Table 6-13 (at serial no 1) are highly conservative for the lowest rainfall year (2002-03) indicating lowest non-monsoon season flow about 27.903 MCM. In second case (serial no.2), the estimated flow at Dam Site using observed discharge at Satyanarayana, the non-monsoon season flow is about 34.77 MCM for 97% dependable year. However, in case 3, actual observed flow at Dam site indicate that the lean season flow is about 29.993 MCM. The above assessment of available flow at Dam site are reasonable and acceptable because the catchment area of Song river above Dam Site is largely forested and has stable forest and vegetation cover with least human interventions. Further, the Song River at Dam site has perennial flow in good quantity in lean season/dry months. The water utilization in the up-steam catchment of the Dam is almost zero or negligible.

Observations on flow series by CWC

Further, the discharge at Song Dam Site has been derived in the corrected catchment area ratio (catchment area at being 963.7 km^2 instead of 635 km^2) by CWC and rainfall ratio of Song Dam site and Satnarayana Site. At Satyanarayana G&D site, discharge data is available for the period for the 1971-72 to 2003-04 and checked for its consistency. Monthly Arial Gridded Rainfall in mm in catchment up to Satyanarayana G&D Site from 1971-72 to 2012-13 has been worked out. The monsoon runoff factors at Satyanarayana vary from 0.89 in year 1997-98 to 0.21 in 1989-90 with average 0.48. The regression between monsoon yield at Satyanarayana and arial grid rainfall up in catchment up to Satyanarayana G&D site has been tired and the R^2 value comes out to be 0.156. The R^2 value of 0.650 is arrived after removing some outlier data and the regression equation of "Q+0.518 * Grid Rainfall – 25.58" is obtained. The removed outlier data have been re-computed using the runoff coefficient of 0.480. Considering 1971-72 to 2003-04 discharge data, the 10 daily/monthly averages have been estimated. Further, the estimated averages are converted into percentage to Annual flow. As the IMD Grid rainfall data is available up to 2012-13, the Satyanarayana discharge data have been extended from 2004-05 to 2012-13 by Monsoon (June-September) regression equation and percentage of non-monsoon to annual discharge. Accordingly, the total monsoon discharge is estimated as 55.51% of Annual discharge and using these annual discharges for the period from 2004-05 to 2012-13 are estimated. The consistency checks on annual discharge data of Satyanarayana site for the period from 1971-72 to 2012-13 have been carried out and found consistent. Further, the ten daily discharges of extended period from 2004-5 to 2012-13 are computed using the monsoon regression equation for monsoon period and using the percentage to annual flow for non-monsoon period.

IMD Dehradun rain gauge station is located about 14Km from the dam site and annual average rainfall (1989-90 to 2016-17) is estimated as 2249.12mm whereas annual average rainfall at Satyanarayana site based on IMD grid rainfall (1971-72 to 2012-13) is estimated as 1365.95mm. The ratio between mean annual rainfall at Satnarayana and Song Dam is 0.61. Further, the mean annual rainfall based on TRMM 2B31 for the years 1998-2009 in Song Dam catchment area is 2500 mm whereas the same for the Satyanarayana G&D site catchment is 1500 mm. The ratio between mean annual rainfall at Satyanarayana and Song Dam site comes out to be 0.60. In view of above, the rainfall data at Dehradun may be considered as the representative rainfall at Song Dam catchment. Water availability Report by CWC is enclosed in **Annexure 6.6**

The water availability series at Song Dam has been derived from the discharge data of Satyanarayana site in catchment area proportion considering rainfall variability. Hence, a ratio of 0.1456(85.225/963.7*2249.12/1365.95) has been used to derive the water availability series at Song dam from the discharge data of Satyanarayana site. Necessary consistency checks have been carried out and found consistent. The ten daily water availability series at song dam for the period from 1971-72 to 2012-13 estimated by CWC is enclosed as **Annexure 6.7**. Thus, based on annual flow volume (MCM), CWC approved 97% dependable (~say 100%) year as 1987-88.

6.4.3. Reservoir Balancing to Access Water Availability

The time distributed 10-daily assessment of water availability in Song River has been carried out using storage reservoir balancing analysis to meet the given drinking water demand of 150 MLD. For the reservoir balancing analysis the following inflow, outflow and storage components have been considered.

1. Storages available in the reservoir during each 10-daily time step in MCM.
2. 10-daily river inflow into the reservoir in MCM.
3. 10-daily outflow (supply) from reservoir storage to meet a given drinking water demand in MCM.
4. 10 daily evaporation losses from storage reservoir in MCM.
5. Environmental flow requirement (EFR) for 10-daiy time step (in MCM) as per the prescribed guidelines of the Govt. of India vide Gazette Notification No. 4009 (S.O. 5195(E)) dated 09 October 2018.

6.4.3.1. ESTIMATION OF EVAPORATION FROM THE STORAGE RESERVOIR:

The detailed approach of estimation of evaporation from the storage reservoir has been described in section 6.3.4 & Table 6-6. The same has been reproduced here for ready reference. Using pan-to-lake conversion coefficients suggested by Ramasastri (1987) in Table 6-6 in section 6.3.4 the pan evaporation values measured at FRI station for the period from 1975-1993 and 2004-2016, monthly average evaporation rates from reservoir storage have been estimated as given in Table 6-14.

Table 6-14: Estimated values of monthly evaporation rate from reservoir storage.

Month	Measured value of average Pan evaporation mm/day	Pan to lake evaporation conversion Coefficient	Evaporation from water reservoir body. mm/day
Jan.	1.27	0.6	**0.762**
Feb.	1.94	0.6	**1.164**
Mar.	3.26	0.7	**2.282**
Apr.	5.32	0.7	**3.724**
May	6.49	0.8	**5.192**
Jun.	5.30	0.8	**4.240**
Jul.	2.70	0.8	**2.160**
Aug.	2.32	0.8	**1.856**
Sep.	2.74	0.7	**1.918**
Oct.	2.61	0.7	**1.827**

Nov.	1.78	0.6	**1.068**
Dec.	1.26	0.6	**0.756**

6.4.3.2. ESTIMATION OF ENVIRONMENTAL FLOW REQUIREMENT (EFR)

The Song River is one of the tributaries of River Ganga and the Ministry of Water Resources River Development and Ganga Rejuvenation, Government of India, vide Gazette Notification No. 4009 [S.O.5195(E)] dated 09 October 2018 (**Annexure 6.8**), notified environmental flow requirement (EFR) for Upper Ganga River basin stretch starting from originating glaciers and through respective confluence meeting at Devprayag up to Haridwar as given in Table 6-15. Accordingly, the water availability assessment has been carried out for Song Dam site after deducting the water demand for EFR for the downstream as prescribed in Table 6-15.

Table 6-15: Environmental flow requirement (EFR) for Upper Ganga River basin stretch starting from origin and Devaprayag to Haridwar *(Source: Gazette notification No. 4009 [S.O.5195(E)] dated 09 October 2018)*.

Sl. No	Season	Month	(%) Percentage of Monthly Average Flow observed during each of preceding 10-daily period.
1	Dry	November to March	20
2	Lean	October, April and May	25
3	High Flow Season	June to September	30*#

**# 30% of monthly flow of high flow season.*

Further, Chipaldi River joins the Song River in the downstream at about 350 m from the proposed Dam site. The catchment area of Chipaldi is about 30.81 Km^2. The Chipaldi is another river with perennial nature having flow characteristics similar to that of Song River at Dam site. Flow from Chipaldi is available in addition to EFR flow from proposed Song Dam. It has sufficient flow to meet any other requirement in the downstream of the Song Dam site including Kalanga canal requirement.

6.4.3.3. RESERVOIR WATER BALANCE ANALYSIS

The reservoir water balance analysis has been carried out for the rainfall year 1987-88 recommended by CWC as mentioned above using, 10 daily inflows into the reservoir recommended in flow series, evaporation losses from reservoir and environmental water requirement (EFR) worked out above. The aforesaid analysis has been carried out for a drinking water demand of 150 MLD with reservoir storage capacity of 26.4 MCM (at FRL980 m).

The 10-daily reservoir balance analysis indicated that the reservoir got filled and reached at FRL by end of August or beginning of September month in the driest year of record i.e. 1987-88. Therefore, the reservoir balancing has been started from first 10-daily period of September month for simplicity. The results of analysis indicated that a regular drinking water supply of 150 MLD, need for EFR release and reservoir evaporation are met and the minimum water level (MWL) in reservoir are above 955 m,

From the 10-daily reservoir balance study for the driest year of 97% dependability level, the analysis revealed that there is sufficient water available at proposed Song Dam site to meet sustainable drinking water demand of 150 MLD with a storage reservoir of MCM 26.40 at 980 m FRL. Thus, it is feasible from water availability point of view to meet the future drinking water demand for the Dehradun. Further, the supply of drinking water from proposed Song Dam will lead to substantial reduction in groundwater withdrawal and will ensure groundwater sustainability in the region.

Table 6-16: Reservoir Balance based on CWC approved data series (1987-1988)
Demand =150 MLD, FRL = 980 m and Storage at FRL =26.40

MONTH	10-DAILY	Flow (MCM) at 97% Dependable yea (say ~ 100%)	Cumulative Inflow to dam (MCM) wit DSL storage= 7.39 MCM		Month		Cwc approved flow (MCM) at 97% Dependable year (say ~ 100%)	Drinking Water Demand (MLD)	Drinking Water Demand (MCM/Day),*C=(B/1000)*	No. of Days	10-daily Drinking Water Demand ((MCM),*E=C*D*	Environmental flow requirement (MCM)	Evaporation Losses (MCM)	10-Daily (Dam Inflow -Demand-EFR-EV),	Part of Demand to be met from Dam Storage (MCM)	Reservoir Storage (MCM)	Reservoir Level. m
		1987-88	*7.39*				*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*26.40*	
JUNE	1	1.71	9.100		SEPT.	**1**	13.14	150.0	0.150	10	1.5	3.9420	0.0125	7.686	0.000	26.400	
	2	1.82	10.920			2	5.02	150.0	0.150	10	1.5	1.5060	0.0125	2.002	0.000	26.400	
	3	1.51	12.430			3	2.51	150.0	0.150	10	1.5	0.7530	0.0125	0.245	0.000	26.400	
JULY	1	1.51	13.940		OCT.	1	1.96	150.0	0.150	10	1.5	0.4900	0.0119	-0.042	0.042	26.358	
	2	1.49	15.430			2	1.74	150.0	0.150	10	1.5	0.4350	0.0119	-0.207	0.207	26.151	
	3	1.73	17.160			3	1.89	150.0	0.150	11	1.65	0.4725	0.0131	-0.246	0.246	25.906	
AUG.	1	1.43	18.590		NOV.	1	1.64	150.0	0.150	10	1.5	0.3280	0.0069	-0.195	0.195	25.711	
	2	1.8	20.390			2	1.62	150.0	0.150	10	1.5	0.3240	0.0069	-0.211	0.211	25.500	
	3	4.19	24.580			3	1.63	150.0	0.150	10	1.5	0.3260	0.0069	-0.203	0.203	25.297	
SEPT.	1	13.14	37.720		DEC.	1	1.61	150.0	0.150	10	1.5	0.3220	0.0047	-0.217	0.217	25.080	
	2	5.02	42.740			2	1.61	150.0	0.150	10	1.5	0.3220	0.0047	-0.217	0.217	24.863	
	3	2.51	45.250			3	1.7	150.0	0.150	11	1.65	0.3400	0.0047	-0.295	0.295	24.569	
OCT.	1	1.96	47.210		JAN.	1	1.53	150.0	0.150	10	1.5	0.3060	0.0046	-0.281	0.281	24.288	
	2	1.74	48.950			2	1.49	150.0	0.150	10	1.5	0.2980	0.0046	-0.313	0.313	23.975	
	3	1.89	50.840			3	1.56	150.0	0.150	11	1.65	0.3120	0.0046	-0.407	0.407	23.569	
NOV.	1	1.64	52.480		FEB.	1	1.35	150.0	0.150	10	1.5	0.2700	0.0064	-0.426	0.426	23.142	
	2	1.62	54.100			2	1.41	150.0	0.150	10	1.5	0.2820	0.0064	-0.378	0.378	22.764	
	3	1.63	55.730			3	1.16	150.0	0.150	8	1.2	0.2320	0.0047	-0.277	0.277	22.487	
DEC.	1	1.61	57.340		MAR.	1	1.29	150.0	0.150	10	1.5	0.2580	0.0114	-0.479	0.479	22.008	
	2	1.61	58.950			2	1.3	150.0	0.150	10	1.5	0.2600	0.0114	-0.471	0.471	21.537	
	3	1.7	60.650			3	1.35	150.0	0.150	11	1.65	0.2700	0.0126	-0.583	0.583	20.954	
JAN.	1	1.53	62.180		APRIL	1	1.22	150.0	0.150	10	1.5	0.3050	0.0168	-0.602	0.602	20.352	
	2	1.49	63.670			2	1.12	150.0	0.150	10	1.5	0.2800	0.0168	-0.677	0.677	19.675	
	3	1.56	65.230			3	1.07	150.0	0.150	10	1.5	0.2675	0.0149	-0.712	0.712	18.963	
FEB.	1	1.35	66.580		MAY	1	1.05	150.0	0.150	10	1.5	0.2625	0.0208	-0.733	0.733	18.230	
	2	1.41	67.990			2	1	150.0	0.150	10	1.5	0.2500	0.0208	-0.771	0.771	17.459	
	3	1.16	69.150			3	1.09	150.0	0.150	11	1.65	0.2725	0.0200	-0.852	0.852	16.607	
MAR.	1	1.29	70.440		JUNE	1	1.71	150.0	0.150	10	1.5	0.5130	0.0148	-0.318	0.318	16.289	
	2	1.3	71.740			2	1.82	150.0	0.150	10	1.5	0.5460	0.0148	-0.241	0.241	16.048	
	3	1.35	73.090			3	1.51	150.0	0.150	10	1.5	0.4530	0.0148	-0.458	0.458	15.590	
APRIL	1	1.22	74.310		JULY	1	1.51	150.0	0.150	10	1.5	0.4530	0.0075	-0.451	0.451	15.140	
	2	1.12	75.430			2	1.49	150.0	0.150	10	1.5	0.4470	0.0075	-0.465	0.465	14.675	MWL -
	3	1.07	76.500			3	1.73	150.0	0.150	11	1.65	0.5190	0.0075	-0.447	0.447	14.228	955 m
MAY	1	1.05	77.550		AUG.	1	1.43	150.0	0.150	10	1.5	0.4290	0.0007	-0.500	0.500	13.729	
	2	1	78.550			2	1.8	150.0	0.150	10	1.5	0.5400	0.0084	-0.248	0.248	13.480	
	3	1.09	79.640			3	4.19	150.0	0.150	11	1.65	1.2570	0.0112	1.272	0.000	14.752	

6.5. Design Flood Estimation

The design flood at proposed Song Dam site has been estimated using synthetic hydrograph method prescribed by CWC (1994) and probable maximum precipitation (PMP). The one-day Standard Project Storm (SPS) and PMP values, and average time distribution of 24-hours storm rainfall for Song Dam catchment are procured from India Meteorological Department (IMD) vide letter no. HS-38/13/2018-DSU dated 23.10.2018. The one-day SPS and PMP values provided by IMD are 34.1 cm and 49.1 cm respectively.

6.5.1. Study Area and Data

The Cartosat Digital Elevation Model (Carto-DEM) of the basin shown in Figure 6-12 is used for catchment delineation and for estimation catchment characteristics. The Carto-DEM is a National DEM developed by the Indian Space Research Organization (ISRO). It is derived from the Cartosat-1 stereo payload launched in May 2005. The V3R1 version is published with Waterbody Flattening (http://bhuvan.nrsc.gov.in/data/download/index.php). Hypsometric curve of the catchment area is shown in Figure 6-13**.**

The National Institute of Hydrology (MIH) Roorkee, vide letter no.NIH/SWDDiv/CS-146/2018 dated 24th Sept. 2018 requested India Meteorological Department (IMD), New Delhi to provide design storm value for the Song Dam Drinking Water Project. The IMD conducted study for design storm and supplied the one-day design storm values of Standard Project Storm (SPS) and PMP values, and average time distribution of 24-hours storm rainfall for Song Dam catchment (Table 6-17), vide letter no. HS-38/13/2018-DSU dated 23.10.2018.

Table 6-17: The average time distribution of 24-hour design storm rainfall for Song Dam catchment supplied by IMD

Duration (hours)	**03**	**06**	**09**	**12**	**15**	**18**	**21**	**24**
% of Storm Rainfall	40	55	66	76	84	91	96	100

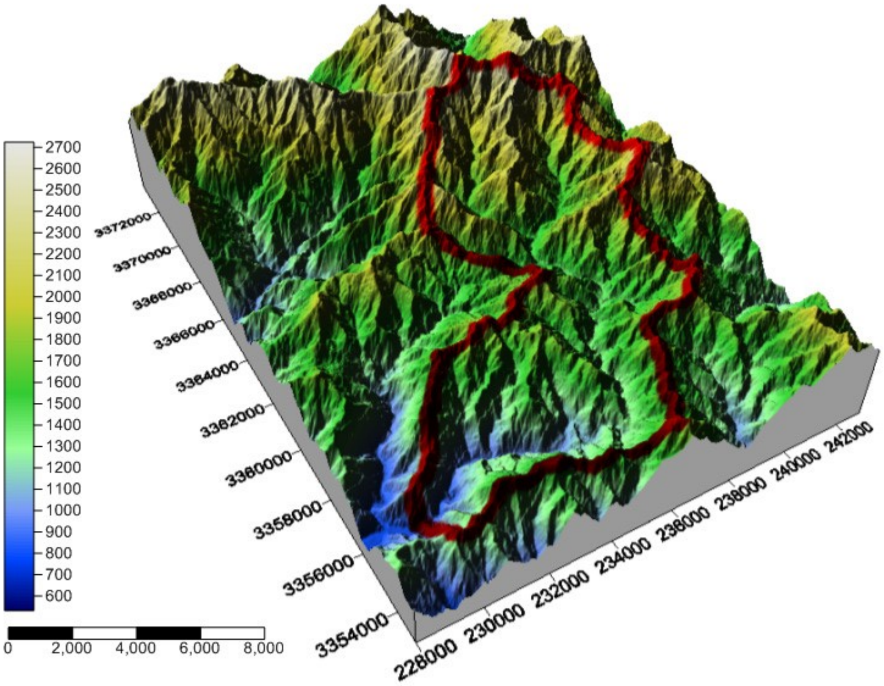


Figure 6-12: Digital Elevation map of the study area

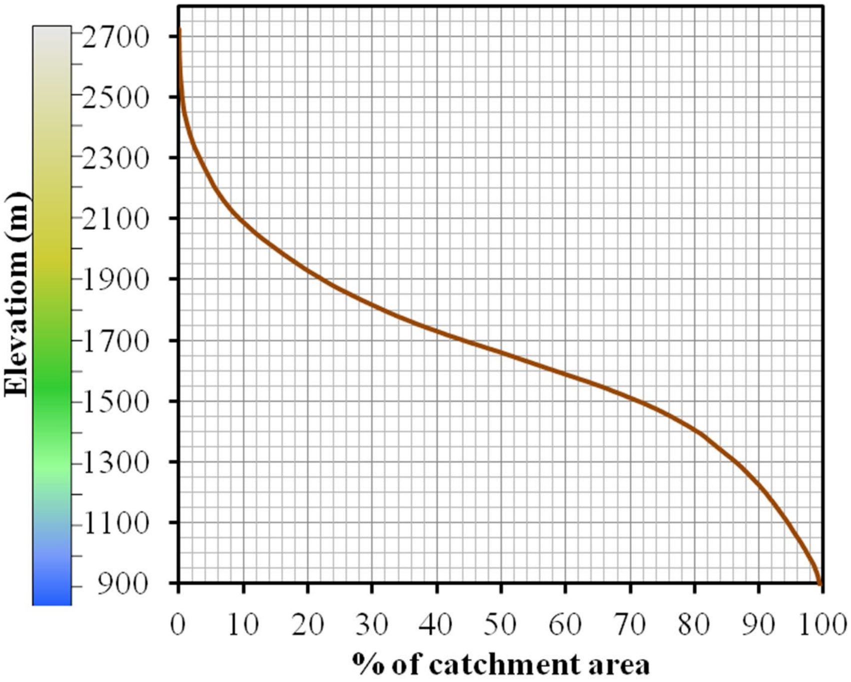


Figure 6-13: Hypsometric curve of the catchment area.

6.5.2. Development of Synthetic Unit Hydrograph

The synthetic unit hydrograph is developed using the approach provided in the flood estimation report for subzone 7 (CWC, 1994). This method requires various catchment characteristics like L = Length of the main stream (km), Lc = Centroid longest flow path (km), S = Equivalent stream slope (m/km), A= Area of the catchment (km^2).

6.5.2.1. CATCHMENT DELINEATION AND ESTIMATION OF CATCHMENT CHARACTERISTICS

The Digital Elevation Model of the study area is developed from the Cartosatdata. Arc Hydro Tool has been used for basin delineation in ArcGIS. The DEM is filled to remove any local sink and then used to derive the flow direction and flow accumulation grids which are further used for defining and segmenting the streams and the catchment grid. Once drainage point is defined, the drainage network and catchment boundary is masked as a separate project. The drainage point is selected on the stream grid near to the point of interest. The delineated catchment area and various catchment characteristics are shown in Figure 6-14. The estimated value of catchment characteristics is given in Table 6-18**.**

Table 6-18: Catchment characteristics

Characteristics	Value
A: Area of the catchment (km2)	85.225
L : Length of the main stream (km)	28.28
L_c: Centroid longest flow path (km)	18.21
S : Equivalent stream slope (m/km)	46.04

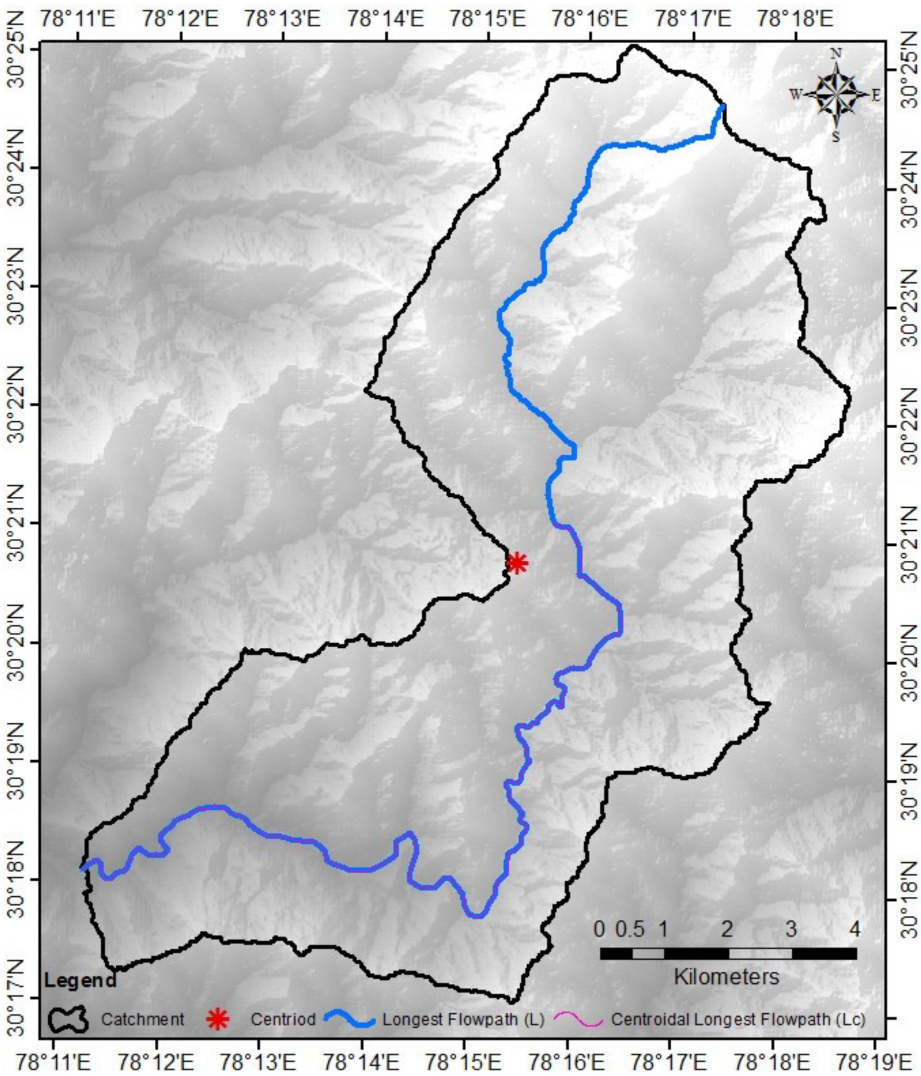
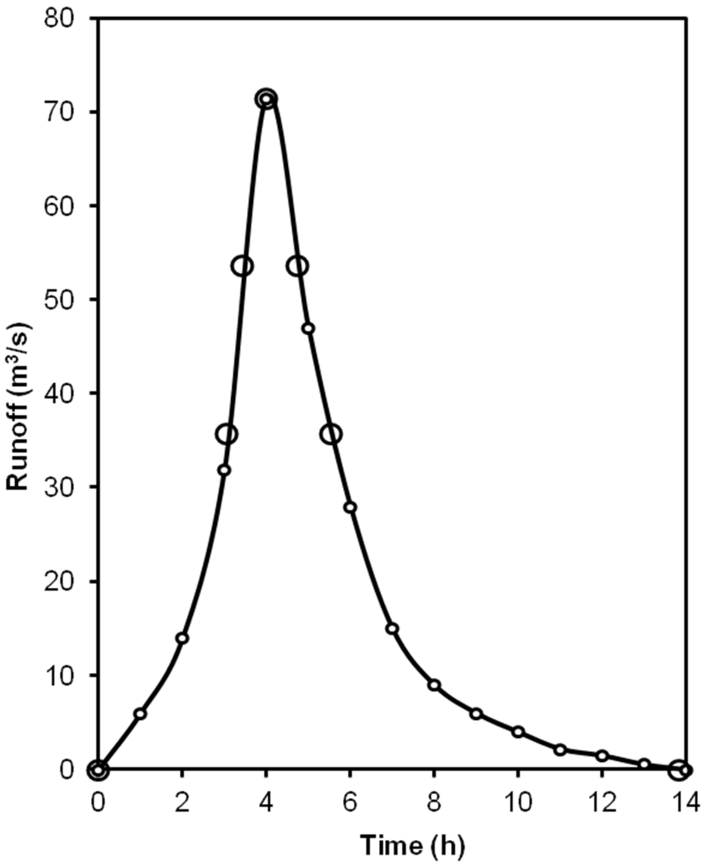


Figure 6-14: Delineated catchment with catchment characteristics

6.5.2.2. ESTIMATION OF SYNTHETIC UNIT HYDROGRAPH

The Synthetic Unit Hydrograph is developed using the above catchment characteristics and flood estimation report for western Himalayan zone 7 (CWC, 1994). The developed SUH with ordinates are shown in Figure 6-15.



The Ordinates of SUH

Time (h)	Discharge (m^3/s)
0	0
1	6.1
2	14
3	32
4	71.504
5	47
6	28
7	15
8	9
9	5.9
10	4
11	2.2
12	1.5
13	0.551
14	0

Figure 6-15: Developed Synthetic Unit Hydrograph

6.5.3. Design Storm Value

The design storm duration (TD) can be estimated using 1.1×t_p as recommended by CWC (1994). Rounding of the design storm duration to nearest hour is 4-hour. However, in this case the 1-day PMP and SPS are used. The design storm values with time distribution of storm rainfall are procured from IMD. The 1day SPS value and PMP values are 34.1 cm and 49.1 cm respectively. As suggested, these values are multiplied with 1.15 for clock hour correction for 24 h, which are 39.22 cm and 56.47 cm respectively. The design storm is split into 1-hour rainfall increments using time distribution coefficient as given in Table 6-19. A design loss rate of 0.20 cm/h as recommended (CWC, 1994) is applied to get effective rainfall increments.

Table 6-19: Time distribution coefficient

Time (h)	Cum. Rainfall %
1	21.9
2	34
3	40
4	45
5	50
6	55
7	59
8	63

9	66
10	70
11	73
12	76
13	79
14	82
15	84
16	87
17	89
18	91
19	92
20	94
21	96
22	97
23	99
24	100

6.5.4. Estimation of Base flow

Taking design base flow of 0.05 $m^3/s/km^2$ as recommended by CWC (1994) the base flow is estimated to be 4.26 m^3/s.

6.5.5. Estimation of Probable Maximum Flood Hydrograph

For, estimation of peak discharge, the effective rainfall increments are re arranged against ordinates such that the maximum effective rainfall is placed against the maximum SUH ordinate, next lower value of effective rainfall against next lower value of SUH ordinate and so on. The effective rainfall increments are then reversed to obtain critical sequence. These critical rainfall sequences are then convoluted with the SUH to estimate the direct surface runoff hydrograph. Finally, the base flow is added to estimate flood hydrograph. The estimated Probable Maximum Flood hydrograph with PMP is shown in Figure 6-16 and the ordinates are given in Table 6-20**.** The peak discharge of PMF hydrograph is estimated to be 1492.66 m^3/s (Say≈ 1493 m^3/s).

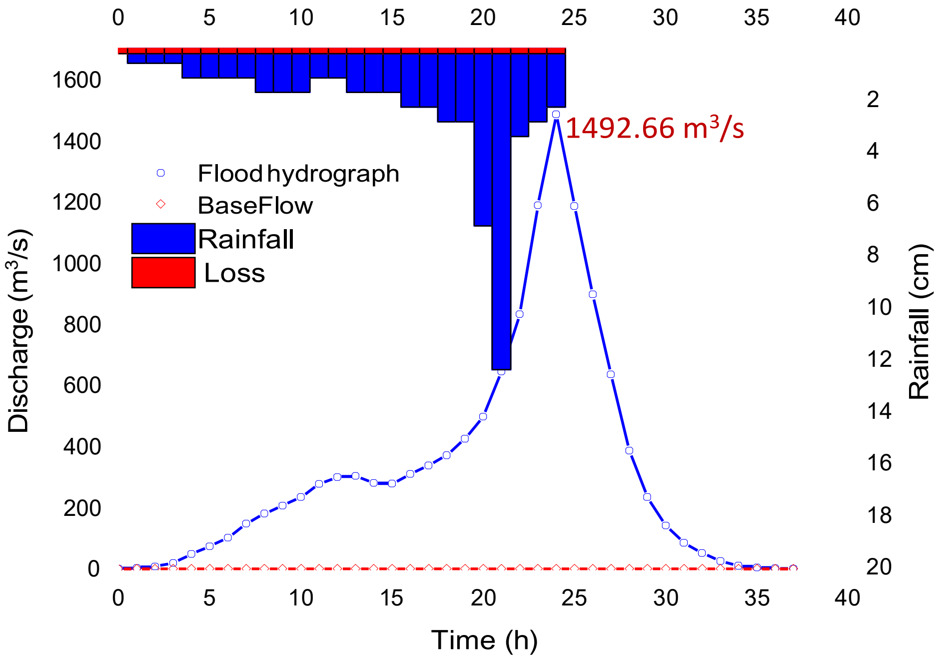


Figure 6-16: Probable maximum flood hydrograph

Table 6-20: Ordinates of PMF hydrographs with ERH

Time (h)	Effective Rainfall (cm)	PMF hydrograph (m3/s)
0	0.000	4.26
1	0.365	6.49
2	0.365	11.60
3	0.365	23.28
4	0.929	52.82
5	0.929	77.87
6	0.929	106.13
7	0.929	151.94
8	1.494	185.18
9	1.494	211.03
10	1.494	239.03
11	0.929	281.87
12	0.929	304.39
13	1.494	308.03
14	1.494	285.26
15	1.494	282.71
16	2.059	314.38
17	2.059	342.63
18	2.623	376.13
19	2.623	430.41
20	6.632	502.61
21	**12.166**	650.73

22	3.188	838.12
23	2.623	1194.46
24	2.059	1492.66
25		1192.16
26		902.58
27		640.62
28		391.41
29		239.10
30		146.20
31		89.18
32		55.82
33		29.75
34		14.48
35		8.79
36		5.39
37		4.26

6.5.6. Estimation of Standard Project Flood Hydrograph

For, estimation of peak discharge, the effective rainfall increments are re arranged against ordinates such that the maximum effective rainfall is placed against the maximum SUH ordinate, next lower value of effective rainfall against next lower value of SUH ordinate and so on. The effective rainfall increments are then reversed to obtain critical sequence. These critical rainfall sequences are then convoluted with the SUH to estimate the direct surface runoff hydrograph. Finally, the base flow is added to estimate flood hydrograph. The estimated Standard Project Flood hydrograph with SPS is shown in Figure 6-17 and the ordinates are given in Table 6-21. The peak discharge of SPF hydrograph is estimated to be 1023.51 m^3/s.

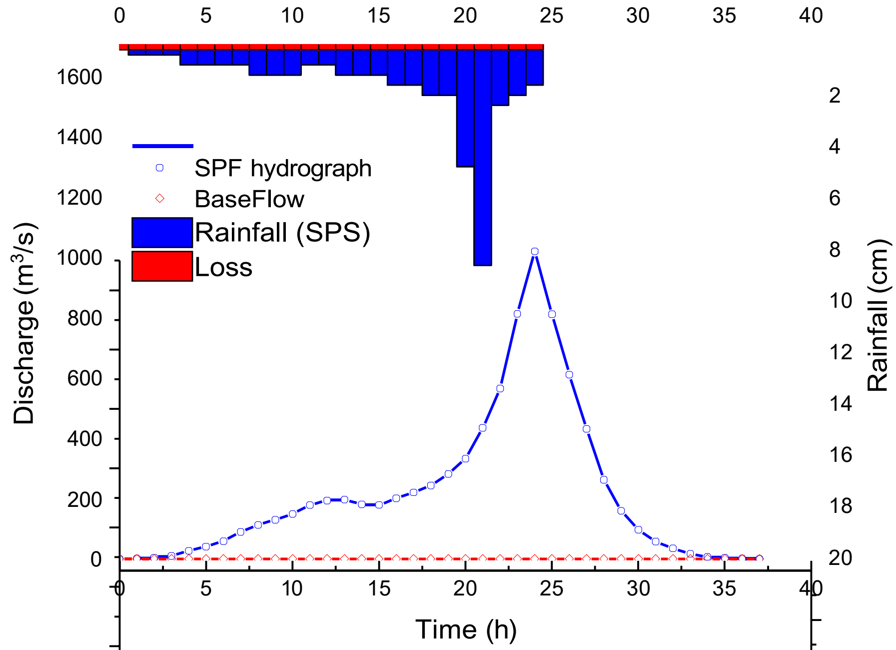
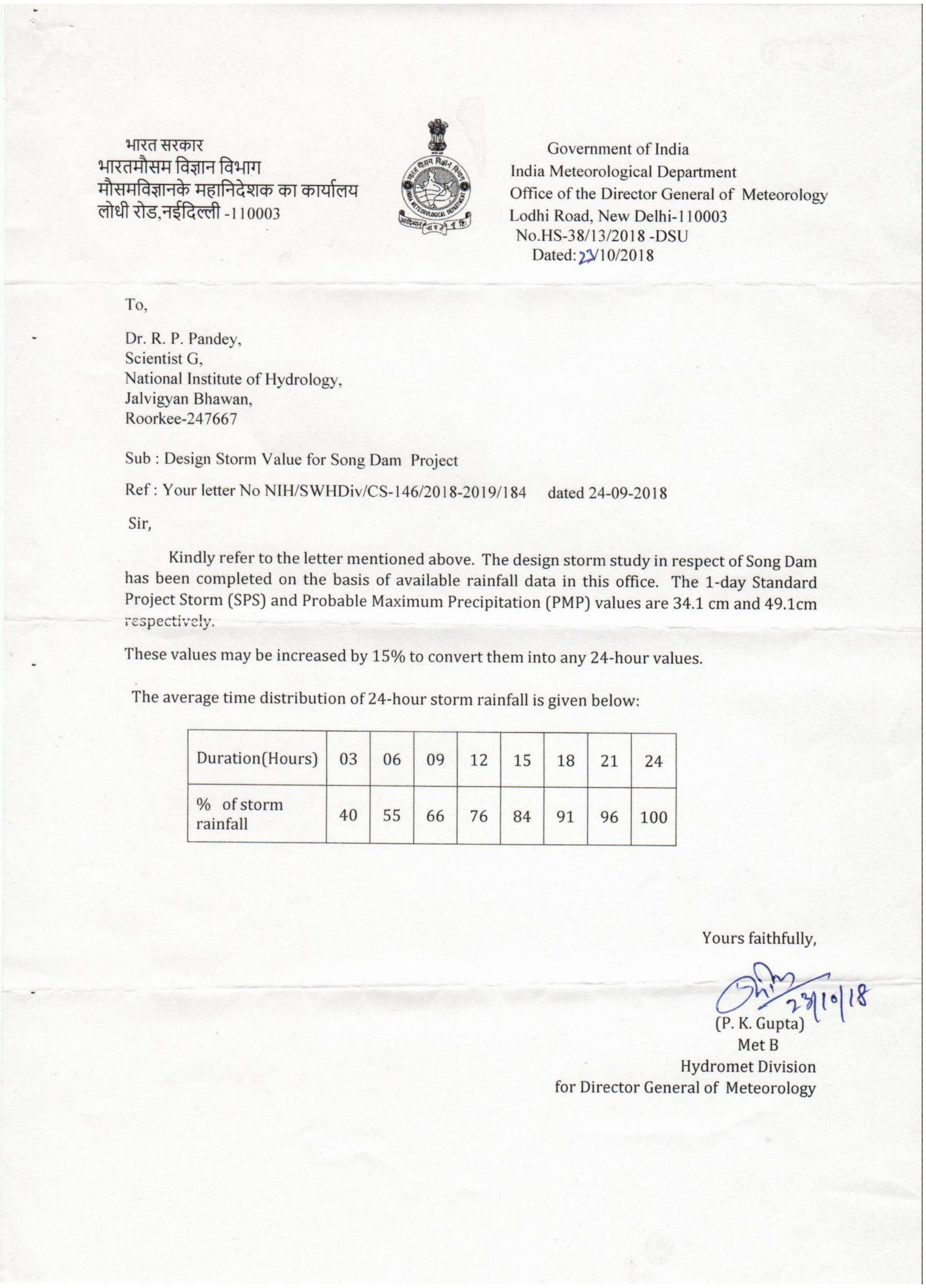


Figure 6-17: Standard project flood hydrograph

Table 6-21: Ordinates of SPF hydrographs with ERH

Time (h)	Effective Rainfall (cm)	PMF hydrograph (m^3/s)
0	0.000	4.26
1	0.192	5.43
2	0.192	8.12
3	0.192	14.26
4	0.584	30.38
5	0.584	44.90
6	0.584	62.82
7	0.584	93.72
8	0.976	116.27
9	0.976	133.86
10	0.976	153.06
11	0.584	182.65
12	0.584	198.18
13	0.976	200.68
14	0.976	184.88
15	0.976	183.12
16	1.369	205.10
17	1.369	224.71
18	1.761	247.99
19	1.761	285.73

20	4.545	335.91
21	**8.388**	438.81
22	2.153	568.96
23	1.761	816.48
24	1.369	**1023.51**
25		815.19
26		614.94
27		434.96
28		266.24
29		163.32
30		100.51
31		61.82
32		39.20
33		21.46
34		11.10
35		7.28
36		5.01
37		4.26



भारत सरकार
भारतमौसम विज्ञान विभाग
मौसमविज्ञानके महानिदेशक का कार्यालय
लोधी रोड,नईदिल्ली -110003

Government of India
India Meteorological Department
Office of the Director General of Meteorology
Lodhi Road, New Delhi-110003

No.HS-38/13/2018 -DSU
Dated: 23/10/2018

To,

Dr. R. P. Pandey,
Scientist G,
National Institute of Hydrology,
Jalvigyan Bhawan,
Roorkee-247667

Sub : Design Storm Value for Song Dam Project

Ref : Your letter No NIH/SWHDiv/CS-146/2018-2019/184 dated 24-09-2018

Sir,

Kindly refer to the letter mentioned above. The design storm study in respect of Song Dam has been completed on the basis of available rainfall data in this office. The 1-day Standard Project Storm (SPS) and Probable Maximum Precipitation (PMP) values are 34.1 cm and 49.1cm respectively.

These values may be increased by 15% to convert them into any 24-hour values.

The average time distribution of 24-hour storm rainfall is given below:

Duration(Hours)	03	06	09	12	15	18	21	24
% of storm rainfall	40	55	66	76	84	91	96	100

Yours faithfully,

23/10/18
(P. K. Gupta)
Met B
Hydromet Division
for Director General of Meteorology

Observations on design flood study by CWC.

As per BIS criteria the project qualifies for probable Maximum Flood (PMF) as design flood. For the design flood review the PMF has been computed in the present study using hydro-meteorological approach.

6.5.7. Data availability

For estimating design flood the synthetic unit hydrograph on the basis of physiographic parameters of the catchment. Flood Estimated Report (FER)-Zone 7 of CWC for western Himalayan Region has been used. Further, the 1-Day PMP value from IMD is also available. The loss and base flow are also available in the FER-Zone7.

6.5.8. Physiographic Parameters.

The physiographic parameters of the river catchment at proposed project site have been estimated by GIS processing of STRM DEM. The catchment area obtained from the GIS is about 85.26 sq.Km. The estimated parameters of the river catchment at proposed project site are given in Table 6-22**.**

Table 6-22: Sub-basin parameters

Catchment Area (Km2)	Longest flow path L (Km)	Equivalent Stream slope (m/Km)
85.26	**26.40**	**42.36**

6.5.9. Unit Hydrograph

Since, drainage area representative concurrent rainfall and discharge data at short interval are not available; the unit hydrograph (UH) for drainage area has been attempted using FER-Zone 7. The estimated UH parameters are given in Table 6-23.

Table 6-23: Unit hydrography parameters as per FER-Zone 7

Parameter	Unit	Value
tm	**Hr**	**4.00**
q_p	**cumec/sq.km**	**0.835**
W_{50}	**Hr**	**2.46**
W_{75}	**Hr**	**1.30**
WR_{50}	**Hr**	**0.93**
WR_{75}	**Hr**	**0.58**
TB	**Hr**	**14.00**
Q_p	**Cumec**	**71.18**
Base flow	**Cumecs**	**4.26**

The details of UH are given in Table 6-24 and Figure 6-18.

Table 6-24: Unit hydrograph Ordinates as per FER-Zone7

Time (hrs)	UH ordinates (cumec)
0	0.00
1	0.00
1	6.86
2	15.70
3	30.70
4	71.18
5	35.00
6	24.00
7	18.00
8	13.00
9	9.00
10	6.00
11	4.00
12	2.30
13	1.10
14	0.00

6.5.10. Design Storm

IMD has provided 1-day PMP value of 49.1cm based on 1day maximum rainfall of 48.7cm occurred on 25th July, 1966 at Dehradun rain gauge station. A clock hour correction of 50mm is applied to convert 1-day PMP to 24 hours PMP value (541.00mm) and the same is considered for further design flood studies.

The smoothened TD Coefficients for 24 hours given by IMD are considered for estimation of hourly rainfall increments. The 24 hours rainfall has been converted into two 12 hourly rainfall bells. For hourly distribution of rainfall normalized distribution coefficient has been worked out for bell of 12 hours each using the hourly distribution coefficient. The hourly distribution coefficient of 24 hour rainfall and normalized distribution coefficient for 12 hour bell are given in Table6-25**.**

Table 6-25: Two Hourly distribution coefficient of 24 hours rainfall for first 12 hour and Normalized distribution coefficient 12 hour bell

Time (hr)	Distribution coefficient for 24 hour rainfall (%)	Normalized Distribution Coefficient for 12 hour bell (%)
1	15.0	19.74
2	29.0	38.16
3	40.0	52.63
4	47.0	61.84
5	51.5	67.76
6	55.0	72.37

7	59.0	77.63
8	62.5	82.24
9	66.0	86.84
10	69.5	91.45
11	73.0	96.05
12	76.0	100.00

6.5.11. Loss rate and base flow

A design loss rate of 0.5cm/hour and base flow @ 0.05 cumecs per Sq.km as per FER-Zone has been adopted. Accordingly, the value of base flow for the design flood study has been taken as 4.26 cumecs.

6.5.12. Critical sequencing of rainfall

Hourly distribution of rainfall of each bell is given in Table 6-27. Critical sequencing of hourly effective rainfall of each bell is given in Table 6-28. The reverse of critically sequenced effective rainfall has been used for convolution with ordinates of unit hydrograph to get SPS Flood Hydrographs.

Table 6-26: 12 Hour bell distribution of rainfall

1 Day PMP value of Ganga basin as per IMD	**491.00mm**
1 Day 24 hrs Areal rainfall (with 15% clock hour correction restricted to maximum 50mm)	**541.00mm**
Depth 1st 12hr bell (0.76 X 509.47)	**411.16mm**
Depth 2nd 12hr bell (0.24 X509.47)	**129.84mm**

Table 6-27: Hourly distribution of rainfall

Time	**Dist Coeff**	**Normalised Distcoeff**	**Cumulative rainfall depth**		**Incremental rainfall depth**		**Loss Rate**	**Effective rainfall depth**	
			1st 12 hr bell	2nd 12 hr bell	**Incre-mental rainfall 1st bell**	**Incre-mental rainfall 2nd bell**		Effective rainfall 1st bell	Effective rainfall 2nd bell
Hr	**%**	**%**	**cm**	**cm**	**cm**	**cm**	**cm/hr**	**cm**	**cm**
1	15.0	19.74	8.12	2.56	8.12	2.56	0.20	7.92	2.36
2	29.0	38.16	15.69	4.95	7.57	2.39	0.20	7.37	2.19
3	40.0	52.63	21.64	6.83	5.95	1.88	0.20	5.75	1.68
4	47.0	61.84	25.43	8.03	3.79	1.20	0.20	3.59	1.00
5	51.5	67.76	27.86	8.80	2.43	0.77	0.20	2.23	0.57
6	55.0	72.37	29.76	9.40	1.89	0.60	0.20	1.69	0.40
7	59.0	77.63	31.92	10.08	2.16	0.68	0.20	1.96	0.48
8	62.5	82.24	33.81	10.68	1.89	0.60	0.20	1.69	0.40

9	66.0	86.84	35.71	11.28	1.89	0.60	0.20	1.69	0.40
10	69.5	91.45	37.60	11.87	1.89	0.60	0.20	1.69	0.40
11	73.0	96.05	39.49	12.47	1.89	0.60	0.20	1.69	0.40
12	76..0	100.00	41.12	12.98	1.62	0.51	0.20	1.42	0.31

Table 6-28: Critical sequencing for effective Hourly rainfalls with respect to UII

Time	UH Ordinate	Critical sequence of hourly effective rainfall		Reversed sequence of hourly effective rainfall		Bell sequence used for convolution (B2-B1)
		1st 12 hr bell	2nd 12 hr bell	Incre- mental Rainfall 1st bell	Incre- mental rainfall 2nd bell	
Hr	Cumec	cm	cm	cm	cm	cm
0	0.00					
1	6.86	1.694	0.398	1.423	0.313	0.313
2	15.70	1.964	0.483	1.693	0.398	0.398
3	30.70	5.751	1.679	1.694	0.398	0.398
4	71.18	7.915	2.363	1.694	0.398	0.398
5	35.00	7.374	2.192	1.694	0.398	0.398
6	71.18	3.587	0.996	2.235	0.569	0.569
7	35.00	2.235	0.569	3.587	0.996	0.996
8	24.00	1.694	0.398	7.374	2.192	2.192
9	18.00	1.694	0.398	7.915	2.363	2.363
10	13.00	1.694	0.398	5.751	1.679	1.679
11	9.00	1.693	0.398	1.964	0.483	0.483
12	6.00	1.423	0.313	1.694	0.398	0.398
13	4.00					1.423
14	2.30					1.693
15	1.10					1.694
16	0.00					1.694
17	0.00					1.694
18						2.235
19						3.587
20						7.374
21						7.915
22						5.751
23						1.964
24						1.964
25						
26						

6.5.13. PMF hydrograph

The reverse sequence of hourly effective rainfall as given in Table 6-28 has been convoluted with ordinates of 1 hr unit hydrograph to get PMF direct runoff hydrograph. The base flow contribution has been added to get the PMF hydrograph at proposed site of Song Dam Drinking Water Project. The estimated **PMF is 1228.93 cumec**. The PMF hydrograph ordinates are given in Table 6-29. A plot of the same is given in Figure 6-15. The same may be utilized for the dam safety review of the project.

Table 6-29: PMF hydrograph

Time (Hrs)	Flood Ordinate (Cumecs)	Time (Hrs)	Flood Ordinate (Cumecs)
0	**4.26**	**26**	**809.46**
1	**6.41**	**27**	**628.12**
2	**11.90**	**28**	**419.67**
3	**22.84**	**29**	**291.85**
4	**47.70**	**30**	**199.73**
5	**64.72**	**31**	**131.03**
6	**76.38**	**32**	**80.61**
7	**89.67**	**33**	**44.21**
8	**115.43**	**34**	**21.88**
9	**164.57**	**35**	**10.32**
10	**238.30**	**36**	**6.13**
11	**330.54**	**37**	**4.26**
12	**358.60**	**38**	**4.26**
13	**324.07**	**39**	**4.26**
14	**263.17**	**40**	**4.26**
15	**258.04**	**41**	**4.26**
16	**311.54**	**42**	**4.26**
17	**345.03**	**43**	**4.26**
18	**366.55**	**44**	**4.26**
19	**397.20**	**45**	**4.26**
20	**470.24**		
21	**619.50**		
22	**849.35**		
23	**1140.09**		
24	**1228.93**		
25	**1085.73**		

6.5.14. Limitations

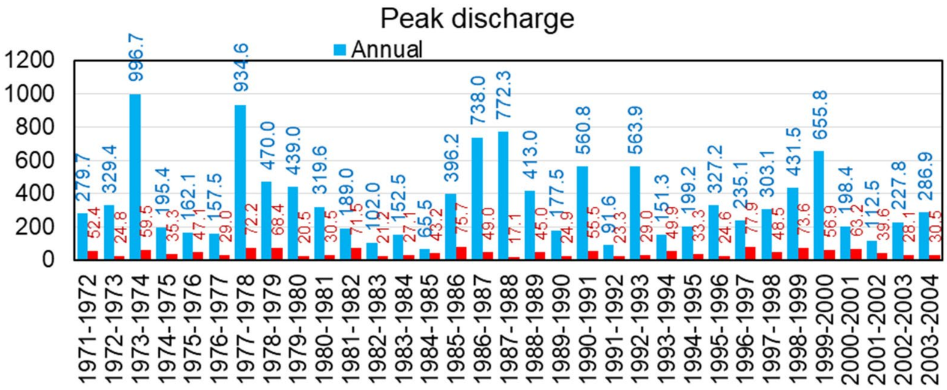
In the absence of concurrent short interval rainfall and runoff data, the unit hydrology has been prepared taking certain assumptions, which may deviate from the actual response function of the catchment. Further, the hourly distribution coefficients adopted from the FER-Zone 7 Atlas may not be truly representatives.

Conclusion

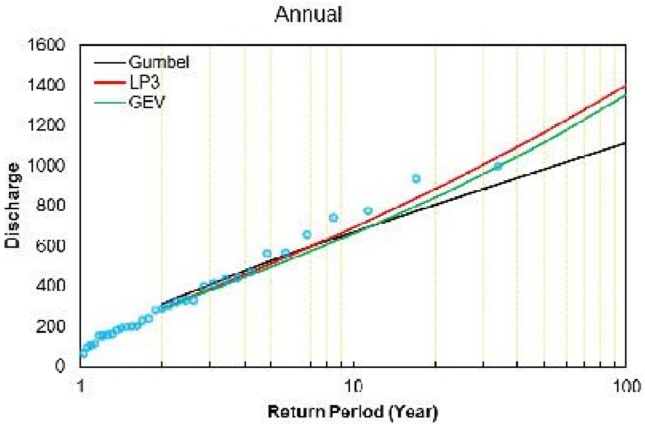
After a thorough scrutiny of the data, CWC has recommended a **PMF value of 1228.93 cumec** in its report dated 1.5.19. The methodology and calculations are well documented in the said report dated 1.5.2019 (**Annexure 6.9**) & also as laid above

6.6. Estimation of Design Flood for Diversion by NIH

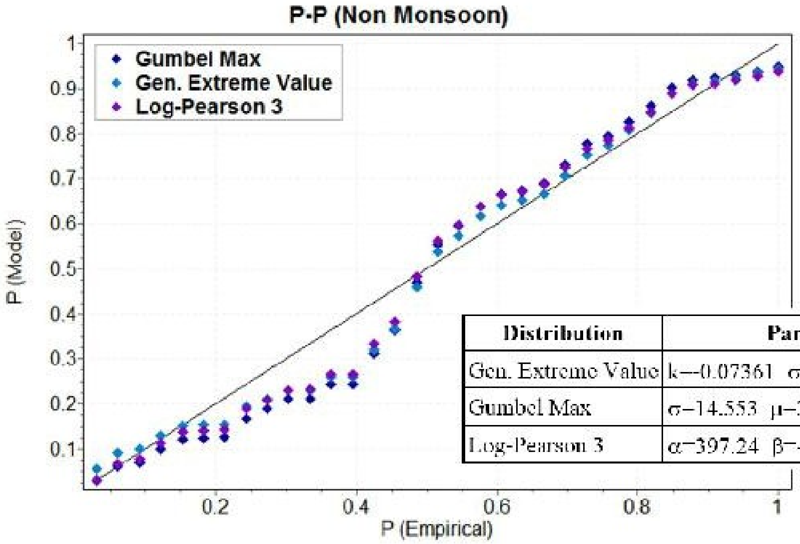
The non-monsoon (Oct-May) and annual maximum peak discharge measured at CWC site (Satyanarayana) during 1971-2004 is presented in Figure below.



Flood frequency analysis methods, Gumbel, General Extreme Value (GEV) and Log Pearson Type III (LP-III), have been applied to the annual series of non-monsoon maximum to obtain non monsoon peak flood at Satyanarayana for given return period of 25, 50, 100 and 500 years.



Distribution	Parameters
Gen. Extreme Value	k 0.18536 σ 155.08 μ 228.6
Gumbel	σ=189.5 μ=243.19
Log-Pearson 3	α=4967.3 β=-0.00975 γ=54.092



Distribution	Parameters
Gen. Extreme Value	k=-0.07361 σ=16.569 μ=35.449
Gumbel Max	σ=14.553 μ=35.481
Log-Pearson 3	α=397.24 β=-0.02223 γ=12.52

The annual and non-monsoon return flood estimated at the Satyanarayana GD site is further transposed to the Song dam site applying Dicken's Formula ($Q= CA^{3/4}$) as:

Q (Song) = Q (Satyanarayana) * $(A2/A1)^{3/4}$

Catchment area at Satyanarayana, A1 =963.7 Km^2 and at Song Dam site, A2= 85.22 Km^2, Therefore, Q (Song) = 0.22 * Q (Satyanarayana). The estimated values of annual and non-monsoon flood for different return period are presented in Table 6-30 and Table 6-31 respectively.

Table 6-30: Estimated values of annual flood for different return period at Satyanarayana and dam Site

Annual flood peak at Satyanarayana Site, m^3/s				Annual flood peak at Dam Site, m^3/s		
Return Period	**Gumbel**	**LP3**	**GEV**	**Gumbel**	**LP3**	**GEV**
2	**312.6**	**288.3**	**287.4**	**50.0**	**46.1**	**46.0**
5	**527.4**	**512.9**	**496.8**	**84.4**	**82.1**	**79.5**
10	**669.6**	**691.8**	**661.6**	**107.1**	**110.7**	**105.9**
20	**806**	**885**	**842.9**	**129.0**	**141.6**	**134.9**
25	**849.3**	**950.6**	**905.6**	**135.9**	**152.1**	**144.9**
50	**982.6**	**1166.3**	**1116.4**	**157.2**	**186.6**	**178.6**
100	**1114.9**	**1401.2**	**1354.7**	**178.4**	**224.2**	**216.8**
200	**1246.7**	**1656.6**	**1624.8**	**199.5**	**265.1**	**260.0**
500	**1420.7**	**2028.3**	**2038.9**	**227.3**	**324.5**	**326.2**

Table 6-31: Estimated values of non-monsoon flood for different return period at Satyanarayana and dam Site

Non-Monsoon flood peak at Satyanarayana Site, m^3/s				Non-Monsoon flood peak at Dam Site, m^3/s		
Return Period	**Gumbel**	**LP3**	**GEV**	**Gumbel**	**LP3**	**GEV**
2	**40.8**	**40.3**	**41.4**	**6.5**	**6.4**	**6.6**
5	**57.3**	**58.2**	**59**	**9.2**	**9.3**	**9.4**
10	**68.2**	**70.3**	**69.8**	**10.9**	**11.2**	**11.2**
20	**78.7**	**81.9**	**79.7**	**12.6**	**13.1**	**12.8**
25	**82**	**85.6**	**82.7**	**13.1**	**13.7**	**13.2**
50	**92.3**	**97.1**	**91.6**	**14.8**	**15.5**	**14.7**
100	**102.4**	**108.6**	**100.1**	**16.4**	**17.4**	**16.0**

(Note: Table 6-30 and Table 6-31 has been revised considering catchment area up to Satyanarayana site as 963.7 km^2.)

The estimated values 13.7 m^3/s, 15.5 m^3/s and 17.4 m^3/s obtained from Log Pearson (Table 6-31) may be taken as Design Diversion Floods for 25, 50 100 years return periods respectively at the Song Dam site.

Further, it is proposed to increase above values of Design Diversion Floods with 15 % increase to account instantaneous peak and to take up conservative values 15.75 m^3/s, 17.86 m^3/s and 19.98 m^3/s are recommended as Design Diversion Floods for 25, 50 100 years return periods respectively at the Song Dam site.

Observations on diversion flood study by cwc

Non-monsoon flood peak of Satyanarayana G&D site for the period from 1971 to 2004 have been used for arriving at Diversion flood at Song Dam site. Non monsoon annual maximum peak series of Satyanarayana G&D Site have been subjected to various statistical checks and then after removing one outlier, the series have been used for arriving at non-monsoon floods of various period. The 25, 50 and 100 year non-monsoon flood at Satyanarayana based on Gumble Distribution have been adopted considering statistical parameters of the events.

The 25,50 and 100 years return period non-monsoon floods value of Satyanarayana G&D site (catchment area=963.7sqkm) thus arrived at are transposed to Song Dam site (catchment area=85.225 sqkm) in (catchment area) proportion. The values of 25, 50 and 100 year return period non-monsoon floods at Song Dam site are given in Table 6-32.

Table 6-32: Diversion Flood

Return Period	**Non-monsoon floods of various return period at Song Dam site**	**Non-monsoon floods of various return period at Song Dam site (Recommended by CWC)**
(Years)	**(Cumecs)**	**(Cumecs)**
25	**15.45**	**15.45**
50	**17.41**	**17.41**
100	**19.36**	**19.36**

Song Dam is proposed to be constructed across Song River, a tributary of river Ganga, near village Sondhana in District Dehradun of the state of Uttarakhand. The catchment area up to the proposed dam site is 85.26sqkm. The dam is proposed to cater the drinking water needs of Dehradun city and surrounding areas.

Conclusion

In response to the report submitted and the replies in compliance to the observations made by CWC. For 25 year, 50 year and 100 year return period, CWC has recommended these values as **15.45**, **17.41** and **19.36** cumec respectively, which is tabulated in “Table 08- Diversion Flood” of the said report dated 01-05-2019 & as laid above (Ref: **Annexure 6.9**) which shall be considered for further design works.

6.7. Assessment of Soil Erosion and Reservoir Sedimentation Rate

Reservoir sedimentation is the process of sediment deposition into a lake formed after a dam construction. The performance of reservoirs depends on loss of storage capacity due to sedimentation process. Analysis of sedimentation survey details with respect to 43 major, medium and minor reservoirs in the country indicated that the sedimentation rate varies between 0.34-27.85 ham/100 km2/year for major reservoirs, 0.15-10.65 ham 100 km2/year for medium reservoirs and 1.0-2.3 ham/100 km2/year for minor reservoirs (Shangle, 1991).

The rate of loss of reservoir capacity depends on the annual sediment load carried by the streams and the extent to which that material is retained in the reservoir known by the trap efficiency (Te) of the reservoir. The amount of sedimentation is affected by a number of factors including the area and geologic origin of the catchment, the land uses, cultivation practices, construction activities, conservation practices, the amount of rainfall, the duration of storage in relation to the sediment load of the stream, the particle size distribution of the suspended sediment, the planform configuration of the reservoir, the location and size of sluices and other outlet works at the dam, and the method of reservoir operation (Arora and Goel, 1994).

The total sediment load of streams usually is considered to be the sum of two components, the suspended load and the bed load. In suspended load transport, the weight of the particles is supported by turbulent forces in the water and they can travel considerable distances without coming into contact with the bed. The bed load, on the other hand, moves by rolling, sliding or hops of the length of a few grain sizes (known as saltation), and they are thus in frequent contact with the channel bed. Whether an individual particle is transported as suspended load or as bed load depends on particle size, weight and shape and on the ambient hydraulic conditions. The rate of sedimentation in a proposed or existing reservoir may be estimated in the following ways (Bureau of Indian Standards 1992):

(i) From sediment discharge rating curves combined with flow-duration relations on major streams entering the reservoir. The sediment discharge rating curves may be prepared using measured or calculated values of sediment loads.

(ii) From calculations of the total amount of land surface erosion, the ability of the sediment to be transported to the reservoir, and the reservoir trapping efficiency. The bed load is often taken as some fraction of the suspended load.

(iii) From predictions based on sedimentation in existing reservoirs in which the accumulated deposits have been surveyed over a sufficiently long period.

The main objective of these sedimentation study presented in this chapter is to estimate the sediment load that may reach the reservoir of the proposed dam at Song River and estimate the sedimentation rate in the reservoir. Since no sediment discharge rating curves are available for Song River, the method (ii) mentioned above has been used to estimate the reservoir sedimentation rate. The detailed procedures and methodologies adopted are presented in this chapter.

6.7.1. Assessment of Soil Erosion

6.7.1.1. ASSESSMENT OF SOIL EROSION

Assessment of on-site soil erosion is required to identify erosion prone areas in the catchment. Estimates of the rate of soil erosion may be compared with what is considered acceptable and the erosion control measures can be planned for the areas that produce heavy sediment. Soil erosion and sediment transport in a river basin is largely governed by topographical, meteorological, land cover, soil and drainage characteristics in the basin. Since it is difficult to measure the soil loss rates physically, erosion prediction models are employed to estimate the soil erosion rates from an area. In the present study, a widely used Universal Soil Loss Equation (USLE) (Wischmeier and Smith, 1978) has been used for estimation of soil erosion in the catchment area of Song reservoir.

6.7.1.2. UNIVERSAL SOIL LOSS EQUATION (USLE)

The USLE was developed to estimate the long term average annual soil loss from sheet and rill erosion on a specified land in a specified cropping and management system. The equation does not estimate soil deposition and therefore the sediment yield. The USLE groups the numerous interrelated physical and management parameters that influence the erosion rate under six major factors, of which site specific values can be expressed numerically. The USLE is represented as:

$$A = R*K*L*S*C*P \qquad (6.1)$$

Where, A = Average annual soil loss in tonnes per ha per year; R = rainfall erosivity factor; K = soil erodibility factor; LS = slope length and slope steepness factor; C = cover management factor; and P = support practice factor.

The R factor expresses the number of rainfall erosion index units for a particular location. It is taken as the long term average of the summation of the product of total rainfall energy (E) and maximum 30 minute rainfall intensity (I_{30}), i.e. EI_{30}. The value of R factor increases as the amount and intensity of rainfall increases.

The K factor is an expression of the inherent erodibility of the soil or surface material and is taken as the soil loss per erosion index unit for a specified soil as measured on a unit plot which is defined as 22.13 m long of uniform 9% slope and tilled continuously fallow. K factor is a function of the percentage of silt and coarse sand, soil structure, permeability of soil and the percentage of organic matter.

The L factor is defined as the ratio of soil loss from the field slope length to that from a 22.13 m length under identical conditions. The S factor is defined as the ratio of soil loss from the field slope gradient to that from a 9% slope under otherwise identical conditions. The combined LS factor represents the effect of topography on soil loss. The value of LS factor increases with the increase in slope length and slope steepness.

The C factor is defined as the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow. The factor expresses the effects of surface cover and roughness, soil biomass, and soil disturbing activities on the rate of soil loss at a particular site. The value of C factor decreases as surface cover and soil biomass increases, thus protecting the soil from rain splash and runoff.

The P factor is defined as the ratio of soil loss with a support practice like contouring, strip cropping, or terracing to that with straight row farming up and down the slope. The P factor expresses the effects of supporting conservation practices on soil loss at a particular site. The value of P decreases with the installation of conservation practices.

6.7.1.3. APPLICATION OF USLE

In the present study, the soil erosion is estimated in the catchment area of proposed Song reservoir. The base maps, USLE factor maps and soil erosion map were prepared in GIS environment using ArcGIS software as described below:

6.7.1.3.1. Base maps preparation

Digital elevation model (DEM)

DEM is required for computing the slope length and steepness factor of the USLE. The DEM of the study area (Figure 6-18) was generated using ALOS PALSAR data. The DEM was then used to create the slope map. The computed area under different slope classes is presented in Table 6-33.

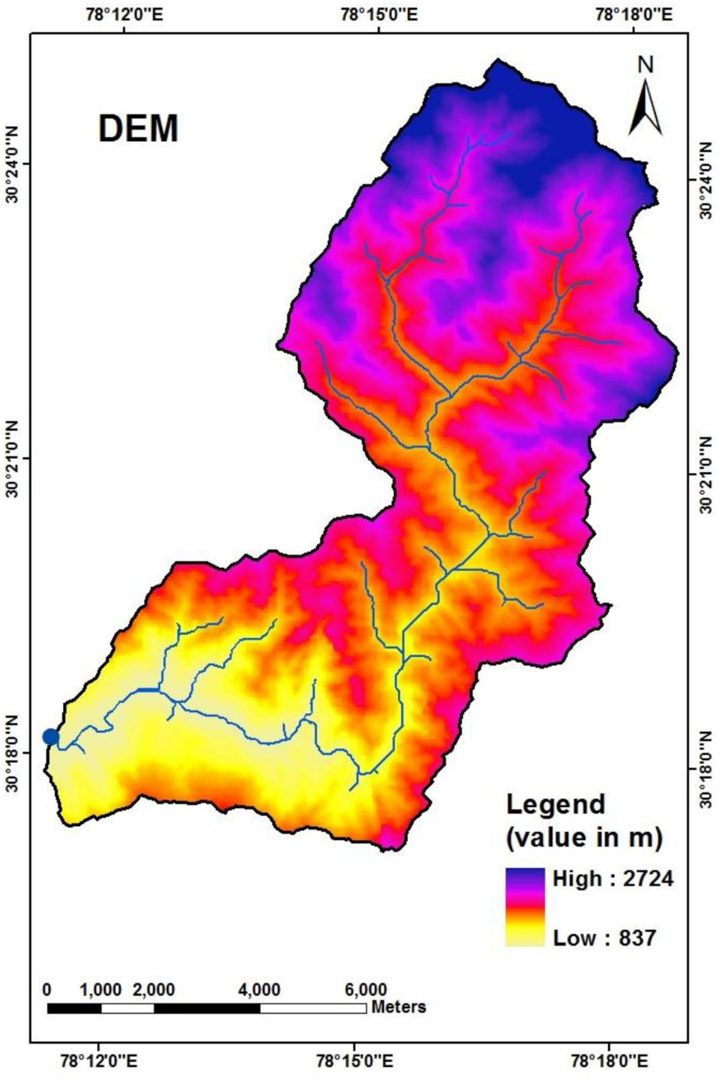


Figure 6-18: DEM of Song reservoir catchment

Table 6-33: Slope class-wise area of Song reservoir catchment

S. No.	Slope Class (%)	Area (Km2)	% of total area
1	<5	0.327	0.384
2	5-10	0.988	1.160
3	10-20	3.814	4.475
4	20-50	34.082	39.989
5	50-100	41.895	49.159
6	100-300	4.114	4.827
7	>300	0.005	0.006
Total		85.225	100.000

Soil map

Soil map at the scale of 1:500,000 prepared by National Bureau of Soil Survey and Land Use Planning (NBSS & LUP), Nagpur have been used. The maps were georeferenced and the relevant soil units pertaining to the catchment area were digitized (Figure 6-19). The description of the soil units shown in the soil map is given in Table 6-34.

Table 6-34: Soil types in the study area (NBBSS & LUP)

Mapping units	Soil description	Area (Km2)
13	Moderately shallow, excessively drained, thermic, loamy skeletal soils on moderately steep slopes with loamy surface, moderate erosion, and moderate stoniness; associated with: shallow, excessively drained, loamy soils with loamy surface, severe erosion and strong stoniness.	9.910
14	Moderately shallow, somewhat excessively drained, thermic, fine loamy soils on moderate slopes with loamy surface, moderate erosion, and slight stoniness; associated with: moderately shallow, excessively drained, loamy-skeletal soils with loamy surface, moderate erosion and slight stoniness.	14.664
17	Very shallow, excessively drained, thermic, loamy soils on very steep slopes with loamy surface, very severe erosion, and strong stoniness; associated with: shallow, excessively drained, loamy-skeletal soils with loamy surface, very severe erosion and moderate stoniness.	48.795
26	Moderately shallow, excessively drained, thermic, loamy-skeletal soils on steep slopes with loamy surface, moderate erosion, and moderate stoniness; associated with: shallow, excessively drained, loamy skeletal soils on very steep slopes with loamy surface, severe erosion and moderate stoniness.	2.743
45	Moderately deep, well drained, thermic, coarse loamy soils on moderate slopes with loamy surface and moderate erosion; associated with: deep, well drained, fine loamy soils with loamy surface and slight erosion.	9.113

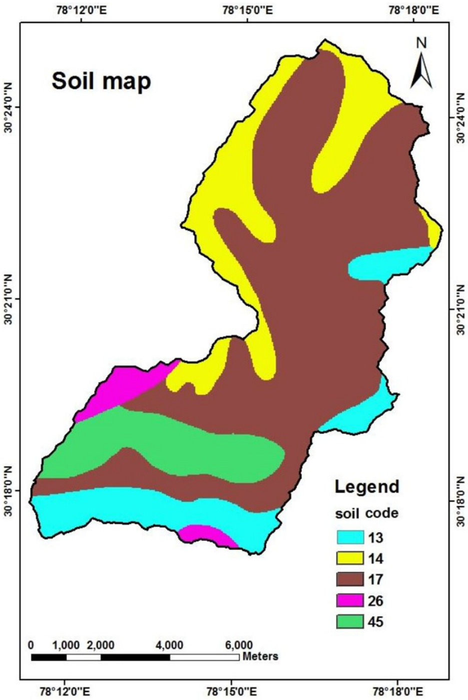


Figure 6-19: Soil map of Song reservoir catchment

Land use map

The land use map is required for estimating the cover and management factor of the USLE. Land use/cover classification was carried out using LISS III satellite data by supervised classification method. Six land use classes viz., forest, agricultural land, range land, settlement, barren outcrop and swampy land were identified in the catchment as shown in Figure 6-20. The area under each land use category is presented in Table 6-35.

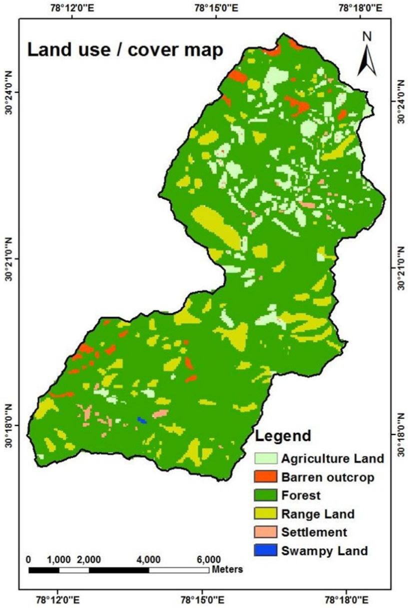


Figure 6-20: Land use/land cover map of Song reservoir catchment

Table 6-35: Details of land use/land cover in the Song reservoir catchment

S. No.	Land use/land cover	Area (Km2)	% of total area
1	Forests	68.163	79.981
2	Agricultural land	6.610	7.756
3	Range land	8.238	9.666
4	Settlement	0.728	0.854
5	Barren outcrop	1.445	1.695
6	Swampy land	0.041	0.048
Total		85.225	100.000

6.7.1.3.2. Estimation of USLE factors

R factor: The rainfall erosivity factor, R, accounts for the potential of falling rain drops and flowing water in a particular area to produce erosion. In India, research has shown that R factor can be computed using the following relation (Singh et al., 1981).

$$R = 79 + 0.363*X \text{..} (6.2)$$

Where, X is the average annual rainfall in mm.

The average annual rainfall data of two rain gauge stations namely, Dhanolti (1320 mm) and Song dam site (2136 mm) were used and a Thiessen polygon map of the rainfall was prepared for the study area. The Thiessen polygon map was converted to raster format using a grid cell size of 30 m. The R factor map (Figure 6-21) was then computed from the rainfall map using **Eq. 6.2.**

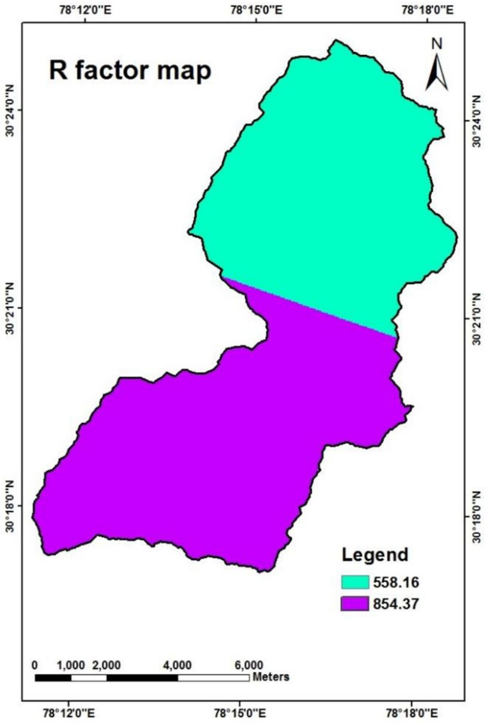


Figure 6-21: Rainfall erosivity factor (R) map of Song reservoir catchment

K Factor: The soil erodibility factor, K, considers soil properties that influence both detachment and transport of soil materials. These include soil organic matter content, texture, structure, size, shape, and stability of aggregates, and the permeability of the soil to water. Soil erodibility tends to increase with greater silt content and decrease with greater sand and clay contents. Organic matter binds individual particles together thus increasing aggregate strength, hence the resistance to detachment. Soil structure, in terms of its size, shape, and aggregate stability, influences the infiltration rate. Erosion will not occur if the infiltration rate is greater than the rainfall rate. Permeability of the soil to water affects erosion because rainfall must enter and move through the soil if runoff is to be minimal.

Based on the description of soil mapping units given in Table 6-34, appropriate K values for each soil polygon were assigned in the soil map. The gridded spatial distribution of K values was then prepared in the form of a K factor map as shown in Figure 6-22**.**

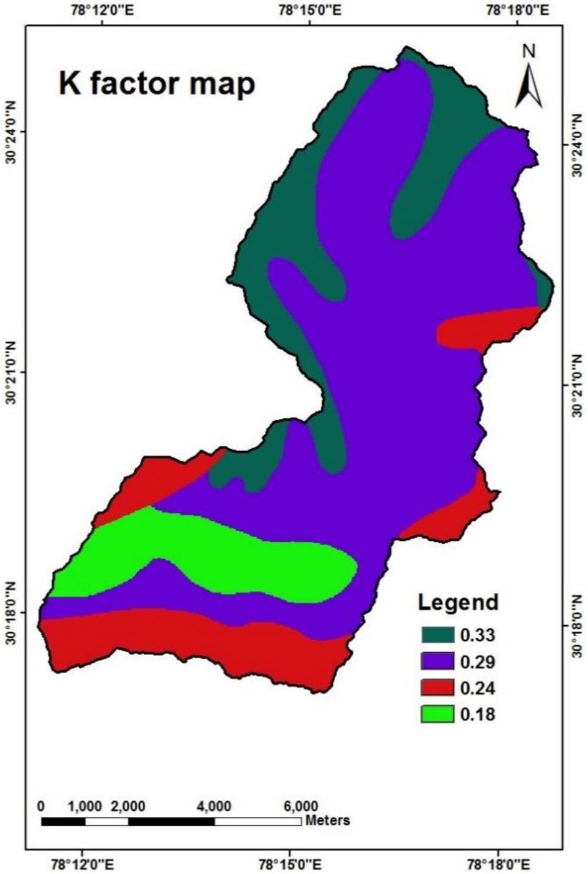


Figure 6-22: Soil erodibility factor (K) map of Song reservoir catchment

LS factor: Soil erosion by water is affected by slope length, L, and slope steepness, S, which jointly determine the amount and velocity of runoff.

As L factor is the ratio of field soil loss to the corresponding soil loss from 22.13 m slope length, its value is computed using Eq. 6.2 (Wischmeier and Smith, 1978).

$$L = (\lambda/22.13)\ m \qquad (6.3)$$

Where λ is the field slope length and m assumes the value of 0.2 to 0.5. Wischmeier and Smith (1978) gave varying values of 'm' for different slopes as given in Table 6-36**.**

A map showing the distribution of m values was created using the slope map as input. The L factor map was then computed by taking the field slope length as 30 m (grid size) using Eq.6.3. The S factor map was computed using Eq.6.3 (McCool et al., 1987; Liu et al., 1994).

$S = 10.80 \sin \theta + 0.03 \qquad \theta < 5.14°(\text{or } 9\%)$

$S = 16.80 \sin \theta - 0.50 \qquad \theta \geq 5.14°(\text{or } 9\%) \qquad (6.4)$

Where, θ is the slope gradient in degrees. The combined LS factor map was calculated by multiplying the L and S factor maps. The combined LS factor map is shown in Figure 6-23**.**

Table 6-36: Values of 'm' for different slope classes

Slope gradient	Value of 'm'
< 1%	0.2
1 - 3%	0.3
3 - 4.5%	0.4
above 4.5%	0.5

C factor: The vegetation cover has a big impact on the erosion. The land cover intercepts the rainfall, increases the infiltration and reduces the rainfall energy. The values of C factor (Table 6-37) for different land uses were taken from the land use attribute data and assigned to each classification. The gridded maps showing the spatial distribution of C factor for the study area is presented in Figure 6-24**.**

Table 6-37: C factor values for different land uses in the study area

Land use	C
Forests	0.004
Agricultural land	0.28
Range land	0.01
Settlement	0.18
Barren outcrop	0.15
Swampy land	0.002

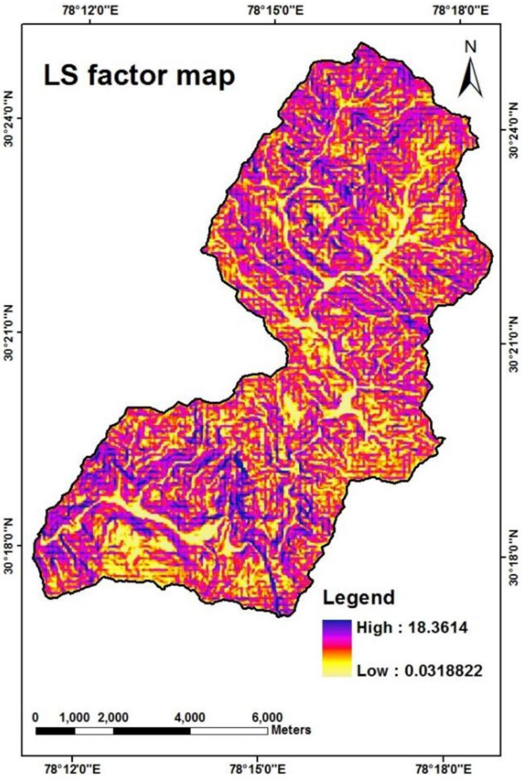


Figure 6-23: LS factor map of Song reservoir catchment

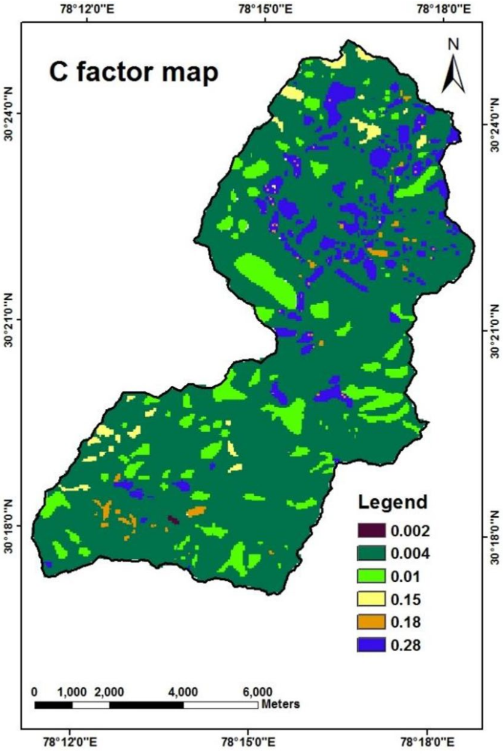


Figure 6-24: C factor map of Song reservoir catchment

P factor: In the study area no major supporting conservation practices are followed except that the agricultural plots under cultivation are bunded. Therefore, agricultural land was assigned P factor of 0.30 and other land uses were assigned P factor of 1. The P factor map is shown in Figure 6-25**.**

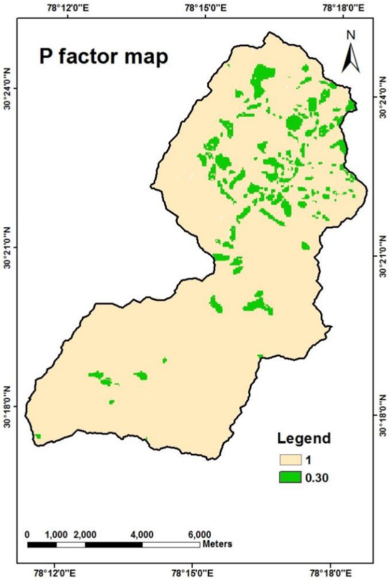


Figure 6-25: P factor map of Song reservoir catchment

6.7.1.3.3. Estimation of soil erosion

All the factor maps of R, K, LS, C and P, generated in the form of raster maps, were multiplied in GIS to produce the final map of soil erosion intensities. The soil erosion intensities were classified into various erosion classes as per the severity of the erosion. The areas computed under each erosion class are presented in Table 6-38. The soil erosion map showing the spatial distribution of erosion intensity classes is shown in Figure 6-26**.**

As can be seen from Table 6-38, about 73% of the catchment of the proposed song reservoir has soil erosion up to 10 t/ha /year and the soil erosion classes of high, very high, severe and very severe erosion (>10 t/ha/year) cover an area of about 27% only. The generally accepted maximum limit of soil erosion (tolerance limit) is 11.2 t/ha/year (Wischmeier and smith, 1978), while Rubio (1986) considered a tolerance limit of 20 t/ha/year. Sudhishri et al. (2014) found that the tolerance limit in North-western Himalayas of India varies from 5 to 12.5 t/ha/year. Considering these tolerance limits, the soil erosion rate in about 73% of the catchment is within safe limits. However, some site-specific soil conservation measures may be planned and implemented in the remaining areas having higher soil erosion. The mean rate of gross soil erosion in the study catchment is computed as 22.16 t/ha/year.

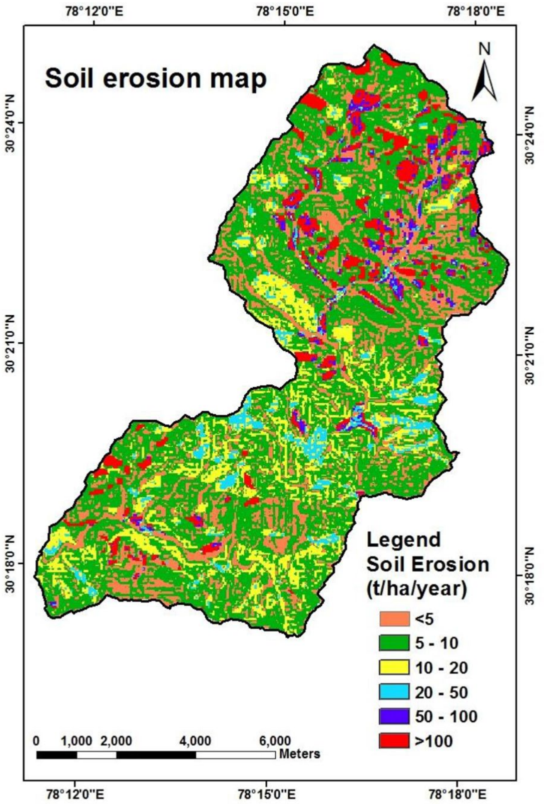


Figure 6-26: Soil erosion map of Song reservoir catchment

Table 6-38: Area under different soil erosion classes in Song reservoir catchment

Erosion class	Rate of soil loss (tons/ha/year)	Area (sq km)	% of total area
Slight	<5	18.527	21.740
Moderate	5-10	43.305	50.811
High	10-20	11.795	13.839
Very high	20-50	3.480	4.084
Severe	50-100	2.242	2.631
Very severe	>100	5.876	6.895
Total		85.225	100.000

Weighted mean rate of soil erosion from the study catchment = 22.16 tonne/ha/year

6.7.2. Assessment of Sediment Yield at Song reservoir

While the USLE computes gross sheet and rill erosion, it does not directly predict downstream sediment yield. All the eroded sediments from the contributing area do not enter the stream network and a part of the sediment load in the surface runoff may get deposited in the area itself depending on transport capacity of the overland flow, which is primarily a function of the depth and velocity of the overland flow and the sediment load in the overland flow. If the transport capacity of the overland flow is less than the sediment load being transported, the excess sediment load is deposited in the watershed.

The sediment delivery ratio (SDR) is commonly used to compute the sediment yield from gross soil erosion. The sediment yield can be estimated by multiplying the gross erosion by the SDR, if it is known or can be approximated for the watershed. The sediment delivery ratio for many watersheds has been estimated at 25 percent, plus or minus 15 percent, depending more on size of the watershed than any other factor. The SDR is generally higher for smaller watersheds and it decreases with increase in the size of the watershed. The USDA-SCS (1983) developed a SDR model based on the data from the few catchments. A power function was derived between SDR and the catchment area (Eq.6.5):

$$SDR = 0.417762\,A^{-0.134958} \qquad (6.5)$$

where A = drainage area in sq. miles.

Vanoni (1975) used the data from 300 watersheds throughout the world to develop a model by the power function. This model is considered a more generalized one to estimate SDR and is given by Eq. 6.5 as:

$$SDR = 0.42\,A^{-0.125} \qquad (6.6)$$

The SDR for the Song reservoir catchment (area = 85.225 sq km or 32.90 sq miles) is computed as 0.260 and 0.271 using Eq. 5.5 and Eq. 5.6 respectively. In this study, higher of the two values of SDR i.e. 0.271 is taken for computation of sediment yield.

Suspended Sediment load

The mean rate of gross soil erosion in the study catchment using USLE is computed as 22.16 t/ha/year. With the computed mean rate of soil erosion of 22.16 t/ha/year, the gross soil erosion from the entire catchment (area=85.225 sq km) works out to 0.189 Million tonnes/year. Using the SDR of 0.271, the sediment yield from the catchment is computed as 0.0512 Million tonnes/year.

The low sediment yield from the catchment can be justified in view of its land use pattern. About 80% of the catchment is covered under thick forest which produces very low soil erosion. Also, the range lands accounting for about 10% of the catchment contribute low sediment load. Remaining about 10% of the area which mainly comprises of agricultural and barren lands has high potential for sediment production.

The computed sediment yield was compared with the observed sediment yield. The daily discharges and sediment concentration were measured at the proposed dam site by the Department of Irrigation, Govt. of Uttarakhand during monsoon seasons (mostly 15th June to 15th October) of the years 2002 to 2005. The sediment yield atthe dam site during four months of monsoon season was found to vary from 0.00363 to 0.0205 Million tonnes per year. Considering that the major sediment load would reach the reservoir during monsoon months only with little sediment load during lean season, the computed sediment yield of 0.0513 Million tonnes/year in the present study is quite safe for adoption in the design of the proposed dam for estimating the dead storage allowance in the reservoir.

Bed Load

The bed load in rivers moves in sliding, rolling or jumping modes along the bed and will not affect the turbidity of water. The bed load is thus in frequent contact with the channel bed. Bed load may vary from 10-20% of the suspended load in general (Simons and Sentürk, 1977; Holland, 1978; Summerfield and Hulton, 1994; Hay, 1998; Basumallick and Mukherjee, 1999; Galy and France-Lanord, 2001; Lavé and Avouac, 2001) and sometimes 20-40% for Mountain Rivers (Dadson et al., 2003; Turowski et al., 2007, 2008). Yang (1996) stated that in most natural rivers, sediments are mainly transported as suspended load, and generally, the bed load to suspension load ratio is about 5-25%. The Himachal Pradesh Electricity Board (HPSEB) regularly calculates the bed-load of Himalayan Rivers as 15-20% of the suspended load.

Measured data of the bed-load for the Song River in the study area was not available. Therefore, the bed load at the dam site is computed by taking a conservative value of 25% of the suspended sediment load as given below.

1. Computed suspended sediment load = 0.0512 Million tonne/year
2. Bed load (@25% of suspended load) = 0.0128 Million tonne/year.

6.7.3. Assessment of Reservoir Sedimentation Rate

Total Sediment Load

The total sediment load that may enter the reservoir is the sum of the suspended load and the bed load. In the present study, it is computed as 0.064 Million tonnes per year as given below.

1. Suspended sediment load = 0.0512 Million tonne/year
2. Bed load = 0.0128 Million tonne/year

Total load = 0.0640 Million tonne/year

Sediment Trap Efficiency of Reservoir

Trap efficiency (Te) is the ratio of deposited sediment to the total amount of sediment inflow for a given period with in the reservoir's economic lifetime; it calculates the percentage of the inflowing sediment mass that remains permanently in the reservoir. It is calculated as:

$$T_e = \frac{\{y_{s(in)} - y_{s(out)}\}}{\{y_{s(in)}\}} \qquad (6.7)$$

Where, T_e is the trap efficiency expressed as decimal, γ_s is the sediment yield in weight units. The reservoir designer multiplies the T_e value by the estimated sediment load for the reservoir design life to determine the sediment storage requirement. This establishes the probable useful life of the reservoir. The trap efficiency depends primarily upon the terminal velocity of the sediment particles, flow rate, and velocity through the reservoir, as well as the size, depth, shape, and operation rules of the reservoir. The particle fall velocity again is a function of particle size, shape, and density; water viscosity; and the chemical composition of the water and sediment.

The sediment trap efficiency of the reservoirs generally varies from 94 to 99%. In the present study, it is taken as 96% for further computations.

Bulk Density of Sediment Deposits in Reservoir

The bulk density (unit weight of dry sediment material in tonne/m3) of the deposits provides a simple and direct conversion from the dry weight of sediments added to the reservoir to the volume of water displaced. The bulk density will vary with the proportions of sand (>0.05 mm), silt (0.01 to 0.05 mm) and clay materials (<0.01 mm), the type of reservoir operation (exposed or submerged sediment deposits), the consolidation period, and the organic material that can sometimes make up a large part of the lake sediments. The variation range is about 1.2 to 1.6tonne/m^3. The lower densities generally occur in the vicinity of the dam under submerged conditions, while the higher densities generally occur in the upstream part of the reservoir and exposed regions after drawdown of the reservoir. In the present study, an average value of bulk density is considered as 1.35 tonne/m3 for computing the sedimentation rate in the Song reservoir.

Reservoir Sedimentation Rate

The sedimentation rate in the proposed Song reservoir is computed as 0.0455 MCM/year or 4.55 ha m/year as shown in Table 6-39. If this uniform rate of sedimentation continues, the loss in live storage would be around 4.55 MCM or 455 ha-m over 100 years.

Table 6-39: Computation of reservoir sedimentation rate

Total sediment load	Reservoir trap efficiency	Bulk density	Sedimentation rate in reservoir	Sedimentation over 100 years
Million tonne/year	%	tonne/m^3	MCM/year (ha-m/year)	MCM (ha-m)
0.0640	96	1.35	0.0455 (4.55)	4.55 (455)

6.7.4. Summary of Results

The soil erosion study in the catchment area of proposed Song reservoir shows wide range of soil erosion rates. High soil erosion rates are present in the regions of steep slopes covered mostly under agriculture and barren lands. The areas covered under forests and range lands mostly show slight to moderate erosion rates. The weighted mean rate of soil erosion in the catchment is computed as 22.16 tonnes/ha/year. The sediment delivery ratio (SDR) for the Song reservoir catchment is computed as 0.271. Using the concept of SDR and the USLE computed gross soil erosion, the sediment yield at Song reservoir is computed as 0.0512 Million tonne/year. The bed load is assumed as 25% of the suspended load amounting to 0.0128 Million tonne/year. The total sediment load, taken as the sum of the suspended load and the bed load, is computed as 0.0640 Million tonne/year. Considering the trap efficiency of the reservoir as 96% and the bulk density of sediment deposits in the reservoir as 1.35 tonne/m^3, the average rate of sedimentation in reservoir has been computed as 0.0455 MCM per year or 4.55 ha-m per year. If this uniform sedimentation rate is assumed for next 100 years, the loss of live storage would be around 4.55 MCM or 455 ha-m.

Observations on Sedimentation Study of proposed Song Dam Drinking Water Project by CWC

Song Dam is proposed to be constructed across Song River, a tributary of river Ganga, near village Sondhana in District Dehradun of the state of Uttarakhand. The catchment area up to the proposed dam site is 85.26 sqkm. The dam is proposed to cater the drinking water needs of Dehradun city and surrounding areas.

Data Availability

The following data have been furnished by the project authorities

Table 6-40: Sediment Data Availability

Name of Station	Type of Data	Period
Song dam site	Sediment/discharge data	01.08.2001 to 15.10.2001
		01.07.2002 to 15.10.2002
		16.06.2003 to 15.10.2003
		15.06.2004 to 15.10.2004
		01.07.2005 to 16.10.2005

As there are gaps in the data, the annual sediment load could not be assessed based on above observed sediment data.

Sedimentation Study

As per the project authorities, weighted mean rate of soil erosion in the Song catchment has been taken as 22.16 tonne/ha/year. The sediment Delivery Ratio (SDR) has been estimated as 0.271. Using the concept SDR and Universal Soil Loss Equation (USLE) computed gross soil erosion, the sediment yield for the Song reservoir has been computed as 0.0512 million tone/year. The bed load has been assumed as 25% of the suspended load amounting to 0.0128 million tonne/year. Thus total sediment load has been taken as 0.0640 million tonne per year. By taking Trap efficiency as 96% and bulk density of sediment deposited as 1.35 tonne/m^3 the average rate of sedimentation in the Song reservoir has been computed as 4.55 ha m per year.

In absence of site specific sediment load data, the sediment rates of observed/ adopted for nearby projects were explored. As per “compendium on silting of Reservoirs in India-2015”, the observed rate of siltation in respect Tehri Dam is 0.932. The cum./sqkm/year. Further, for Himalayan Region (Indus, Ganga and Brahmaputra basin), the median value of rate of siltation is 1.581 th.cum/sqkm/year as per the compendium. the sediment rates adopted for LakhvarVyasi and Renuka Dam is 1.280. the cum/sqkm/year and 1.581 th.cum/sqkm/year respectively. Considering these facts, sediment rate of 0.932 th.cum/sqkm/year as observed at Tehri, Dam has been adopted for sediment studies of Song Dam and the annual sediment load of 7.95Ham is computed for the catchment area of 85.26sqkm. The FRL of Song Dam is EL 980.00m and the river bed level is EL 875.00m.

Inflow into the Song reservoir has been considered as 138.14 MCM based on average 10-daily discharge series at dam site for the period from 1971-72 to 2012-13 (approved series). Considering initial reservoir elevation area capacity curve, the slope (m) works out as 2.41 and hence, the dam comes under Type III category (Hill Type) i.e. m=1.5 to 2.5 as per IS: 5477-Part II-1994.

The ratio of average annual volume of sediment deposition (7.95Ham) and the gross storage (3782.55HaM) is 0.21% and as per IS: 12182-1987, the problem of siltation is categorized as "Significant and requires further studies" (between 0.10% and 0.50%) Hence, the Trap efficiency has been rechecked ever 5year based on Brune's Curve and details are given below;

After assessing the expected volume of total sediment deposition and type of reservoir, revised elevation area capacity curve and new zero elevation are calculated by Empirical Area Reduction Method. As per IS: 12182-1987 for an Irrigation project, the new zero elevation after 100 years and Revised Reservoir Elevation Area Capacity curve after 50 years have to be computed.

The revised Reservoir Elevation Area Capacity of Song Dam reservoir after 50 years is given in the Table 6-41 below.

Table 6-41: Revised Reserved Elevation Area Capacity of Song Dam Reservoir after 50 years

Elevation (m)	Revised Area (Ha)	Revised Capacity (HaM)
995	83.46	3411.39
990	77.10	3009.98
985	71.48	2638.53
980	64.20	2299.32
975	58.38	1992.86
970	53.76	1712.52
965	48.28	1457.42
960	43.45	1228.08
955	39.48	1020.77
950	34.59	835.61
945	30.21	673.61
940	25.64	533.99
935	21.86	415.25
930	18.14	315.24
925	15.67	230.71
920	12.21	161.02
915	10.05	105.36
910	6.88	63.03
905	5.22	32.80
900	2.50	13.50
895	1.28	4.04
890	0.02	0.78
889.60	0.00	0.00
885	0.00	0.00

880	0.00	0.00
875	0.00	0.00

Thus, after a thorough scrutiny of the data, CWC has recommended, **the new zero elevation after 100 years** is computed as **EL 910.366m** in its report dated 1.5.19. The methodology and calculations are well documented in the said report dated 1.5.2019 (**Annexure 6.10**) & also as laid above.

6.8. Conclusions

The detailed hydrological study of proposed Song Dam Drinking Water Project revealed that sufficient water is available in the Song Dam site to meet the drinking water supply of 150 MLD to the Dehradun city and adjoining area with a storage reservoir of 26.4 MCM capacity at 980 m FRL.

The probable Maximum Flood has been estimated as 1228 m^3/s. The average rate of sedimentation in reservoir has been computed as 0.0795 MCM per year. Thus, in 100 years, the total loss to reservoir storage would be around 7.95 MCM or 795 ha-m.

In view of the above, it is concluded that the creation of 26.4 MCM reservoir storages is feasible from water availability point of view to meet the demand of 150 MLD.

6.9. References

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7. DESIGN FEATURES AND CRITERIA FOR DIFFERENT STRUCTRES- CIVIL STRUCTURES, HYDRO MECHANICAL EQUIPMENTS AND ELECTRO MECHANICAL EQUIPMENTS

7.1. General

The general layout of the entire project has been discussed in earlier sections. The dam axis has been finalised as per earlier sections. A RCC Dam is proposed at the selected location. From the dam, a 15km long Water conductor system will start to carry water to the treatment plant located near Khalanga War Memorial. The overall layout is shown in Figure 7-1.

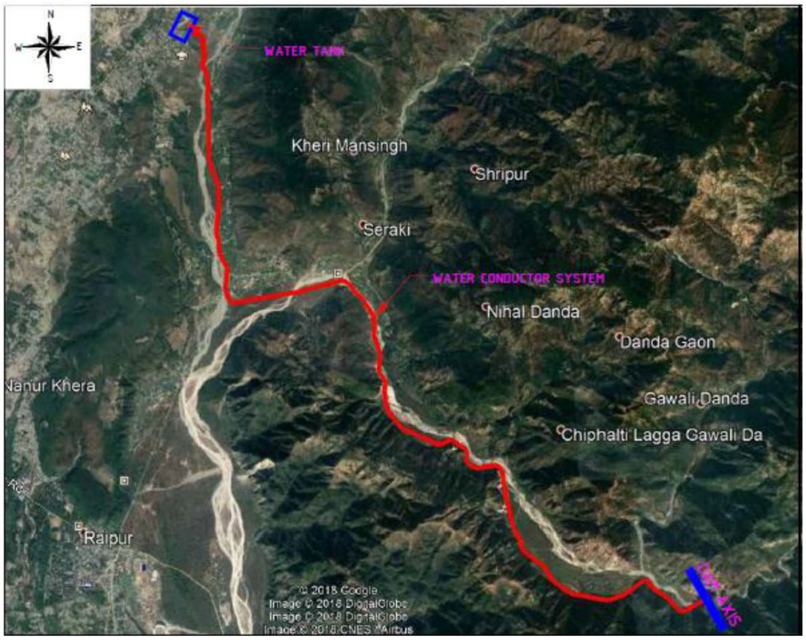


Figure 7-1: Layout of the project

The chapters discusses the design aspects of all the structures as encountered in the project- from civil structures, Hydro-mechanical equipment and electro-mechanical equipment. The salient features and basic design criteria are discussed in respective sections.

7.2. Civil Structures

7.2.1. Dam

Project envisages 130.6m high dam from deepest foundation level.

The Song Dam is of height 130.60m with Founding Level at EL.851.40m and top level at El.982. m. The FRL has been fixed at EL. 980.00m with water supply of 150 MLD. The dam layout has been finalised with arrangements of total 3nos of Spillways i.e. 1 no. high level spillway and 2 no. of Sluice type spillway at lower levels. The FRL in the previous DPR was kept at EL. 995m. However, owing to the topography and geological aspects of the site, it was decided to be kept top level of Dam at El. 982.00 As per the MOM dated 17.11.2018.

Intake with a trash rack arrangement is also provided at left bank of dam with invert level 918.00. The water conductor of 1.5m diameter starts from intake and continues for 15kms towards the WTP location near Khalanga War Memorial. Water Conductor is having two river crossing to reach the WTP. Water pipe is supported with anchor blocks and saddle supports at various location.

The location of the dam axis is fixed. The dam axis is fixed and the following figure shows the location of dam axis.

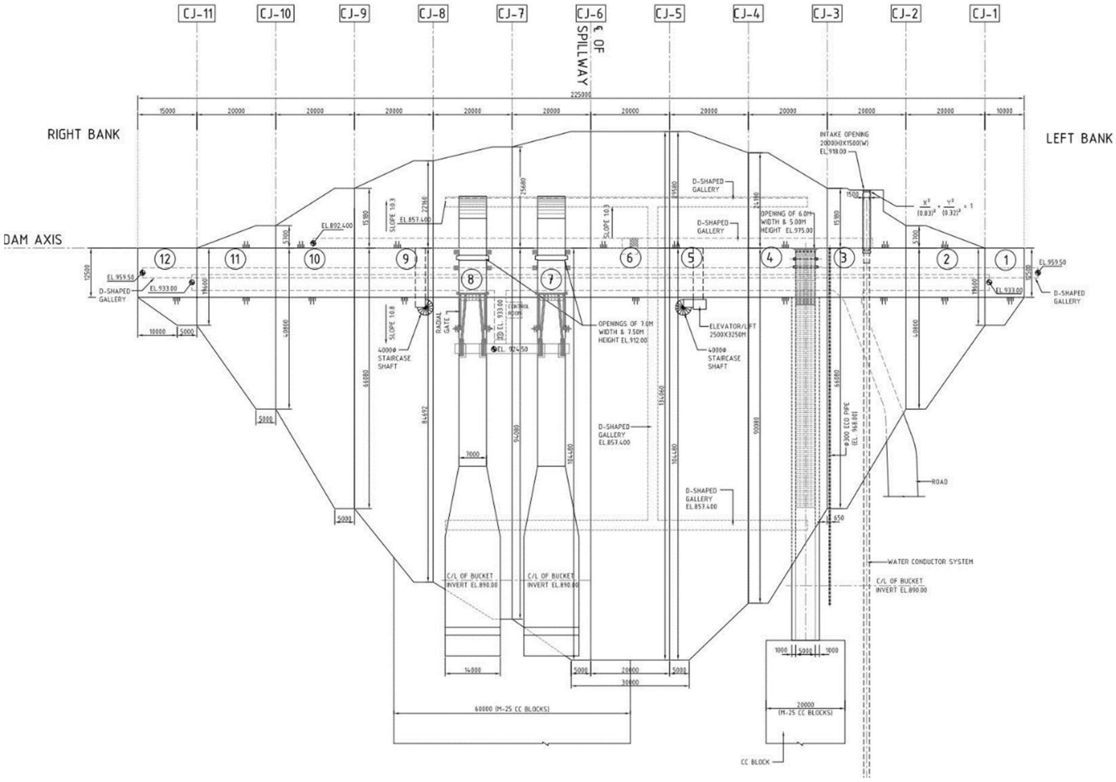


Figure 7-2: Layout of Dam with Dam Axis.

This reports deals with hydraulic design of dam and spillway. Detail design of dam includes following aspect as follows:-

Hydraulic calculation

- Dam classification
- Capacity of spillway
- Geometry of spillway profile‘s
- Energy dissipation system.
- Free board.

Stability Calculation

7.2.1.1. HYDRAULIC DESIGN

7.2.1.2. UPSTREAM WORKS AND DESCRIPTION

The layout and other upstream view of the Dam are given in Figure 7-2 and Figure 7-3. The main features of the upstream components of the Project are summarized below:

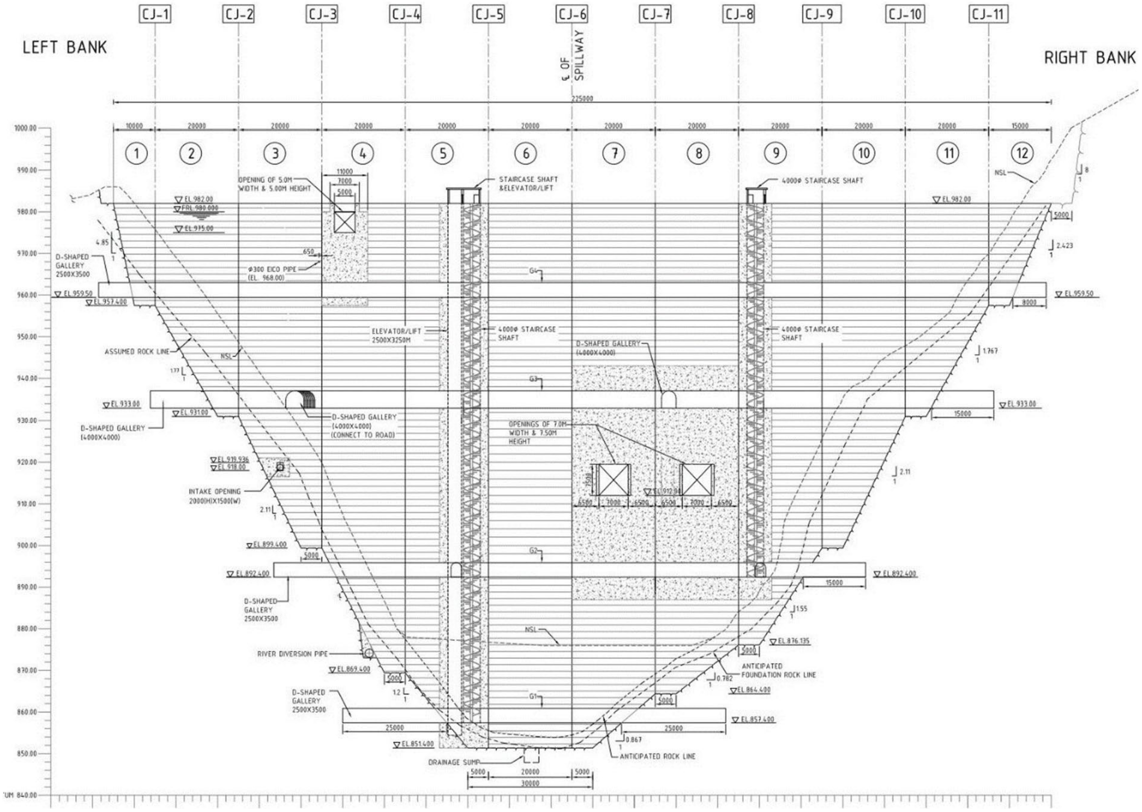


Figure 7-3: Upstream view of Dam

a) Reservoir

A 5.03 km long reservoir is with maximum reservoir level of 980.0 m.a.s.l. same as maximum reservoir. Minimum Drawdown Level (MDDL) is at 923.00 m.a.s.l. The total storage volume at FRL (EL 980 m asl) is 26.4 Million m^3. The dead storage at MDDL (EL 923.00m asl) is 4.0 Million m^3.

b) Dam

A concrete Gravity dam with maximum height of 130.6m at deepest foundation level of 851.40 m.s.a.l has been proposed. The length of the dam at top is 225 m. An upstream slope of 0.3 H: 1.0 V (950 m.a.s.l. to foundation.) is proposed. The road width of dam is 12.5 m and the base of the dam at deepest level has a width of 134.06 m.

c) Intake Structure

The intake is proposed in NOF Block no.3 within the dam body to carry water for drinking purpose through 1.5m diameter steel pipe to Water Treatment plant near Khalanga War Memorial. The Intake invert is kept at 918.0 m.a.s.l.

7.2.1.3. SALIENT FEATURES OF DAM

The characteristics of spillways are summarized below and the relevant sketches are shown in the figures attached subsequently.

Table 7-1: Characteristics of Main Orifice and High Level Spillway

Description	**Main orifice spillway**	**High level Spillway**
FRL	EL. 980.0 m	
Gates	Radial and StoplogType	service and StoplogType
Crest Level	EL. 912.0	EL. 975.0
Sill elevation [m a.m.s.l.]	EL 911.0 / EL. 911.975	EL. 974.5 / EL. 974.88
Stoplog gate size	7.0(w)x7.525(h)	5.0(w)x 5.12(h)
Service Gate	-	5.0 (w) x 5.5 (h)
Radial Gate	7.0(w) x 8.5 (h)	-
Number of openings	2	1
Width of opening (each) [m]	7.0	5.0
Height of opening (each) [m]	7.5	5.0
Energy dissipater	Trajectory Bucket	Trajectory Bucket
Invert Level of bucket [m a.s.l.]	890.00	
Radius of Bucket [m]	25	

7.2.1.4. CLASSIFICATION OF DAM

As per IS 11223:1985 reaffirmed 2004, the dams may be classified according to size by using the static head (FRL- Minimum tail water level corresponding to ecological discharge) and the gross storage behind the dam as given below. The overall size classification for the dam would be the greater of that indicated by either of the following two parameters:

Table 7-2: Classification of Dams

Classification	**Gross Storage**	**Static head**	**The inflow design flood**

Small	Between 0.5 and 10 million m^3	between 7.5 m and12 m	100 year flood
Intermediate	Between 10 and 60 million m^3	Between 12 m and 30 m.	SPF
Large	Greater than 60 million m^3	Greater than 30 m.	PMF

As the hydraulic head of Song Dam is 105.0m (FRL= 980.00 - 875.0 = 105m; and the gross storage of dam is 26.4 Million m^3 (>60 Million m^3), the dam is classified as a large dam. Hence, the PMF of 1229 m^3/s has been considered as inflow design flood to pass through the 2 numbers of openings (one as stand by to satisfy n-1 condition).

The hydraulic design of the under sluices spillways & energy dissipation shall be for best performance probable maximum flood (1229 m^3/s). The Hydraulic design for Song Dam orifice spillway is given in **Annexure 7.1**. Hydraulic Design for Song Dam Overflow Spillway is given in **Annexure 7.17**.

7.2.1.5. TAIL RATING CURVE

Computations for estimating tail water level at 50 m downstream of the dam site has been done using Manning's equation based on longitudinal section and cross section prepared from contour map with 1 m contour interval. Manning's n has been assumed as 0.05, as the bed material comprises of boulders with thick vegetation near the upper levels. Average river slope near the dam site has been estimated as 34.44 m/km. The rating curves at 50m d/s of dam axis is shown in Figure 7-4 below.

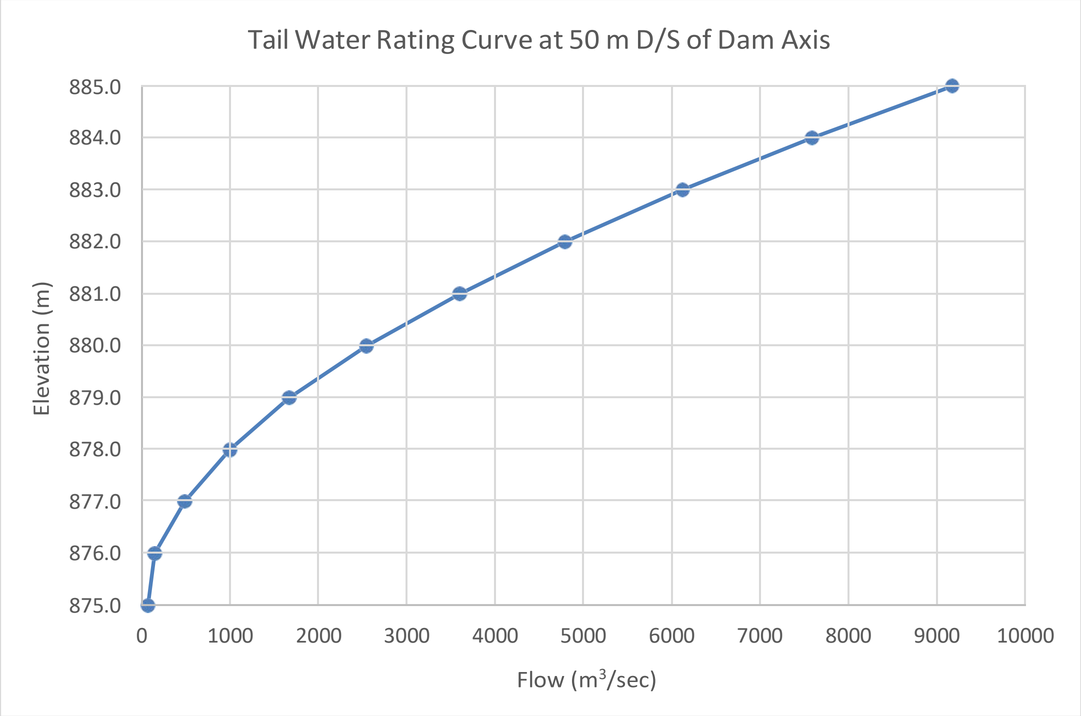


Figure 7-4: Tail Water Rating Curve at 50m D/s of Dam Axis

The water level corresponding to 1229 m^3/s (PMF) is at EL ± 878.70 m.s.a.l.

7.2.1.6. ELEVATION STORAGE CURVE

The Elevation vs. storage curve of reservoir is given in Figure 7-5. The area elevation curve is developed from topographic survey of reservoir area.

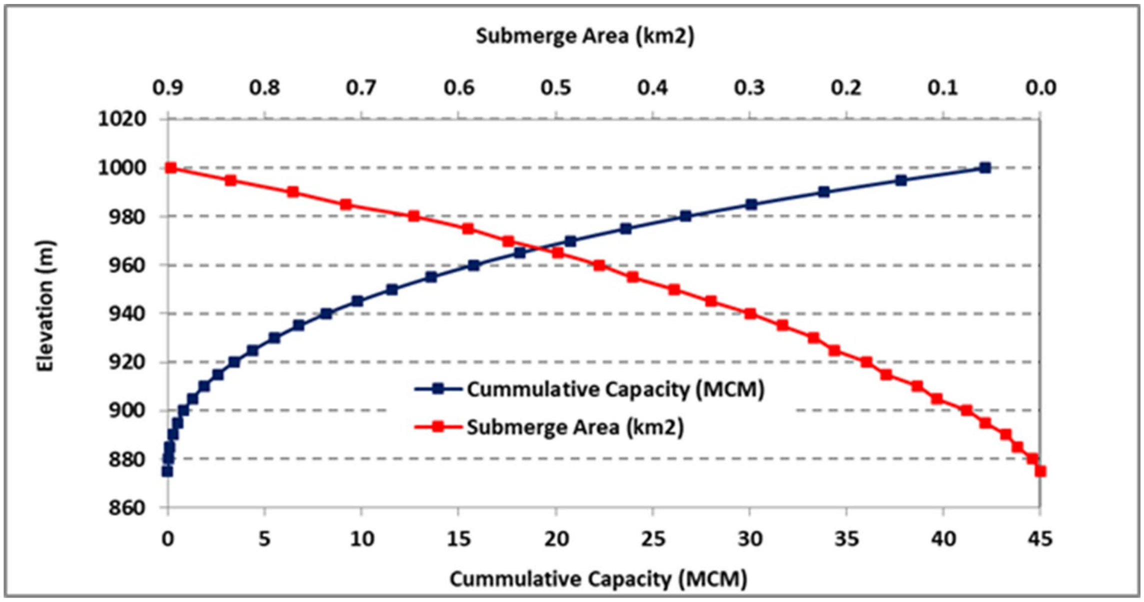


Figure 7-5: Cumulative Volume vs. Elevation (m.s.a.l) Curve and Area Elevation Curve

The total storage volume at FRL (EL 980.00 m.s.a.l) is 26.68 Million m^3. The dead storage at MDDL (EL 923.00 m.s.a.l) is 4.00 Million m^3 and active storage will be 22.40 Million m^3.

7.2.1.7. GEOMETRY OF SPILLWAY

Orifice Type Spillway

River cross section at dam site is very narrow and spillway has been designed to pass probable maximum flood of 1229 cumec from orifice spillway

The orifice sluice type spillway with 2 bays at crest of 912.00 will have an opening within the dam body. This big opening is created in NOF block and stability analysis is done accordingly. The size of radial gates in these bays shall be 7.0m (W) x8.5 m(H) with sill level at 911.0 m. The design is done as per details given in the IS 6934:1998.

Trajectory type of energy dissipation with plunge pool has been provided with bucket invert level 890.0. Spillway has to pass discharge of 1229.0 cumec. Therefore opted option for energy dissipation is best suited. Stilling basin and bucket type energy dissipater may not be provided due to very long length of basin.

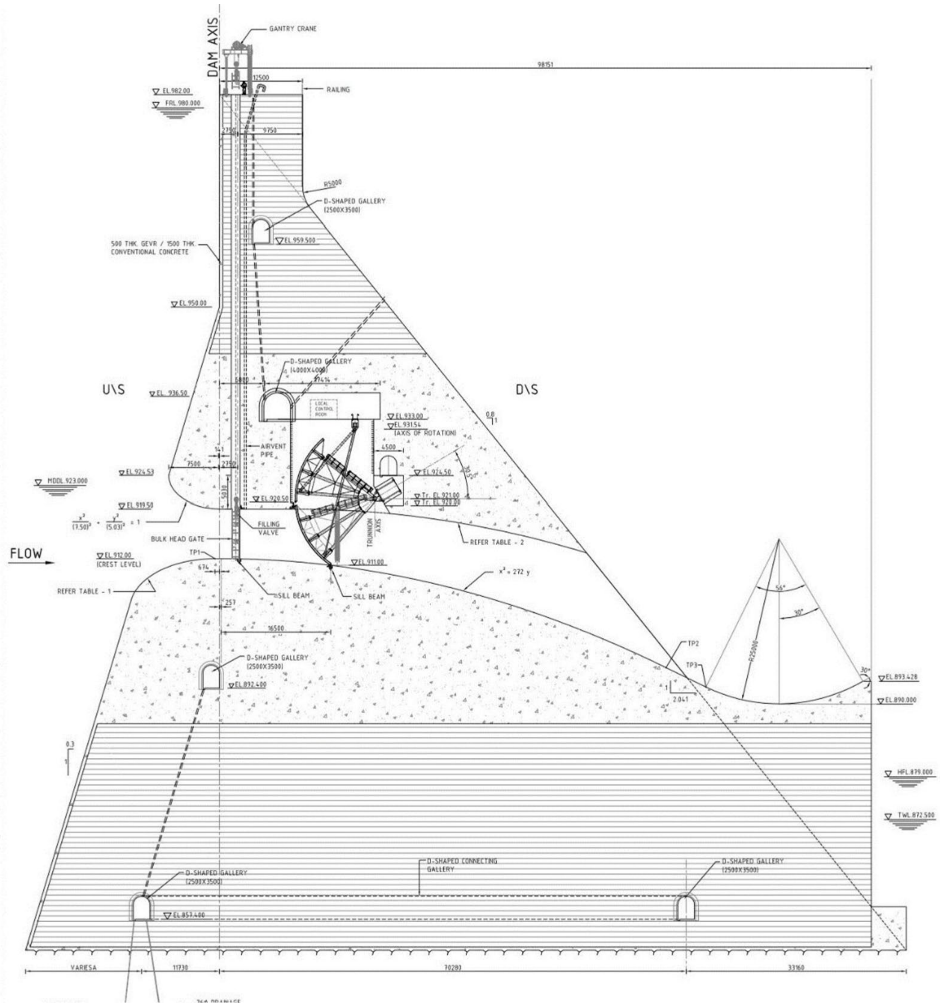


Figure 7-6: Main Orifice Spillway Section of Dam

7.2.1.8. HYDRAULIC DESIGN OF SPILLWAY

The hydraulic design consists of determination of size & profile of spillway to cater the design flood & selection of suitable energy dissipation structure downstream of dam. Detailed calculations are shown in **Annexure 7.2** and **Annexure7.3.**

Size of Spillway

The size of spillway is determine considering (N-1) gate creation as per IS 11223 & IS 6934. Orifice type spillway capacity calculation has been done as specified in IS 6934. Spillway has been kept close to river bed level to act as sediment cleaning with area of opening 51m^2 as per CWC guidelines (draft version). Size of spillway is not governed by discharge carrying capacity rather this is governed by minimum size of opening provided for sediment cleaning criteria. Therefore, for one gate inoperative also the discharging capacity of one spillway is 1414 cumec, hence even full gate opening is not desired to pass design PMF. Orifice type spillway with invert at EL 912.0 and opening size 7.0m (W)×7.5m (H) is having a capacity to pass 1213.0 cumecs discharge and the high level spillway with invert 975.00 and opening size 5.0 m (W)×5.0m (H).

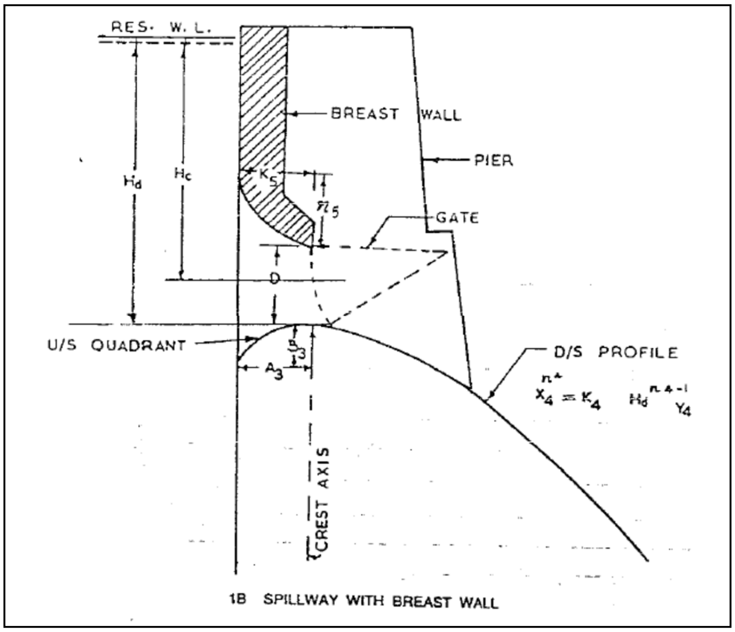


Figure 7-7: Main Orifice Spillway Profile

The main orifice spillway and high level spillway shall be model tested to ensure the efficacy of discharge carrying capacity.

Main Orifice Spillway

Detailed calculations of u/s, d/s and breast wall are as follows.

i) Upstream Profile

Profile of spillway upstream of crest has to be adopted as per Clause 6. 3.1 of IS 6934. The profile calculations are as follows:

Table 7-3: Upstream Profile Coordinates of Orifice Spillway

Distance X1 (in M)	Distance Y1 (In M)	Distance X1 (in M)	Distance Y1 (In M)	Distance X1 (in M)	Distance Y1 (In M)
0.00	9.66	-5.50	9.10	-11.00	7.16
-0.25	9.66	-5.75	9.04	-11.25	7.02
-0.50	9.65	-6.00	8.99	-11.50	6.88
-0.75	9.65	-6.25	8.93	-11.75	6.73
-1.00	9.64	-6.50	8.86	-12.00	6.58
-1.25	9.63	-6.75	8.80	-12.25	6.41
-1.50	9.62	-7.00	8.73	-12.50	6.24
-1.75	9.60	-7.25	8.66	-12.75	6.07

-2.00	9.58	-7.50	8.59	-13.00	5.88
-2.25	9.57	-7.75	8.51	-13.25	5.68
-2.50	9.54	-8.00	8.43	-13.50	5.47
-2.75	9.52	-8.25	8.34	-13.75	5.25
-3.00	9.49	-8.50	8.26	-14.00	5.02
-3.25	9.46	-8.75	8.16	-14.25	4.77
-3.50	9.43	-9.00	8.07	-14.50	4.50
-3.75	9.40	-9.25	7.97	-14.75	4.21
-4.00	9.36	-9.50	7.87	-15.00	3.89
-4.25	9.33	-9.75	7.76	-15.25	3.54
-4.50	9.29	-10.00	7.65	-15.50	3.14
-4.75	9.24	-10.25	7.53	-15.75	2.67
-5.00	9.20	-10.50	7.41	-16.00	2.09
-5.25	9.15	-10.75	7.29	-16.25	1.25
				-16.38	0.30

ii) Downstream Bottom Profile

As per IS 6934, Clause 5.1, When spillways are equipped with gates (the most common type of gate is radial gate), discharges for partial gate openings will occur as orifice flow. With full head on the gate and with the gate partially opened the jet emerging from the gate will be in the form of a trajectory conforming to a parabola;

Where H (68 m) is the acting head for gate.

Hence adopted downstream profile is $x^2 = 272 \times Y$

Table 7-4: Downstream Profile Coordinates of Orifice Spillway

Distance X1 (in M)	**Distance Y1 (In M)**	**Distance X1 (in M)**	**Distance Y1 (In M)**	**Distance X1 (in M)**	**Distance Y1 (In M)**	**Distance X1 (in M)**	**Distance Y1 (In M)**
0.00	912	19.50	910.6	39.00	906.41	58.50	899.42
0.50	912	20.00	910.53	39.50	906.26	59.00	899.2
1.00	912	20.50	910.45	40.00	906.12	59.50	898.98
1.50	911.99	21.00	910.38	40.50	905.97	60.00	898.76

2.00	911.99	21.50	910.3	41.00	905.82	60.50	898.54
2.50	911.98	22.00	910.22	41.50	905.67	61.00	898.32
3.00	911.97	22.50	910.14	42.00	905.51	61.50	898.09
3.50	911.95	23.00	910.06	42.50	905.36	62.00	897.87
4.00	911.94	23.50	909.97	43.00	905.2	62.50	897.64
4.50	911.93	24.00	909.88	43.50	905.04	63.00	897.41
5.00	911.91	24.50	909.79	44.00	904.88	63.50	897.18
5.50	911.89	25.00	909.7	44.50	904.72	64.00	896.94
6.00	911.87	25.50	909.61	45.00	904.56	64.50	896.7
6.50	911.84	26.00	909.51	45.50	904.39	65.00	896.47
7.00	911.82	26.50	909.42	46.00	904.22	65.50	896.23
7.50	911.79	27.00	909.32	46.50	904.05	66.00	895.99
8.00	911.76	27.50	909.22	47.00	903.88	66.50	895.74
8.50	911.73	28.00	909.12	47.50	903.7	67.00	895.5
9.00	911.7	28.50	909.01	48.00	903.53	67.50	895.25
9.50	911.67	29.00	908.91	48.50	903.35	68.00	895
10.00	911.63	29.50	908.8	49.00	903.17	68.50	894.75
10.50	911.59	30.00	908.69	49.50	902.99	69.00	894.5
11.00	911.56	30.50	908.58	50.00	902.81	69.50	894.24
11.50	911.51	31.00	908.47	50.50	902.62	70.00	893.99
12.00	911.47	31.50	908.35	51.00	902.44	70.50	893.73
12.50	911.43	32.00	908.24	51.50	902.25	71.00	893.47
13.00	911.38	32.50	908.12	52.00	902.06	71.50	893.2
13.50	911.33	33.00	908	52.50	901.87	72.00	892.94
14.00	911.28	33.50	907.87	53.00	901.67	72.50	892.68
14.50	911.23	34.00	907.75	53.50	901.48	73.00	892.41
15.00	911.17	34.50	907.62	54.00	901.28	73.50	892.14

15.50	911.12	35.00	907.5	54.50	901.08	74.00	891.87
16.00	911.06	35.50	907.37	55.00	900.88	74.50	891.59
16.50	911	36.00	907.24	55.50	900.68	75.00	891.32
17.00	910.94	36.50	907.1	56.00	900.47	75.50	891.04
17.50	910.87	37.00	906.97	56.50	900.26	76.00	890.76
18.00	910.81	37.50	906.83	57.00	900.06	76.50	890.48
18.50	910.74	38.00	906.69	57.50	899.84	77.00	890.2
19.00	910.67	38.50	906.55	58.00	899.63	77.50	889.92

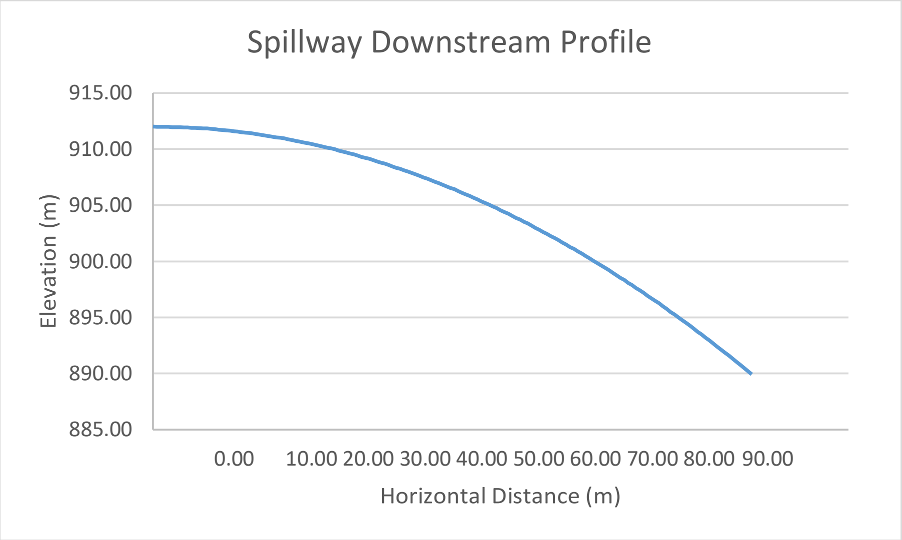


Figure 7-8: Downstream Profile of Orifice Spillway

7.2.1.9. ENERGY DISSIPATION STRUCTURE

The trajectory bucket type has been provided for energy dissipation arrangement and it has been designed as per recommendations of IS 7365:1985. The tail water level for design flood (PMF) 1229 m^3/s is 880.00 m.s.a.l. The invert level of bucket for orifice spillway is fixed at 890.0 m.s.a.l and the lip elevation is 893.0 m.s.a.l. The radius of bucket is provided 25 m after satisfying the minimum radius criteria.

The principle features of hydraulic design of trajectory bucket are as follows and detailed calculations are shown in **Annexure 7.2**.

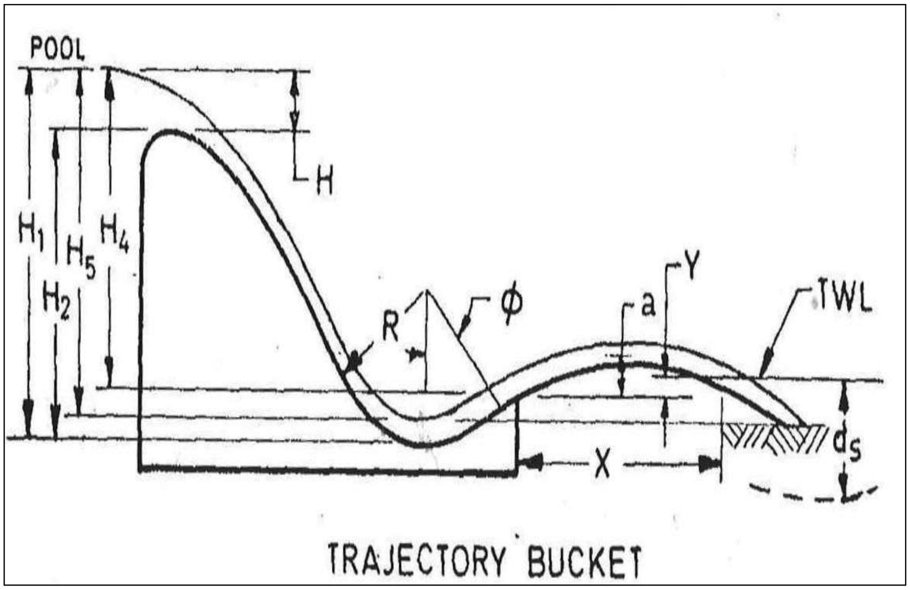


Figure 7-9: Trajectory Bucket Type Energy Dissipation

Bucket Shape

The performance of trajectory buckets is judge by trajectory height and length of thrown in flip action. Generally circular shape performs well.

Bucket Invert Elevation

The Bucket invert Level kept at El. 890.0 m.

Radius of bucket

The pressure distribution on the bucket and the trajectory length are affected by the radius. To maintain the concentric flow and to avoid the tendency for the water to spring away from the bucket the radius has to be substantially large so that streamline distribution of the flow is not altered by the floor pressure. Therefore the radius of the bucket should not be less than three times the maximum depth of flow (d1) entering the bucket to avoid separation tendencies. The detailed calculations are shown in **Annexure 7.2**.

Lip elevation and exit angle

The lip angle affects the horizontal thrown distance. The factor affecting the horizontal thrown distance also include the initial velocity of the jet and the difference in elevation of the lip and tail water. Normally adopted lip angle is between 30°and 40°, as greater the exit angle within this range greater will be the distance of thrown, but the jet impinges on the tail water at steeper angle which result in deeper scour, the final selection depending upon the minimum throw permissible under the local rock conditions. Keeping above all the conditions in mind and based on topography of dam downstream lip angle of 28°is provided to minimize the sub atmospheric pressure and scour. For clear flip action the lip elevation is fixed at 893.00m.

Trajectory length

The following expression used for calculating the thrown distance

X = horizontal distance from bucket lip to the center point of impact with tailwater in metres

Ý = difference between the lip level and tailwater level, sign taken as positive for tailwater below the lip level and negative for tailwater level above the lip in metres

H_v = Velocity head of jet at the bucket lip in metres

Ø = bucket lip angle with horizontal in degrees

Vertical distance of throw above the lip level calculated from following formula

Where,

a = vertical distance from lip level to the highest point of the center of jet in metres

V_a = actual velocity of flow entering the bucket in m/s

Ø = bucket lip angle with horizontal in degrees

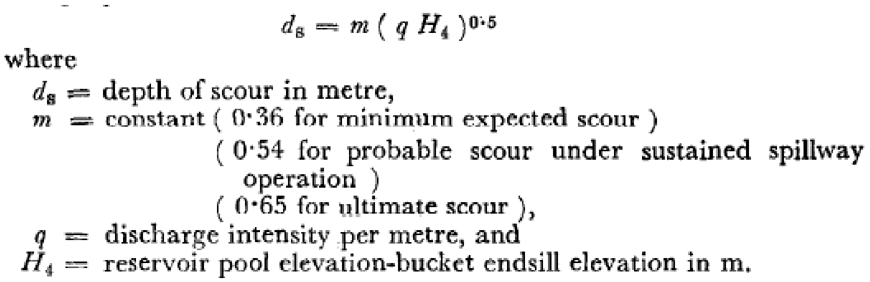
g = acceleration due to gravity in m/sec^2

The performance of the trajectory bucket is judged by the trajectory height and length of throw in flip action. For that circular section has been proposed. Based on the above Indian standard formulas, Final behavior of energy dissipation system shall ensure by Model Studies. The trajectory length from the bucket lip and the vertical distance of throw from the lip level are calculated which are 165.0m and 19m respectively.

Scour Depth

There are a lot of different investigations and approaches on the determination of the final scour depth. The depth of the scour hole and the distance from the trajectory bucket to the deepest scour are calculated as per Indian Standards.

As per IS 7365-1985



$$d_s = m\ (\ q\ H_4\ )^{0\cdot5}$$

where

d_s = depth of scour in metre,

m = constant (0·36 for minimum expected scour)

(0·54 for probable scour under sustained spillway operation)

(0·65 for ultimate scour),

q = discharge intensity per metre, and

H_4 = reservoir pool elevation-bucket endsill elevation in m.

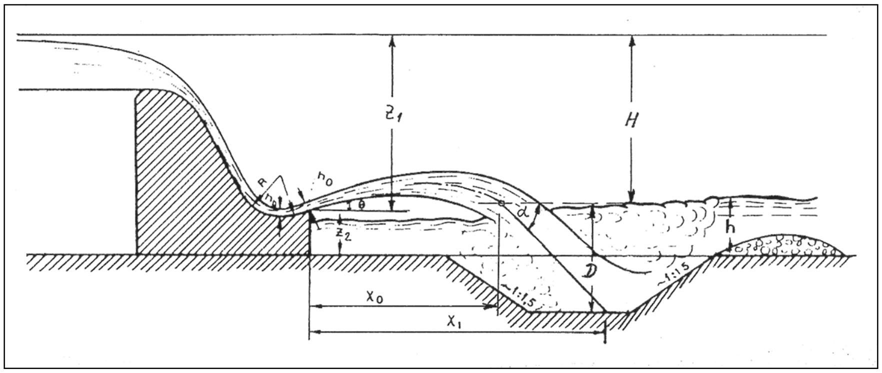


Figure 7-10: Conditions for the Jet Scour Depth

The depth of the scour hole and the distance from the trajectory bucket to the deepest scour are calculated in accordance to the approach. IS code and considering tailrace water levels as per the tail water rating curves given in the section 1.6 of this report. The average rock line is at 24m from river bed level at the location of the plunge pool. Detailed calculations of scour depth are shown in **Annexure 7.2**.

Based on the above results it is recommended that rock level is far below the river bed level of 875.00m, therefore plunge pool invert may be kept as 850.0 based on the calculation of minimum expected scour which is the most frequent happening case.

The trajectory bucket shall be model tested to ensure satisfactory hydraulic performance of the bucket which is judged by the trajectory height and the throw distance and also the depth and extent of scour. Also it shall be ensured that sub atmospheric pressures do not exist on the bucket profile and on the bucket lip.

7.2.1.10. DAM TOP ELEVATION (FREE BOARD CALCULATION)

IS: 6512-1984 provides guidelines for calculation of expected wave run-up and required freeboard. Freeboard has been calculated with reference to FRL as FRL and MWL are same in this project. The calculations of required freeboard with reference to FRL is given in **Annexure 7.3**. The full/maximum reservoir fetch has been measured from available topographic survey and works out as 0.10km for FRL. The maximum wind speed for 50yrs return period over land at dam site has been taken from Fig. 1 of IS: 875-1964 (Part-3) as 47m/s.

The minimum freeboard requirement is calculated as 1.8m with reference to FRL. Therefore, top of the dam is set at 982.0 m.s.a.l, giving a freeboard of 3m above FRL/MWL.

7.2.1.11. STABILITY ANALYSIS

7.2.1.11.1. Input parameters

Hydraulic design data

MWL/FRL	980.00 m
Normal TWL	872.5m
Tail water at HFL	879.0m
Minimum draw down level	923.00m

Material Properties

Concrete

The following values have been adopted in the analysis for conventional concrete:

Compressive Strength (f_{ck})	20 MPa
Unit mass (γ):	24.0 kN/m^3

Foundation Rock

The values have been taken from report “Geotechnical investigations and their evaluation for Song dam”. The following rock to concrete interface properties for left bank blocks are used.

For stability analysis residual values has been used for Pseudo dynamic analysis:

Concrete- Rock Interface (Left bank)

Friction Angle (□)	48°
Cohesion (residual)	0 MPa

Concrete Rock-Interface (Right Bank)

Friction Angle (□)	50°
Cohesion (residual)	0 Mpa

Seismic Coefficient

The time period of both the non-overflow and overflow blocks falls on the sloping plateau of the response spectrum. Therefore maximum spectral acceleration is considered for the corresponding damping. The 5% damping is assumed for the structural analysis for Design Basis Earthquake (DBE) condition.

However it is to be noted that the 5% damping assumed by the code takes into considerations only the damping of the structure and damping due to structure – foundation interaction and damping due to structure - water interaction has been conservatively ignored when 5% damping is considered. While considering the extreme condition like MCE case, the conservative value of 5% damping can be replaced by 7%. At this stage 5% is considered.

The horizontal seismic coefficient for DBE are adopted as site specific report no-NCSDP letter no 2/2/2018/FE&SA/146 dt 1103-2019 and EQD/6036 17-18 March 2018 of IIT Roorkee attached as **Annexure 1.6 of Volume II Project Geology (Site Specific Design Earthquake Parameters for Song H. E. Project Site, Uttarakhand).**

The present analysis has been done for Horizontal Peak Spectral Acceleration of 0.18g for DBE Condition and 0.495g for MCE Condition. The tension in the structure has been allowed for DBE condition as per Indian Standard.

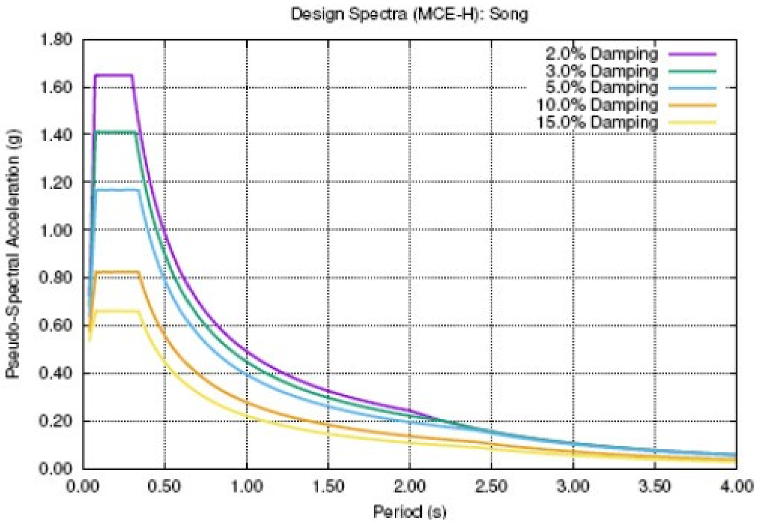


Figure 7-11: MCE horizontal spectral acceleration for various damping for project site

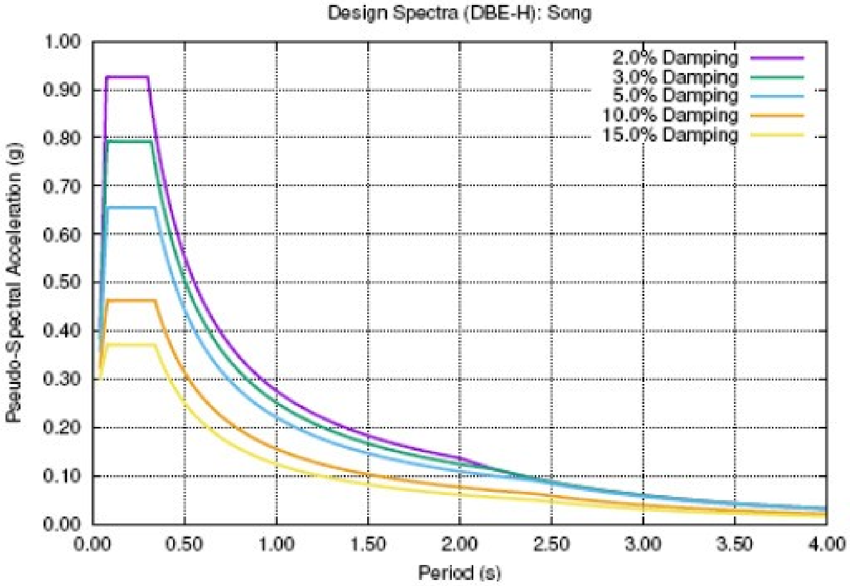


Figure 7-12: DBE horizontal spectral acceleration for various damping for project site

7.2.1.11.2. Stability Analysis of Overflow

Methodology & Assumptions

Following steps states the method adopted and assumption for stability analysis.

1. The forces acting on the structure are determined by the gravity method based on the rigid body equilibrium.

2. Stresses are computed considering the beam theory.

3. The stress distribution over a horizontal section is therefore assumed linearly.

4. The resultant of all horizontal and vertical forces including uplift under any load combination is balanced by an equal and opposite reaction at the foundation consisting of total vertical reaction and the total horizontal shear and friction at the base. For the dam to be in equilibrium the location of this force has to be such that the summation of moments is equal to zero.

5. Stability analysis has been done for all load combinations as specified in Para 5.

6. To take the effect of shape of entire monolith or NOF block has been divided in strips of 2.0m and inertia forces are calculated for each strip.

The stability analysis would be done for all loads and load combination which is defined in IS -6512.

Design Loads

a) Dead load

b) Hydrostatic loads (reservoir and tail water loads)

c) Uplift pressure

d) Earthquake loads

e) Earth and silt pressure

f) Equipment loads

g) Silt load

7.2.1.12. DEAD WEIGHT OF STRUCTURE

The following unit weights have been used in design:

Unit weight of concrete	:	24 kN/m³
Unit weight of water	:	9.81 kN/m³
Unit weight of structural steel	:	78.5 kN/m³

7.2.1.13. HYDROSTATIC LOAD

Hydrostatic load would be considered for design. Triangular pressure diagram from FRL to foundation level has been considered.

7.2.1.14. UPLIFT PRESSURES

Uplift pressures have been calculated for different loading conditions as per provision of IS 6512:1984 (Clause 5.3.2).For calculating sliding factor of safety, compressive and tensile stresses straight line pressure distribution have been considered.

For calculation of uplift pressure, 2/3rd pressure relief has been considered at the line of drainage holes on D/S side of curtain grouting (according to IS:6512-1984).

In case of drains chocked condition (100% clogging), the ground water pressure has been considered as uniformly varying from U/S water level to Tail Water at the D/S dam end.

7.2.1.15. EARTHQUAKE LOADS

These loads have been worked out as per provisions given in IS 6512:1984, IS 1893:1984 (Clause 7.3), and IS 1893:2002 (Part I) considering both horizontal and vertical seismic acceleration as mentioned in clause 3.4.Seiesmic coefficient calculation have been shown in clause 3.4 above.

Earthquake coefficient varies in triangular form from top to bottom as given in IS-1893-1984, 1.5 times on top to zero at bottom.

Seismic forces in horizontal as well as in vertical direction have been considered in the analysis. While combining the effect of earthquake forces, 100% effect of design horizontal earthquake along with 30% effect of design vertical earthquake has been considered in the analysis.

7.2.1.16. HYDRODYNAMIC PRESSURES

The hydrodynamic pressure has been worked out as per procedure given in IS 1893:1984 (Clause 7.2). Due to horizontal acceleration of the foundation and dam there is an instantaneous hydrodynamic pressure (or suction) exerted against the dam in addition to hydrostatic forces. The direction of Hydrodynamic force is opposite to the direction of earthquake acceleration. Based on the assumption that water is incompressible, the hydrodynamic pressure at depth y below the reservoir surface shall be determined as follows:

p = Cs*□h*w*h

p := hydrodynamic pressure in kg/m2 at depth y,

Cs = coefficient which varies with shape and depth (see 7.2.1.1),

□h = design horizontal seismic coefficient [see 3.4.2.3 (b) and 7.3.1 1,

w = unit weight of water in kg/m3, and

Approximate values of C, for dams with vertical or constant upstream slopes may be obtained as follows:

Where;-

c, = maximum value of C, obtained from Fig. 10,

y = depth below surface, and

h = depth of reservoir.

Effect of Horizontal Earthquake Acceleration on the Vertical Component of Reservoir and Tail Water Load Since the hydrodynamic pressure (or suction) acts normal to the face of the dam, there shall, therefore, a vertical component of this force at the face of the dam against which it is acting, the magnitude at any horizontal section being:

$W_h = (V_2 – V_1)$ tan □

The hydrodynamic forces are taken accordingly.

7.2.1.17. EQUIPMENT LOADS

Loads from the radial gates and hoisting equipment to be introduced in the concrete structure will be calculated in overflow block.

7.2.1.18. SILT LOAD

For the design purposes the top of the silt deposits will be assumed up to crest level at EL 590.00m.

The following criteria are recommended for calculation of silt forces as per IS-6512.

Vertical silt and water pressure is determined as silt and water together to have a density of 1925 kg/m^3.

Horizontal silt and water pressure is assumed to be equivalent to that of a fluid mass of 1360 kg/m^3.

The typical force diagram is shown in Figure 7-13**.**

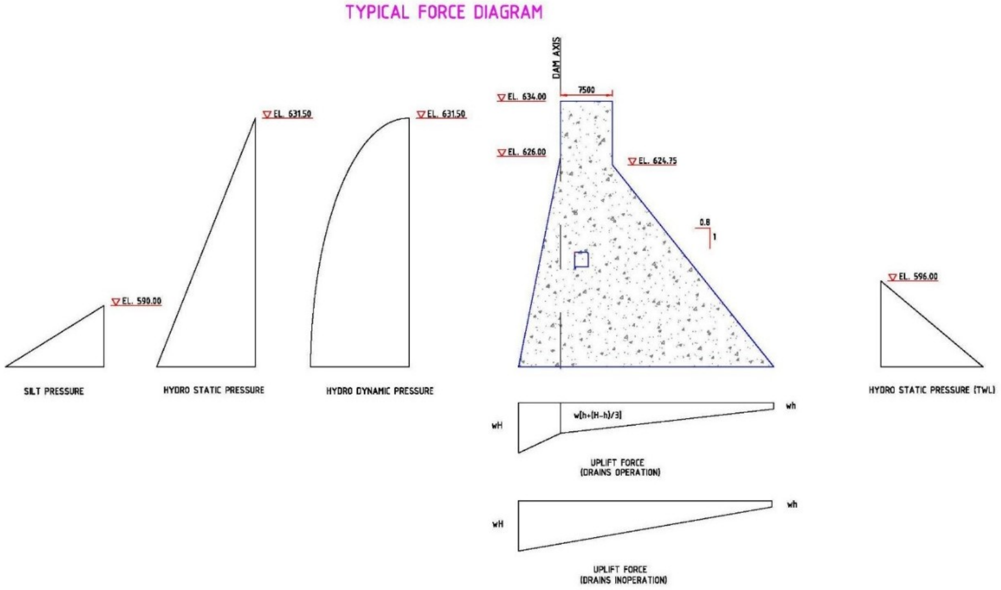


Figure 7-13: Typical Force Diagram

a. Load Combination

Static Conditions

The static part of the structural analysis considers the following loading conditions:

1. Load Condition A: Construction Condition
2. Load Condition B: Normal Operation Condition
3. Load Condition C: Flood Discharge Condition
4. Load Condition F: Combination C but with extreme Uplift (Drains Inoperative)

Earthquake Conditions

The analysis considers the effects of unusual and extreme load conditions during earthquakes. The Dam Structure has been designed using seismic coefficient calculated as per recommendation. The seismic forces considered are for Design Basis Earthquake (DBE) and Maximum Considered Earthquake (MCE).

The structural analysis considers the following loading conditions:

1. Load Condition D: Load Combination A with Earthquake
2. Load Condition E: Load Combination B with Earthquake
3. Load Condition G: Combination E but with extreme Uplift (Drains Inoperative)
4. Load Condition H: Combination B but with Maximum Considered Earthquake and drains operative.

Static Analysis

The following loading conditions are considered in the static analysis:

Table 7-5: Static Loading Conditions

Static Loading Condition	**Loads**								
	Self weight	**FRL**	**HFL**	**max Water level d/s**	**Normal Water level d/s**	**Silt Load**	**FRL Uplift, drains operating**	**FRL Uplift, drains blocked**	**HFL Uplift, drains operating**
End of Construction LC “A”	X								
Normal Operation Condition LC “B”	X	X			X	X	X		
Flood Discharge Condition LC “C”	X		X	X		X			X
LC C+ Extreme Uplift LC “F”	X		X	X		X		X	

Psuedo-Dynamic Analysis

The following loading conditions are considered in the Earthquake analysis. As IS-6512 does not specify any thing about M.C.E condition, however according to “US Army corps engineers’ code” this condition has been taken into account.

Table 7-6: Dynamic Loading Conditions

Static Loading Condition	**Loads**							
	Self weight	**FRL**	**Normal Water level d/s**	**Silt Load**	**FRL Uplift, drains operating**	**FRL Uplift, drains blocked**	**D.B.E Earthquake**	**M.C.E Earthquake**
End of Construction +Earthquake LC D	X						X	
Normal Operation Condition + Normal Uplift +Earthquake LC E(DBE)	X	X	X	X	X		X	
Normal Operation Condition + Earthquake+ Extreme Uplift LC G	X	X	X	X		X	X	

Normal Operation Condition + Normal Uplift + Earthquake(MCE) LC H*	X	X	X	X	X			X

Note:-* – case is not mentioned in IS-6512

Safety Criteria

The dam has to be safe against failure by overturning about its toe, safe against sliding along the interface of the dam and foundation or along any plane within the dam and safe against development of excessive compressive and tensile stresses.

Safety against Overturning

Safety against overturning will be checked in accordance with Cl 5.11 of IS: 6512 - 1984 which is given below.

As per clause 5.11, resistance against Overturning - before a gravity dam overturns bodily, other types of failures may occur, such as cracking of the upstream material due to tension, increase in uplift, crushing of toe material and sliding. A gravity dam is, therefore, considered safe against overturning if the criteria of no tension on the upstream face, the resistance against sliding as well as the quality and strength of concrete / masonry of the dam and its foundation is satisfied assuming the dam and foundation as a continuous body.

Therefore calculation for overturning factor has not been done.

Safety against Sliding

The factor of safety against sliding is calculated using formulae given in IS-6512, Cl. 5.12.2.1 and partial factor of safety specified in Table 3 of IS-6512. FOS should not be less than 1.0 for given partial factor of safety.

Where

F = factor of safety against sliding

w = total mass of the dam

u = total uplift force

tan φ = coefficient of internal friction of the material

C = cohesion of the material at the plane considered

A = area under consideration for cohesion

Partial factor of safety Fφ for friction and Fc for cohesion are specified in Table-1 of Cl. 5.12.2 of IS:6512-1984 as below.

All permissible compressive and tensile stresses are as IS-6512, clause-5.13.2.3, table-2. Tensile stresses for earthquake condition are as per Roorkee Site Specific Earthquake Design Parameters.

Table 7-7: Partial Safety Factors for Sliding

Loading Condition	Partial factors of safety			
	Fφ	Fc		
		For dam and the Contact Plane with Foundation	For Foundation	
			Thoroughly investigated	Others
A, B, C	1.50	3.60	4.0	4.50
D, E	1.20	2.40	2.7	3.00
F, G,	1.00	1.20	1.35	1.50
H*	1.00	1.00	1.15	1.20

Note:-.H* is not defined in IS 6512:1984.

b. Results

Results of the rigid body analysis for Non Overflow Block number 5 are summarized in the Table 7-8 and for Overflow block number 7 are summarized in Table 7-9.

As per IS Codes-6512, the maximum compressive strength 7N/mm^2 is allowed, However maximum compressive strength as 0.3 times cube compressive strength has been taken for static load case or load case A,B, and C.

Tensile strength has also been taken from IS-6512, code is allowing some small tensile stresses for construction condition but not recommended any value, therefore permissible tensile stresses Load case" D "has been combined with load case "G", which is justified ,because both cases are defined as extreme conditions (refer USACE-EM-1100-11-2200) and same permissible stresses can be used.

Permissible tensile stresses for load case "H" is taken from "Site specific report from IIT Roorkee".

Detail calculations of Non-overflow & Overflow block number 5 & 7 have been attached as **Annexure 7.4 & Annexure 7.5** respectively.

Non Overflow Block

Following Table 7-8 shows results for sliding factor and stresses at interface of dam body and rock. Geological parameters are used for same.

Table 7-8: Stability Analysis Results of Non overflow Block 5

Load Combination	Factor of Safety	Maximum Stresses (N/mm^2)		Permissible tensile stress (N/mm^2)	Permissible compressive stress (N/mm^2)
	Sliding	Toe	Heel		
Load Combination A	INFINITY	0.59	2.43	0	6
Load Combination B	1.57	1.39	1.14	0	6
Load Combination C	1.79	1.34	1.61	0.2	6
Load Combination D	9.10	0.20	2.73	0.8	7
Load Combination E	1.39	2.11	0.38	0.4	7
Load Combination F	1.80	1.34	0.63	0.4	7
Load Combination G	1.30	2.05	-0.10	0.8	7
Load Combination H	1.28	2.84	-0.38	2	7

Maximum tensile stress is 0.38 N/mm² for load combination “H” for Maximum Considered Earthquake. The value so obtained is less than permissible value. Maximum compressive for all load cases are within permissible limit as shown in Table 7-8

Overflow Block

Following Table 7-9 shows results for sliding factor and stresses at interface of dam body and rock. Geological parameters are used for same.

Table 7-9: Stability Analysis Results of Overflow Block 7

Load Combination	Factor of Safety	Maximum Stresses (N/mm^2)		Permissible tensile stress (N/mm^2)	Permissible compressive stress (N/mm^2)
	Sliding	Toe	Heel		
Load Combination A	INFINITY	0.62	2.32	0	6
Load Combination B	1.50	1.45	1.08	0	6
Load Combination C	1.69	1.32	1.51	0.2	6

Load Combination D	10.25	0.23	2.66	0.8	7
Load Combination E	1.40	2.10	0.43	0.4	7
Load Combination F	1.66	1.32	0.53	0.4	7
Load Combination G	1.24	1.95	-0.09	0.8	7
Load Combination H	1.33	2.74	-0.22	2	7

Maximum tensile stress is 0.22 N/mm² for load combination “H” for Maximum Considered Earthquake. The value so obtained is less than permissible value. Maximum compressive for all load cases are within permissible limit as shown in Table 7-9.

c. Conclusion

Load case “C” and “B” are similar in this case due to same FRL and MWL, except change in tail water level due to gate opening.

The shear parameters taken are on conservative, therefore section may be optimized further.

Overflow block

The resulting safety factors and maximum/minimum stresses are within permissible limits for all load combinations. This block is having diversion sluices also, which will be plugged in later stage, but entire concrete mass have been deducted in stability calculations and further may be optimized.

Maximum tensile stress is 0.38 N/mm² for load combination “H” i.e for Maximum Considered Earthquake, which is less then permissible. Maximum compressive for all load cases are within permissible limit as shown in Table 7-8.

d. Recommendation

The two dimensional analysis from SAP/ STAAD/ANSYS design soft wares shall be done in later stage to calculate the stresses at every point within the dam body and actual principal stresses. Dam block may further optimized because of high factor of safety. The same will be done during dynamic analysis or FEM analysis.

7.2.1.19.2-DIMENSIONAL ANALYSIS OF NOF BLOCK

a. Input Parameters

Hydraulic design data

MWL/FRL	980.00 m
Normal TWL	872.5m

Tail water at HFL 879.0m

Minimum draw down level 923.00m

Foundation Rock

The values have been taken from report “Geotechnical investigations and their evaluation for Song dam”. The following rock to concrete interface properties for left bank blocks are used.

For stability analysis residual values has been used for Pseudo dynamic analysis:

Concrete- Rock Interface (Left bank)

Friction Angle (□)	48°
Cohesion (residual)	0 MPa

Concrete Rock-Interface (Right Bank)

Friction Angle (□)	50°
Cohesion (residual)	0 Mpa

b. Model and Analysis

Assumptions of Analysis in STAAD PRO

For an analysis of the structure, the necessary matrices are generated on the basis of the structure is idealized into an assembly solid element. One-meter strip (along flow) of dam bodies is solid model. Dam body is instigated with Rock and its modeled 100 m from dam base in all side (u/s, d/s and in depth).

The assemblage is loaded and reacted by pressure acting at the solid surface. These loads may be both forces and moments, which may act in any specified direction.

Supports

Dam body and 100 m depth rock mass have model In STAAD model. Concrete and rock mass are integrated. At bottom of rock have considered as Fixed, and both face of dam block up to bottom of dam have laterally (in FZ direction)

The typical force diagram is shown in Figure 7-13.

C. Load Combination

Static Conditions

The static part of the structural analysis considers the following loading conditions:

1. Load Condition A: Construction Condition
2. Load Condition B: Normal Operation Condition
3. Load Condition C: Flood Discharge Condition
4. Load Condition F: Combination C but with extreme Uplift (Drains Inoperative)

Earthquake Conditions

The analysis considers the effects of unusual and extreme load conditions during earthquakes. The Dam Structure has been designed using seismic coefficient calculated as per recommendation. The seismic forces considered are for Design Basis Earthquake (DBE) and Maximum Considered Earthquake (MCE).

The structural analysis considers the following loading conditions:

1. Load Condition D: Load Combination A with Earthquake
2. Load Condition E: Load Combination B with Earthquake
3. Load Condition G: Combination E but with extreme Uplift (Drains Inoperative)
4. Load Condition H: Combination B but with Maximum Considered Earthquake and drains operative.

D. Static Analysis

The following loading conditions are considered in the static analysis:

Table 7-10: Static Loading Conditions

Static Loading Condition	**Loads**								
	Self weight	**FRL**	**HFL**	**max Water level d/s**	**Normal Water level d/s**	**Silt Load**	**FRL Uplift, drains operating**	**FRL Uplift, drains blocked**	**HFL Uplift, drains operating**
End of Construction LC "A"	X								
Normal Operation Condition LC "B"	X	X			X	X	X		
Flood Discharge Condition LC "C"	X		X	X		X			X
LC C+ Extreme Uplift LC "F"	X		X	X		X		X	

E. Psuedo-Dynamic Analysis

The following loading conditions are considered in the Earthquake analysis. As IS-6512 does not specify any thing about M.C.E condition, however according to "US Army corps engineers' code" this condition has been taken into account.

Table 7-11: Dynamic Loading Conditions

Static Loading Condition	**Loads**							
	Self weight	**FRL**	**Normal Water level d/s**	**Silt Load**	**FRL Uplift, drains operating**	**FRL Uplift, drains blocked**	**D.B.E Earthquake**	**M.C.E Earthquake**
End of Construction +Earthquake LC D	X						X	
Normal Operation Condition + Normal Uplift +Earthquake LC E(DBE)	X	X	X	X	X		X	
Normal Operation Condition +	X	X	X	X		X	X	

Earthquake+ Extreme Uplift LC G								
Normal Operation Condition + Normal Uplift + Earthquake(MCE) LC H*	X	X	X	X	X			X

Note:-* – case is not mentioned in IS-6512

Table 7-12: Load combination for STAAD Analysis

Loading Combinations for stress																	
Load	Sr.	Load	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Remarks
	No.	Comb	Self	US Water Pressure	Ds water pressure -	Ds water pressure - flood	Us water pressure - with silt	Ds water pressure - with silt	Us ver Water	Uplift force (normal)	Uplift force(drains inoperative)	Hydrodyanamic	EQX	EQY	EQX (MCE)	EQy (MCE)	
	1	*101*	*1.00*														A-Self Weight - No Water
	2	*102*	*1.00*	*1.00*	*1.00*		*1.00*		*1.00*	*1.00*							B-(Full Resevoir)
	3	*103*	*1.00*	*1.00*		*1.00*	*1.00*	*1.00*	*1.00*	*1.00*							C-(Full Resevoir-Flood)
	4	*104*	*1.00*										*1*	*0.30*			D - LC_A with Seismic X
	5	*105*	*1.00*										*-1*	*-0.30*			D - LC_A with Seismic -X
	6	*106*	*1.00*	*1.00*	*1.00*		*1.00*		*1.00*	*1.00*		*1.00*	*1*	*0.30*			E - LC _B with Seismic X
	7	*107*	*1.00*	*1.00*	*1.00*		*1.00*		*1.00*	*1.00*		*-1.00*	*-1*	*-0.30*			E - LC _B with Seismic -X
	8	*108*	*1.00*	*1.00*		*1.00*	*1.00*	*1.00*	*1.00*		*1.00*						F - LC_C with Extreme Uplift)
	9	*109*	*1.00*	*1.00*	*1.00*		*1.00*	*1.00*	*1.00*		*1.00*	*1.00*	*1.00*	*0.30*			G - LC _E with Extreme Uplift)
	10	*110*	*1.00*	*1.00*	*1.00*		*1.00*	*1.00*	*1.00*		*1.00*	*-1.00*	*-1.00*	*0.30*			G - LC _E with Extreme Uplift
	11	*111*	*1.00*	*1.00*	*1.00*		*1.00*		*1.00*	*1.00*		*1.00*			*1.00*	*0.30*	H - X (MCE)
	12	*112*	*1.00*	*1.00*	*1.00*		*1.00*		*1.00*	*1.00*		*1.00*			*-1.00*	*0.30*	H - X (MCE)

F. Results

Results of the rigid body analysis for Non Overflow Block number 5 are summarized in the Table 7-8.

As per IS Codes-6512, the maximum compressive strength 7N/mm2 is allowed, However maximum compressive strength as 0.3 times cube compressive strength has been taken for static load case or load case A,B, and C.

Tensile strength has also been taken from IS-6512, code is allowing some small tensile stresses for construction condition but not recommended any value, therefore permissible tensile stresses Load case" D "has been combined with load case "G", which is justified ,because both cases are defined as extreme conditions (refer USACE-EM-1100-11-2200) and same permissible stresses can be used.

Permissible tensile stresses for load case "H" is taken from "Site specific report from IIT Roorkee".

G. Conclusion

The resulting maximum/minimum stresses are within permissible limits for all load combinations. This block is having diversion sluices also, which will be plugged in later stage, but entire concrete mass have been deducted in stability calculations and further may be optimized.

Maximum tensile stress is 0.38 N/mm² for load combination “H” i.e for Maximum Considered Earthquake, which is less then permissible. Maximum compressive for all load cases are within permissible limit are shown in Table 7-8. Approval of CMDD Directorate of CWC, New Delhi is given in **Annexure 7.15**. Observations & Reply of FE&SA directorate of CWC, New Delhi are given in **Annexure 7.16**.

7.2.2. River Diversion Arrangement

Excavation of dam foundation and concreting of the dam and construction of plunge pool are planned to be done in non monsoon period. This part of the construction is protected against a maximum non monsoon flood of 1 in 100 year’s frequency. Upstream cofferdam is provided for this protection. Accordingly, a diversion arrangement is proposed on the left bank of the Roller Compacted Concrete (RCC) gravity dam. Downstream Coffer dam is not required. The location and the alignment of the river diversion arrangement have been fixed on the basis of the topographical and geological data.

7.2.2.1. DESIGN DIVERSION FLOOD DURING CONSTRUCTION

The construction work at proposed diversion site will be carried out during non monsoon period. Diversion discharges for 1 in 25 years is 15.45 cumec, 1 in 50 years is 17.41 cumec and 1 in 100 years is 19.36. Discharge values are low therefore the diversion has been designed to pass the 1 in 100 year non-monsoon flood of 19.36m3/s. The diversion arrangement has been designed for a diversion discharge of 19.36 m3/sec, which is 1 in 100 years non monsoon return period flood.

7.2.2.2. DIVERSION PIPE

The diversion pipe is proposed for diversion of flood discharge. Single stage diversion Scheme is proposed. In this scheme, the diversion flood of 19.36 m³/s is allowed to flow through the diversion pipe proposed to be erected on Left bank and the construction of coffer dam has been planned accordingly. The proposed internal diameter of pipe is 2.0 m. The diversion pipe is proposed to be laid in a bed slope of 1.33% (1 in 75). The proposed thickness of pipe is 10 mm. Stoplog Gate is proposed at the Inlet of Diversion pipe with sill level at EL 878.0 m and Deck level at EL 887.0 m.

7.2.2.3. UPSTREAM COFFER DAM

Upstream Coffer Dam is planned for effecting the diversion. The coffer dam is made of colcrete with nominal size of aggregate as 50 mm and cement sand ratio of 1:2. Average upstream slope of the cofferdam is 0.1H:1V, and downstream slope is 0.5H:1V. The top width of coffer dam is 5.0 m. Top of the cofferdam is kept to provide sufficient free-board over the water levels for passing the design diversion discharge through the pipe.

Upstream cofferdam is located about 75m upstream from dam axis. The average river bed level at this location is at EL + 875.0 m. The coffer dam has top level at El. 887.0 m and height of 12m with a free-board of about 2m. The length of colcrete coffer dam is about 75.45 m at top.

There is no requirement of Coffer dam on Downstream and accordingly, no Coffer Dam is proposed on Downstream side. One row of CC concrete grouting of 0.75 times of height of coffer dam is proposed undernearth coffer dam to restrict seepage.

The details of river diversion arrangement and coffer dam are shown in drawing no P.012745-W-20302-002. The Design calculations are given as below.

Design of River Diversion Arrangement for Song Dam Drinking Water Project, Dehradun

River Diversion Discharge (Diversion Flood)	=	43.0	m^3/sec
Permissible velocity of Flow in Pipe	=	8.00	m/sec
Required Area of flow	=	5.38	m^2
Required diameter of Circular Steel Pipe	=	2.62	m
	Say	2.75	m
Area of Cross section of Pipe	=	5.94	m^2
Average River Bed level at location of Upstream Coffer Dam (50 m u/s of Dam Axis)	=	875.000	m
Deepest River Bed level at Inlet Location of Diversion Pipe (100 m u/s of Dam Axis)	=	877.643	m
Proposed Invert EL at Inlet of River Diversion Pipe	**=**	**878.00**	**m**
Overt EL at Inlet of Diversion Pipe	**=**	**880.75**	**m**
Velocity of Flow in Pipe	=	7.24	m/sec
Length of River Diversion Pipe	=	350.0	m
Proposed Slope of River Diversion Pipe	=	0.013333	(1 in 75)
Invert Level of River Diversion Pipe at Outlet	=	873.33	m
Overt Level of River Diversion Pipe at Outlet	=	876.08	m
Location of Outlet of River Diversion Pipe (200 m d/s of Dam Axis)	=	869.846	m
Assumed Manning's n value for Silted water in Steel Pipe	=	0.014	
Friction factor (f) = 125 $n^2/D^{1/3}$	=	0.0175	
Entry Loss of Pipe (Considering Headloss Coefficient = 0.1)	=	0.27	m
Exit Loss of Pipe (Considering Headloss Coefficient = 1.0 for Free Outfall)	=	2.67	m
Friction Head Loss = $flv^2/2gd$	=	5.94	m
Bed Loss (2 Bends of 90 degree, considering Head loss Coefficient = 0.1)	=	0.53	m
Total Head Loss	**=**	**9.42**	**m**
i.e. Total Head required to pass diversion discharge	=	9.42	m
Assumed Upstream Water Level	=	**885.5**	m
Considering, Downstream Water Level = Overt Level of Pipe at Outlet	=	876.08	m
Available Head for Flow in Pipe	=	9.42	m
Goal Seek	**=**	**0.00**	
Proposed Top Level of Upstream Coffer Dam	**=**	**887.0**	**m**
Height of Upstream Coffer Dam	**=**	**12.00**	**m**

No Coffer Dam is required on Downstream Side

7.2.3. Water conductor system

Water conductor system is the part of the Song Dam Drinking Water project. The system spanning over a length of 15kms originates from intake at Song Dam (Block No. 03). Thereby, it traverses on left bank of Song River. At Maldeota location, the water conductor crosses Song Dam and from the point of confluence of Baldi River and Song River, it runs on the left bank of Baldi River. Thereafter, it crosses Baldi River near Khalanga War Memorial and discharges to Water Treatment Plant. Further distribution of water to selected areas of Dehradun shall be taken up by separate agency.

Figure 7-14 shows the geographical location of the alignment.

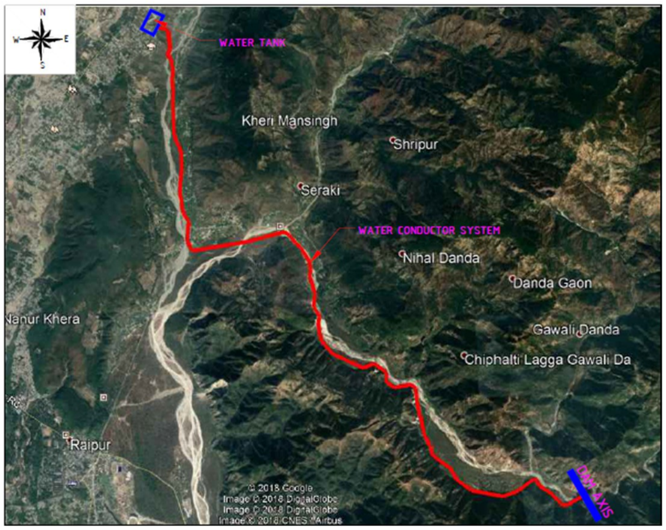


Figure 7-14: Geographical location of Water conductor system

The layout has been finalized as described. Table 7-13 shows the salient features of the Water Conductor System. Figure 7-15 shows the layout plan of the water conductor system.

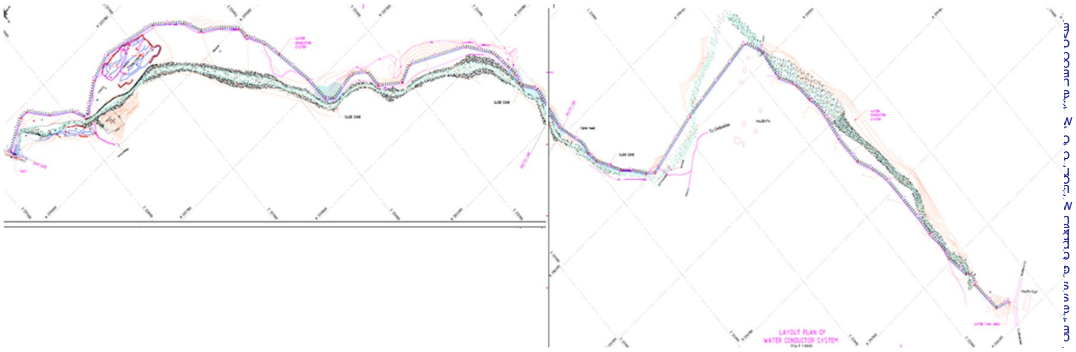


Figure 7-15: Layout Plan of Water Conductor System

Table 7-13: Salient Features of Water Conductor System

Sl No	Features	Values
1	Total Length	14.7 km
2	Start Location	Dam Block No. 03
3	End Location	WTP near Khalanga War Memorial
4	Diameter of the Pipeline	1.5m
5	Length along Song River	10.5 km
6	Length Along Baldi River	4.2 km

The alignment runs on left bank of both River Baldi and River Song. It crosses River Song at chainage 9+575 before its confluence with River Baldi. It crosses River Baldi at chainage 10+425 near WTP location.

The alignment is finalized considering following features:

- The alignment is kept along the natural ground level to minimise the height of saddle supports.
- The invert level of pipe has been kept above the HFL to avoid floatation of Pipeline.
- The alignment at river bed shall be susceptible to scouring and hence excess foundation depth will be necessary to hold it in place. Therefore, the invert is raised and proposed along the road at the adjoining hill so that minimum foundation depth will suffice.
- The alignment is proposed to be taken by the road route so as to maintain the ease of accessibility to the water conductor and ensure easy maintenance. This also resulted in lower amount of cutting and filling as compared to the previous alignment.
- It has been tried to keep number of crossings of the existing road to minimum.
- At two locations, aqueducts or similar arrangements are proposed to carry the pipeline across rivers. This arrangement is kept same as in original proposal.

It is tried to keep the alignment towards the hill side while running along with the roads for ease of erection and transportation of penstock.

The water conductor system starts from the intake located at the upstream side of the Dam Body. At the mouth of intake, a trash rack arrangement with mechanical cleaning arrangement has been proposed. It is followed by a bell mouth shaped opening for smooth intake of water to the system. Following it, bulkhead gates of size 1.5m x 1.5m is proposed. The bulkhead gate then gradually transits to the circular shaped water conductor system. On exit from the dam body, the water conductor system follows natural ground profile. At about 80m from the intake point, a small Valve chamber is proposed to house a butterfly valve of 1.5m diameter. This shall act as a control room for the entire system. From valve chamber, the pipe system follows natural ground profile along River Song and then along River Baldi and reaches the Water Treatment Plant at Pacific Golf covering a distance of around 15kms. In between, several anchor blocks, saddles, piers and river crossing structures are encountered which are discussed in following sections in detail.

A roadway up to the El. 918.00 is also proposed.

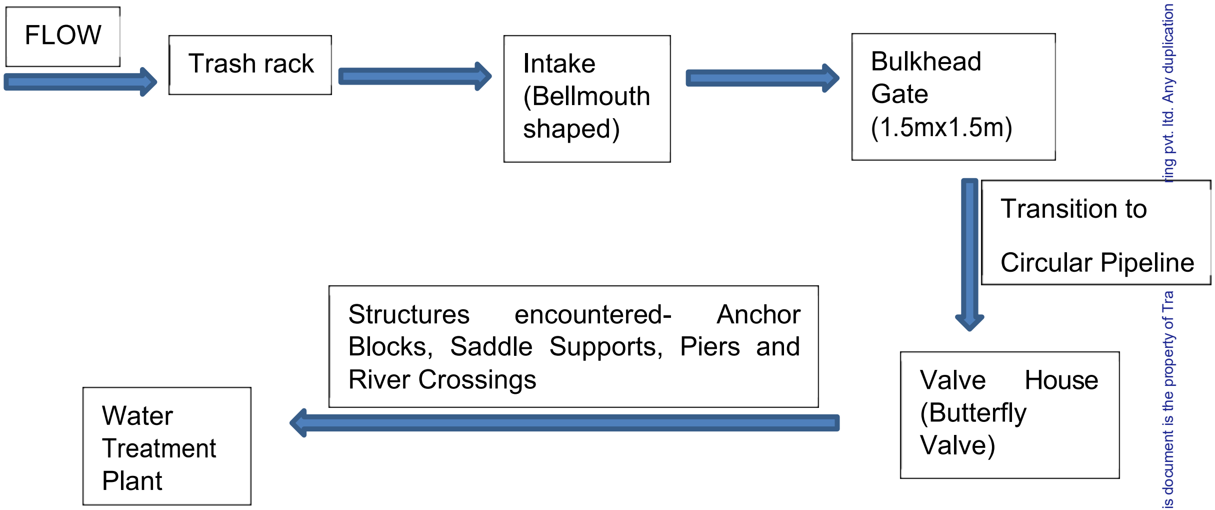


Figure 7-16: Schematic order for Water Conductor System.

2. HYDRAULIC DESIGN

Hydraulic Calculation of the alignment is worked out. Hydraulics of the water conductor system includes following:

- Trash rack structure
- Intake structure
- Head Loss Computation along the pipe network
- Transient/Surge Analysis of the entire network is worked out.

a. Trash rack structure

Trash rack is an important item in a water conveyance system. It is used to keep out debris, sediments and other materials carried by water which are likely to damage or can leave the control equipment inoperative. For design of trash rack, several factors like velocity of water flow, spacing of bars, allowable clogging, cleaning mechanisms etc. are considered.

The invert of trash rack is kept at El. 918.00m. It extends up to MDDL level of El. 923.00m.

Trash rack structure of size 1.5m (W) x 6m (H) is provided inclined at an angle of 07 deg to vertical achieving a velocity of 1m/s at trash rack location. The trash rack structure shall be cleaned mechanically. Clogging up to 60% is assumed while finalising the section.

Sufficient submergence is required to avoid vortex formation and air entrainment in the system. As per IS 9761, the submergence measured to the centre line of a system should not be less than 1.0 to 1.5 times the tunnel diameter. The provided depth is almost 1.9 times the intake opening and hence considered safe.

Assuming a symmetrical type of flow approach and submergence criteria, the invert of intake has been kept at El. 918.00m. Figure 7-17 shows the proposed arrangement of trash racks.

The detailed salient features are discussed in the HM Equipment section. Calculations for finalising the size of trash rack and intake has been attached as **Annexure 7.7.**

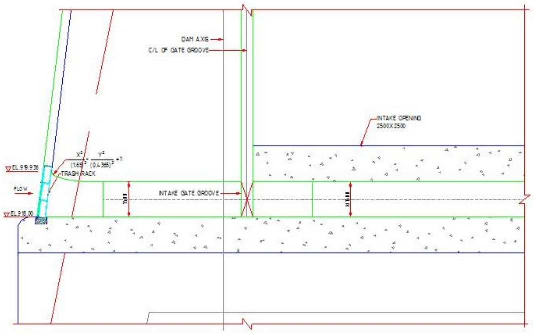


Figure 7-17: Trash rack arrangement and intake opening –sectional view

b. Intake structure

The entrance is provided with bell mouth to reduce the hydraulic losses at the intake thereby minimizing the risk of cavitation zones and promoting positive boundary pressures. The intake structure has been checked for minimum submergence to prevent the entry of air into the tunnel using the criteria as specified in the IS 9761.

The computation of bell mouth equation as per IS 9761 is attached as **Annexure 7.8.** The equation follows an ellipse given by following relation

For Plan :

$$\frac{x^2}{1.1^2}+\frac{y^2}{0.43^2}=1$$

For Section :

$$\frac{x^2}{2.0^2}+\frac{y^2}{1.34^2}=1$$

Following the opening, at a distance of 8.5m from the trash rack groove, a bulk head gate of 1.5m x 1.5m is provided in the intake. It further goes to a circular pipe of diameter 1.5m. Figure 7-18 shows a typical arrangement of intake opening.

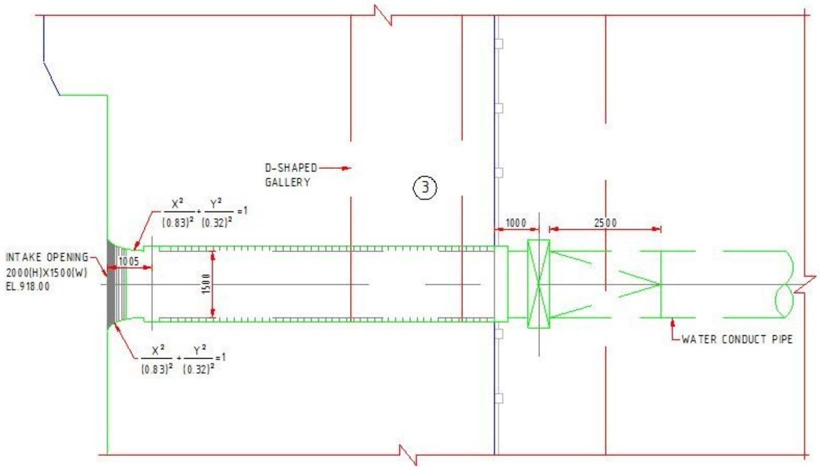


Figure 7-18: Bellmouth intake

c. Head Loss of the water conductor system

Head Loss of the entire Water Conductor System is worked out. The head loss is computed as per IS 2951-Part 1. The various types of head losses considered are discussed below. Detailed computation for head loss is attached as **Annexure 7.9**.

Head loss due to trash rack

Trash rack located at the inlet point of the Water Conductor System. The obstruction provided by the bars to the flow results in some amount of head loss at the entry point. As per Cl. 4.2.1- IS 11623-1986, head loss in trash rack is given by

$$h_t = \frac{k_t V^2}{2g} = 0.0281\text{m}$$

Where,

h_t = head loss due to trash rack

k_t = coefficient for loss at trash rack

$$k_t = 1.45 - 0.45 \left(\frac{a^n}{a_t}\right) - \frac{a_n}{a_t}^2 = 0.55$$

V = velocity of water in pipeline

Entrance head loss

Water from the reservoir may enter into the pipe through the bell mouth shaped inlet. Suitable coefficient for head loss of 0.6 has been considered as per Table 1 of IS 4880-Part 3.

The entry loss is given by the relation as per Cl 4.3, IS 11625-1986.

$$h_e = \frac{f_e V^2}{2g} = 0.0307\text{m}$$

Where,

h_e = entrance head loss

f_e = coefficient for loss at entrances

V = velocity of water in pipeline

Frictional head loss

The friction loss due to skin friction occurs due to effect of fluid's viscosity near the surface of the pipe. It also depends on the length diameter of pipeline.

Since, the alignment is 15kms long, this component accounts for the maximum of head loss in the entire water conductor system. The head as per Cl 4.4, IS 11625-1986

$$h_f = \frac{fLv^2}{2gD} = 12.1 \text{ m}$$

Where,

h_f = frictional head loss

V = velocity of water in pipeline

D = Diameter of the pipeline

f = loss coefficient depending upon nature of pipe and Reynold's Number =0.013 (Detailed computation is attached in **Annexure 7.9**).

Head loss due to valves

A butterfly valve of 1500mm diameter is proposed at the downstream of the Dam body as a control device to regulate the flow through the Water Conductor. As per Cl. 4.5.1, IS 11625-1986,

$$h_v = \frac{k_v V^2}{2g} = 0.0159\text{m}$$

Where,

h_t = head loss due to valve passage

k_t = coefficient for loss at valve location= 0.310 (obtained from Figure 4, IS 11625-1986 depending upon the valve diameter and pressure at location of butterfly valve.

V = velocity of water in pipeline

Head loss due to bends

The water pipeline is envisioned to follow the natural topography wherever possible. In order to do so, 70 bends (59 horizontal and 11 vertical) are encountered all through the alignment. Some energy loss is encountered when the water is forced to change the direction of flow at bend locations. Bend loss (after excluding friction loss) for a circular conduit depends on the shape of the bend, deflection angle and ratio of radius of bend to diameter of pipe. It is expressed as per Cl 4.5.2, IS 11625-1986 is given by:

$$h_b = \frac{k_b v^2}{2g} = 0.2 \text{ m}$$

Where,
D = Diameter of the pipeline

V = velocity of water in pipeline

K_b = coefficient for bend depending upon angle, radius and type of bend.

Exit head loss

The head loss due to change in cross sectional area at exit point. It is denoted by the change in kinetic energy in between the two locations:

$$h_{ex} = \frac{v^2}{2g} = 0.05 \text{ m}$$

Where

h_{ex} = head loss aty exit point.

V = velocity of water in pipeline

Net head loss of the entire system

Some other types of losses occurring due to change in cross sectional area in between the alignment, branching of pipes etc. are excluded as such conditions are not encountered in the alignment.

Net head loss of the system comes to 6.68m.

A residual head of about 16.32m is available after accounting for all major losses. They act as a cushion for maintenance, wear and tear of the system over the years.

Detailed head loss computation of the entire system is attached as **Annexure 7.9**.

d. Transient Analysis

Variation in drinking water demand and supply patterns, the fluctuations in alignment in gravity flow systems owe to trigger transients in a pipe flow. Transient analysis for the entire system has been worked out and attached as **Annexure 7.10.**

The maximum and minimum water pressures under various likely scenarios during operation are computed and analyzed.

3. STRUCTURAL DESIGN

The pipeline covers a stretch of 15kms, and head varies up to a maximum of 300m at about chainage of 10+500. The variation in head or the pressure at different locations will govern the pipe thickness all through the alignment.

The pipeline is thereby supported on several saddles and anchor blocks fitted on the ground. All such civil structures will be designed against stability and sliding so that they support the pipeline adequately.

a. Pipe Thickness

The thickness of the pipeline is computed along its entire length. Thickness varies with respect to available water head as it depends on the internal water pressure. The thickness of steel liner is computed to vary between 15mm to 20mm all through the alignment.

The thickness required so that the stresses generated are within permissible limits as per IS 11639-1-1986 are computed. The calculation for thickness to be adopted for the pipeline is attached as **Annexure 7.11**.

b. Civil Structures

The entire stretch of water conductor system from intake at Song Dam to water Treatment Plant location is covered with different types of support structures. The requirement and basic dimensions of these depend on the topography of the area.

The different types of structures encountered are shown in Table 7-14.

Table 7-14: Types of structures encountered in the alignment

Sl No	Type of Structure	Nos
1	Saddle Supports/Piers	527 Nos.
2	Anchor Blocks	85 Nos.
3	River crossings	8 Nos.

Anchor Blocks

Anchor blocks are mass structures provided at bend locations to cater the bend forces in the water pipeline. They balance/ transfer the bend forces generated in the system.

Figure 7-19 shows some typical type of Anchor blocks encountered in the alignment.

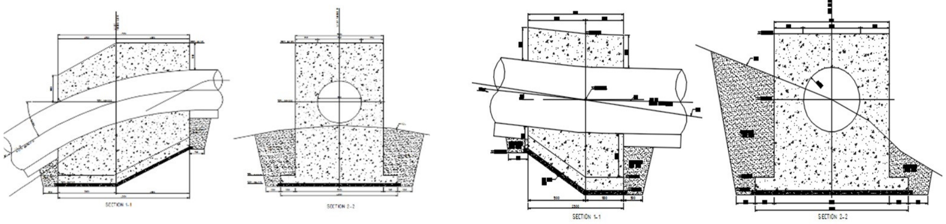


Figure 7-19: Typical Anchor block diagram

Structural design of Anchor blocks comprises of Stability check and check of base pressures.

Detailed calculation of Anchor blocks are given in **Annexure 7.12.**

Saddle Supports

Saddles are provided on the straight reach of penstock, thus maintaining its alignment and transferring the loads of penstock and water to the ground. Pipe forces are transferred through the ring girder- base plate arrangement to the concrete saddle support. Detailed calculations are attached in **Annexure 7.13.**

The vertical and horizontal loads from penstock are transferred equally to the pedestals of the support through appropriate arrangement.

Saddle supports are proposed at a spacing of every 10m all through the alignment. In total, 530 nos. of saddle supports are required in the alignment. Saddles act as intermediate supports in between two anchor blocks.

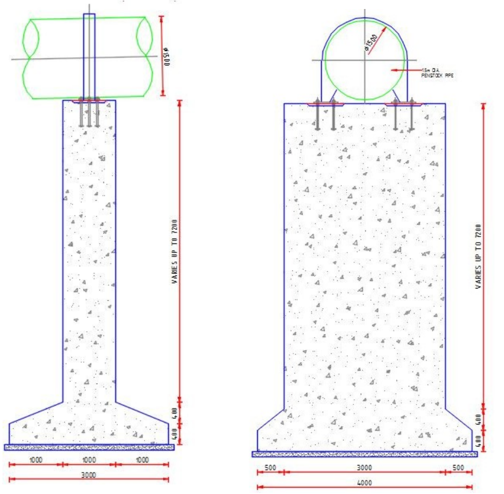


Figure 7-20: Typical section of Saddle support

River crossing at Ch. 9+575 AND 14+125

From the Song dam location towards the WTP, the alignment crosses River Baldi at chainage 9+575 just before the confluence of Baldi River with Song River. The river crossing is skewed with respect to the direction of the river. The skewed span is of 20m.

After the crossing at chainage 9+575, the alignment runs on the left bank of Song River parallel to the existing road towards the WTP location near Khalanga War Memorial. At Chainage 14+125, the alignment crosses Song River and rises along the hill side towards the proposed WTP location.

Figure 7-21 shows a typical arrangement proposed at river crossing. The detailed computations are attached as **Annexure 7.14.**

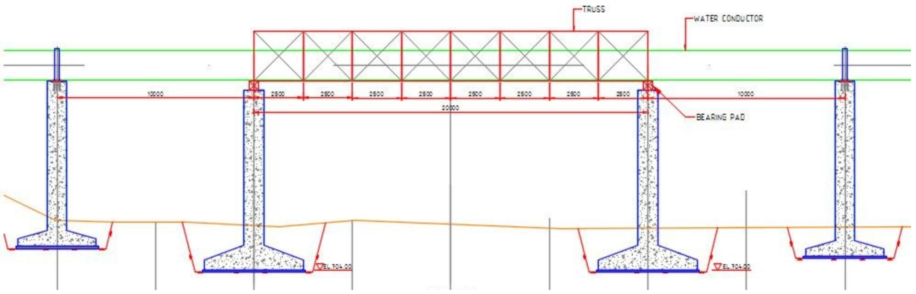


Figure 7-21 : Typical arrangement of river crossing

Valve chamber at Ch. 82.500

A valve chamber of plan area 5m x 5m is proposed at chainage 60.00 is proposed near dam body. The valve house is to contain and protect a butterfly valve of diameter 1.5m.

The valve house will be a simple frame with roof truss and isolated footings are proposed**.** Figure 7-22 shows a typical arrangement for the Valve chamber.

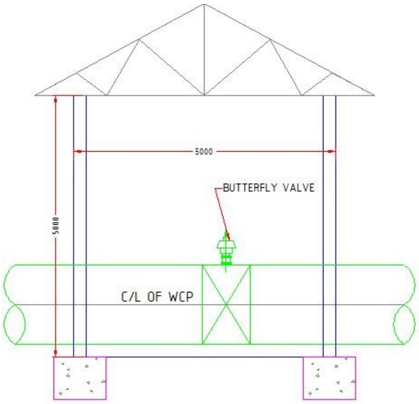


Figure 7-22 : Typical sketch of a Valve House

Butterfly valve is proposed to regulate the flow in the Water Conductor from the Intake. The butterfly valve will also be used during repair and maintenance of the pressure shaft and steel liner. The Valve House is located on the surface as shown in the layout drawing for Song Dam.

7.2.4. Dam Break Analysis

7.2.4.1. GENERAL

7.2.4.1.1. Necessity of Dam Break Analysis

The city of Dehradun, the capital of Uttaranchal is important town and tourist place of the country. Town is facing water shortage which become worsen during summer. To overcome the shortage problem, the Song dam has been proposed over Song River (a Perennial river in eastern part of Dehradun valley and tributary of Ganga River) as a storage reservoir scheme for water supply. The dam height of 130.6 m from the deepest foundation level has been proposed. The index map of the project region including dam locations, watersheds up to the Ganga River CWC GD site at Satyanarayana, rainfall stations, and townships, etc. are shown in Figure 7-23:

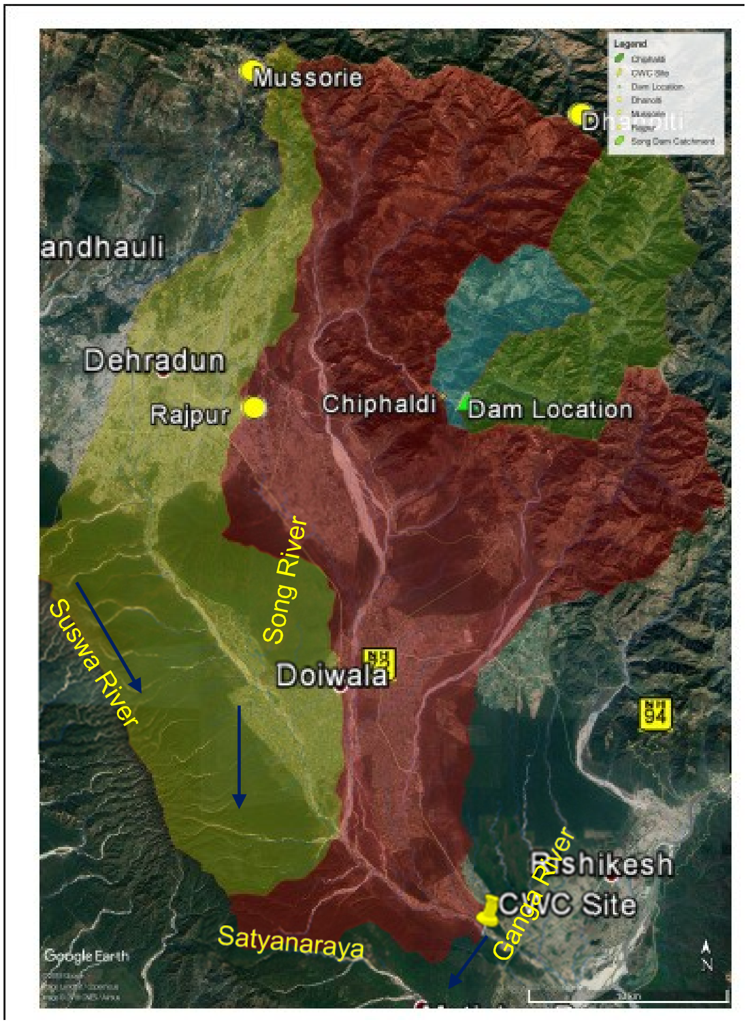


Figure 7-23 : Index Map –Song Drinking Water Project

The construction of dam/barrage in rivers can provide considerable benefits such as the supply of drinking and irrigation water as well as generation of electric power or flood protection. However, the consequences which would result in the event of their failure could be catastrophic.

Dam breach may be summarized as the partial or catastrophic failure of a dam leading to uncontrolled release of water. Such an event can have a major impact on the land, communities, and other developments downstream of the failed structure. A dam break may result in a flood wave up to tens of metres deep travelling along a valley at high speeds. The impact of such a wave on developed areas can be very devastating which causes an inevitable loss of life, if advance warning and evacuation was not possible. They vary drastically depending on the extent of the inundation area, the size of the population at risk and the amount of warning time available. Additional features of such extreme flooding include movement of large amounts of sediment (mud) and debris along with the risk of distributing pollutants from any sources suchas chemical works or mine workings in the flood risk area.

Dam break is most likely to occur during the monsoons under the occurrence of extremely heavy storms (when, there is hardly any storage space available in the dam). The dam may breach on account of some structural failure or faulty reservoir operation. Simulation of hypothetical dam breach events and the resulting floods are crucial for characterizing risk assessments and preparation of disaster management plan in case of potential dam failures.

7.2.4.1.2. Objective of Dam Break Modeling

In India, risk assessment and disaster management plan has been made a mandatory requirement while submitting application for environmental clearance in respect of river valley projects. The extreme nature of dam break floods means that flow conditions will far exceed the magnitude of most natural flood events. Under these conditions flow will behave differently to conditions assumed for Normal River flow modelling and areas will be inundated that are not normally considered. This makes dam break modelling a separate study for the risk management and disaster management plan. The objective of dam break modelling or flood routing is to simulate the movement of a dam break flood wave along a valley or indeed any area downstream that would flood as a result of dam failure. The key information required at any point of interest within this flood zone is generally:

- Travel time of flood water
- Peak water level – extent of inundation
- Time of peak water level
- Peak discharge
- Depth and Velocity of flood water (allowing estimation of damage potential)
- Duration of flooding

There are various numerical models such as MIKE 11, HEC RAS, and DMBRK etc., which are used for dam break simulation studies to achieve the above objectives. In the present case, HEC RAS 5.0.7 was used which is briefly described below.

7.2.4.1.3. HEC RAS Model

Selection of an appropriate model to undertake dam break flood modelling is essential to ensure the right balance between modelling accuracy and cost in terms of time spent developing the model setup. In the instant case HEC-RAS version 5.0.7 model developed by Hydrologic Engineering Centre of U.S. Army Corps of Engineers has been selected. HEC-RAS is an integrated system of software, designed for interactive use in a multi-tasking environment. The system comprises a graphical user interface, separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities. The model contains advanced features for dam break simulation.

The basic theory for dynamic routing in one dimensional analysis consists of two partial differential equations originally derived by Barre De Saint Venant in 1871.

The equations are:

i. **Conservation of mass (continuity) equation**

$$(\partial Q/\partial X) + \partial(A + A_0) / \partial t - q = 0$$

ii. **Conservation of momentum equation**

$$(\partial Q/\partial t) + \{\partial(Q^2 /A)/\partial X \} + g\ A\ ((\partial h/\partial X) + S_f + S_c) = 0$$

Where Q = discharge;

A = active flow area

A_0 = inactive storage area

h = water surface elevation

q= lateral outflow

x = distance along waterway

t = time

S_f = friction slope

S_c = expansion contraction slope and

g = gravitational acceleration.

The present version of HEC-RAS system contains three one-dimensional hydraulic components for: i) Steady flow surface profile computations; ii) unsteady flow simulation; iii) Quasy-unsteady flow simulation. The steady/unsteady flow components are capable of modelling subcritical, supercritical, and mixed flow regime water surface profiles. The system can handle a full network of channels, a dendric system, or a single river reach. The basic computational procedure is based on the solution of one-dimensional energy equation. Energy losses are evaluated by friction (Manning’s equation) and contraction/expansion (coefficient multiplied by the velocity head). The momentum equation is utilized in situations where the water surface profile is rapidly varied. The model solves the one dimensional unsteady flow equations using the four-point implicit scheme, also known as the box scheme.

The graphics include X-Y plots of the river system schematic, cross-sections, profiles, rating curves, hydrographs, and many other hydraulic variables. Users can select from pre-defined tables or develop their own customized tables. All graphical and tabular output can be displayed on the screen, sent directly to a printer, or passed through the Windows clipboard to other software, such as word processor or spread sheet. Reports can be customized as to the amount and type of information desired.

7.2.4.1.4. Appraoch

In the present study, 1D and 2D hydrodynamic simulations using HEC RAS have been carried out to understand impact of dam breach in downstream reaches. The following steps have been taken up.

Step 1: carrying out 1D HEC RAS dam breach modelling and generating flood hydrograph through the breach for different time of breach formations.

Step 2: Carrying out 2D hydrodynamic simulation using hydrograph generated in 1D Dam breach simulation as in Step 1 and generation of 2D outputs for inundation map, velocity and water depth.

7.2.4.2. 1D MODEL DAM BREAK MODEL STUDY

7.2.4.2.1. Model Setup

- Model domain: Ideally we need to carry out flood routing up to a location where the breach flood hydrograph gets moderated to a minimum and is expected that it will not pose risk and threat furrher downsntream reaches. In the present case , Song River reach of about 60 KM from the tail end of the reservoir to the confluence with Ganga River downstream of CWC gauge site at Satyanarayan as shown in Figure 7-24 was considered for the dam break simulation study

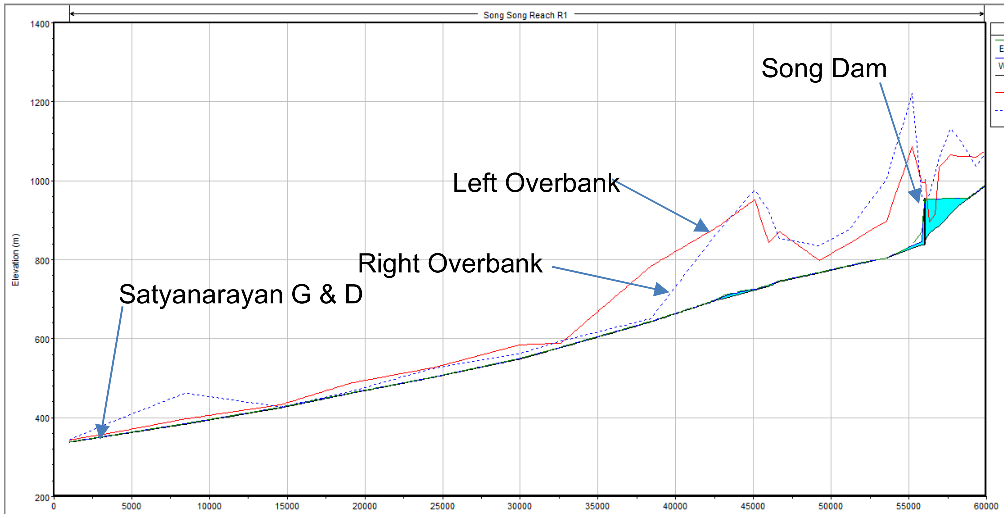
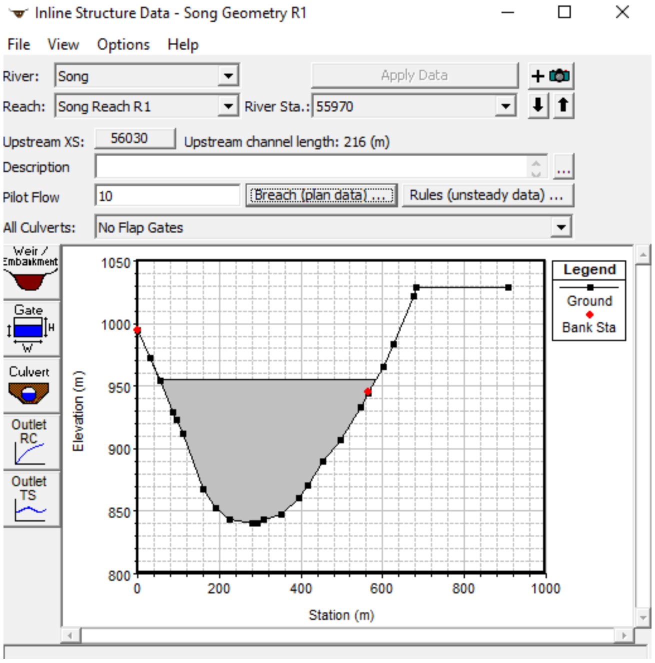


Figure 7-24: Longitudinal profile of Song River with its bank and Song Dam Location

- Reservoir Capacity: The capacity of the reservoir at the between RL 875 m to RL 980 m (FRL) is about 26.69 MCM (gross capacity).

- Cross Section: Actual surveyed cross sections were available for the reservoir area only. The model domain (river reach) of 60 Km length was considered for dam breach flood routing simulation. Therefore, SRTM DEM 30 M DEM was used to generate cross sections for the entire model reach and was used for simualtions. It was taken care that the reservoir capacity from the model simulation matches with the gross reservoir capacity (i.e 26.69 MCM) corresponding to maximum heigth of the water colume, i.e., FRL - River bed level, 980 m-875 m= 105 m. It is to be noted that, in general, topographical elevation from SRTM DEM data is higher than the actual survyed topographcial elevation. Therefore, while using SRTM DEM data in the present case, we needed to tweek the emabment top level and the final breach level in the HEC RAS Model to match the desired reservoir capcity of 26. 69 MCM.

- Inline structure and Breach Parametes: In the model, Song dam was was included and simuated as a weir/embakment inline structure with top of the embankment at EL 955 m. The top of the embankment (i.e., EL 955 m) and the final breach level (i.e, average river bed level at the dam location RL 855 m) was arrived after trial simlations to match the simulated reservoir volume of 26.69 MCM, the inline structure (weir/Emabnkment) and breach parameters are shown in Figure 7-25 and Figure 7-26 respectively.



Inline Structure Data - Song Geometry R1

River: Song

Reach: Song Reach R1

River Sta.: 55970

Upstream XS: 56030

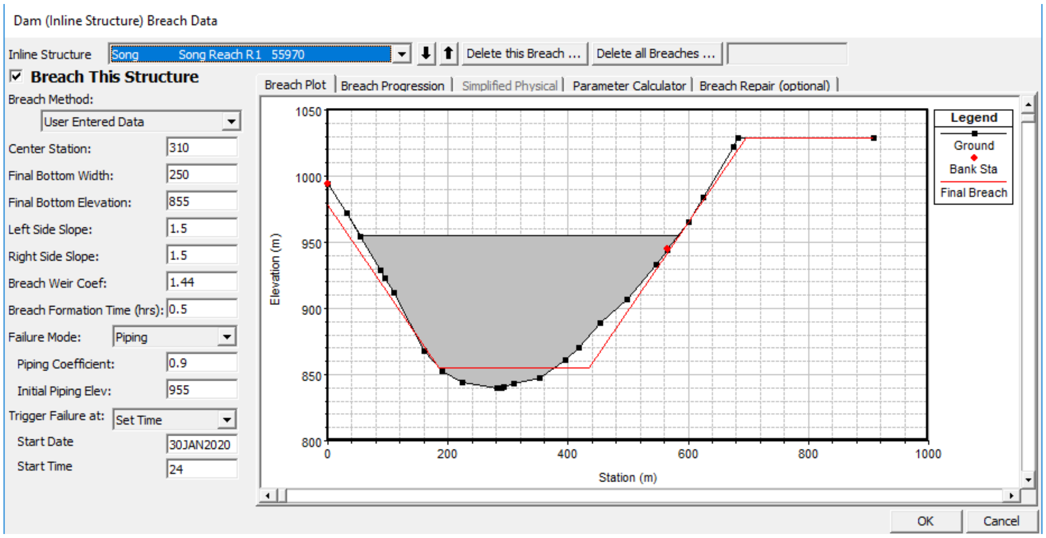
Upstream channel length: 216 (m)

Description

Pilot Flow: 10

All Culverts: No Flap Gates

Figure 7-25 : Cross-section of Song River at Dam location



Dam (Inline Structure) Breach Data

Inline Structure: Song Song Reach R1 55970

☑ **Breach This Structure**

Breach Method: User Entered Data

Center Station: 310

Final Bottom Width: 250

Final Bottom Elevation: 855

Left Side Slope: 1.5

Right Side Slope: 1.5

Breach Weir Coef: 1.44

Breach Formation Time (hrs): 0.5

Failure Mode: Piping

Piping Coefficient: 0.9

Initial Piping Elev: 955

Trigger Failure at: Set Time

Start Date 30JAN2020

Start Time 24

Figure 7-26 : Breach Parameters-0.5 hours breach formation time

- Boundary condition:

  Upstream boundary: Constant hydrograph (say 50 m3/s) at the upstream boundary (reservoir tail end)

  Downstream boundary: Normal depth with friction slope of 0.0008

- Initial condition: 200 m3/s
- Manning coefficient considered 0.035 (conservatively)
- Breach Simulations: Dam breach simulations carried out for different breach time such as, 0.25 Hrs, 0.5 Hrs, 0.75 Hrs and 1 Hrs

7.2.4.2.2. Results

7.2.4.2.2.1. Breach Flood Hydrograph

It has been assumed that during dam break, the huge volume of stored water from the reservoir will flow downstream at a sudden. The entire reserved water will outflow within a small span of time. The magnitude of peak flood depends upon the breach formation time as shown in Figure 7-27. It has been estimated that considering the severity, with breach formation time of 0.25 hours, peak flood of 47326 m3/s will pass from the breach portion. Below figure show that the magnitude of peak flood decreases with increase of breach formation time.

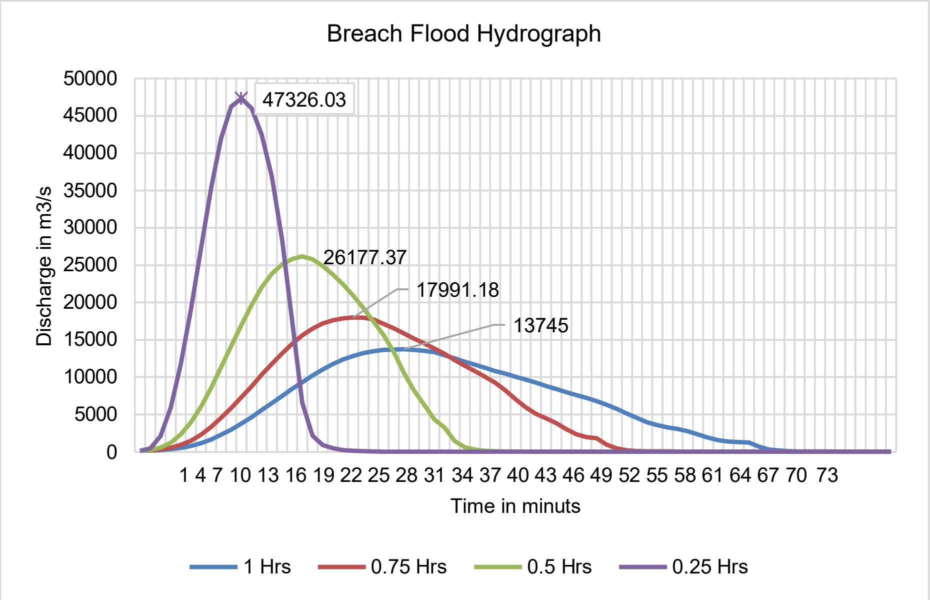


Figure 7-27 : Flood hydrograph corresponding to different breach formation time

7.2.4.2.2.2. Velocity and Depth

Considering most sevier case, the detail outcomes corresponding to least breach formation time have been analysed.

- Breach formation time: 0.25 Hrs (15 minutes)
- Peak dsicharge through the breach: 47326 m3/s

The maximum velocity and depth profile along the entires Song River has been shown in Figure 7-28. Figure shown that in the velly region downstream of dam, flow of water depth vaies in the range of 10 m to 15 m and gradually decrease to about 8 m and finally water depth in the range of 1.5 m to 2 m at the end location (bridge on Dehradun-Haridwar Road at connfluence with the Ganga River near Satyanarayana). Similarly, flood velocity just downstream of dam in the velly region are in the range of 10-15 m/s. In the main river channel velocity decrease to 3.5-3.75 m/s at end of study domain area.

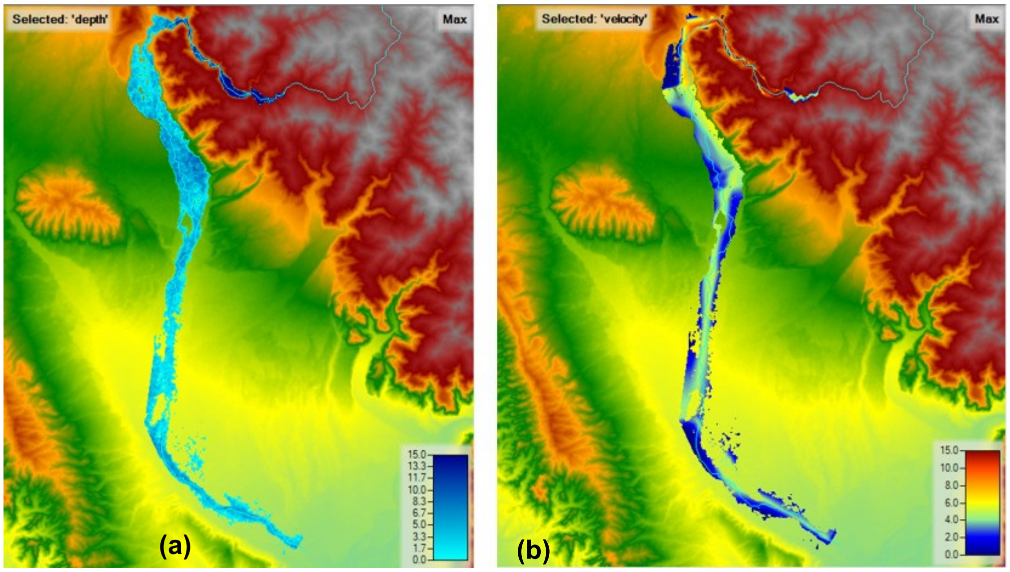


Figure 7-28 : (a) Max depth profile and (b) Max velocity profile

Maximum arrival time profile to reach the peak flood along the river reach is shown in Figure 7-29. Its shows that within 185 minutes the peak flood will reach in Song River near the confluence of Ganga River. Peak flood will cross near the Dehradun within 30 minutes and Miywala location within 36 minutes after the breach.

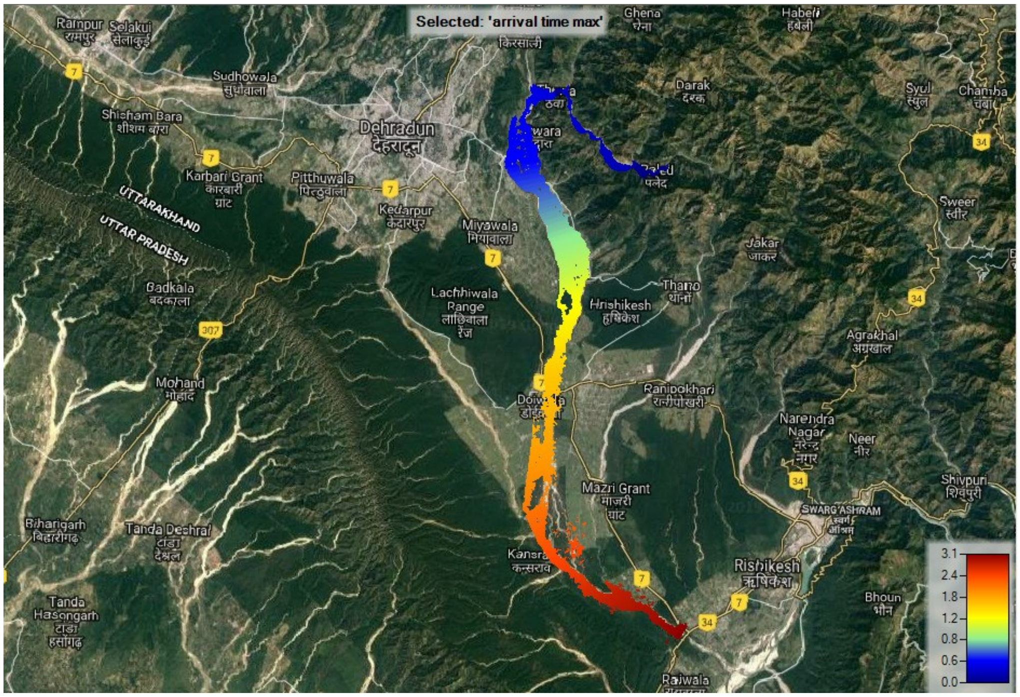


Figure 7-29 : Arrival time (in hrs) profile to reach maximum flood along the Song River Reach

The Maximum depth and velocity profile using google map showing important location are shown in Figure 7-30 and Figure 7-31.

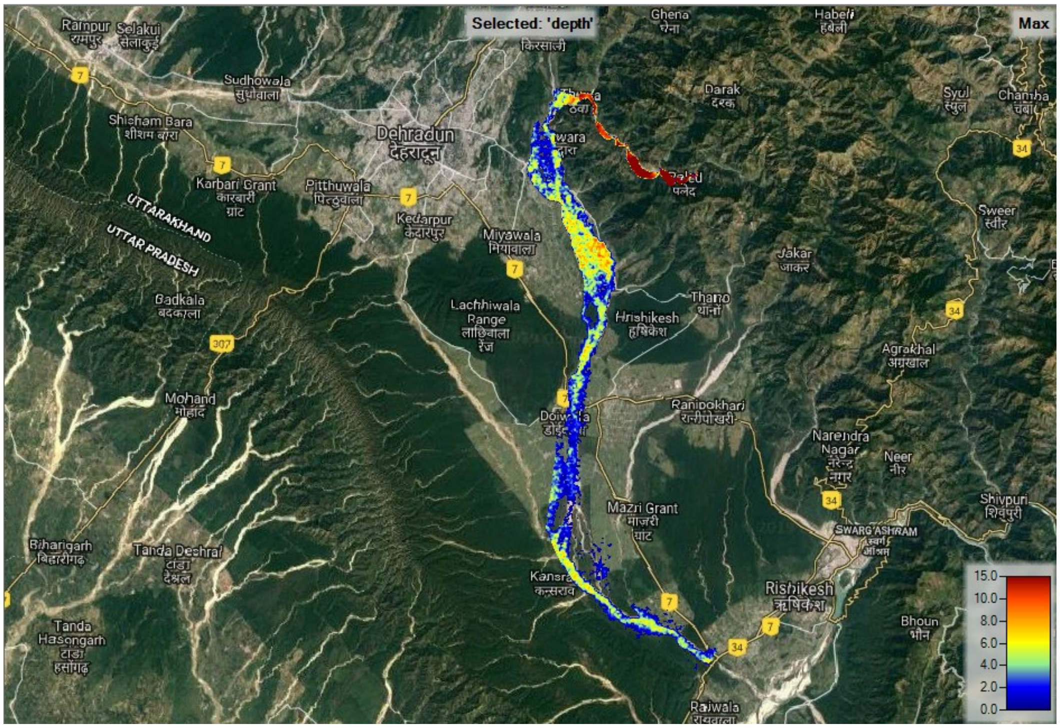


Figure 7-30 : Maximum depth profile along the Song river reach

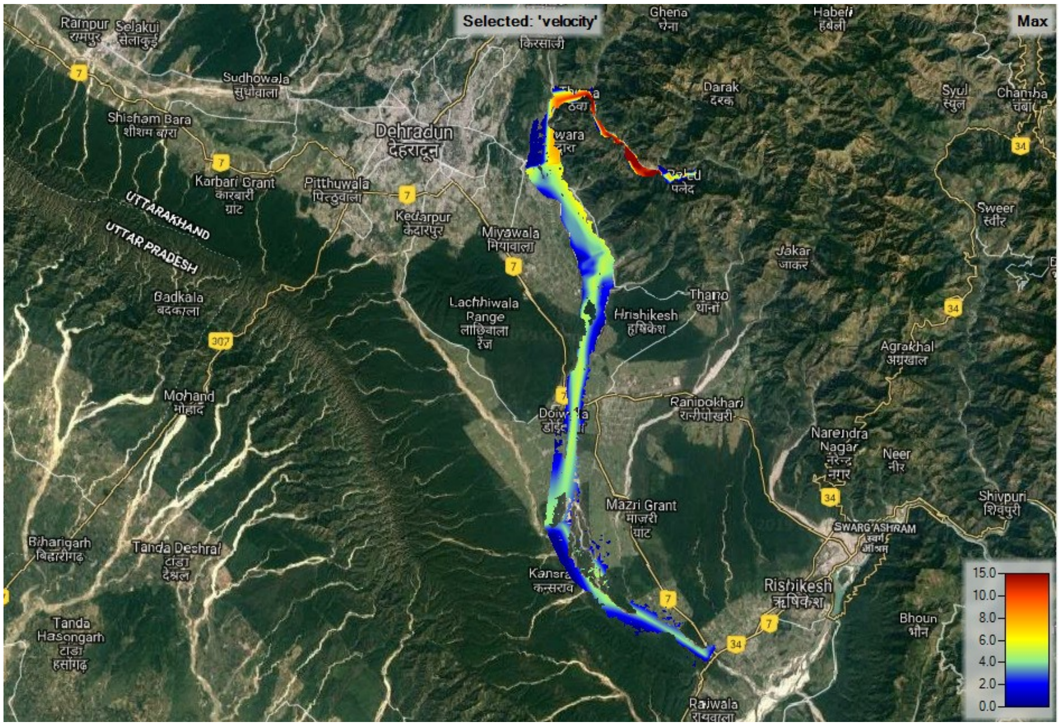


Figure 7-31 : Maximum velocity profile along the Song river reach

Maximum duration to recede the complete flood along the river reach is sown in Figure 7-32.

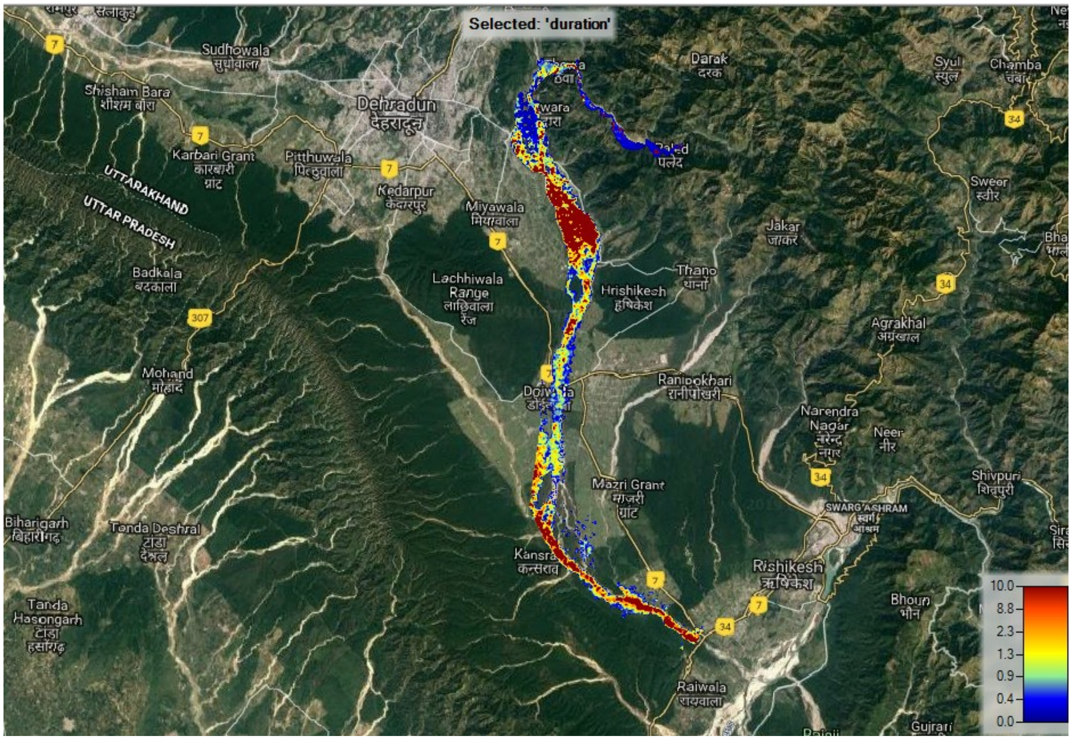


Figure 7-32 : Maximum duration to pass the flood hydrograph at various location

Above figure shown that near Miywala and Kansra region, the river reach is flatter and hence takes long duration of about 10 hrs to pass the complete hydrograph.

The summary of various output corresponding to various breach formation time have been given in Table 7-15.

Table 7-15 Summary of output Parameters for various Breach formations

	Breach Location		**Outlet location (Near the confluence with Ganga River)**		
Breach formation time (Hrs)	Peak discharge, (m³/s)	Time of peak discharge, (minute)	Peak discharge (m³/s)	Time of peak discharge, (Hrs: min)	Total time to pass the breach hydrograph through the stretch between Dam to Ganga Confluence, (Hrs: min)
0.25	47326	10	5103	3:07	9:01
0.50	26177	17	6055	3:10	9:22
0.75	17991	22	6092	3:19	9:40
1.00	13745	26	5995	3:28	9:55

7.2.4.3. 2D MODEL INUNDATION MODELLING

7.2.4.3.1. Model Setup

2D hydrodynamic modelling and simulation is also carried out to understand the extent of inundation area during passing of a flood hydrograph in river valley. In the present case also, HEC RAS 2D hydrodynamic modelling and simulation carried out using SRTM DEM and Flood Hydrograph generated from 1D HEC RAS dam breach simulation. The 2D model domain includes area along the Song River between Song Dam locations to the Ganga River as shown in Figure 7-33.

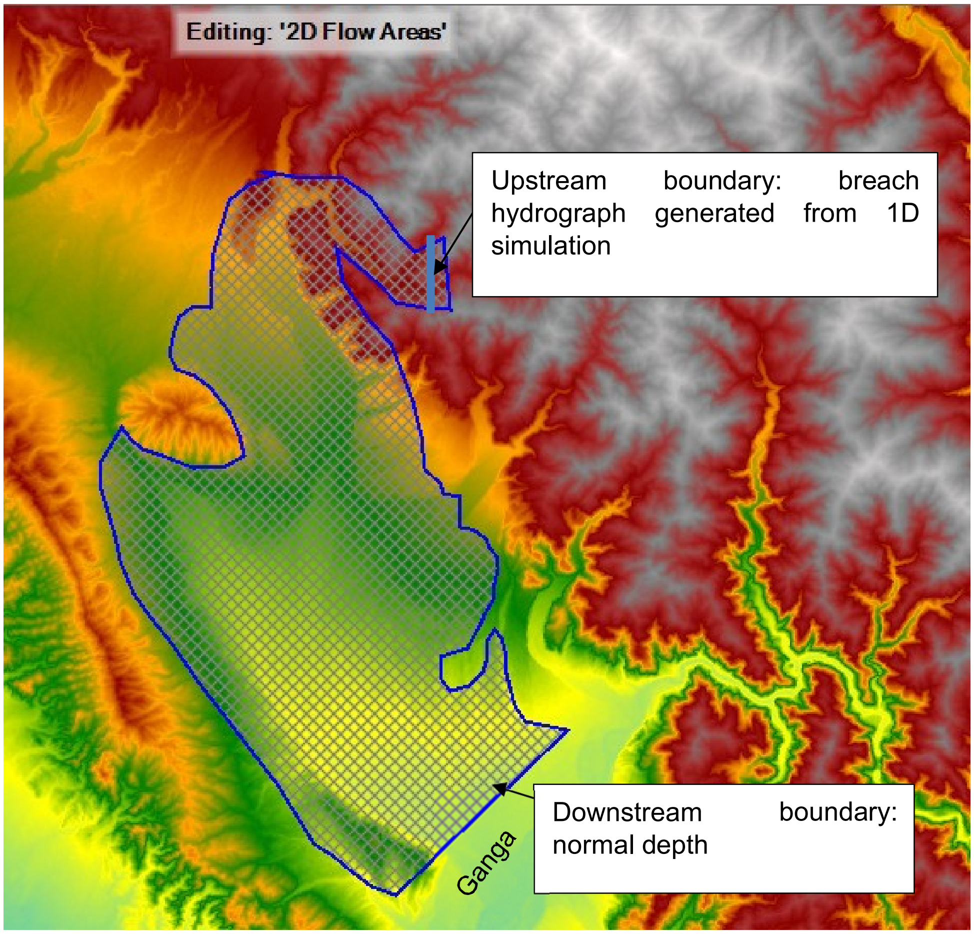


Figure 7-33 : Flow area for 2D-hydrodynamic analysis along the Song River Reach

7.2.4.3.2. Input parameters

- 2D flow area computation points: 44478 cells
- Average cell size: 10068 m2
- Upstream boundary: breach hydrograph generated from 1D simulation as above (section 7.2.4.2.2.1, Figure 7-27)
- Downstream boundary condition: Normal depth
- Manning coefficient: 0.03
- DEM: SRTM 30 M

7.2.4.3.3. Results

Using 2D model, velocity, depth of water and arrival time at various location along the river reach have been analysed for simulated breach hydrograph generated by 1D Model for breach formation time of 0.25 Hrs (i.e., Peak Flood of 47326 m^3/s) and 0.75 Hrs (Peak Flood of 17991 m^3/s) as shown in Figure 7-27 above. The maximum velocity, maximum water depth and maximum arrival time profile along the river reach are shown below in Figure 7-34 through Figure 7-39 respectively.

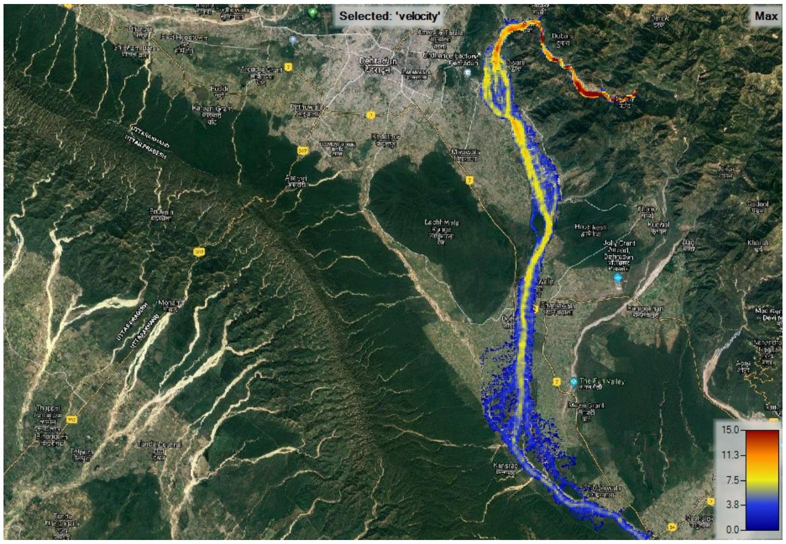


Figure 7-34 : Maximum velocity profile (m/s) for dam breach in 0.25 Hrs

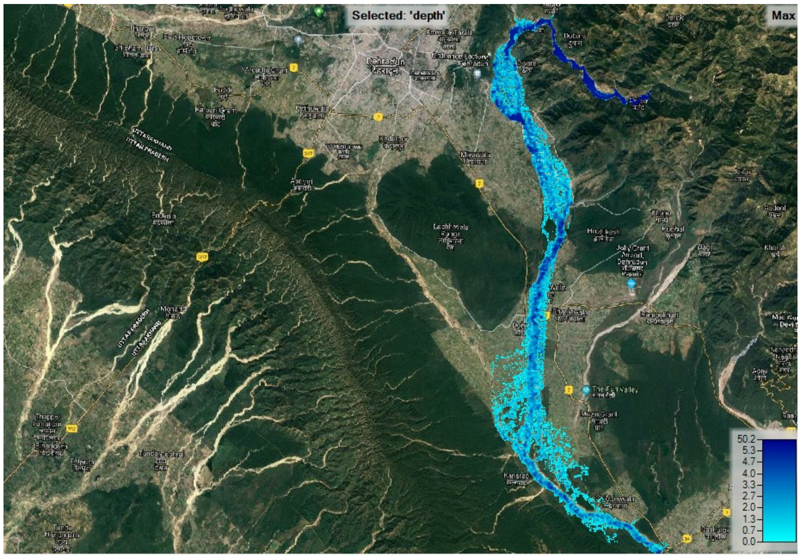


Figure 7-35 Maximum depth profile (m) for dam breach in 0.25 Hrs

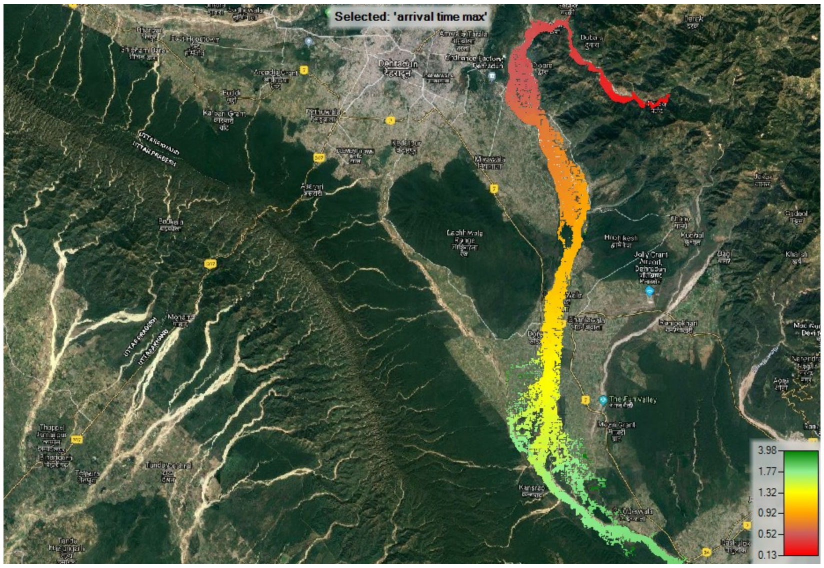


Figure 7-36 : Maximum arrival time (Hrs) for dam breach in 0.25 Hrs

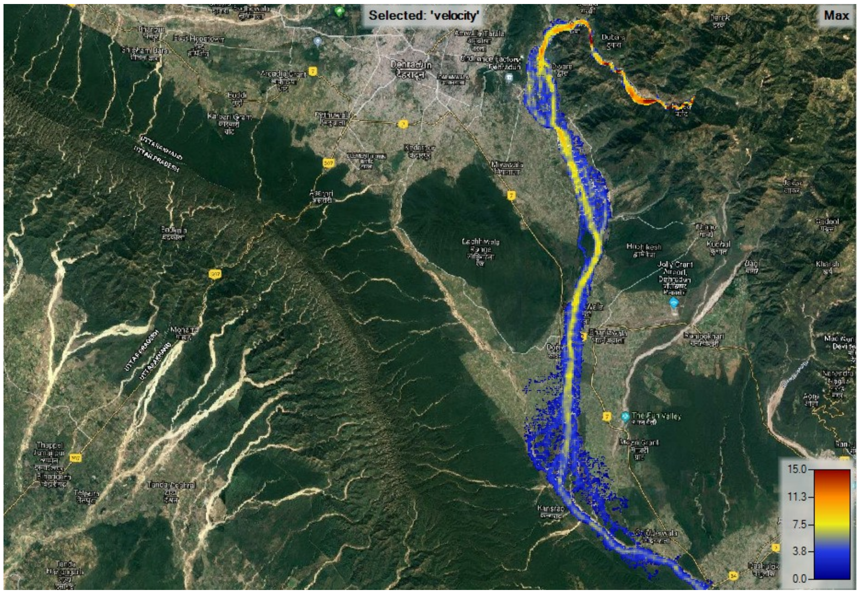


Figure 7-37 : Maximum velocity profile (m/s) for dam breach in 0.75 Hrs

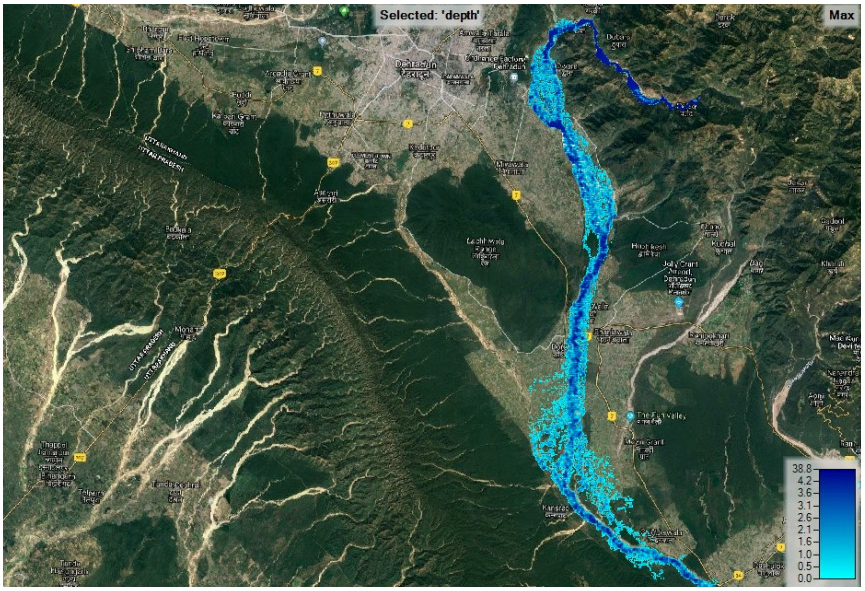


Figure 7-38 : Maximum depth profile (m) for dam breach in 0.75 Hrs

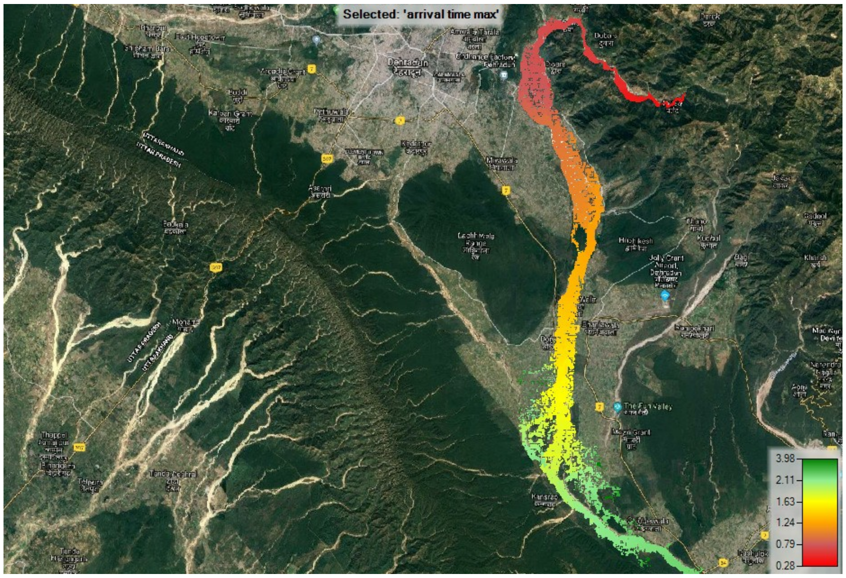


Figure 7-39 : Maximum arrival time (Hrs) for dam breach in 0.75 Hrs

7.2.4.4. RESULT DISCUSSION AND CONCLUSION

Dam break modelling and simulation studies were carried out using HEC RAS 1D and 2D models. The findings of the studies corresponding to an event of a hypothetical dam breach in 0.25 Hours (i.e., entire volume of water, 26.69 MCM is released in 15 minutes) are concluded as:

- In the valley area, between the dam location and Rajpur (where the river comes of the valley), the velocity and water depth will be very high. The flood gets moderated as it moves downstream in the plain area.

- The peak discharge at the breach location will be in order of 47326 m3/s which will reach in 10 minutes from the start of breaching. This peak flood moves downstream reaches and get moderated to 5103 m3/s after 3.07 Hrs near the Dehradun-Haridwar highway.
- Velocity in valley reaches will be in the range of 15-18 m/s near the downstream of the breach and about 8-10 m/s at the outlet of the valley near Rajnagar. The velocity get reduced to about 3 m/s near the Dehradun-Haridwar Highway Bridge at Satyanarayana.
- Peak flood will cross near the Dehradun within 30 minutes and Miywala location within 36 minutes after the breach.
- The area between river and Thano Marg near Bhupal Pani Reserve forest (RF) are venerable along the Song River on the left bank side for a length of about 6.5 Km.
- The left and right bank sides area near Doiwala area are venerable for a length of 7.2 Km. At this location flood peak will reach in 1.2 Hours.
- Left bank near Chiddarwala are venerable for a length of about 3.0 Km.
- Left bank near Khari Khurd, located upstream of bridge (NH-58, Haridwar-Dehradun Road near Satyanarayana) are venerable.

7.3. Hydro-Mechanical Equipments

Song Dam Drinking water project is a drinking water scheme with a 130.6m high dam along with a 15km long water conductor system. For smooth functioning of the project, a few Hydro-Mechanical equipment are necessary at different locations. This chapter discusses the general features of the Hydro-mechanical equipment for day to day working of the project.

Following are the main equipment as required in the project:

02 Lower Spillway Sluice Radial Gate
03 Lower Spillway Sluice Stoplogs
04 Upper Spillway Service Gate
05 Upper Spillway Stoplogs
06 Intake Bulkhead Gate
07 Intake Trash Racks
08 Butterfly Valves

The features of each component are discussed below:

7.3.1. Lower Spillway Sluice Radial Gate

Two radial Gates of size 7000mm x 8500mm each have been proposed for the lower spillway sluices with crest level at El. 912.00m. These gates shall be designed for an unbalanced hydrostatic head of 49m corresponding to FRL of El. 980.00m in accordance with IS 4623-2000. Each radial gate shall be operated with help of two hydraulic hoist of adequate capacities to be designed in accordance with the provisions contained in IS 10210-1993 (Under unbalanced head condition).

The salient features of radial gates are as under:

Table 7-16: Salient Features of Lower Spillway Sluice Radial Gate

Sl No	Description	Features	Remarks
1	Number of gates/ Openings	02 Nos.	
2	Clear Span	7000 mm	
3	Clear height above Sill Level	8500 mm	
4	Sill Level	EL. 911.000 m	
5	Top of Opening	EL. 919.500 m	
6	CL of Top Seal Seats	EL. 919.60 m	
7	Radius of gates	12000 mm	Inside of skin plate to centre of Trunnion
8	Skin Plate cladded with 3mm(Minimum) S.S. Plate	•	
9	Trunnion Girder	•	RCC Girder
10	FRL	EL. 960.000 m	
11	Design Head	69.000 m	
12	Seals (Rubber) IS 15466-2004 per gate		
i	Side Seals _ Music Mat Type	02 Nos.	As shown in the drawings
ii	Top Seal- Double Stem Type	02 Nos.	
iii	Bottom Seal – Flat seals	01 No.	
13	Guide Roller	04 Nos.	As shown in the drawings
14	Hydraulic hoists of adequate capacities	02 Nos.	
15	Drawings P.012745-W-20321-X01 (Sheet 1 of 3, 2 of 3, 3 of 3)	03 Nos.	

Erection procedure for Lower Spillway Sluice Radial Gate

The size of the radial gate is 7000 mm x 8500 mm. The gate shall be fabricated in suitable size vertical and horizontal pieces with a view of transportation and handling limitations. But no cutting at the centre of the span shall be done. All pieces of the gate and hoist shall be brought to the top of dam at EL 982.00 m.

All pieces of the gate and its components including hoist shall be lowered from top of dam to the bell mouth of the sluice at crest level EL 912.00 m with the help of a gantry crane or a mobile crane. The gate and hoist shall be transported from bell mouth to the gate erections location with the help of a trolley. Now the gate pieces and other components shall be bolting at sluices and welded after proper alignment. After assembly of the gate and its components. The hydraulics hoists shall be erected at EL 933.00 m and its sterns shall be connected at the bottom horizontal beam. All welds on the upstream face of the skin plate shall be ground finish smooth since the top rubber seal shall be submit on it during the operation in order to prevent the damage.

After completion of gate and hoist the hoist shall be connected with control room located at EL 933.00 m. Now the gate shall be operated on trial till smooth operation of the gate is achieved. The gates and its components shall be pointed in three coats of approved paint plus one coat of primer. The Hydraulic hoists shall be designed as per the provisions contained in IS 10210-1993.

7.3.2. Lower Spillway Stoplog

One set of Slide type stop logs for two openings of size 7000mm x 7525mm, each consisting of 3 units of equal size i.e. bottom two units shall be interchangeable whereas the top unit shall be non-interchangeable are proposed to facilitate the repairs and maintenance of Radial Gates. The stoplogs shall be designed in accordance with the provisions contained in IS 9349- 2006 for an unbalanced hydro static head of 68.025 m corresponding to FRL 980.00m. The stoplogs shall be operated under balanced conditions duly achieved with the help of two filling valves to be provided in the top unit and a gantry crane and a lifting beam of adequate capacities from the top of the dam i.e. EL. 982.00m. The stoplog units, when not in use, shall be stored in storage pits at EL. 982.00 m. The gantry crane and lifting beam having automatic engaging and disengaging arrangement of adequate capacities shall be designed in accordance with provisions contained in IS 3177 and IS 13591 respectively.

The salient features are as under:

Table 7-17: Salient Features of Lower Spillway Stoplog

Sl No	Description	Features	Remarks
1	Number of Openings	02 Nos.	
2	Number of Stoplogs having two interchangeable and top unit as non-interchangeable	01 Set	
3	FRL	EL. 980.000 m	
4	Sill Level	EL. 911.975 m	

5	Design Head (unbalanced head)	68.025 m	
6	Clear Spans	7000 mm	
7	Clear Height	7525 mm	
8	Skin Plate	D/S	
9	Sealing arrangement	D/S	
10	Type of stoplogs	Slide Type	
11	Operation of stoplogs	Unbalanced Head conditions	
12	c/c of side seal seats	7100 ± 3.0 mm	
13	c/c of track plates	7500 ± 3.0 mm	
14	Operation with help of		
i	Lifting beam (IS:13591-)	Adequate Capacity	
Ii	Gantry Crane (IS:3178……)	Adequate Capacity	
15	Type of seals (IS 15466)		
i	Side and Top Seals	Music Note Type	
ii	Bottom Seals	Flat Type	
16	Drawings P.012745-W-20322-X01 (Sheet 1 of 2, 2 of 2)	02 Nos.	

Erection procedure for Sluice Spillway Stoplog gate

The size of the stoplogs is 7000 mm x 7525 mm. The stoplogs shall be fabricated in 3(three) pieces i.e. bottom two unis shall be interchangeable and top unit as non-interchangeable. The size of bottom two units shall be 7000 mm x 2542 mm and size of top unit shall be 7000 mm x 2650 mm. The units shall be fabricated in pieces to meet the transportation limitations. All pieces shall be transported to the top of dam where these shall be assembled and welded to make three units. After fabrication the units shall lowered in the stoplog groove from Top of dam El 982.00 m. The sill level EL 911.975 m with the help of a automatic lifting beam and gantry crane for trial. After smooth trail the stoplog units shall be painted with three coats an approved paint plus one coat of primer.

7.3.3. Upper Spillway Service Gate

Upper Spillway Opening (01 No.) has been provided with crest level at EL. 975.00 m to facilitate the removal of floating trash and debris. Therefore, one no. of fixed wheel type vertical lift gate of size 5000 mm x 5000 mm at sill level EL. 974.50 m has been provided. The gate shall be designed in two equal size units for an un-balanced hydro static head of 5.50 m corresponding to FRL at EL. 980.00 m in accordance with the provisions contained in IS 4622-2003. The gate shall be operated with the help of an Electrically operated Rope Drum Hoist of adequate capacity to be designed in accordance with the provisions contained in IS 6938-2005.

The salient features are given below:

Table 7-18: Salient Features of Lower Spillway Service Gate

Sl No	**Description**	**Features**	**Remarks**
1	Number of Openings	01 Nos.	
2	Number of Gates	01 Nos.	
3	Type of Gate	Fixed Wheel Type	
4	FRL	EL. 980.000 m	
5	Sill Level	EL. 974.500 m	
6	Height of Gate + Freeboard	5800 mm	
7	Clear Width of Opening	5000 mm	
8	C/C of Side Seal Seats	5100 ± 3.0 mm	
9	C/C of Side Track Plates	5500 ± 3.0 mm	
10	Design Head (Unbalanced head)	5500 mm	
11	Sealing Arrangement	Upstream	
12	Type of seals (Rubber) IS 15466-2004		
i	Side Seals	Music Mat Type	
Ii	Bottom Seals	Flat Type	
13	Splice Joint	Semi-flexible	
14	Skin Plate	Up stream	
15	Hoisting Arrangement	Electrically operated Rope Drum Hoist of adequate capacity	

16	Operation	Unbalanced Head	
17	Drawings P.012745-W-20323-X01 (Sheet 1 of 2, 2 of 2)	02 Nos.	

7.3.4. Erection Procedure for Upper Spillway Service Gate

One No. of Fixed Wheel Type Vertical Lift Gate of size 5800 mm x 5000 mm shall be fabricated for erection at EL 947.50. The gate shall be fabricated in two equal size units having upstream skin plate, upstream sealing. The both units shall be spliced to make it one piece. The gate shall be fabricated in pieces to meet the transportation limitations. The pieces shall be transported to the site and welded into two units. Both the units shall be spliced together with semi flexible splicing and lowered the gate groove on the sill level EL 974.80 m with the help of Rope Drum Hoist in stable and on hoist supporting structure to be installed at El 982.00 m. The Rope Drum Hoist of approved capacity shall be designed as per IS : 6938-2005 and fabricated as per approved design and drawing. The gate shall operate on trial basis with the help of the Rope Drum Hoist till the smooth operation is achieved. The hoist supporting structure shall be designed and fabricated as per approved design and drawings

7.3.5. Upper Spillway Stoplogs

For the maintenance of vertical service gate, one set of stoplogs of size 5000 mm x 5120 mm has been provided. The stoplogs shall be designed in two equal size units. The stoplogs shall be operated under balanced head conditions to be achieved with the provision of filling valve of adequate capacity to be provided in the top unit. The stoplogs shall be designed for an unbalanced head of 5120mm corresponding to FRL at El.980.000m. The stoplog units shall be operated with the help of a lifting beam and monorail crane of adequate capacities to be designed in accordance with the provisions contained in IS 13591 and IS 3938 .respectively of adequate capacities under balanced head condition to be achieved with the help of two sets of filling valves to be provided in the top unit. When stoplogs are not in use, the units shall be stored in storage pits at EL. 982.000m.

The salient features are discussed below:

Table 7-19: Salient Features of Upper Spillway Stoplogs

Sl No	**Description**	**Features**	**Remarks**
1	Number of Openings	01 No.	
2	Number of Stoplogs	01 Set	
3	Type of Stoplogs	Sliding Type	
4	FRL	EL. 980.000 m	

5	Sill Level	EL. 974.880 m	
6	Total Height of Stoplog + Freeboard	5.32 m	
7	Clear Width of Opening	5000 mm	
8	C/C of Side Seal Seats	5100 ± 3.0 mm	
9	C/C of Side Track Plates	5600 ± 3.0 mm	
10	Design Head (Unbalanced hydrostatic head)	5120 mm	
11	Sealing Arrangement	Downstream	
12	Type of seals (Rubber) IS 15466-2004		
i	Side Seals	Music Note Type	
Ii	Bottom Seals	Flat Type	
13	Skin Plate	Downstream	
14	Hoisting Arrangement	Electrically operated Monorail Crane of adequate capacity & Lifting beam	
15	Operation	Balanced hydrostatic head condition	
16	Drawings P.012745-W-20322-X02 (Sheet 1 of 2, 2 of 2)	02 Nos.	

Erection Procedure of Upper Spillway Stoplogs

One set of stoplogs of sixe 5000 mm x 5120 mm shall be fabricated into two equal size interchangeable units as per approved design and drawings. The units are to be fabricated into pieces to meet the transportation limitations. The pieces of each units shall be assembled at site and welded with sluice plates. Each unit shall be operated with the help of a lifting beam and monorail crane of adequate capacity till the smooth trial is achieved.

The lifting beam and monorail crane shall be designed as per IS: 13591 and IS: 3938 respectively. The smooth trial is achieved the stoplog units and the lifting beam shall paint with 3 coats of approved paint and one coat of primer

7.3.6. Intake Bulkhead Gate

A sliding type bulk gate of 1500 mm x 1500 mm has been proposed for Intake to be located in CJ-2 and CJ-3 Block at 2100 mm from the Dam Axis. The bulkhead gate shall be designed for an unbalanced hydro-static head of 62.0 m as a slide types gate with provisions of filling valve corresponding to FRL 980.00 m in accordance with the provisions contained in IS 9349-2006. The gate shall be operated under balanced conditions achieved with the help of filling valve to be provided in the gate leaf. The gate shall be operated with the help of an electrically operated Rope drum of adequate capacity installed hoist bridge structure at top of the Dam at EL. 982.00m

The salient features are discussed below:

Table 7-20: Salient Features of Intake Bulkhead Gate

Sl No	Description	Features	Remarks
1	Number of Openings	01 Nos.	
2	Number of Bulkgates	01 Set	
3	Type of Bulkhead Gate	Slide Type	
4	FRL	EL. 980.00 m	
5	Top of Dam	EL. 982.00 m	
6	Sill Level	EL. 918.00 m	
7	Top of Opening	EL. 919.50 m	
8	C/L of top seal seat	EL. 919.60 m	
9	Clear Width of Opening	1500 mm	
10	C/C of Side Seal Seats	1600 mm	
11	C/C of Track Plates	2100 mm	
12	Skin Plate	Downstream	
13	Sealing Arrangement	Downstream	
14	Design Head (Unbalanced hydrostatic head)	62.00 m	
15	Operation		
i	Under balanced head	Achieved By filling Valve	
16	Type of Hoisting Arrangement	Electrically operated Rope Drum hoist	
17	Design		

i	Gate	IS 9349 - 2006	
ii	Electrically operated Rope Drum hoist of adequate capacity	IS 6938 - 2005	
18	Type of seals (Rubber IS 15466 (Latest edition)		
i	Side and Top Seals	Music Note Type	
ii	Bottom Seals	Flat Type	
19	Drawings P.012745-W-20323-X02 (Sheet 1 of 2, 2 of 2)	• Nos.	

Erection Procedure of Intake Bulkhead Gate

The sliding type bulkhead gate of size 1500 mm x 1500 mm shall be fabricated in one piece accordingly to the approved design and drawings. The gate shall have downstream skin plate, sealing and fitting valve. The gate shall be operated with the help of a deictically operated Rope Drum Hoist installed at EL 982.00 m. The Rope Drum Hoist shall be fabricated and installed as per approved design and drawings. After the smooth trail run the gate and hoist shall be painted with 3 coats of approved paint and one coat of primer.

7.3.7. Intake trash rack for Intake

Trash rack is provided at the Intake inclined at 7 degrees from the vertical. The clear width of the opening is 1500mm and inclined height is 2200 mm. the spacing of trash bars shall be 112mm. The trash racks shall be designed in accordance with the provisions contained in IS 11388-212. The trash racks shall be cleared manually during lean season when the water level is at minimum level. For repairs and maintenance, if required, shall be done during lean season by taking out the trash rack panel to the top of the dam with the help of a lifting beam and electrically operated monorail crane.

Table 7-21: Salient Features of Intake trash rack for Intake

Sl No	Description	Features	Remarks
1	Number of Openings	01 No.	
2	Clear width of Opening	1500 mm	
3	Sill Level	EL. 918.00 m	
4	Top of opening	EL. 919.936 m	
5	Inclined height	22000 mm	

6	No of Panels	01 No.	
7	Trash Bars	12th x 100 mm	
8	Spacing of trash bars	112 c/c	
9	Minimum size of bars	100 x 12th	

Erection Procedure of Trash Rack for Intake

One set of Trash Rack Panel for the opening size 1500 mm x 2200 mm (inclined) shall be fabricated as per approved design and drawings. The Trash Rack Panel for repair maintenance shall be operated with the help of a lifting beam and electrically operated monorail crane of the approved design and drawings

7.3.8. Butterfly Valve

One number of butterfly valve of 1500 mm bore has been provided at 60m downstream of the dam on the water conductor. Butterfly valve shall be double eccentric butterfly valve confirming to EN 593W.SS seat and 180 input IP 64 gear box for drinking water supply to max 70°C Temperature. The disc seal shall be made of AVK's drinking water approved EPDM rubber featuring an excellent compression set and thus ability to regain its original shape. It shall operate under a head of 62m.

The features are discussed as under:

- The tilted disc releases the compression of the disc sealing after a few degrees of opening, which extends the durability and gives low operating torques.
- The disc is fixated to prevent wear and fluttering.
- The disc seal profile and rubber quality ensure low closing torques.
- Seal retainer ring of stainless steel.
- The threaded bolt holes in the disc are corrosion protected with O-rings.
- Replaceable seat ring of stainless steel fixed with bolts sealed with epoxy and sealed with an O-ring.
- Shaft of stainless steel AISI 431 with self-lubricating bearings.
- The shaft ends are fully encapsulated in the disc and are fixed with dowels corrosion protected with O-rings and a stainless steel security plate. Key and keyway as backup.
- Replaceable shaft sealing with two EPDM O-rings on each side of a bronze bushing and a flat NBR gasket.
- Optional locking device.
- DN 700-1600, body and disc coated with fusion bonded epoxy (FBE) to DIN 30677-2, GSK approved, blue RAL 5017, according to WRAS-DVGW/W270/UBA.
- DN≥1800, body and disc coated with 2-pack epoxy, blue RAL 5017 externally, ribbon blue or cream white internally, according to WRAS.

7.4. References

a. Plain and Reinforced Concrete – Code for Practice, IS 456:2000

b. Criteria for the Design of Solid Gravity Dams, IS 6512: 1984
c. Criteria for Earthquake resistant Design of Structures, IS 1893: 1984
d. Criteria for Earthquake resistant Design of Structures and Buildings Part I, IS 1893 (Part I): 2002
e. US Army corps of engineers EM-1110-12 and 2200
f. DPR-August-2011 –Detail project report Voume-1 –Engineering
g. EQD/6036 17-18 March 2018 of IIT Roorkee Site Specific Design Earth quick Parameter.

8. RESERVOIR PLANNING

8.1. Introduction

Detailed hydrology computation to estimate the inflow has been discussed in Chapter 6. In continuation to section 6.4.3, Reservoir balancing to access water availability has been discussed in this chapter.

The time distributed 10-daily assessment of water availability in Song river has been carried out using storage reservoir balancing analysis to meet the given drinking water demand of 150 MLD. For the reservoir balancing analysis the following inflow, outflow and storage components have been considered.

1. Storages available in the reservoir during each 10-daily time step in MCM.
2. 10-daily river inflow in to the reservoir in MCM.
3. 10-daily outflow (supply) from reservoir storage to meet a given drinking water demand in MCM.
4. 10 daily evaporation losses from storage reservoir in MCM.
5. Environmental flow requirement (EFR) for 10-daiy time step (in MCM) as per the prescribed guidelines of the Govt. of India vide Gazette Notification No. 4009 (S.O. 5195(E)) dated 09 October 2018.

8.2. Estimation of evaporation from the storage reservoir:

The detailed approach of estimation of evaporation from the storage reservoir has been described in Section 6.3 (part 6.3.3 & Table 6-6). The same has been reproduced here for ready reference. Using pan-to-lake conversion coefficients suggested by Ramasastri (1987) in Table 6-5 (in Section-6.3) the pan evaporation values measured at FRI station for the period from 1975-1993 and 2004-2016, monthly average evaporation rates from reservoir storage have been estimated as given in Table 8-1.

Table 8-1: Estimated values of monthly evaporation rates from reservoir storage.

Month	Measured value of average Pan evaporation mm/day	Pan to lake evaporation conversion Coefficient	Evaporation from water reservoir body. mm/day
Jan.	1.27	0.6	**0.762**
Feb.	1.94	0.6	**1.164**
Mar.	3.26	0.7	**2.282**
Apr.	5.32	0.7	**3.724**
May.	6.49	0.8	**5.192**

June.	5.30	0.8	**4.24**
July.	2.70	0.8	**2.16**
Aug.	2.32	0.8	**1.856**
Sept.	2.74	0.7	**1.918**
Oct.	2.61	0.7	**1.827**
Nov.	1.78	0.6	**1.068**
Dec.	1.26	0.6	**0.756**

8.3. Estimation of environmental flow requirement (EFR)

The Song River is one of the tributaries of River Ganga and the Ministry of Water Resources River Development and Ganga Rejuvenation, Government of India, vide Gazette Notification No. 4009[S.O.5195(E)] dated 09 October 2018, notified environmental flow requirement (EFR) for Upper Ganga River basin stretch starting from originating glaciers and through respective confluence meeting at Devaprayag up to Haridwar as given in Table 8-2. Accordingly, the water availability assessment has been carried out for Song Dam site after deducting the water demand for EFR for the downstream as prescribed in Table 8-2**.**

Table 8-2: Environmental flow requirement (EFR) for Upper Ganga River basin stretch starting from origin and Devaprayag to Haridwar (*Source: Gazette notification No. 4009 [S.O.5195(E)] dated 09 October 2018)*

Sl. No.	Season	Months	(%) Percentage of Monthly Average Flow observed during each of preceding 10-daily period.
1	Dry	November to March	20
2	Lean	October, April and May	25
3	High Flow Season	June to September	30*#

*# 30% of monthly flow of high flow season.

Further, Chipaldi River joins the Song River in the downstream at about 350 m from the proposed Dam site. The catchment area of Chipaldi is about 30.81 Km^2. The Chipaldi is another river with perennial nature having flow characteristics similar to that of Song river at Dam site. Flow from Chipaldi is available in addition to EFR flow from proposed Song Dam. It has sufficient flow to meet any other requirement in the downstream of the Song Dam site including Kalanga canal requirement.

8.4. Reservoir water balance analysis

The reservoir water balance analysis has been carried out for the lowest rainfall year (i.e., 2002-03) 10 daily inflows in to the reservoir, evaporation losses from reservoir and environmental water requirement (EFR)

- For drinking water demand of 150 MLD with reservoir storage capacity 26.68 MCM (at FRL980 m).

The 10-daily reservoir balance analysis has been carried out using following three flow series for the driest rainfall year 2002-03 (i.e. 97% dependable year).

A. Observed flow series at the Dam site.

B. Estimated flow series for Dam site using observed discharge data at Satyanarayana site by CWC.

C. Simulated flow series generated using rainfall-runoff modelling through application of Mike Basin NAM model (MIKE by DHI).

The results of reservoir water balance using above three flow series (at A, B & C) for option drinking water demand of 150 MLD with reservoir storage capacity 26.4 MCM (at FRL= 980 m) are presented in respective Tables (Table 8-3, Table 8-4 and Table 8-5). The 10-daily reservoir balance analysis indicated that the reservoir got filled and reached at FRL by end of August or beginning of September month in the driest year of record. Therefore, the reservoir balancing has been started from first 10-daily period of September month for simplicity. The results of analysis using all the three flow series indicated that a regular drinking water supply of 150 MLD, need for EFR release and reservoir evaporation are met and the minimum water level (MWL) in reservoir are above 928 m, 954 m and 924 m, respectively during the year.

The summary results is presented in Table 8-6. From the 10-daily reservoir balance study for the driest year of 97% dependability level (2002-03), the analysis revealed that there is sufficient water available at proposed Song Dam site to meet sustainable drinking water demand of 150 MLD corresponding to 980m FRL, with a storage reservoir of 26.40 MCM capacity. Thus, it is feasible from water availability point of view to take up any suitable options to meet the future drinking water demand forthe Dehradun. Further, the supply of drinking water from proposed Song Dam will lead to substantial reduction in groundwater withdrawal and will ensure groundwater sustainability in the region.

10-daily observed flow series at dam site, 10-daily estimated from Satyanarayana at Dam site and 10-daily simulated flow series for Dam Site Using Mike Basin NAM Model has been computed and attached as **Annexure 8.1, Annexure 8.2** and **Annexure 8.3** respectively**.**

Table 8-3: Reservoir Balance Analysis Using Observed Flow Series at Dam Site for Demand =150 MLD, FRL = 980 m and Storage at FRL =26.40

MONTH	**10-DAILY**	**Observed flow (MCM) for 97% Dependable year at Dam Site (say ~ 100%)**	**Cumulative Inflow to dam (MCM) with DSL storage= 4.55 MCM**		**MONTH**	**10-DAILY**	**Observed flow (MCM) for 97% Dependable year a Dam Site**	**Drinking Water Demand (MLD)**	**Drinking Water Demand (MCM/Day), C=(B/1000)**	**No. of Days**	**10-daily Drinking Water Demand ((MCM), E=C*D**	**Environmental flow requirement (MCM)**	**Evaporation Losses (MCM)**	**10-Daily (Dam Inflow -Demand-EFR-EV), H=A-E-F-G**	**Part of Demand to be met from Dam Storage (MCM)**	**Reservoir Storage (MCM)**	**Reservoir Level. m**
		002-03	***4.55***				*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	***26.40***	
JUN.	1	0.484	5.034		SEPT.	1	**9.793**	150	0.15	10	1.50	2.9378	0.0125	5.342	0.000	26.400	
	2	0.412	5.446			2	10.323	150	0.15	10	1.50	3.0969	0.0125	5.714	0.000	26.400	
	3	0.457	5.903			3	6.012	150	0.15	10	1.50	1.8035	0.0125	2.696	0.000	26.400	
JULY	1	1.093	6.996		OCT.	1	4.493	150	0.15	10	1.50	1.1232	0.0119	1.858	0.000	26.400	
	2	0.993	7.989			2	3.288	150	0.15	10	1.50	0.8219	0.0119	0.954	0.000	26.400	
	3	4.252	12.240			3	2.627	150	0.15	11	1.65	0.6569	0.0131	0.307	0.000	26.400	
AUG.	1	6.998	19.238		NOV.	1	1.909	150	0.15	10	1.50	0.3817	0.0069	0.020	0.000	26.400	
	2	13.460	32.698			2	1.529	150	0.15	10	1.50	0.3059	0.0069	-0.284	0.284	26.116	
	3	11.731	44.429			3	1.397	150	0.15	10	1.50	0.2794	0.0069	-0.389	0.389	25.727	
SEPT.	1	9.793	**54.221**		DEC.	1	1.312	150	0.15	10	1.50	0.2623	0.0049	-0.456	0.456	25.272	
	2	10.323	64.544			2	1.159	150	0.15	10	1.50	0.2319	0.0049	-0.577	0.577	24.694	
	3	6.012	70.556			3	1.147	150	0.15	10	1.50	0.2295	0.0049	-0.587	0.587	24.107	
OCT.	1	4.493	75.049		JAN.	1	0.937	150	0.15	10	1.50	0.1875	0.0049	-0.755	0.755	23.352	
	2	3.288	78.336			2	0.818	150	0.15	10	1.50	0.1636	0.0046	-0.850	0.850	22.502	
	3	2.627	80.964			3	0.737	150	0.15	11	1.65	0.1474	0.0050	-1.065	1.065	21.437	
NOV.	1	1.909	82.872		FEB.	1	1.179	150	0.15	10	1.50	0.2359	0.0064	-0.563	0.563	20.874	
	2	1.529	84.402			2	0.975	150	0.15	10	1.50	0.1949	0.0064	-0.727	0.727	20.147	
	3	1.397	85.799			3	0.928	150	0.15	8	1.20	0.1856	0.0051	-0.463	0.463	19.684	
DEC.	1	1.312	87.110		MAR.	1	1.464	150	0.15	10	1.50	0.2927	0.0126	-0.342	0.342	19.343	
	2	1.159	88.270			2	0.931	150	0.15	10	1.50	0.1863	0.0126	-0.767	0.767	18.575	
	3	1.147	89.417			3	0.625	150	0.15	11	1.65	0.1249	0.0138	-1.164	1.164	17.411	
JAN.	1	0.937	90.355		APR.	1	0.487	150	0.15	10	1.50	0.1218	0.0186	-1.153	1.153	16.258	
	2	0.818	91.173			2	0.447	150	0.15	10	1.50	0.1117	0.0186	-1.184	1.184	15.075	
	3	0.737	91.910			3	0.428	150	0.15	10	1.50	0.1069	0.0168	-1.196	1.196	13.879	
FEB.	1	1.179	93.089		MAY.	1	0.389	150	0.15	10	1.50	0.0972	0.0234	-1.232	1.232	12.647	
	2	0.975	94.064			2	0.370	150	0.15	10	1.50	0.0924	0.0208	-1.243	1.243	11.403	
	3	0.928	94.992			3	0.417	150	0.15	11	1.65	0.1043	0.0228	-1.360	1.360	10.044	
MAR.	1	1.464	96.455		JUN.	1	0.484	150	0.15	10	1.50	0.1452	0.0169	-1.178	1.178	8.865	
	2	0.931	97.387			2	0.412	150	0.15	10	1.50	0.1236	0.0148	-1.226	1.226	7.639	
	3	0.625	98.011			3	0.457	150	0.15	10	1.50	0.1371	0.0127	-1.193	1.193	6.446	
APR.	1	0.487	98.499		JULY	1	1.093	150	0.15	10	1.50	0.3279	0.0065	-0.741	0.741	5.705	**MWL-**
	2	0.447	98.945			2	0.993	150	0.15	10	1.50	0.2978	0.0065	-0.812	0.812	4.893	**928 m**
	3	0.428	99.373			3	4.252	150	0.15	10	1.50	1.2755	0.0054	1.471	0.000	6.364	
	1	0.389	99.762			1	6.998	150	0.15	10	1.50	2.0993	0.0056	3.393	0.000	9.757	

MAY.	2	0.370	100.132		AUG.	2	13.460	150	0.15	10	1.50	4.0381	0.0065	7.916	0.000	17.672
	3	0.417	100.549			3	11.731	150	0.15	11	1.65	3.5192	0.0102	6.551	0.000	24.224

Table 8-4: Reservoir Balance Analysis Using Estimated Flow Series from Satyarayana observed flow data for Dam Site Demand =150 MLD, FRL = 980 m and Storage at FRL = 26.40

MONTH	10-DAILY	Observed flow (MCM) for 97% Dependable year at Dam Site (say ~ 100%)	Cumulative Inflow to dam (MCM) with DSL storage= 4.55 MCM		MONTH	10-DAILY	Observed flow (MCM) for 97% Dependable year a Dam Site	Drinking Water Demand (MLD)	Drinking Water Demand (MCM/Day), C=(B/1000)	No. of Days	10-daily Drinking Water Demand ((MCM), E=C*D	Environmental flow requirement (MCM)	Evaporation Losses (MCM)	10-Daily (Dam Inflow -Demand-EFR-EV), H=A-E-F-G	Part of Demand to be met from Dam Storage (MCM)	Reservoir Storage (MCM)	Reservoir Level. m
		2002-03	*4.55*				*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	***26.40***	
JUN.	1	1.362	5.912		SEPT.	**1**	**6.272**	150	0.15	10	1.50	1.8816	0.0125	2.878	0.000	26.400	
	2	1.323	7.235			2	6.150	150	0.15	10	1.50	1.8450	0.0125	2.792	0.000	26.400	
	3	1.331	8.566			3	3.073	150	0.15	10	1.50	0.9220	0.0125	0.639	0.000	26.400	
JULY	1	1.561	10.126		OCT.	1	2.088	150	0.15	10	1.50	0.5221	0.0119	0.054	0.000	26.400	
	2	1.327	11.453			2	2.151	150	0.15	10	1.50	0.5378	0.0119	0.102	0.000	26.400	
	3	1.296	12.750			3	1.743	150	0.15	11	1.65	0.4357	0.0131	-0.356	0.356	26.044	
AUG.	1	2.090	14.839		NOV.	1	1.724	150	0.15	10	1.50	0.3448	0.0069	-0.128	0.128	25.916	
	2	10.272	25.112			2	1.689	150	0.15	10	1.50	0.3378	0.0067	-0.156	0.156	25.761	
	3	4.023	29.135			3	1.599	150	0.15	10	1.50	0.3198	0.0067	-0.227	0.227	25.533	
SEPT.	1	6.272	**35.407**		DEC.	1	1.595	150	0.15	10	1.50	0.3190	0.0045	-0.228	0.228	25.305	
	2	6.150	41.557			2	1.603	150	0.15	10	1.50	0.3205	0.0045	-0.222	0.222	25.082	
	3	3.073	44.630			3	1.473	150	0.15	11	1.65	0.2947	0.0041	-0.475	0.475	24.607	
OCT.	1	2.088	46.719		JAN.	1	1.621	150	0.15	10	1.50	0.3242	0.0042	-0.207	0.207	24.400	
	2	2.151	48.870			2	1.516	150	0.15	10	1.50	0.3031	0.0042	-0.292	0.292	24.108	
	3	1.743	50.613			3	1.398	150	0.15	11	1.65	0.2795	0.0046	-0.536	0.536	23.571	
NOV.	1	1.724	52.337		FEB.	1	1.493	150	0.15	10	1.50	0.2987	0.0058	-0.311	0.311	23.260	
	2	1.689	54.026			2	1.402	150	0.15	10	1.50	0.2805	0.0058	-0.384	0.384	22.877	
	3	1.599	55.625			3	1.275	150	0.15	8	1.20	0.2550	0.0047	-0.185	0.185	22.692	
DEC.	1	1.595	57.220		MAR.	1	1.483	150	0.15	10	1.50	0.2966	0.0114	-0.325	0.325	22.367	
	2	1.603	58.823			2	1.254	150	0.15	10	1.50	0.2508	0.0114	-0.508	0.508	21.859	
	3	1.473	60.296			3	1.259	150	0.15	11	1.65	0.2518	0.0113	-0.654	0.654	21.204	
JAN.	1	1.621	61.917		APR.	1	1.193	150	0.15	10	1.50	0.2983	0.0168	-0.622	0.622	20.583	
	2	1.516	63.433			2	1.151	150	0.15	10	1.50	0.2877	0.0168	-0.654	0.654	19.929	
	3	1.398	64.830			3	1.076	150	0.15	10	1.50	0.2690	0.0149	-0.708	0.708	19.221	
	1	1.493	66.324			1	1.059	150	0.15	10	1.50	0.2647	0.0208	-0.727	0.727	18.494	

FEB.	2	1.402	67.726		MAY.	2	0.933	150	0.15	10	1.50	0.2331	0.0208	-0.821	0.821	17.673	
	3	1.275	69.001			3	1.001	150	0.15	11	1.65	0.2502	0.0200	-0.919	0.919	16.753	
MAR.	1	1.483	70.484		JUN.	1	1.362	150	0.15	10	1.50	0.4086	0.0148	-0.561	0.561	16.192	
	2	1.254	71.738			2	1.323	150	0.15	10	1.50	0.3968	0.0148	-0.589	0.589	15.603	
	3	1.259	72.997			3	1.331	150	0.15	10	1.50	0.3993	0.0148	-0.583	0.583	15.020	
APR.	1	1.193	74.190		JULY	1	1.561	150	0.15	10	1.50	0.4682	0.0086	-0.416	0.416	14.604	
	2	1.151	75.341			2	1.327	150	0.15	10	1.50	0.3980	0.0097	-0.581	0.581	14.023	
	3	1.076	76.417			3	1.296	150	0.15	11	1.65	0.3889	0.0129	-0.755	0.755	13.267	**MWL-**
MAY.	1	1.059	77.476		AUG.	1	2.090	150	0.15	10	1.50	0.6269	0.0121	-0.049	0.049	13.218	**954 m**
	2	0.933	78.408			2	10.272	150	0.15	10	1.50	3.0817	0.0121	5.679	0.000	18.897	
	3	1.001	79.409			3	4.023	150	0.15	11	1.65	1.2070	0.0133	1.153	0.000	20.050	

Table 8-5: Reservoir Balance Analysis Using Simulated Flow Series at Dam Site for Demand =150 MLD, FRL = 980 m and Storage at FRL =26.40

MONTH	**10-DAILY**	**Observed flow (MCM) for 97% Dependable year at Dam Site (say ~ 100%)**	**Cumulative Inflow to dam (MCM) with DSL storage= 4.55 MCM**		**MONTH**	**10-DAILY**	**Observed flow (MCM) for 97% Dependable year a Dam Site**	**Drinking Water Demand (MLD)**	**Drinking Water Demand (MCM/Day), C=(B/1000)**	**No. of Days**	**10-daily Drinking Water Demand ((MCM), E=C*D**	**Environmental flow requirement (MCM)**	**Evaporation Losses (MCM)**	**10-Daily (Dam Inflow -Demand-EFR-EV), H=A-E-F-G**	**Part of Demand to be met from Dam Storage (MCM)**	**Reservoir Storage (MCM)**	**Reservoir Level. m**
		002-03	*4.55*				*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	***26.40***	
JUN.	1	0.245	4.795		SEPT.	**1**	**10.109**	150	0.15	10	1.5	3.0326	0.0125	5.564	0.000	26.400	
	2	1.009	5.804			2	9.905	150	0.15	10	1.5	2.9714	0.0125	5.421	0.000	26.400	
	3	0.606	6.410			3	5.904	150	0.15	10	1.5	1.7713	0.0125	2.621	0.000	26.400	
JULY	1	1.562	7.972		OCT.	1	3.757	150	0.15	10	1.5	0.9391	0.0119	1.306	0.000	26.400	
	2	1.915	9.887			2	3.670	150	0.15	10	1.5	0.9174	0.0119	1.240	0.000	26.400	
	3	2.149	12.036			3	2.764	150	0.15	11	1.65	0.6910	0.0131	0.410	0.000	26.400	
AUG.	1	5.708	17.744		NOV.	1	2.198	150	0.15	10	1.5	0.4396	0.0069	0.251	0.000	26.400	
	2	8.334	26.078			2	1.795	150	0.15	10	1.5	0.3591	0.0069	-0.071	0.071	26.329	
	3	10.136	36.214			3	1.467	150	0.15	10	1.5	0.2934	0.0069	-0.333	0.333	25.996	
SEPT.	1	**10.109**	**46.323**		DEC.	1	1.090	150	0.15	10	1.5	0.2179	0.0047	-0.633	0.633	25.363	
	2	9.905	56.227			2	0.890	150	0.15	10	1.5	0.1781	0.0047	-0.792	0.792	24.571	
	3	5.904	62.132			3	0.798	150	0.15	11	1.65	0.1596	0.0047	-1.016	1.016	23.554	
OCT.	1	3.757	65.888		JAN.	1	0.710	150	0.15	10	1.5	0.1419	0.0046	-0.937	0.937	22.618	
	2	3.670	69.558			2	0.481	150	0.15	10	1.5	0.0962	0.0046	-1.120	1.120	21.498	
	3	2.764	72.322			3	0.561	150	0.15	11	1.65	0.1123	0.0046	-1.205	1.205	20.293	
NOV.	1	2.198	74.520		FEB.	1	1.631	150	0.15	10	1.5	0.3262	0.0064	-0.201	0.201	20.091	
	2	1.795	76.315			2	0.952	150	0.15	10	1.5	0.1905	0.0064	-0.745	0.745	19.347	
	3	1.467	77.782			3	1.403	150	0.15	8	1.2	0.2807	0.0047	-0.082	0.082	19.265	
	1	1.090	78.872			1	1.860	150	0.15	10	1.5	0.3721	0.0114	-0.023	0.023	19.241	

DEC.	2	0.890	79.763
	3	0.798	80.561
JAN.	1	0.710	81.270
	2	0.481	81.751
	3	0.561	82.313
FEB.	1	1.631	83.944
	2	0.952	84.896
	3	1.403	86.300
MAR.	1	1.860	88.160
	2	0.523	88.683
	3	0.417	89.100
APR.	1	0.247	89.347
	2	0.202	89.549
	3	0.165	89.714
MAY.	1	0.126	89.840
	2	0.103	89.943
	3	0.092	90.035

MAR.	2	0.523	150	0.15	10	1.5	0.1045	0.0114	-1.093	1.093	18.148	
	3	0.417	150	0.15	11	1.65	0.0835	0.0126	-1.329	1.329	16.820	
APR.	1	0.247	150	0.15	10	1.5	0.0617	0.0168	-1.332	1.332	15.488	
	2	0.202	150	0.15	10	1.5	0.0504	0.0168	-1.365	1.365	14.123	
	3	0.165	150	0.15	10	1.5	0.0412	0.0149	-1.391	1.391	12.731	
MAY.	1	0.126	150	0.15	10	1.5	0.0316	0.0208	-1.426	1.426	11.305	
	2	0.103	150	0.15	10	1.5	0.0258	0.0208	-1.443	1.443	9.862	
	3	0.092	150	0.15	11	1.65	0.0230	0.0200	-1.601	1.601	8.261	
JUN.	1	0.245	150	0.15	10	1.5	0.0736	0.0148	-1.343	1.343	6.918	
	2	1.009	150	0.15	10	1.5	0.3027	0.0148	-0.809	0.809	6.109	
	3	0.606	150	0.15	10	1.5	0.1818	0.0148	-1.091	1.091	5.019	
JULY	1	1.562	150	0.15	10	1.5	0.4685	0.0075	-0.414	0.414	4.604	
	2	1.915	150	0.15	10	1.5	0.5745	0.0075	-0.167	0.167	4.437	**MWL -**
	3	2.149	150	0.15	11	1.65	0.6447	0.0075	-0.153	0.153	4.284	**924 m**
AUG.	1	5.708	150	0.15	10	1.5	1.7123	0.0007	2.495	0.000	6.779	
	2	8.334	150	0.15	10	1.5	2.5002	0.0084	4.325	0.000	11.104	
	3	10.136	150	0.15	11	1.65	3.0409	0.0112	5.434	0.000	16.538	

Table 8-6: Assessment of lowest available water in storages and reservoir level for 150 MLD drinking water demand in 97% dependable year (2002-03).

Sl. No.	**Flow Series**	**FRL-980, 150 MLD demand and FRL-Storage 26.4 MCM**	
		Minimum Storage in MCM	Minimum Water Level of Dam in m
A	Actual observed flow series at Dam site	4.893	928
B	Estimate flow for Dam site using observed flow series at Satyanarayana	13.218	954
C	Simulated flow at Dam site	4.284	924

Observations on Reservoir water balance Planning of proposed Song Dam Drinking Water Project by CWC

Song Dam is proposed to be constructed across Song River, a tributary of river Ganga, near village Sondhana in District Dehradun of the state of Uttarakhand. Based on the annual flow volume (MCM) from the long-term water available series CWC approved the 97% dependable (~say 100%) year as 1987-88.

River Ganga concern with Inter-sate river and hence it has been analysed using interstate policy. Considering, Indo -Bangladesh water treaty, 1996 on Farakka, withdrawal is not permitted from Ganga basin during lean period (i.e. from 1st January to 31st May).

Reservoir water balance planning has been done considering below parameters

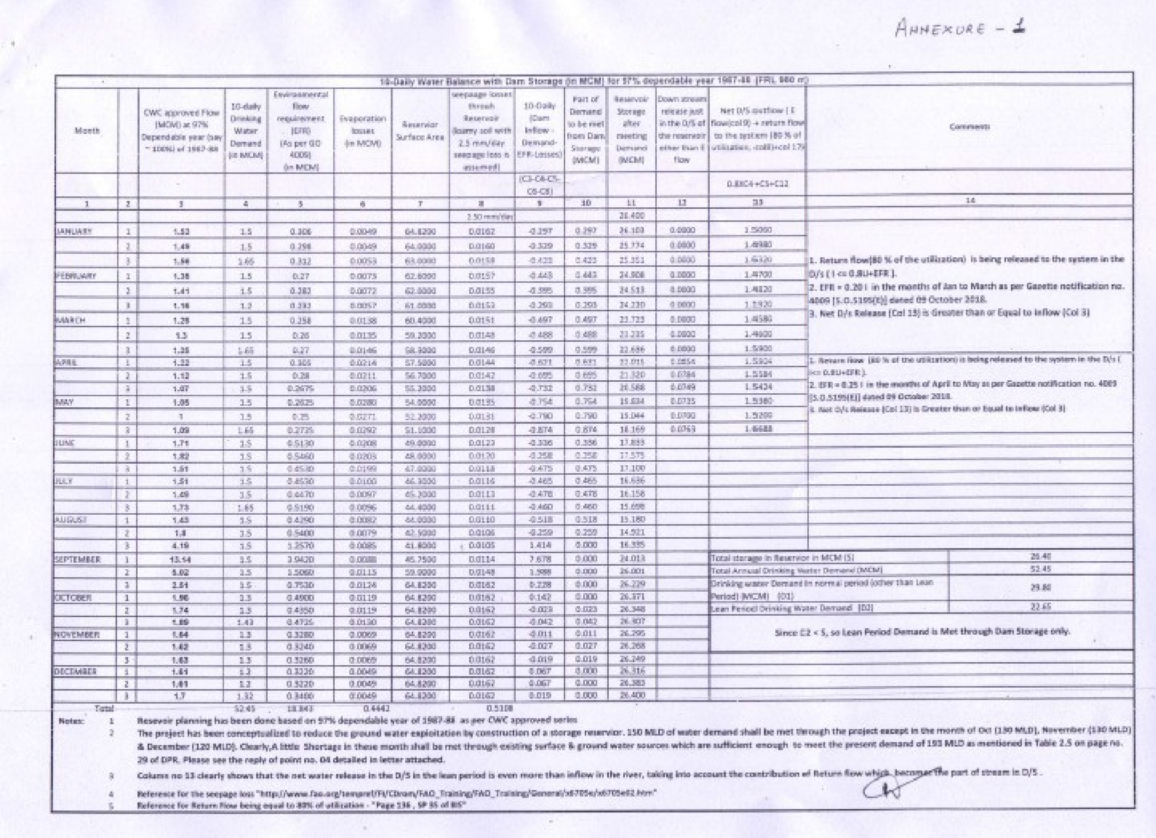
- 97% dependable year inflow series
- Drinking water demand

- Environmental release as per Govt. Policy for upper Ganga Basin
- Evaporation loss
- Seepage loss through reservoir

In reservoir planning, 80 % of the domestic demand has been considered being released back to the river system in the downstream as return flow. Hence net utilization including evaporation and seepage losses from the reservoir are worked out as:

i.) Total annual Demand = 52.45 MCM
ii.) Less 80% as return flow = 41.96 MCM
iii.) Evaporation Loss= 0.4442 MCM
iv.) Seepage loss= 0.511 MCM
v.) Hence annual utilization = 52.45-41.96+0.4442+0.511 = 11.4452 MCM

For finalizing the reservoir planning of Song Dam, many correspondences (detailed discussed in Chapter 4- International/interstate Issue) takes place between Irrigation department, Govt. of Uttarakhand with CWC, New Delhi. Reservoir water planning approved by CWC (Letter No- CWC,2/6/ISM/-2/2017/395 dated 06.01.2020) has been given in **Annexure 8.4**. The final reservoir planning sheet has been given below:



Annexure - 1

10-Daily Water Balance with Dam Storage (in MCM) for 97% dependable year 1987-88 (FRL 980 m)

Month		CWC approved Flow (MCM) at 97% Dependable year (say ~ 100%) of 1987-88	10-daily Drinking Water Demand (in MCM)	Environmental flow requirement (EFR) (As per GO 4009) (in MCM)	Evaporation losses (in MCM)	Reservior Surface Area	seepage losses through Reservoir (loamy soil with 2.5 mm/day seepage loss is assumed)	10-Daily (Dam Inflow - Demand-EFR-Losses)	Part of Demand to be met from Dam Storage (MCM)	Reservoir Storage after meeting Demand (MCM)	Down stream release just in the D/S of the reservoir other than E flow	Net D/S outflow (E flow(col 9) + return flow to the system (80 % of utilisation; col8)+col 17)	Comments
		-						(C3-C4-C5-C6-C8)				0.8XC4+C5+C12	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
							2.50 mm/day			26.400			
JANUARY	1	1.53	1.5	0.306	0.0049	64.8200	0.0162	-0.297	0.297	26.103	0.0000	1.5060	
	2	1.49	1.5	0.298	0.0049	64.0000	0.0160	-0.329	0.329	25.774	0.0000	1.4980	
	3	1.56	1.65	0.312	0.0053	63.0000	0.0158	-0.423	0.423	25.351	0.0000	1.6320	1. Return flow(80 % of the utilization) is being released to the system in the D/s (I <= 0.8U+EFR). 2. EFR = 0.20 I in the months of Jan to March as per Gazette notification no. 4009 [S.O.5195(E)] dated 09 October 2018. 3. Net D/s Release (Col 13) is Greater than or Equal to inflow (Col 3)
FEBRUARY	1	1.35	1.5	0.27	0.0073	62.6000	0.0157	-0.443	0.443	24.908	0.0000	1.4700	
	2	1.41	1.5	0.282	0.0072	62.0000	0.0155	-0.395	0.395	24.513	0.0000	1.4820	
	3	1.16	1.2	0.232	0.0057	61.0000	0.0153	-0.293	0.293	24.220	0.0000	1.1920	
MARCH	1	1.29	1.5	0.258	0.0138	60.4000	0.0151	-0.497	0.497	23.723	0.0000	1.4580	
	2	1.3	1.5	0.26	0.0135	59.2000	0.0148	-0.488	0.488	23.235	0.0000	1.4600	
	3	1.35	1.65	0.27	0.0146	58.3000	0.0146	-0.599	0.599	22.686	0.0000	1.5900	
APRIL	1	1.22	1.5	0.305	0.0214	57.5000	0.0144	-0.671	0.671	22.015	0.0854	1.5904	1. Return flow (80 % of the utilization) is being released to the system in the D/s (I <= 0.8U+EFR). 2. EFR = 0.25 I in the months of April to May as per Gazette notification no. 4009 [S.O.5195(E)] dated 09 October 2018. 3. Net D/s Release (Col 13) is Greater than or Equal to inflow (Col 3)
	2	1.12	1.5	0.28	0.0211	56.7000	0.0142	-0.695	0.695	21.320	0.0784	1.5584	
	3	1.07	1.5	0.2675	0.0206	55.3000	0.0138	-0.732	0.732	20.588	0.0749	1.5424	
MAY	1	1.05	1.5	0.2625	0.0280	54.0000	0.0135	-0.754	0.754	19.834	0.0735	1.5360	
	2	1	1.5	0.25	0.0271	52.2000	0.0131	-0.790	0.790	19.044	0.0700	1.5200	
	3	1.09	1.65	0.2725	0.0292	51.1000	0.0128	-0.874	0.874	18.169	0.0763	1.6688	
JUNE	1	1.71	1.5	0.5130	0.0208	49.0000	0.0123	-0.336	0.336	17.833			
	2	1.82	1.5	0.5460	0.0203	48.0000	0.0120	-0.258	0.258	17.575			
	3	1.51	1.5	0.4530	0.0199	47.0000	0.0118	-0.475	0.475	17.100			
JULY	1	1.51	1.5	0.4530	0.0100	46.3000	0.0116	-0.465	0.465	16.636			
	2	1.49	1.5	0.4470	0.0097	45.3000	0.0113	-0.478	0.478	16.158			
	3	1.73	1.65	0.5190	0.0096	44.4000	0.0111	-0.460	0.460	15.698			
AUGUST	1	1.43	1.5	0.4290	0.0082	44.0000	0.0110	-0.518	0.518	15.180			
	2	1.8	1.5	0.5400	0.0079	42.5000	0.0106	-0.259	0.259	14.921			
	3	4.19	1.5	1.2570	0.0085	41.8000	0.0105	1.414	0.000	16.335			
SEPTEMBER	1	13.14	1.5	3.9420	0.0088	45.7500	0.0114	7.678	0.000	24.013		Total storage in Reservior in MCM (S)	26.40
	2	5.02	1.5	1.5060	0.0113	59.0000	0.0148	1.988	0.000	26.001		Total Annual Drinking Water Demand (MCM)	52.45
	3	2.51	1.5	0.7530	0.0124	64.8200	0.0162	0.228	0.000	26.229		Drinking water Demand in normal period (other than Lean Period) (MCM) (D1)	29.80
OCTOBER	1	1.96	1.3	0.4900	0.0119	64.8200	0.0162	0.142	0.000	26.371			
	2	1.74	1.3	0.4350	0.0119	64.8200	0.0162	-0.023	0.023	26.348		Lean Period Drinking Water Demand (D2)	22.65
	3	1.89	1.43	0.4725	0.0130	64.8200	0.0162	-0.042	0.042	26.307		Since D2 < S, so Lean Period Demand is Met through Dam Storage only.	
NOVEMBER	1	1.64	1.3	0.3280	0.0069	64.8200	0.0162	-0.011	0.011	26.295			
	2	1.62	1.3	0.3240	0.0069	64.8200	0.0162	-0.027	0.027	26.268			
	3	1.63	1.3	0.3260	0.0069	64.8200	0.0162	-0.019	0.019	26.249			
DECEMBER	1	1.61	1.2	0.3220	0.0049	64.8200	0.0162	0.067	0.000	26.316			
	2	1.61	1.2	0.3220	0.0049	64.8200	0.0162	0.067	0.000	26.383			
	3	1.7	1.32	0.3400	0.0049	64.8200	0.0162	0.019	0.000	26.400			
Total			52.45	18.343	0.4442		0.5108						

Notes:
1 Resevoir planning has been done based on 97% dependable year of 1987-88 as per CWC approved series
2 The project has been conceptualized to reduce the ground water exploitation by construction of a storage reservior. 150 MLD of water demand shall be met through the project except in the month of Oct (130 MLD), November (130 MLD) & December (120 MLD). Clearly,A little Shortage in these month shall be met through existing surface & ground water sources which are sufficient enough to meet the present demand of 193 MLD as mentioned in Table 2.5 on page no. 29 of DPR. Please see the reply of point no. 04 detailed in letter attached.
3 Column no 13 clearly shows that the net water release in the D/S in the lean period is even more than inflow in the river, taking into account the contribution of Return flow which becomes the part of stream in D/S .
4 Reference for the seepage loss "http://www.fao.org/tempref/FI/CDrom/FAO_Training/FAO_Training/General/x6705e/x6705e02.htm"
5 Reference for Return Flow being equal to 80% of utilization - "Page 136 , SP 35 of BIS"

8.5. Conclusion

The detailed hydrological study of proposed Song Dam Drinking Water Project revealed that sufficient water is available in the Song Dam site to meet the drinking water supply of 150 MLD to the Dehradun city and adjoining area with a storage reservoir of 26.4 MCM capacity at 980 m FRL.

9. CONSTRUCTION PROGRAMME & PROJECT SCHEDULE, CONSTRUCTION PROGRAM, MANPOWER & PLANT PLANNING

9.1. General

The construction methodology and equipment planning for construction of various components of the project are discussed in this chapter. The construction methodology for each type of structure, type and sizes of the equipment to be used for the construction has been described under the relevant sub sections of this chapter. The construction/ deployment schedule for various components of the project has been prepared and based on this, the number of machines/equipment and total requirement for each type and size of the key equipment required for construction of each component of the project has been worked out.

The work is to be executed by awarding the contract through two package of works. The contractors may execute the work based on the equipment as planned and as actually available with them, thereby suitably adopting the related construction techniques. The tentative requirement of machines / equipment are worked out herein have been used in analysis of rates of various items, cost estimation and in evaluating the viability of construction techniques and equipment, within overall construction schedule and cost estimate.

The key salient feature of the project is provided below in Table 9-1.

Table 9-1: Key Salient features of Project Components

Sl. No.	Particulars	Details
River Diversion Pipe		
1	Number of Pipe	1 no.
2	Pipe size	2.0 m diameter steel pipe
3	Length of pipe	350 m (Approx.)
4	Inlet Invert Elevation	EL. 878.00 M
5	Proposed Longitudinal Slope	1:75
6	Outlet Invert EL	873.33
Coffer Dam		
1	Type of Material	Colcrete
2	Average Side Slopes, u/s & d/s	0.1H:1V & 0.5H:1V
3	Height	12.00 m
4	Length	75.45 m
5	Top Elevation	887.0 M
6	Base Width	12.2 m
Song Dam (RCC)		
1	Length at top	225m
2	Length at foundation (Deepest)	30m
3	Height (From deepest foundation level)	130.6m
4	Width at Bottom	134.06m

5	Width at Top	12.5m
6	Slope U/s	0.3 H : 1 V
7	Slope D/s	0.8 H : 1 V
8	Bottom of Deepest Block of Dam	EL. 851.60 m
9	River Bed Level	EL. 874.75 m
10	Anticipated Silted Bed Level	EL. 905.0 m
11	Minimum Draw down Level	EL. 923.0 m
12	Full Reservoir Level	EL. 980.0 m
13	Top of Dam	EL. 982.00 m

9.2. Basis of Construction Planning

9.2.1. General

Methodology for construction of Song Dam Drinking Water Project has been adopted with due consideration of the construction schedule, the compatibility of the construction equipment to site conditions, the quantities and utilization factor of the equipment within the scheduled construction period. Number of machines required for construction of each component of the project has been worked out and the total requirement for each type and size of machine for the project as a whole has been arrived at after drawing up the construction/deployment schedule for the main components of the project.

Mechanized construction has been planned for almost all types of construction jobs so as to achieve consistent quality at a faster rate and also to minimize the requirement of skilled manpower. Moreover, very high degree of quality standards are required to be maintained as water supply schemes are in operation throughout the year.

Sequencing of construction activities, wherever possible, has been planned in such a way that equipment are utilised one after the other activity. Thus, the total requirement of equipment at a time would be reduced and also, sufficient utilization of equipment on the project would be ensured.

9.2.2. Infrastructure Development

The development of infrastructure facilities for the Owner and Contractor along with Construction Power requirement is detailed in Chapter 14, Item 14.2. The key items for development of Infrastructure facilities, as planned, is provided in drawing P.012745-W-20302-004.

During the infrastructure development period, construction/improvement of roads and arrangements for construction power of the project site will be undertaken. The construction power at all the project components is proposed to meet by Grid supply and in addition DG sets are proposed to meet the power backup supply, in case of failure of grid power supply. After the infrastructure setup has been created to the required extent, for start of the construction activities, the construction of civil components will be taken up.

The scope of pre-construction activities is to build site roads network including infrastructure facilities. A period of three months is proposed as pre construction activities for the construction of the following:

- Roads and approach to work fronts.
- Temporary camp development for construction stage.
- Up gradation of the existing project approach road.
- Construction of site office, workshop, stores, QC labs. etc. and installation of all temporary services.
- Erection & commissioning of stationary plants.
- Setting up of stationary equipment like Aggregate Crushing Plant / Batching Plant / DG sets.
- Colonies development for residence of project staff. Different type of quarter will be constructed for different category of staff. Facilities such as cafeteria, recreation centre is proposed to be developed for various categories of workers.

9.2.3. Construction Material Source

The key construction materials required for construction of the project, such as- coarse aggregate, fine aggregate, fly ash, cement, steel, explosives, oil & lubricants along with its source is detailed in Chapter - 5 “Survey & Investigations”.

Suitable aggregate is found to be available in the borrow area on left and right bank on upstream of dam axis and on right bank of downstream of the proposed Song dam. The borrow areas is planned considering suitability of the construction material with minimum lead distance for better utilisation during construction of the dam.

The type of dam is Roller Compacted Concrete Dam and therefore the concrete is required to be produced by blending Portland cement and fly ash. The fly ash procurement is required to be well planned in line with the construction activity / requirement and accordingly the stacked (in Bins / Silo) at batching plant. In order to procure fly ash Uttarakhand Irrigation Department (UKID) has already been tied up with thermal power agencies. The total quantity of concrete consisting of different grades, required for construction of the dam is estimated as 12,00,000 cum and accordingly 1,10,000 metric ton of fly ash is required.

9.2.4. Basic Consideration

For implementation of Song Dam Drinking Water Project, the construction time has been estimated based on Central Water Commission guidelines, industry practices, standard norms, equipment employed, productivity of equipment and over and above the past project experiences. Construction work shall remain suspended during the months of July to September (i.e. monsoon season) for three months every year as work of the project shall be completely affected with virtually no work at surface area. Hence no construction activity has been considered to take place during these months, Working period has been planned for the months of October to June only (nine months) which covers the non-monsoon season for construction activities. However, the work will be partially effected in the month of June and October during pre-monsoon and post monsoon. Twenty-six (26) working days have been considered in a month and twenty (20) working hrs have been considered per day for barrage work activities.

The construction period shall be reviewed and adjusted upon availability of more results on geotechnical field and laboratory investigations. The preparation of tender document along with finalisation and signing of the contract agreement for construction of the project shall be completed before the start of the construction. The zero date of the schedule has been taken as the date of signing of contract for construction. The construction schedule of the project is provided as **Annexure 9.1**.

The cycle time of operations is the criteria for hourly/ daily output of machinery/ work force. However actual progress of work is dependent upon several other factors such as interruptions of construction power, break downs of construction equipment, meal break and other needs such as work force, stray rains etc. Hence it is general practice to consider 50 min. as the actual working time per hour. Further where the work is carried out in more than one shift, there is further reduction in daily production hours due to time required for change in shift & for daily maintenance needs of plant & machinery. On the basis of the above computation, in accordance with “Guidelines for Detailed Calculations for the Requirement of Each Category and Size of the Production Equipment, August 2000 published by the Central Water Commission” following scheduled working hours has been considered in surface works.

- Total days in a year: 365 days
- Monsoon Period: 90 days (3 months)
- Effect of Pre-monsoon and Post-monsoon: about 30 days (15 days + 15 days). Thus effective 10-15 days
- Non-working days considered on account of holidays: 10-15 days
- Thus, Effective Working Days: 250 days (considered for planning purposes)

The scheduled working hours considering 26 working days per month accordingly works out as under Table 9-2:

Table 9-2: Assumptions Considered in Project Schedule

No. of Shift	Total Time	Availability factor	Actual Available Time	Working Days/ Year	Schedule Machine Hour	Utilization factor	Schedule Production Hour
(No.)	(Hr.)		(Hr.)	(No.)	(Hr.)		(Hr.)
1	8	0.9	7.2	200	1440	0.85	1224
1.5	12	0.85	10.2	250	2550	0.85	2167
3	16	0.8	12.8	200	2560	0.8	2048
4	24	0.7	16.8	200	3360	0.75	2520

The construction work is proposed in three shifts or 2 shifts of 12 hours each for working throughout the day and to avoid cold joints between subsequent layers of concrete. Thus planning for all surface works has been carried out based on three shifts per day working.

9.3. Construction Period

A total period of four years has been considered for completion of the project. The infrastructural development, pre-construction surveys and investigations, preparation of design/ specifications and tender documents are proposed to be taken up during the first year.

The main features of the construction schedule are as follows:

Preparation of Tender Document including finalisation: 6 months

Tendering and Award of Contract: 3 months

Project Period: 3 years and 3 months (including infrastructure & mobilization)

Infrastructure & mobilization Period: 3 months

Construction Period: 3 years

The construction of the project is planned to be constructed through awarding Single package on EPC (Engineering Procurement Construction) contract. The contract package proposed is as follows:

EPC Contract for Civil and Hydro-mechanical Works

9.4. Construction Methodology & Equipment

9.4.1. Setting out Work

The setting out comprises the work for establishment of permanent Bench Marks and reference Bench Marks along the Project and shall be approved by the client, before starting of the project construction. The Bench Mark point and Coordinates shall be clearly carved and painted on the Bench Mark stone. The reference line shall comprise of a base line marked on the ground with number of masonry pillar. The Bench Marks shall be of such material and shall be located at such place as to ensure execution for all the activities for all components of the project. The work shall be performed with layout in all levels/control points with respect to Bench Mark and reference line and correlate levels and locations of the work to be performed. The Bench Mark proposed to be re-checked at certain interval of time and if any discrepancies are found should be corrected and brought to the notice of the client.

9.4.2. River Diversion Works

The river diversion arrangement comprises of upstream cofferdam along with a diversion pipe. There is no requirement of downstream coffer dam. Diversion discharges for 1 in 25 years return period is 15.45 cumec, 1 in 50 years return period is 17.41 cumec and 1 in 100 years return period is 19.36 m^3/sec. The diversion flood discharge values are relatively lower and therefore the diversion system has been designed to pass the 1 in 100 year return period non-monsoon flood of 19.36m^3/s. Song Dam Drinking water project is envisaged as left bank development scheme and river diversion has also been planned on the left side of Song river through the diversion pipe and upstream coffer dam. Based on the topography, inlet and outlet of the diversion pipe are planned for a total length of about 350 m. The proposed longitudinal slope of the diversion pipe from Inlet to Outlet is 1 in 75 (1.33%). From the pipe outlet, the water is discharged in to the river where the bed level is ± EL. 873.0 m. The diversion pipe is 2.0 m diameter steel pipe upstream of dam and the same pipe is at downstream of Dam.

The upstream cofferdam is proposed to be constructed of Colcrete material with a top width of 5.0 m. The bottom width of Colcrete coffer dam is 12.2 m. The cross section of cofferdam is provided in Figure 9-1 and as per drawing- P.012745-W-20302-002. The cofferdam is proposed in steps with an average upstream slope of 0.1H: 1V and average downstream slope of 0.5H: 1V. The width of coffer dam is increased in steps. For upstream slope, a horizontal trend of 0.4 m with 3.0 m rise of concrete is proposed and for downstream slope, a horizontal tread of 2.0 m with 3.0 m rise of concrete is proposed for a total 12.0 m height. One row of CC grouting of 0.75 times of height of coffer dam is proposed for restricting seepage underneath the coffer dam.

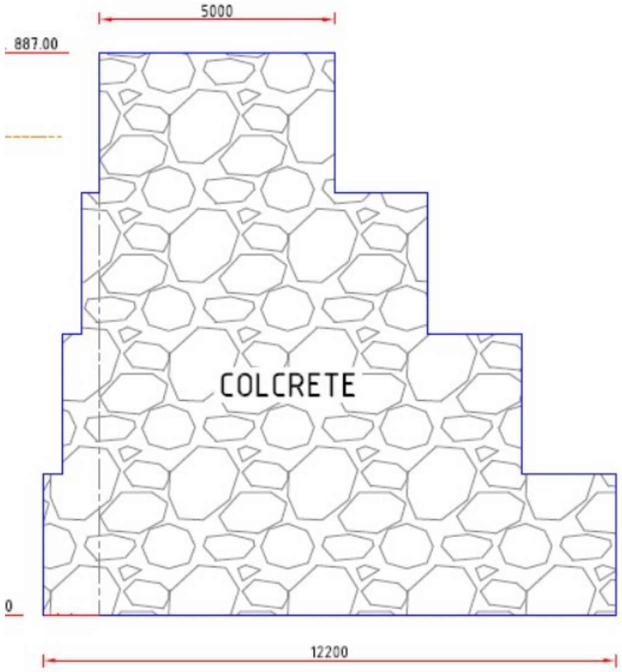


Figure 9-1: Colcrete Coffer Dam for Upstream

The construction of cofferdam is proposed to be carried out in the lean season. It is proposed to construct a dyke (temporary small cofferdam) for installation of 2.0 m diameter with a length of about 350 meter diversion pipe which is to be located on the left bank of river. The diversion pipe will rest over saddles along with a provision of gate at the Inlet location.

The inlet and outlet structure for diversion pipe will be constructed and the excavation work for installation of diversion pipe will be advanced from both the ends. The excavation for diversion pipe installation will be carried out by conventional process. Mucking may be carried out by Loader/Excavator and 10-Ton tippers.

The diversion arrangement is planned to be carried out in single phase. The estimated quantities for various items of river diversion arrangement is given in Table 9-3.

Table 9-3: Item quantities for River Diversion Arrangement

Sl No	Description of work	Type	Quantity, In situ	Unit
1	Stripping			
2	Excavation			
		Common	1802.52	m³
		Rock	1802.52	m³
		Total	3605.04	m³
3	Backfilling	By excavated Material	901.26	m³
4	Concreting			
		PCC (1:2:4)	150.1	m³
5	Reinforcement	RCC (M25/M30)	50.79 507.95	MT m³
6	Steel for Pipe	Structural Steel	190.84	MT

1) Excavation

The surface excavation for river diversion arrangement involves both common and rock excavations. Total stripping of about 7 to 8m from NSL is envisaged along the length of pipe.

A time period of about 15 days has been estimated for undertaking surface excavation pertaining to river diversion works. The time required for the excavation activity of cofferdam is given in Table 9-4.

Table 9-4: Time Period Calculation for Excavation of Cofferdam

1	Calculation Basis & Assumptions		
	Common excavation of Cofferdam	1802	m³
	Rock excavation of Cofferdam	1802	m³
	Total Excavation quantity of Cofferdam	3604	
	Number of working fronts	1	No.
	Swell factor for common excavation	40%	
	Swell factor for rock excavation	60%	
	Distance between dump area & dam	1.5	km
	No. of excavators	1	No.
	No. of cycles per hour for excavators	85	No.
	Volume of bucket	2	m³
	Dumper capacity	20	T
	Density of excavation material	1.40	T/m³
	Dumper speed with material loaded	10.00	kmph
	Dumper speed after unloading (return speed)	15.00	kmph
	Number of working days per month	26.00	days

Working time for excavation	10	hr./day

Total quantity to be handled has been increased by 20% to consider for peak requirement

Spotting time for dumpers has been assumed as 1 min.

Dumper unloading time including meneavour/turning has been assumed as 3 min.

Excavator efficiency factor has been considered as 80%

2 Computations

Total quantity to be handled (20% peak quantity) per front	5406	m^3
Ripping & loading rate for excavators	136.00	m^3/hr.
20 T Dumper capacity	14.29	m^3
Dumper Cycle Time Calculations		
Loading time from excavators	7.00	min.
Spotting time	1.00	min.
Dumper transportation time from dam to dump area1.5 km	9.00	min.
Dumper unloading time (including turning/meneavouring time)	3.00	min.
Dumper transportation time from dump area to dam (return time) 1.5 km	6.00	min.
Total dumper cycle time	26.00	min.
Hourly output of dumper (Effective working time of 50 minutes per hour)	27.48	m^3/hr.
No. of dumpers of capacity 20 T required per excavator	5.00	No.
Total time required for each working front	3.98	days

3 Results & Conclusions

No. of Excavators required having bucket capacity 2 m^3		1	No.
No. of dumpers of capacity 20 T required for each excavator		5	No.
Total No. of dumpers of capacity 20 T is		5	No.
Total time required for each working front along with allied works		8	days
Total time required for dam excavation		8	days
	Say	0.5	Months

2) Backfilling

All excavated materials from surface excavation will be transported from excavation location to designated dump locations or in backfilling by dumpers. Moreover, useful materials, if any approved by Project authorities for its incorporation in works, would be stacked separately in stock piles near crushing/ aggregate processing plant. The balance muck shall be disposed in the dumping areas. Proper levelling of disposed muck will be done at all disposed areas as shown in infrastructure works drawing. The diversion pipe backfilling quantity is given in Table 9-5

Table 9-5: Diversion pipe Works Quantity

Sl. No.	Item of Works	Unit	Quantity
A	**Diversion Pipe Works**		
1	Backfilling	m^3	901.26

After excavation, backfilling at left side of diversion pipe shall be done by the excavated material including compaction. Half of the common excavated material is assumed to be backfilled i.e. 901.26m^3 of the excavated soil shall be backfilled after construction of the pipe. A period of 10 days after construction of the arrangement is envisaged for backfilling.

The fill placement will require loading of material at the borrow areas/quarries, transportation of the material to the placement site and unloading. It is necessary that various alternative methods and equipment are evaluated and appropriate construction methods and suitable construction equipment are selected.

3) Concreting

The river diversion pipe is proposed for passage of diversion flood. The internal diameter of river diversion pipe is 2.0 m and proposed thickness of steel is 10 mm. A nominal quantity of concrete will be required for levelling concrete (M-15 Grade) and few structural concrete for supporting the diver diversion pipe. The work being small in nature, suitable construction methodology will be adopted by EPC contractor. .

9.4.3. Upstream Coffer Dam

Prior to River diversion, the construction of upstream cofferdam having top EL. 887.0 m and 12m height will be constructed. The upstream cofferdam of Colcrete material with a top width of the upstream coffer dam as 5.0 m and with average upstream slope of 0.1H: 1V and average downstream slope of 0.5H:1V is proposed. The upstream coffer dam quantity is given below in Table 9-6**.**

Table 9-6: Coffer Dams (Upstream) Quantity

Sl No	Description of work	Type	Quantity, In situ	Unit
1	Stripping			
2	Excavation			
		River bed material	294	m^3
		Rock	196	m^3
		Total	490	m^3
3	Colcrete		9127	m^3
4	PCC Railing at top of Coffer Dam		150.10	m^3

1) <u>Excavation</u>

The surface excavation for coffer dam involves excavation of river bed material. It is considered that top stripping for 300 mm of river bed material and 200 mm of rock excavation shall be done for the entire area. The volume required is mentioned in Table 9-6.

A period of about 10 days has been estimated for undertaking surface excavation pertaining to coffer dam and the requirement of equipment for the surface excavation is estimated and given in Table 9-7.

Table 9-7: Estimation of Hourly Quantity of Excavation

Description	**Type**	
	River bed Excavation	Rock Excavation
Total Volume (m^3)	294	196
Time Period (Days)	10	10
Shift Proposed (Day time only)	02	02
Total Operational hours (hours)	100 (10x10)	100 (10x10)
Volume to be handled in-situ (m^3/hour)	2.94	1.96
Volume to be handled loose (m^3/hour)	4.1	3.1
Volume to be handled loose, considering 20% additional for peak requirement (m^3/hour)	4.9	3.7
Total quantity (m^3/hour)	4.9 + 3.7 = 8.6 m^3/hr	

In order to avoid large number of equipment, the equipment proposed for excavation of main dam have been proposed for excavation of river diversion works. However, the contractor may plan for other suitable equipment for cofferdam.

- Stripping and excavation for trenching & preparation of base of coffer dam loading of the soft material (earth and alluvium) by 0.65 / 1 cum bucket capacity hydraulic excavators assisted by 90 HP crawler dozer.
- Transportation to the disposal area by 10t capacity rear dumper.
- A 90 HP bulldozer is also considered to stay in the disposal area for spreading of the unloaded materials.
- Strip rock excavation to be undertaken by suitable equipment.

2) Colcrete

The colcrete work will be executed with concrete portion through transit mixers from both ends. While pouring of concrete, care will be taken for that proper vibration shall be done in colcrete material to avoid air voids.

The overall quantities are given in Table 9-6.

A period of 1 month has been planned for the placement of Colcrete. The rate of placement works out to about 36.5 m^3/hour (9127 /25/10 = 36.5) considering day time working of 10 hours only. Considering peak requirement of 120%, the required peak rate of placement works out to about 44 m^3/hour. The plant shall be located in the vicinity of the dam. In addition, one number batching & mixing plant of capacity 90 m^3/ hour will be provided. This batching plant will also be used for construction of main dam. The concrete from the plant will be transported with the help of transit mixers of 6.0 m^3 capacity to the diversion site.

The construction equipment required for main dam have been considered for concreting of Colcrete coffer dam. However, in case of non availability of these equipment at this stage, the suitable alternate equipment may also be used:

- Placing of concrete with the help of concrete pumps of 38 m^3/hr capacity is proposed to be used for concrete placement
- Concrete transportation by transit mixers of 6.0 m^3 capacity

- Batching and mixing plant of capacity 90 m^3/hr is proposed to be located 0.5 km downstream of dam axis.
- The aggregate crushing and screening plant of 200 TPH for preparation of coarse and fine aggregates.

The sequence for construction of Colcrete coffer dam is provided as below-

- Surface stripping including stripping of top 200 mm thick rock excavation
- Construction of upstream cofferdam made of colcrete material
- Erection of gate at the inlet of diversion pipe

The complete activity is planned to be completed in a time frame of about 20 days.

9.5. Roller Compacted Concrete (RCC) Dam

Song Dam is a 130.6m high Roller Compacted Concrete Dam (EL 851.4 m to EL 982.0 m). The salient features of the dam are mentioned in para 9.1.

The main activities involved in the construction of Song Dam are surface excavation (which includes stripping and slope stabilization of both left and right banks, laying of Roller Compacted Concrete (both above and below river bed), concreting, instrumentation and hydro-mechanical works.

The quantities for the key activities associated with the construction of dam are given in Table 9-8 and further discussed in the following sub sections. On the basis of the quantities, the requirement and capacity of various equipment are evaluated and accordingly construction schedule is prepared. It is envisaged that three (3) working seasons are required for construction of the dam.

The key activities involved for construction of Song dam (over flow & non-over flow sections) are surface excavations and concreting. Surface excavations will comprise of common excavation in overburden area and rock excavation. The total excavation estimated for construction of dam is about 5,73,115 cum, roller compacted concrete is about 8,90,586 cum and conventional concrete is about 1,28,780 cum. Details of key activities for dam construction are provided below in Table 9-8:

Table 9-8:- Key Activities Quantities in Construction of Roller Compacted Concrete Dam

Sl No	Description of work	Type	Quantity, In situ	Unit
1	Stripping			
2	Excavation			
		Common	171934	m^3
		Rock	401181	m^3
		Total	573115	m^3
3	Concreting			
		PCC (1:2:4)	7172	m^3
		RCC (M25/M30)	128780	m^3

	Roller Compacted Concrete	900380	m^3
	Block	9460	m^3

9.5.1. Excavation of Dam

1) Stripping and slope stabilization of left and right banks

The dam excavation proposed to commence with the excavation of abutments from each side of dam. Access road will be constructed reaching the top of the abutments on either sides taking care of a gradient not steeper than 1 in 12 for the stripping works. The excavation work will be carried out in stages adopting a bench height of about 3-4 m in each stage followed by stabilization of the excavated slope. Open cut blasting method will be adopted. During excavation of dam below the river bed level, trenches and pits will be provided along the diversion channel to collect and dewater the water off the working area. Provision of submersible pumps shall be kept for dewatering if required. As the excavation proceeds downwards the position and depth of the submersible pumps will be modified accordingly.

Stripping of left and right banks are the first activity to be done. Left bank excavation will start from EL.985 and right bank excavation will start from EL.1010. Excavation will be done bench wise with berms of 2.5 to 3.0m width in between. Berms shall be wide enough for the movement of small trucks or installation of equipment for slope stabilisation. Rig on Crawler (RoC) is used for drilling of holes for rock bolting or rock anchoring. After stabilisation of one bench only next bench should be excavated for safety and stability.

2) River bed Excavation

The total surface excavations have been planned to be completed within 1 working season (6 months). The surface excavation for dam involves both common and rock excavations. It is estimated that the complete excavation will take about 3.5 months. The excavated material will be transported to the designated muck disposal area by tippers. The cycle time for excavation above river bed is provided below in Table 9-9.

Table 9-9 - Cycle Time for excavation of Dam below river bed

1	Calculation Basis & Assumptions		
	Common excavation of Dam- below river bed	154902	m^3
	Rock excavation of Dam below river bed	17211	m^3
	Total Excavation quantity of Dam below river bed	172113	
	Number of working fronts	1	No.
	Swell factor for common excavation	40%	
	Swell factor for rock excavation	60%	
	Distance between dump area & dam	1.5	km
	No. of excavators	1	No.
	No. of cycles per hour for excavators	85	No.
	Volume of bucket	2	m^3
	Dumper capacity	20	T
	Density of excavation material	1.40	T/m^3
	Dumper speed with material loaded	10.00	kmph
	Dumper speed after unloading (return speed)	15.00	kmph
	Number of working days per month	26.00	days
	Working time for excavation	20	hr./day

Total quantity to be handled has been increased by 20% to consider for peak requirement
Spotting time for dumpers has been assumed as 1 min.
Dumper unloading time including meneavour/turning has been assumed as 3 min.
Excavator efficiency factor has been considered as 80%

2 Computations

Total quantity to be handled (20% peak quantity) per front	244400.4	m^3
Ripping & loading rate for excavators	136.00	m^3/hr.
20 T Dumper capacity	14.29	m^3
Dumper Cycle Time Calculations		
Loading time from excavators	7.00	min.
Spotting time	1.00	min.
Dumper transportation time from dam to dump area1.5 km	9.00	min.
Dumper unloading time (including turning/meneavouring time)	3.00	min.
Dumper transportation time from dump area to dam (return time) 1.5 km	6.00	min.
Total dumper cycle time	26.00	min.
Hourly output of dumper (Effective working time of 50 minutes per hour)	27.48	m^3/hr.
No. of dumpers of capacity 20 T required per excavator	5.00	No.
Total time required for each working front	89.85	days

3 Results & Conclusions

No. of Excavators required having bucket capacity 2 m3	1	No.
No. of dumpers of capacity 20 T required for each excavator	5	No.
Total No. of dumpers of capacity 20 T is	5	No.
Total time required for each working front	90	days
Total time required for dam excavation	90	days
Say	3.5	Months

The below equipment's are foreseen for surface excavations of dam:

i. Hydraulic Excavator (2 cum bucket capacity): 1 no.
ii. Crawler Dozer (90 HP): 1 no.
iii. Tipper (20 T capacity): 5 nos.
iv. ROC (Rig-on-crawler): 1 no.
v. Pneumatic Jack Hammer: 3 nos.
vi. Compressor (250 cfm): 1 no.

3) <u>Excavation above River Bed</u>

The excavation above river bed is planned to be completed in a period of 5 months. The cycle time for excavation above river bed is provided below in Table 9-10:

Table 9-10 - Cycle time for excavation of Dam above river bed

1 Calculation Basis & Assumptions

Common excavation of Dam- above river bed	17211	m^3
Rock excavation of Dam above river bed	383969	m^3
Total Excavation quantity of Dam above river bed	401180	
Number of working fronts	2	No.
Swell factor for common excavation	40%	
Swell factor for rock excavation	60%	
Distance between dump area & dam	1.5	km
No. of excavators	2	No.
No. of cycles per hour for excavators	85	No.
Volume of bucket	2	m^3
Dumper capacity	20	T
Density of excavation material	1.40	T/m^3
Dumper speed with material loaded	10.00	kmph
Dumper speed after unloading (return speed)	15.00	kmph
Number of working days per month	26.00	days
Working time for excavation	20	hr./day

Total quantity to be handled has been increased by 20% to consider for peak requirement

Spotting time for dumpers has been assumed as 1 min.

Dumper unloading time including meneavour/turning has been assumed as 3 min.

Excavator efficiency factor has been considered as 80%

2 Computations

Total quantity to be handled (20% peak quantity) per front	319222.9	m^3
Ripping & loading rate for excavators	136.00	m^3/hr.
20 T Dumper capacity	14.29	m^3
Dumper Cycle Time Calculations		
Loading time from excavators	7.00	min.
Spotting time	1.00	min.
Dumper transportation time from dam to dump area1.5 km	9.00	min.
Dumper unloading time (including turning/meneavouring time)	3.00	min.
Dumper transportation time from dump area to dam (return time) 1.5 km	6.00	min.
Total dumper cycle time	26.00	min.
Hourly output of dumper (Effective working time of 50 minutes per hour)	27.48	m^3/hr.
No. of dumpers of capacity 20 T required per excavator	5.00	No.
Total time required for each working front	58.68	days

3 Results & Conclusions

No. of Excavators required having bucket capacity 2 m^3	2	No.
No. of dumpers of capacity 20 T required for each excavator	5	No.
Total No. of dumpers of capacity 20 T is	10	No.
Total time required for each working front	59	days
Total time required for dam excavation	118	days
Say	5	Months

The below equipment's are foreseen for surface excavations of dam:

i. Hydraulic Excavator (2 cum bucket capacity): 2 no.
ii. Crawler Dozer (90 HP): 1 no.
iii. Tipper (20 T capacity): 10 nos.
iv. ROC (Rig-on-crawler): 1 no.
v. Pneumatic Jack Hammer: 5 nos.
vi. Compressor (1000 cfm): 1 no.

9.5.2. Concreting of Roller Compacted Concrete Dam

A 130.6 meter high Roller Compacted Concrete Dam is proposed for this project. It is estimated that about 9,00,380 cum of concreting is required to be done for Roller Compacted Concrete**.**

Roller Compacted Concrete technology is adopted for Song Dam Drinking Water Project due to its better performance with respect to concrete dams. This dam replicates a good performance in seismic area (Song Dam lies in Seismic Zone IV) and being more impervious the chances of seepage is reduced considerably. They also require lesser space as compared to other types of dam leading to lesser excavation for foundations and accordingly less quantity providing economical solution during construction.

It is recommended to use fly ash in concreting which lead to reduction in consumption of cement. It is recommended to adopt conveyor belt system for laying of concrete directly from batching plant to the pour area. This methodology is a better methodology than transporting and pumping of the concrete. The laying of concrete may also be done by use of dumper for transportation of concrete with directly dumping to the pour area. The laying of concrete is proposed to be laid in 300mm thick layers. The laid concrete will be spread by help of Dozers and are compacted by vibratory rollers. Proper compacted to ensure homogeneity so that adequate strength can be achieved. Skilled workmanship is an essential for this mode of construction. The highly mechanized process leads to substantial time saving and better compaction and homogeneity of concrete.

The construction time for Roller Compacted Concrete Dam is less compared to other type of dams. It is considered that the average rate of concreting will be about 50,000 cum/month and accordingly the time envisaged for completing the entire dam is about 18 months (3 seasons).

The dam comprises of Intake at El. 918.00m leading to the water conductor system of 1.5m diameter. Moreover, the dam is facilitated with a diversion sluices at EL 912.0 and high level spillway at EL.975m. The concreting for this section will be conventional due to reinforcement and interfaced with Hydro mechanical works. It is proposed to construct a temporary approach road to facilitate the construction activity at EL. 918.00m to the dam. The concreting of Roller Compacted Concrete Dam is split to two sections- i) below river bed; ii) above river bed.

1) **Concreting below River Bed**

The deepest foundation level is EL. 851.6m and the river bed is at EL. 874.75m, with a height of about 23.15m and is proposed to be laid in layers of 300mm thick in each pour.

After excavation in the river bed to the founding level the rock foundation of the dam will be prepared as per the requirements and specification of the contract. Then rock surface will be cleaned with air & water jetting. The foundation will also be inspected for any seams of soft material and will be treated as per the directions of the Geologist/Engineer-in-Charge. Concreting will start from the lowest level of the dam using conveyor belt system delivered directly from the Batching Plant. The placement temperature of concrete will be maintained as per technical specifications. Vibration and compaction of concrete will be done with the help of 150 mm dia. & 62 mm dia. immersion type needle vibrators operated with frequency changers. After the concrete surface gets hardened, which will be in about 6 to 8 hours after pouring concrete, the surface will be green cut with air water jet pump to remove the laitance from the surface and to expose the coarse aggregates. This is necessary to have a proper bond between two lifts. In case the concrete has hardened to such an extent that green cutting is not possible, then the laitance required to be removed by high pressure water jets or by sand blasting or by mechanical chipping. The surface will be thoroughly cleaned with air and water jets before placing the next layer of concrete. We propose to use conveyor belt with 300mm thick layers and concrete is poured in each layer followed by proper compaction through vibratory rollers.

The volume for each lift of 300mm below river bed is computed and given in Table 9-11

Table 9-11: Lift wise Volume for RCC below river bed level

SL.	Dam EL (m)	Thickness (m)	Width Along Flow (m)	Width Across Flow (m)	Volume (Cum)
1	851.400		124.200	30.000	
2	851.700	0.300	123.900	30.596	1127.54
3	852.000	0.300	123.600	31.192	1146.95
4	852.300	0.300	123.300	31.788	1166.25
5	852.600	0.300	123.000	32.385	1185.44
6	852.900	0.300	122.700	32.981	1204.52
7	853.200	0.300	122.400	33.577	1223.50
8	853.500	0.300	122.100	34.173	1242.36
9	853.800	0.300	121.800	34.769	1261.13
10	854.100	0.300	121.500	35.365	1279.78
11	854.400	0.300	121.200	35.961	1298.33
12	854.700	0.300	120.900	36.558	1316.76
13	855.000	0.300	120.600	37.154	1335.10
14	855.300	0.300	120.300	37.750	1353.32
15	855.600	0.300	120.000	38.346	1371.44
16	855.900	0.300	119.700	38.942	1389.45
17	856.200	0.300	119.400	39.538	1407.35
18	856.500	0.300	119.100	40.134	1425.15
19	856.800	0.300	118.800	40.731	1442.84
20	857.100	0.300	118.500	41.327	1460.42
21	857.400	0.300	118.200	41.923	1477.89
22	857.700	0.300	117.900	42.519	1495.26
23	858.000	0.300	117.600	43.115	1512.52
24	858.300	0.300	117.300	43.711	1529.67
25	858.600	0.300	117.000	44.308	1546.71

26	858.900	0.300	116.700	44.904	1563.65
27	859.200	0.300	116.400	45.500	1580.48
28	859.500	0.300	116.100	46.096	1597.20
29	859.800	0.300	115.800	46.692	1613.82
30	860.100	0.300	115.500	47.288	1630.32
31	860.400	0.300	115.200	47.884	1646.72
32	860.700	0.300	114.900	48.481	1663.02
33	861.000	0.300	114.600	49.077	1679.20
34	861.300	0.300	114.300	49.673	1695.28
35	861.600	0.300	114.000	50.269	1711.25
36	861.900	0.300	113.700	50.865	1727.12
37	862.200	0.300	113.400	51.461	1742.87
38	862.500	0.300	113.100	52.057	1758.52
39	862.800	0.300	112.800	52.654	1774.07
40	863.100	0.300	112.500	53.250	1789.50
41	863.400	0.300	112.200	53.846	1804.83
42	863.700	0.300	111.900	54.442	1820.05
43	864.000	0.300	111.600	55.038	1835.16
44	864.300	0.300	111.300	60.634	1933.75
45	864.600	0.300	111.000	61.268	2032.41
46	864.900	0.300	110.700	61.901	2047.99
47	865.200	0.300	110.400	62.535	2063.46
48	865.500	0.300	110.100	63.168	2078.81
49	865.800	0.300	109.800	63.802	2094.05
50	866.100	0.300	109.500	64.435	2109.18
51	866.400	0.300	109.200	65.069	2124.19
52	866.700	0.300	108.900	65.702	2139.08
53	867.000	0.300	108.600	66.336	2153.87
54	867.300	0.300	108.300	66.969	2168.53
55	867.600	0.300	108.000	67.603	2183.09
56	867.900	0.300	107.700	68.236	2197.53
57	868.200	0.300	107.400	68.870	2211.86
58	868.500	0.300	107.100	69.503	2226.07
59	868.800	0.300	106.800	70.136	2240.17
60	869.100	0.300	106.500	70.770	2254.15
61	869.400	0.300	106.200	76.403	2347.78
62	869.700	0.300	105.900	76.937	2439.26
63	870.000	0.300	105.600	77.470	2449.29
64	870.300	0.300	105.300	78.004	2459.22
65	870.600	0.300	105.000	78.537	2469.05
66	870.900	0.300	104.700	79.071	2478.78
67	871.200	0.300	104.400	79.604	2488.42
68	871.500	0.300	104.100	80.138	2497.97
69	871.800	0.300	103.800	80.671	2507.42
70	872.100	0.300	103.500	81.205	2516.77
71	872.400	0.300	103.200	81.738	2526.03
72	872.700	0.300	102.900	82.272	2535.19

73	873.000	0.300	102.600	86.005	2593.57
74	873.300	0.300	102.300	86.426	2649.84
75	873.600	0.300	102.000	86.847	2654.98
76	873.900	0.300	101.700	87.268	2660.04
77	874.200	0.300	101.400	87.689	2665.03
78	874.500	0.300	101.100	88.110	2669.94
79	874.800	0.300	100.800	88.531	2674.77
80	875.100	0.300	100.500	88.951	2679.53
81	875.400	0.300	100.200	89.372	2684.22
82	875.700	0.300	99.900	89.793	2688.83
83	876.000	0.300	99.600	95.214	2768.17

As illustrated above, the total concrete below river bed is estimated as 1,58,195 cum. On the basis of the volume, hourly quantity of concreting for finalisation of equipment in computed and given in Table 9-12.

2) Concreting of Main Dam- above river bed

Continuous batching and mixing is performed by concrete batching plant with a continuous-flow, twin-screw pug mill. This pug mill has a mixing chamber containing two horizontal, counter-rotating shafts fitted with paddles. The mix components are metered through a certain size opening or volumetric metering device and carried to the mixing chamber on a conveyor belt that runs under the bins and silos. Water is added at a point near the entrance to the mixing chamber. The continuous flow systems are equipped with computers and sensors that monitor the weight of materials and continuously adjust the feed rates. The ingredients are pushed through the mixing chamber by the paddles. The angle of the paddles is fixed so that at the proper rotational speed the ingredients are thoroughly mixed as they are being pushed through the mixing chamber. The mix plant shall be adjusted along with the belt speed that feeds the mixing chamber and the rotational speed of the pug mill to those best suited for the mix being produced. The ingredients are proportioned and fed into the drum where they are repeatedly picked up and dropped similar to the mixing action of a concrete ready-mix truck. When a tilting drum mixer is used, care must be taken not to overcharge the drum, as inadequate mixing and buildup of material on drum surfaces are common problems when the drum is overcharged. The mix must be retained in the drum mixer for a time similar to that for conventional concrete. The mixing time should be well maintained as prescribed. The bottom of the mixing chamber opens to drop the mix onto a delivery belt that delivers the RCC to the conveyance system. The horizontal shaft mixers thoroughly mix the ingredients much faster than drum mixers. Mix retention times of less than 20 seconds are generally adequate for thorough mixing with a compulsory mixer. Admixtures are introduced into the mix in small quantities, and when introduced alone may not be evenly distributed throughout the mix. The batching and mixing plant should be operated according to the manufacturer's recommendations, maintained in satisfactory operating condition, and cleaned as needed after each production run. During production, all supply bins and silos should be kept sufficiently full to ensure a uniform and constant flow of all materials. Uniformity of the mix is critical to good quality RCC.

The mix is conveyed either by belt conveyor or hauling equipment. Hauling equipment is typically used on low-volume jobs, whereas conveyor belts are typically used on high-volume jobs. The main concerns with conveyance of the RCC mixture from the plant to the placement area are segregation, contamination of the mix, drying of the mix, wetting of the mix from rainfall, contamination of the lift surface, and damage to the lift surface from hauling equipment. Segregation occurs on conveyor belts or chutes that are significantly inclined and at the end of conveyor belts or chutes where the mix is propelled off the end and allowed to fall more than 5 feet. In some cases, baffles can prevent segregation that occurs at the end of a conveyor. A baffle is a piece of wood, steel, or heavy flexible material (like a mud flap behind a truck tire) that is positioned just beyond the end of the conveyor belt.

After the foundation or lift surface preparation is complete and if applicable, forms are well anchored, placing and spreading may begin. Any loosened materials or contaminants must be removed prior to covering the lift surface with the next layer of RCC. Small dozers can be used to spread and level RCC, but should never operate directly on compacted RCC surfaces if doing so damages the surface. They should spread the uncompacted material in front of them as they extend the lift. When it is necessary to traverse compacted RCC surfaces, protective sheets, such as waste conveyor belts or plywood, should be placed on the surface to protect it from the dozer cleats that would otherwise damage the surface. RCC should be spread to a uniform thickness. It is important to develop a process of depositing and spreading the mix so that any premature compaction of the loose lift is minimized or is uniform over the entire lift. The placement of RCC should be performed in as nearly a continuous, nonstop operation as possible. To the extent practicable, the structure should be brought up in level lifts across the entire area. The direction of RCC placement and compaction should be parallel to the main axis of the structure so that the number of lanes and specifically the number of edge joints are minimized. The RCC mix should be placed as near to its final location as possible. RCC should be spread into an uncompacted, uniform lift thickness that can be compacted to produce a lift of the specified thickness and density. The RCC mix should be sampled after spreading to obtain material for testing. Samples are commonly taken for making compressive strength cylinders.

The strength and durability of RCC improves as the density increases, but excessive rolling can actually decrease density of some mixtures and induce surface cracking. Therefore, it is desirable to compact the RCC with a large roller that can attain the specified density in as few passes as possible. Typically, four to six passes of the production roller are adequate to achieve desired densities for RCC lifts up to 12 inches thick. Special compaction equipment such as walk-behind rollers, power tampers (also known as jumping jacks) and manually directed vibratory plate compactors may be used in confined spaces and up against formwork. The lift surface should be cleaned, as necessary, prior to placement of the next lift. The cleanup should include the removal of all loose material, laitance, dirt, debris, standing water, snow, ice, oil, and grease. Cleaning of previously placed RCC layers should be accomplished by compressed air, low-pressure washing, high-pressure washing, or sand blasting. The lift joint for this type of RCC mix would have few, if any, voids, providing for good overall contact between the lifts. The neat cement grout would only serve to bond the joints, not fill voids. The neat cement grout may be mixed before applying it to the lift surface or made by applying dry cement to a moist surface. The time between spreading of the concrete, mortar, or grout and the placement of the RCC should be minimized to ensure the concrete, mortar, or grout does not set up or dry out prior to being covered with the RCC mix. Bonding mortar, bonding concrete, or grout may be deposited onto the lift surface from the chute of a ready-mix truck, a front-end loader bucket, or a concrete bucket. Bonding mortar or grout can then be spread with rakes to the specified thickness.

The total concrete for Roller Compacted Concrete Dam is estimated as 9,00,380 cum, above the river bed. A period of 3 working seasons has been planned for the placement. The rate of placement works out to 133 m^3 /hour approximately (considering 26 working days in a month and 15 effective working hours in a day (corresponding to three shifts). Considering peak concrete requirement as 125% of average, the peak placement requirement works out to about 166 m^3/hour. The concrete required for main dam is proposed to be produced in two centralized Batching Plant with capacity of 90 m^3/hour. The plant is proposed to be located about 0.5 m downstream of dam axis. The concrete from the plant will be transported with the help of conveyor belt to the placement.

Placement of Roller Compacted Concrete (RCC) will be carried out through dozers and concrete will be compacted through Vibratory Rollers. The lift height of each layer will be 300 mm.

The thickness of green concrete layers will be such that the vibratory roller will be able to penetrate below the previous layer of concrete being placed, so that the whole mass becomes homogeneous. Accordingly concrete placement planning & programme will be developed.

Table 9-12: Estimation of hourly Quantity for concreting

Description	**Type**
Total Volume (m^3)	9,00,380
Average placement of RCC	50000 m^3/month
Time Period (Months)	18 (3 seasons)

Height of each layerplacement	300mm
Shift Proposed	03- with 8 hrs each / 02- with 12 hrs each
Total Operational hours (hours) ina month	375 (26 days p.m. @ effective 15hours per day)
Volume to be handled (m^3/hour)	133
Peak Volume to be handled (m^3/hour) 125% of Average	166

Table 9-13 : Lift wise Volume for RCC above river bed level

SL.	Dam EL (m)	Thickness (m)	Width Along Flow (m)	Width Across Flow (m)	Volume (Cum)
1	877.500	1.500	98.100	96.369	14203.47
2	879.000	1.500	96.600	97.524	14156.57
3	880.500	1.500	95.100	98.678	14104.47
4	882.000	1.500	93.600	99.833	14047.17
5	883.500	1.500	92.100	101.550	14023.83
6	885.000	1.500	90.600	103.267	14032.53
7	886.500	1.500	89.100	104.984	14033.52
8	888.000	1.500	87.600	106.701	14026.77
9	889.500	1.500	86.100	108.418	14012.30
10	891.000	1.500	84.600	110.135	13990.10
11	892.500	1.500	83.100	111.852	13960.18
12	894.000	1.500	81.600	113.569	13922.53
13	895.500	1.500	80.100	115.286	13877.15
14	897.000	1.500	78.600	117.003	13824.05
15	898.500	1.500	77.100	118.720	13763.22
16	900.000	1.500	75.600	130.436	14267.29
17	901.500	1.500	74.100	132.335	14751.35
18	903.000	1.500	72.600	134.234	14664.66
19	904.500	1.500	71.100	136.133	14569.42
20	906.000	1.500	69.600	138.032	14465.63
21	907.500	1.500	68.100	139.931	14353.30
22	909.000	1.500	66.600	141.830	14232.43
23	910.500	1.500	65.100	143.729	14103.01
24	912.000	1.500	63.600	145.627	13965.05
25	913.500	1.500	62.100	147.526	13818.54
26	915.000	1.500	60.600	149.425	13663.48
27	916.500	1.500	59.100	151.324	13499.89
28	918.000	1.500	57.600	153.223	13327.74
29	919.500	1.500	56.100	155.122	13147.05

30	921.000	1.500	54.600	157.021	12957.82
31	922.500	1.500	53.100	158.920	12760.04
32	924.000	1.500	51.600	160.818	12553.72
33	925.500	1.500	50.100	162.717	12338.85
34	927.000	1.500	48.600	164.616	12115.44
35	928.500	1.500	47.100	166.515	11883.48
36	930.000	1.500	45.600	168.414	11642.97
37	931.500	1.500	44.100	170.313	11393.93
38	933.000	1.500	42.600	172.577	11148.21
39	934.500	1.500	41.100	174.841	10904.59
40	936.000	1.500	39.600	177.105	10650.78
41	937.500	1.500	38.100	179.369	10386.78
42	939.000	1.500	36.600	181.634	10112.60
43	940.500	1.500	35.100	183.898	9828.23
44	942.000	1.500	33.600	186.162	9533.66
45	943.500	1.500	32.100	188.426	9228.91
46	945.000	1.500	30.600	190.690	8913.97
47	946.500	1.500	29.100	192.954	8588.84
48	948.000	1.500	27.600	195.219	8253.53
49	949.500	1.500	26.100	197.483	7908.02
50	951.000	1.500	24.800	199.747	7582.12
51	952.500	1.500	23.600	202.011	7291.90
52	954.000	1.500	22.400	204.275	7008.44
53	955.500	1.500	21.200	206.539	6716.82
54	957.000	1.500	20.000	208.803	6417.05
55	958.500	1.500	18.800	211.068	6109.12
56	960.000	1.500	17.600	212.598	5783.04
57	961.500	1.500	16.400	214.129	5440.77
58	963.000	1.500	15.200	215.659	5092.99
59	964.500	1.500	14.000	217.190	4739.70
60	966.000	1.500	12.800	218.721	4380.90
61	967.500	1.500	12.500	220.251	4164.75
62	969.000	1.500	12.500	221.782	4144.06
63	970.500	1.500	12.500	223.312	4172.76
64	972.000	1.500	12.500	224.843	4201.46
65	973.500	1.500	12.500	226.374	4230.16
66	975.000	1.500	12.500	227.904	4258.86
67	976.500	1.500	12.500	229.435	4287.56
68	978.000	1.500	12.500	230.966	4316.25
69	979.500	1.500	12.500	232.496	4344.95
70	981.000	1.500	12.500	224.381	4283.22
71	982.000	1.000	12.500	225.000	2808.63

3) <u>Conventional Concrete</u>

We propose to use one tower crane with a capacity of 10 ton at 70 metre placement with 3.5 cum capacity bucket for placing of the concrete and concrete pumps.

Considering 6 minutes cycle time for placing 3.0 cum of concrete, 10 cycles of concrete bucket can be placed in an hour. Thus 30 cum of concrete can be placed using the tower crane. We propose to deploy one tower crane along with two 38 cum/hr capacity concrete pumps combination covering the conventional concrete for complete 8 blocks of the dam area.

With the above installed total placing capacity of 76 cum (38+38) of concrete, the proposed placement per hour, considering 70% of the equipment capacity is about 53 cum. Moreover the requirement of concrete is considered as 75% of the peak capacity of equipment which is about 39 cum. Thus 780 cum of concrete shall be placed with a daily working time of 20 hrs. The lift height is proposed as 1.5 meter.

We propose to use transit mixers of 6 cum capacity for transporting the concrete to tower crane and concrete pump location.

Time cycle for 6 cum capacity transit mixers
Positioning = 2 min
Loading 6 cum = 4 min
Travelling 1.5 km = 9 min
Unloading = 8 min
Return = 5 min

Total Time = 28 min
In one hr it can carry 39/28*6= 8 cum.

Thus for placing 39 cum of concrete per hour, 6 (5 + 1-standby) transit mixers shall be required. All construction joints will be kept continuously moist until they are covered with concrete. The exposed surfaces of the concrete will be kept moist or the moisture in the concrete will be prevented from evaporating by means of continuous sprinkling or spraying with water. The concreting of the dam is planned to be carried out as given in Table 9-14 below:

Table 9-14: Duration for Conventional Concreting

Sl. No.	Items	Quantity (cum)	Rate of concreting
1	Conventional Concrete	128780	780 Cum/day =20,280 cum/month

Concreting conventional concrete is estimated to be completed in about 6.5 months time, considering 1 set of tower crane, 2 Nos. of concrete pumps of 38 m^3/ hour supported by 6 transit mixers of 6 m^3 capacity working during day and night for 20 hours of effective working time.

<u>Batching Plant</u>

It is proposed to deploy two Batching Plants of 90 cum/hr for dam concreting. With the installed batching plants capacity, totalling 180 cum (90+90) of concrete, 70% of the capacity is considered as working capacity. Thus 2500 cum of concrete shall be produced with a daily working time of 20 hrs.

9.5.3. Reinforcement of RCC

No reinforcement is proposed for Roller Compacted concrete. The reinforcement is provided for Conventional Concrete and will be placed as per usual practice and the time required is same as for the conventional concreting (including placing of reinforcement).

9.5.4. Instrumentation

The below instruments are proposed in the dam and embedded will be done as proposed by the supplier:

– Uplift Pressure Meters, Pore Pressure Meters, Stress Meters, Strain Meters, Joint Meters, Thermocouples, Normal Plumb Line, Inverted Plumb Line.

The conduits for the cables to the instruments need to be planned well. Protection of vibration is a before the placement. The instruments and cables under roller necessity.

9.5.5. Hydro mechanical

After completion of civil activities, hydro-mechanical works will be taken up, which involves erection of trash rack, Gates and hoists.

9.5.6. Key Construction Equipment for Dam

The key construction equipment for construction of Roller Compacted Concrete Dam are listed in Table 9-15:

Table 9-15: Key Construction Plant and Equipment

Sl No	**Equipment**	**Size/ Capacity**	**Quantity**
1	Hydraulic Excavator	2.0 m^3	04
2	Crawler Dozer	90 HP	02
3	Front End Loader	2.5 m^3	02
4	Rig-On-Crawler Drill	600 cfm	02
5	Jack Hammer	120 cfm	06
6	Rear Dumper	18/20 T	15
7	Tippers	4.5 m^3	03
8	Conveyor Belt for transportation of Roller compacted Concrete from Batching Plant to Dam site	set	1
9	Aggregate Processing Plant	200 TPH	02
10	Batching & Mixing Plant	90 m^3/hr	02
11	Concrete Vibrator (Electrical/ Pneumatic)	-	08
12	Compressed Air	Cfm	1500

13	Grout Pump	20kg/m^2	04
14	Transit Mixer	6 cum	10
15	Mobile Cranes	16 T	02
16	Tower Crane	10 ton capacity at 70 metre placement with 3.5 cum capacity bucket	01

9.5.7. Construction Program Sequence

The sequence of construction of concrete dam takes into account the following aspects:

- Surface excavation of concrete dam to start during the 3rd quarter of Year 1.
- The total quantity of excavation to be completed in a period of 1 working season. The activity to be completed by the end of 1st quarter of year 2.
- Concreting to start in the 2nd quarter of Year 2 and will continue for 3 working seasons and to be completed by the end of the 2nd quarter of year 4.
- Since, river diversion is proposed in single phase, the conventional concrete around gated spillway portion is to be carried out parallel with roller compacted concrete.
- Gate installation work to start in the beginning of 3rd quarter of year 4 and will be completed by the end of 4th quarter of Year 4.

9.6. Water Conductor System

9.6.1. General

The fabrication of water conductor pipe is proposed to be done in 2.5 m length in mechanical workshop established at/near the project site. The rolling of steel plates to the required diameter of ferrule shall be done by use of rolling machine followed by longitudinal welding along the length of ferrule. It is proposed to establish the workshop during the mobilization period with start of the ferrule fabrication from zero date of construction. Necessary stacking arrangement shall be facilitated near the workshop area with adequate and suitable arrangements. The fabrication of pipeline ferrules will be followed by sand blasting and preliminary painting (inside & outside), however the final painting will be done after erection.

The workshop will be facilitated by overhead gantry crane, which will facilitate the shifting of material, shifting of penstocks and loading of penstocks. The ferrules from workshop will be transported on flatbed trucks to the designated location of water conductor alignment along the road side from where they will be shifted to the desired fronts by sliding them on the rail tracks laid parallel to the water conductor alignment.

It is proposed to install rail track having width of 1 meter between each sequence of two anchor blocks, adjacent / parallel to the alignment of penstock. It is proposed to install a gantry perpendicular to the axis of penstock which will facilitate unloading of the ferrule and loading to the rail mounted trolley. The power driven winches shall be used for pulling of ferrules on rail tracks from top to down. The penstock will be laid in position after completion of first stage concrete of anchor blocks. The ferrule will be unloaded from the Trolley by means of Jacks & Sleepers. The ferrules will be aligned for line & level followed by adequately locking in position. The ferrules will be erected in the desired alignment with initial tack welding followed by final welding of ferrules and erection of the manholes along with their testing. The entire water conductor will be laid over saddles and anchor blocks. The second stage concreting of anchor blocks will follow the final welding and testing of water conductor alignment.

The fabrication and erection of steel liner will be individual with erection followed by fabrication. The construction time is dependent on the working fronts selected for laying of water conductor pipe. The total time period estimated for fabrication and erection of water conductor system, including construction of saddle support and anchor blocks as per the industry practice, standard norms and past experience is estimated to be about 24 months.

The total length of water conductor system is about 14.8 kms. In order to execute the entire length of penstock, it is proposed to split in 15 working fronts. The scheduled working hour in a day is considered as 20 hrs and 26 working days per month. The typical cycle time for erection of 5 meter length (2 nos. of 2.5 meter each) of ferrule is provided as below-

Loading, shifting and lowering in position	8 hrs.
Positioning, alignment and lockingin position	6 hrs.
Preheating and initial welding	6 hrs.
Full welding	24 hrs.
Post heat weld treatment	6 hrs.
Total Time for installation of 2 ferrules; 5 meter length	50 hrs. = 2.5 days (considering 20 working hours per day)
Time for installation of 1000 meter length of ferrule	500 working days says 19.20 months

Thus, water conductor system (ferrule) for 14.8 kms length is feasible to be completed in 24 months period. The anchor blocks and saddles will be constructed in parallel to the erection of ferrules. The final painting and testing will be done after completing of respective sections.

The QAP plan is provided as below-

Key to Inspection Code

01	Material Verification	11	Pressure test	21	Shop/Site weld	W- Witness Point
02	Mechanical tests	12	Operating test	22	Final Inspection	H- Hold Point
03	Visual Examination	13	Coating Inspection	23	Packing / Protection	R- Documentation Record
04	Dimensional Checks	14	Thickness check	24	Manufacturing History Review	S- Surveillance
05	Surface finish	15	Hardness check	25	Alignment/Offsets Post weld Heat Treatment	RC- Test Required
06	Trace-ability control	16	Spark testing			RI- Inspection Report Required
07	Dye Penetrant Examination	17	Meggar test			JIR- Joint Inspection Report
08	Magnetic Particle Examination	18	Flash test			P- Perform
09	Ultrasonic Examination	19	Weld Procedure App.			V- Verify
10	Radiography Examination	20	Welder's Qualification Approval			

Stage No	**Stage Description**	**Insp. Code**	**Quantum of check**	**Controlling Document (To be filled by Cont.)**	**Acceptance Standard (To be accepted by the Employer)**	**Test Certificate or Report**	**Inspection Auth.**				**Instruction/Remarks**	**Insp. Signature**
							A	**B**	**C**	**D**		
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**				**9**	**10**
	Penstock Liners											
1	Material Verification	01 02 03 06 09	100 %		Technical Specifications/Approved Drawings/Relevant IS	RC/RI	R	V			Manufacturer’s TC	
2	Prepare/ Cut plate	03 04 06	100 %		-do-	RI	S	R				
3	Plate Rolling/ Trial shop assembly	04 14 21	100 %		-do-	RI	W	S				

4	Longitudinal / Circumferential welds & NDT	10 19 20 21 25	100 %		-do-	RC	P	V	W			
5	Fabrication of Specials, Bifurcation & NDT.	07, 10 19, 20 21, 25 26,	100		Technical Specifications/Approved Drawings/Relevant IS	RI	H	W				
6	Shop trial assembly of Bifurcation	04 06	100 %		-do-	RI	P	S	W	W		
7	Site assembly / NDT of: a) Ferrules etc. b) Specials/ Bifurcation	04, 06 07, 08 09, 1019,2021,25 26	100 %		-do-	RI	P H	S	W			
8	Surface preparation/ Painting	03 05 13 14 17	100 % 100 % 20% 5% 5%			RI	P	S	W			
9	Protection / Packing	23	100 %				H		W			

Inspection Authority Code		CONTRACT NO:
A	CONTRACTOR'S INSPECTOR	CONTRACT TITLE: ………
B	THIRD PARTY	CONTRACTOR'S NAME: ………………..
C	OWNER: QA & I	EMPLOYERS NAME: ……….
D	OWNER: HM DESIGN	

9.6.2. Valve House

The valve house will be a simple frame structure with roof truss and isolated footings are proposed. The detailed construction methodology is discussed in following sections:

9.6.2.1. EXCAVATION

Valve house shall be accessed through available approach road. The common as well as rock excavation will be carried out as per excavated profile of the Valve House.

Total time required for excavation of Valve House will be about one month.

9.6.2.2. CONCRETING

The concreting of valve house is proposed to be carried out from bottom proceeding upwards. Shuttering of 1.50 m height is proposed to be used for concreting of the Valve house. The valve house RCC and structural part will be erected forming the valve house along with concreting of footing and columns. Roof Truss is proposed over these columns. The valve is proposed to be operated through monorail hoist. All the hydro mechanical components of the valve house will be placed in position along with its concrete. The ferrules at the upstream and the downstream of the butterfly valve will be placed in line and level of the water conductor.

The total time period estimated for construction of Valve house as per the industry practice, standard norms and past experience is about 6 months. Construction of valve house is not critical activity and can be carried out in parallel with other activities.

9.7. Deployment Schedule

Based on equipment planning and construction programme described in preceding Sections, a construction schedule for whole of the project has been prepared in the form of a Bar Chart and is placed at **Annexure 9.1**. Keeping this construction schedule as one of the major criteria, a deployment schedule of major construction equipment that would be required to be made by EPC contractor for the project. The number of equipment shown in the list has been arrived at after scheduling the equipment in such a way that minimum number of equipment, in general, would be needed. The basis for planning, indicating the type of equipment to be used, has already been dealt with in the respective sections and sub-sections corresponding to different items of the structures. As the deployment schedule may differ depending upon the number of executing agencies, the total number of equipment required will have to be reviewed at the time of project execution.

9.8. Total requirement of major construction Equipment

The requirement of major construction equipment and plants for various project components are mentioned above under construction methodology of each project component. In the cost estimate, the hourly use rate of equipment have been worked out based on capital cost of the project (from similar projects) and further CWC methodology for determination of hourly use rate of equipment have been adopted.

The provision on this account will not be included in the sub-head Q - Special T&P of Cost Estimate, as these works are proposed to be executed by the contracting agencies on EPC basis.

9.9. Manpower Planning

9.9.1. Organisation Set up

The project will be implemented under an organisation set-up headed by an officer of the rank of General Manager. The works will be executed under the overall supervision of four Officers of the rank of Chief Engineers who will report to General Manager. In addition, there will be four officers of the rank of Superintending Engineer to assist General Manager: Director (Administration), Director (Finance), Director (Technical Coordination) and Director (Planning) and Public Relation Officer and Labour Welfare Officer. Each will be assisted by appropriate subordinate officers and staff.

There will be four Chief Engineers for the Project to look after the works, viz., Chief Engineer (Head works), Chief Engineer (Water Conductor System), Chief Engineer (Designs) and Chief Engineer (Electrical & Mechanical). Each Chief Engineer except Chief Engineer (Designs) will be supported by two officers of the rank of Superintending Engineer who will be heading the field formations of circles. Each circle will have three to four division offices which will be headed by the officers of the rank of Executive Engineers. Executive Engineers in turn will have Assistant Engineers as their subordinate officers who will man Sub-Divisional offices. The Chief Engineer (Designs) will be supported by four officers of the rank of Superintending Engineer: two for design units, one for Quality control and one SE for EMP and R&R. These SEs will be further supported Executive Engineers/ Assistant Engineers and other supporting staff.

Chief Engineer (Head Works) will be responsible for execution of works related to construction of Coffer dam, Diversion Arrangement and Song Dam. One of the Superintending Engineers under him will be responsible for construction of Diversion arrangement and Coffer Dam and another Superintending Engineer will be responsible for construction of Song Dam. They will be supported by appropriate subordinate officers as elaborated under the organisation chart. The designs of various components of the project will be carried out by the Chief Engineer (Designs).

Chief Engineer (Water Conductor System) will be responsible for execution of works related to construction and laying of the water conductor system. It shall involve construction of Valve House, anchor blocks, saddle supports and river crossings to facilitate the alignment of 15km from Song Dam to Water Treatment Plant.

The civil designs of all the components of the project will be carried out by the Chief Engineer (Designs). The Chief Engineer (Electrical & Mechanical) will look after the electro-mechanical works. His formation will also provide assistance in respect of electrical and mechanical works for whole of the project. Chief Engineer (Electrical & Mechanical) will also have one Superintending Engineer (Hydro-mechanical) under him, who will take care of Hydro-mechanical aspects of the project i.e. Gates and Hoists of the project.

9.10. General Purpose Equipment & Inspection Vehichles

The entire works is proposed to be executed through award of contract on EPC basis. The general purpose equipment for infrastructure works, inspection and transport vehicles, which are required to be procured and used by the project owners for the project have been estimated and indicated under Q-Special tools and Plants in the in Volume – III Cost Estimate. The total cost considered under Q-Special Tool and Plant for general purpose equipment and inspection vehicles has been considered as Rs. 228.0 lakh.

9.11. Year wise allocation of cost

The total construction period of the project is considered as 3 years (excluding pre-construction and Infrastructure facilities). As per construction schedule of the project, the cost allocation may be considered as 30% in first year, 35% in second year and balance 35% in third year of construction.

10. ENVIRONMENTAL, ECOLOGY AND FOREST ASPECTS OF THE PROJECT

10.1. General

The proposed site of Dam in the song River is located at the boundary of District Dehradun and Tehri-Garhwal near village Sondhana which is about 25 kms from the rail-head of Dehradun and is approachable through metaled road upto Maldeota and then through seasonal track along the left bank of Song River.

Planning and Investigation have already been carried out by the Uttaranchal Irrigation Department. The basic activities were collections of field data related with topography, hydrology, geology and their interpretations and then planning of the project carrying out EIA studies etc.

10.2. Description of Environment

The proposed Song river drinking water Project is located in the rugged hilly terrain of lesser Himalaya at latitude 300 l8'08"N and longitude 78011'30"E with an elevation of, 875M above MSL. The hills are made up of rock formations of Chandpur and Krol belt, which are' composed of quartzites, phyllites, states, limestone, fragmented limestone and dolomite. The limestone belt in the area in the past had been degraded due to reckless mining, due to which the hills are now having barren and deserted looks. With the partial ban on mining activities, the ecology of the area is under regeneration process. The site is in the temperate humid region of lesser Himalaya, close to the town of Dehradun and one of the main hill stations, the Queen of Hills-Mussoorie.

The annual mean rainfall of the region is 2500mm with maximum 24 hrs rainfall of 302mm. The mean maximum wind speed varies in the range of 6- 7 km/hr. with the predominant wind direction being N and NW. Ambient temperature (dry bulb) ranges between 2°C and 26°Cin the winters and between 24°C and 40°C in the summer. The soil is gritty to sandy and calcareous in nature.

The Song Dam Project is located in an open Valley running by the side of the Dehradun-Chamba Highway. This highway witness's regular traffic during the summers, when the tourists season to the hills is on its peak In the Song valley cultivation in the plain as well as in the terraced fields is common.

The Song River is not receiving any significant sewerage or domestic effluent from the urban or rural settlements, whereas the small quantity of water flowing down from the upper reaches is always contaminated due to interactions with the human beings.

All around the dam reservoir human settlements are observed scattered throughout in the surroundings.

10.3. Scope of EIA Studies

The scope of the study includes cross-sectional characterization of the existing environment in an area of 10 km. radius from the diversion site of the project as well as regional background status for environmental components viz. air, noise, water, land, biological and socio-economic.

The main objectives of the study are :

(i) To collect base line information on various components of environment.
(ii) To identify and quantify significant impact of the proposed project.
(iii) To prepare EMP to be adopted for mitigation of adverse impacts, if any.
(iv) To delineate post project environmental status.

10.4. Methodology for Environmental Impact Assessment

Keeping in view the importance of the project, and the guidelines for the EIA studies, it was decided to cover the zone of 1 0 km. radius from the dam site for the purpose of baseline data collection, EIA and to delineate the scheme for EMP. The impact identification is being done with the impact identification network developed for the various activities of the project.

10.5. Impact Identification

In the implementation of Song river drinking water Project, a number of activities will be involved as discussed earlier. The construction activity, which will last for 6 years only, will be having a significant impact on the environment due to its high magnitude. The different activities of construction have been narrated earlier. During the construction, the immediate surroundings will face influx of labour, high mobility of heavy traffic, maneuverings of construction equipment, blasting of rock formations for excavation of foundation, tunneling, quarrying of construction material, and a number of other related activities. The post construction activities are purely non-interfering with the environment. The formation of reservoir due to submergence of 83.85 hectares of land will have ,direct ,impacts on land and biological environment. The. Impact identification has been carried out with network method.

10.6. Air Environment

The air environment will be significantly affected during the construction phase only, therefore, base line data has been collected here. The brief data on the micrometeorology has also been incorporated.

For ambient air quality monitoring ten sampling station were selected within a ten km radius zone on the basis of physiography and micro-metrological data (wind; speed\directions). The parameters for ambient air quality included suspended particular matter (SPM) sulphur- dioxide (SO2) and oxide of nitrogen (NOx). Gaseous pollutants were monitored on 8-hour average. High Vol. sampler APM-415 was used for monitoring the ambient air. As the process of water conveyance and electricity generation is not going to emit or discharge any kind of air or water pollution this data has been presented for base line information only.

10.7. Water Environment

The in-situ sampling of surface water of the Song river has been done from the dam site, village Rangargaon just at the apex of the proposed reservoir, and d/s of village Salyo in the upstream segment of the river Song. Spring water sampling has been done from the villages Sarauna, Dubra, and Nakraunda. Ground water samples (hand pump) have been collected from the villages Kaddukhal, Kulhan and Raipur. One water sample has also been collected from the water supply network of village Sindhwal gaon. The hydrology of the river system has been studied in detail for preparing the project proposal. The hydrogeological studies have also been carried out to generate the base line data.

10.8. Noise Environment

Noise pollution survey was conducted in and around the project site and at the dam site. The noise pollution observations were made from ten locations in the project area.

10.9. Land Environment

Land environment is of somewhat concern in the project. This environment will be primarily impacted as a consequence of making the dam, tunneling, excavation 'and the various construction activities. A considerable change in the soil structure and other land environment is likely to happen due to pounding of the reservoir. To a minor extent the land environment may also be affected due to influx of work force and heavy movement of construction equipment, in small stretches.

The land use, geology, geomorphology and drainage pattern in the area around 10 km. radius has also been studied in detail. The stability of slopes and erosion of the soil in the catchment's area has been studied in detail for base line information. The physico-chemical properties of soil have been also studied.

10.10. Biological Environment

The construction of Song river drinking water Project will cause maximum damage to the flora of the region. Accordingly, the qualitative and quantitative studies on terrestrial biology have been done. The aquatic biology has also been studied in the area. Base line data on flora and fauna has been collected in detail in the BIA Report.

10.11. Socio Economic Environment

Data on demographic pattern, population density, educational facilities,, agricultural pattern, other employment sources, fuel use shifts and changes in public demand for domestic, commercial or industrial fuel, medical facilities, health status, water supply and sanitation problem, transport system, cultural and entertainment facilities have been collected on random basis from the rural settlements spread over 10 km. radius. Socio-economic status of the possible oustees has also been studied from the proposed submerged area.

Table 10-1: Details of project affected households

District	**Block**	**Village**	**No. of affected houses**
Tehri	Jaunpur	Sondhana (Tehri)	17
Tehri	Jaunpur	Ragad Gaon	1
Tehri	Chamba	Ghursalgaon	24
Dehradun	Raipur	Paled	8
Total	3	4	50

Source: Field Survey

Table 10-2: Details of private land affected due to the project

Source: Field Survey

Name of Village	**Population (under the direct impact area)**	**No. of Families/ Beneficiaries**	**Private Land affected (Hect.)**
Ragadgaon	4	3	0.123
Ghursalgaon	155	141	4.45
Sondhana(Tehri)	274	106	3.818
Paled	53	25	1.94
Total	486	275	10.33

10.12. Construction Scenario

During construction a number of activities will be noted which will have direct or indirect bearing on the environment. These activities have been evaluated and a I management plan has been drawn.

Apart from above, the detailed studies have been carried out under the following subheads of EIA.

- **Catchment Area Treatment Plan :** The detailed study of catchment of song river upstream of the Dam site has been carried out and the suitable treatment measures have been incorporated as per details given in the EIA
- **Compensatory Afforestation :** The forest land of District Dehradun and Tehri Garhwal which is to be sub merged has been accounted for and the compensatory a forestation in lieu of the above forest has been provided as per latest prevailing forest act 1980.
- **Rehabilitation Master Plan :** Rehabilitation survey has been Completed according to which 275 families having 10.332 hectares of agriculture land one gharat and one school have to be rehabilitated. The Rehabilitation has been planned in the forest land near Maldeota as per rehabilitation rules. Financial allocation of Rs 14500.00 lacs has been provided in the Project estimate.
- **Command Area Development :** The project for utilization of song water for drinking purpose has been framed accordingly. Kalanga canal which is the carrier for water of song river from the New proposed water channel has a vast command for Irrigation which shall be further modernized accordingly along with the network of drinking water scheme.

10. **Flora and Fauna :** A total of 26 trees, 13 shrubs, and 17 herbs, 55 species of avi-fauna, 4 species of fish and 3 species of reptiles and fauna were recorded during the field survey. Among other terrestrial animals, 14 reptiles and mammals were recorded through secondary literature review and interactions with local villagers The details of Flora and Fauna has been given in the separate BIA Report and suitable efforts shall be made so as to avoid and damage to it during the construction of the project. If however during the execution of the project works. There may be any damage of Flora and Fauna suitable measures shall been taken as per the guidelines of the Forest Act 1980 and instructions of Uttarakhand Forest Department.

Table 10-3: REET Status of recorded Tree Species

Species	IUCN Status
Bombax ceiba	Not evaluated
Albizia procera	Not evaluated
Acacia Catechu	Not evaluated
Falconeria insignis	Not evaluated
Jacaranda mimosifolia	Vulnerable[1]

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[1] IUCN Red List of Threatened Species 1998: e.T32027A9675619

Leucaena leucocephala	Not evaluated
Euphorbea royleana	Not evaluated
Zizyphus mauritiana	Not evaluated
Mallotus phillipensis	Not evaluated
Pinus roxburghii	Least concern
Sizygium cuminii	Not evaluated
Alstonia scholaris	Least concern
Butea monosperma	Data deficient
Pterospermum acerifolium	Not evaluated
Carica papaya	Data deficient
Mangifera indica	Data deficient
Pyrus communis	Least concern
Prunus persica	Least concern
Juglans regia	Least concern
Psydium guajava	Least concern
Emblica officianalis	Not evaluated

Table 10-4: REET Status of recorded shrub species

Species	IUCN Status
Murraya koengii	Not evaluated
Ricinus communis	Not evaluated
Carissa opaca	Not evaluated
Lantana camarra	Not evaluated
Ageratum conizoides	Not evaluated
Colebrookia oppositifolia	Not evaluated
Opuntia sp.	Not evaluated
Adhathoda vesical	Not evaluated
Debregeasia longifolia	Not evaluated
Solanum chrysotrichum	Not evaluated
Rumex hastatus	Not evaluated
Reinwardtia indica	Not evaluated
Berberis lyceum	Not evaluated

Table 10-5: REET status of recorded herb species

Species	IUCN Status
Urticaria dioica	Least concern
Oxalis corniculate	Not evaluated
Ageratina adenophora	Not evaluated
Cirsium spp.	Not evaluated
Agave spp	Not evaluated
Asparagus adscendens	Not evaluated
Dicliptera paniculate	Not evaluated
Cissampelos perriera	Not evaluated
Smilax spinosa	Not evaluated
Alternanthera sessilis	Least concern
Abrus Pulchellus	Not evaluated
Parthenium hysterophorus	Not evaluated
Gallium aparine	Not evaluated
Holmskioldia sanguinea	Not evaluated
Mentha arvensis	Not evaluated
Musa sapientium	Not evaluated
Brassica juncea	Not evaluated

10.13. Proximity of project to any National Park/ Sanctuaries

The Song Drinking Water Project or a part thereof is not located in any Protected Area or their Eco-sensitive zone. The nearest boundary of Rajaji National Park has found to be approx 18km from the project site (Please refer map below). As the project does not falls under any ecologically sensitive zone, a 'No Objection Certificate' will be obtained from the concerned authorities.

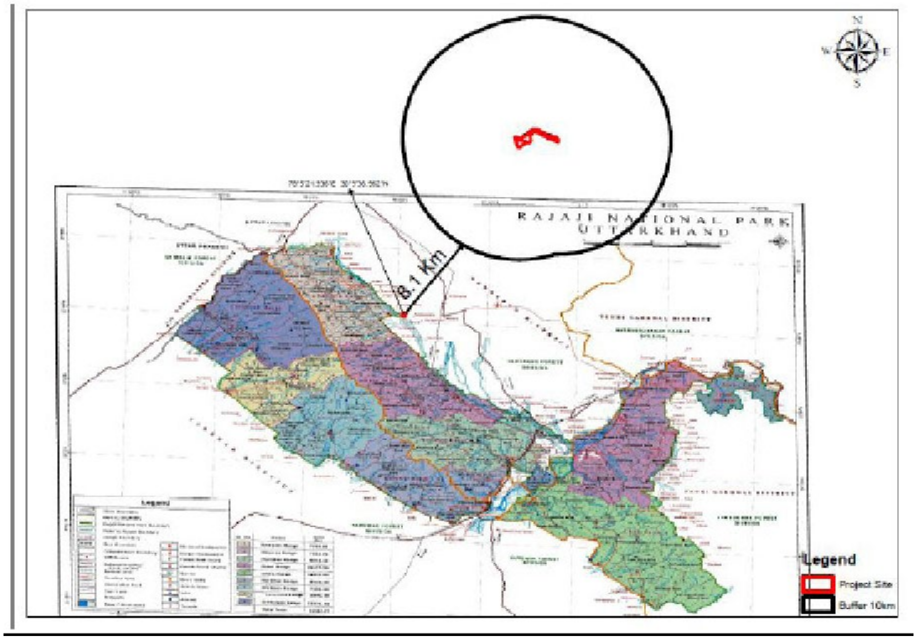


Figure 10-1: Aerial distance of project site from protected area

10.14. Scope of the Study

To ascertain the environmental impact of the Song drinking water project as a result of the construction and operation of the proposed project and identify the site-specific measures to mitigate the negative impacts.

Primarily, objective of this study would be three folds-

(i) To ascertain the existing baseline environmental conditions through field study/monitoring, assess the effects/impacts of all the factors as a result of construction and operational phase of the Song Dam Drinking Water Project in three seasons viz. Pre-monsoon, Monsoon and Winter seasons.

(ii) To analyse the possible impacts on the existing environment in the area and to suggest suitable mitigation measures for minimizing the impacts and develop a post study monitoring plan

(iii) To assist Investigation & Planning Division, Uttarakhand Irrigation Department to obtain necessary obtain necessary Environmental clearances at State and Central Government departments as perthe approved ToR of MoEF&CC.

EIA Process

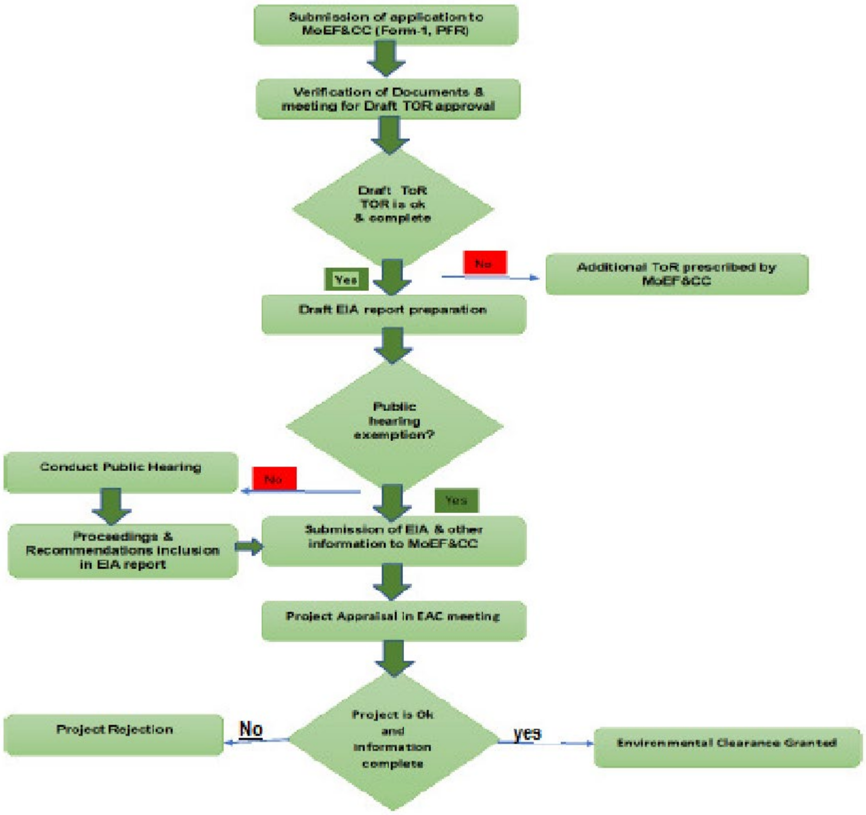


Figure 10-2: Flow chart of EIA

Table 10-6: Environmental Attributes and its Land Use Pattern

Environmental attributes, parameters and source of information Land Use	**Land use pattern**	**District Planning Map**
Land Environment		
Soil	Soil Characteristics Soil erosivity in catchment area	Field studies, GIS based information
Geology	Geological Status	Project Pre-Feasibility Report
Seismology	Seismic Hazard	Pre-Feasibility Report
Water Environment		
Water Resources	Catchment Area, Flow, Design	Project Pre-Feasibility Report

Water Quality	Physical, Chemical and Biological parameters	Field studies
Hydrology	Drainage area and pattern	Project Pre-Feasibility Report
Ambient Air Quality	SPM, RPM, SO2, NOx and CO	Field Studies
Meteorology	Temperature and Relative humidity	Field Studies
	Temperature, Relative humidity, Rainfall, Wind Speed and Wind Direction	India Meteorological Department,, Pune
Noise	Noise levels in dB (A)	Field Studies
Biodiversity		
Ecology	Flora & Fauna Diversity	Field Studies, Information from Forest department and Literature Study
Aquatic Ecology	Density & diversity of aquatic species	Field studies, Fisheries Department, Literature review
Socio-economic		
Socio-economic aspects	Socio-economic characteristic of the affected area	Field Studies, Literature review

11. PROJECT COSTING

11.1. General

Cost estimate of Song Dam Drinking Water Project has been worked out by calculating the quantities of different work items involved and multiplying with the applicable unit rates. The applicable unit rates are based upon the basic items rates prevailing in Uttarakhand, with labour rates and cost of transportation including loading, unloading & stacking charges.

11.2. Basis of the Cost Estimate

The cost estimate has been prepared to give an idea of total project cost at January, 2020 price level which includes civil works, infrastructure facilities, electrical / mechanical works and hydro mechanical works for Song Dam Drinking Water Project.

The quantities have been worked out on the basis of various designs/drawings relating to project components. Unit Rate analysis and project costing has been done as per "Guidelines for Preparation of Detailed Project Report of Irrigation and Multipurpose Projects" issued by Central Water Commission" in 2010 and "Guidelines for Formulation of Detailed Project Reports for Hydro Electric Schemes, their Acceptance and Examination of Concurrence" by Central Electricity Authority in January, 2015 (Revision 5.0). Basic Construction materials like Cement, Reinforcement steel, structural steel, Boiler Grade Steel and all types of drill steel have planned to be purchased from Dehradun Goods Market. Gelatine Power Gel and Electric Detonator have also been planned to be procured from Dehradun Market. It has been decided to arrange High Speed Diesel (HSD) and Petrol from nearby available Fuel depot from project site.

11.3. Cost of Civil & Hydro-Mechanical Works

This head incorporates the civil work cost of various components like Diversion Pipe, Upstream Cofferdam, Main Dam, Intake, water conductor pipe and Valve house. It also includes the cost of related hydro-mechanical works like main orifice spillway gate, high level spillway gate, Intake Trashrack and Gate, Diversion Pipe Gate, valves for environmental release pipe and water conductor pipe. Total hard cost which includes cost of civil works, hydro-mechanical works and other miscellaneous works comes out to be Rs. 1300.78 Crores without GST and Rs. 1408.66 Crores with GST. The estimate has been worked out under two sub-headings viz. Direct Charges and Indirect charges as per CEA "Guidelines for Formulation of Detailed Project Reports for Hydro-electric Schemes, their acceptance and examination for concurrence" issued by Central Electricity Authority in Jan. 2015 (revision 5). Direct Charges take account of cost of I-Works, Establishment, Tools & Plants, Suspense and Receipt & Recoveries. Indirect Charges consists of Capitalization of Abatement of Land Revenue and Audit & Account Charges. Cost under various heads has been given as follows.

11.3.1. Direct Charges

Direct charges are the expenses incurred on various civil & Hydro-mechanical works and are further classified into five categories:

- I - Works
- Establishment
- Tools and Plants
- Suspense
- Receipt and Recoveries.

The details of above sub-heads under Direct Charges are given in the following paragraphs.

11.3.1.1.I-WORKS

Under this heading, provision has been made for Civil Works and Hydraulic Steel Structures for various components of the project as detailed hereunder:

A - Preliminary

This head covers works relating to various studies, preparation of DPR & tender documents, pre-construction survey & investigations, hydrological & meteorological surveys, investigation for foundation & rock mechanics testing, detailed engineering & design, seismological studies, model tests, environmental & ecological studies, training of engineers, preparation & printing of project reports and preliminary soil tests & establishing soil testing laboratory etc. An amount of Rs. 24.81 Crores has been kept under this head.

B – Land

B-Land incorporates acquisition of land, rehabilitation & resettlement including compensation for property, interest charges, solatium charges, demarcation & measurement charges, etc. The total anticipated amount of Rs. 254.52 crores will be used on B- Land.

C - Civil Works

An expected cost of Rs. 912.44 Crores has been reserved for the civil works of the various components of head works viz. diversion pipe, upstream cofferdam, Main Dam and related H-M works viz. main orifice spillway gate, high level spillway gates, diversion pipe gate including embedded parts, trestles, hoist supports & hoists etc.

K – Buildings

A total cost of Rs. 38.29 crores is likely to be held in reserve for this head which covers the Residential / Non Residential buildings of temporary & permanent nature, office buildings, guest house, field stores, field workshops, testing laboratory and other service buildings. The cost has been worked out on the basis of plinth area at the rate provided by the client all types of temporary & permanent residential & non-residential buildings. This also includes the charges for fencing, land development, internal colony roads and plantation within the colony etc.

M – Plantation

A probable amount of Rs. 0.24 crores is there to meet the requirement of plantation in the colony area including nursing, sapling etc. required for beautification as considered necessary downstream of dam and appurtenances and other important structure. It also incorporates the amount needed for manure, fertilizers and maintenance.

O – Miscellaneous

O- Miscellaneous contains the capital cost & maintenance of construction power, Water supply, Sewage disposal, drainage works, fire fighting arrangements, telecom & wireless communication, medical assistance, recreation facilities and security arrangements. It also includes visit of dignitaries, inaugural ceremonies, compensation to workmen, publicity & information centres. The sum of Rs. 21.74 crores has been estimated for these services.

P – Maintenance

As per applicable norms, P- maintenance holds the cost of maintenance of all works during the construction period and should be 1% of the total cost under the heads of C - Works and K - Buildings. The cost comes out to be Rs. 10.21 crores for maintenance.

Q – Special T&P

Since the projects are presently being executed through limited contract packages and is the responsibility of contractor to arrange all the equipment required for construction, erection and commissioning of plant. As per norms, a token provision of Rs.1-2 Crores under this head may be adequate to provide for essential equipment not covered under contract packages. Therefore a token provision has been made amounting to be Rs. 2.06 Crores under this head.

R – Communication

The total expected cost of Rs. 70.86 crores has been set aside for the construction of various approach roads to project components & colonies, bridge over river, road side drains, breast walls, retaining walls and widening & repair of existing roads. It also takes into account the contingencies and work charged staff @ 3% and 2% respectively.

X – Environment and Ecology

This sub-head consists of the items like compensatory afforestation, restoration of land in construction areas, removal of trees, control of aquatic weeds in submerged areas, measures to prevent forest fires, public health measures, treatment of the watershed around reservoir rim, catchment area treatment and treatment of degraded/highly degraded lands along the reservoir etc. A total cost of Rs. 54.91 crores have been decided to be spent on above mentioned items.

Y-Losses on Stock

A provision of Rs. 2.37 Crores has been made under this sub-heading. As per applicable norms; this has been worked out as 0.25% of the total cost of C – Works and K – Buildings only.

11.3.1.2. ESTABLISHMENT

Since land acquisition staff is separately provided under the sub-head B – Land, the percentage terms for Establishment has been considered as Rs.60 crores plus 4% of the cost of works (which is cost of I- works less B-Land cost) exceeding Rs.750 crores as per CEA guidelines. The cost for establishment works out to be Rs. 72.51 crores.

11.3.1.3. TOOLS & PLANTS

The probable cost of Rs.1.0 crores have been reserved for Tools & Plants to meet the demand for survey instruments, camp equipments, office equipments and other small tools.

11.3.1.4. SUSPENSE

The net provision under this minor head will be “NIL” as all the outstanding suspense accounts are expected to be cleared by adjustment to appropriate heads on completion of the project.

11.3.1.5.V-RECEIPTS AND RECOVERIES

This head is meant to account for estimated recoveries by way of resale or transfer of temporary buildings and special T&P. Miscellaneous receipts like rent charges of buildings, electricity charges etc., may also be accounted for under this head.

The recoveries on account of temporary buildings may generally be taken at 15% of the cost unless a higher recovery is anticipated due to some special reason such as tubular construction, vicinity to city / village / town industrial undertaking etc.

A sum of Rs. 1.88 crores has been considered for receipt and recoveries.

11.3.2. Indirect Charges

The complete estimate for a project besides including all anticipated direct charges further include as indirect charges, the amount required to cover the capitalization of abatement of land revenue on the area occupied by the works and allowance for the cost of Audit & Accounts and Establishment. Here a lump sum cost of Rs. 3.63 Crores @ 0.25% of I-works has been taken into consideration to bear audit and account charges.

11.4. Abstract of Cost

Table 11-1: Abstract of Cost

i) State :	**Uttarakhand**
ii) Name of Project :	**Song Dam Drinking Water Project**
Items	**Total**

	Amount (Rs. Lakhs)
I- Works	
A- Preliminary	2481.00
B- Land	25451.98
C-Civil Works	91243.64
K-Building	3829.0
M-Plantation	24.11
O-Miscellaneous	2174.43
P-Maintenance during Construction @ 1% of total cost of C-Civil works & K-buildings	1021.5
Q-Special T & P	206.00
R-Communication	7086.00
X-Environment & Ecology	5491.39
Y-Losses on stock @ 0.25% of total cost of C-Civil works & K-buildings.	237.68
Total (I- Works)	**139246.81**
II. Establishment Cost	7551.79
III. Tools And Plants	100
IV. Suspense	0
V. Receipt And Recoveries	-188.18
Total (Direct Cost)	146710.43
Indirect Cost	
Capitalisation of Abatement of Land Revenue	15.86
Audit and Account Charges	348.00

Total (Indirect Cost)	363.86
Total Cost (Direct & Indirect Cost)	147074.29
Grand Total (Civil & HM Works Cost) (Rs. In Lacs)	**147074.29**
Add GST @12%	10949.24
Total Cost with GST @12% (Rs. Lacs)	**158023.53**
Note :	

1. Head-wise cost of Various Works have been furnished in as per "Guidelines for Formulation of Detailed Project Reports for hydro electric schemes, their acceptance and examination for concurrence" issued by CEA in Jan, 2015 (Revision.5).

12. FINANCIAL RESOURCES

The song Dam drinking water project is a government sector project being implemented by Uttarakhand Irrigation Department (UID), Govt. of Uttarakhand. The financial resources required for the project are not yet firmed up and currently, it is open to be financed by State Government / State and Central government and through International funding organizations also. The studies done so far and land acquisition is funded by state government and discussions are going on, on various aspects of funding of the project.

13. REVENUES, FINANCIAL RETURN & INTERNAL RATE OF RETURN

13.1. Introduction

Song Dam Drinking Water Project is located on Song River, a tributary of River Ganga in the state of Uttarakhand. The project is located about 25 km from Dehradun and about 9 km upstream of Maldeota. The project is intended to ensure water supply in Dehradun city and Sub-Urban area.

The project envisages construction of Diversion pipe, upstream coffer dam, about 130.6 m high Roller compacted concrete Dam and water conductor system of about 14.7 km for drinking water supply through Gravity for Dehradun city and Suburban areas up to year 2071. The benefits likely from the project, sources of revenue generation and financial analysis of the project is presented in this chapter.

13.2. Benefits of the Project

The following benefits of the project are envisaged;

- The project envisages supply of 150 MLD (Million Liters per day) of drinking water supply through gravity flow for Dehradun city and suburban areas up to year 2071.
- The Project will check the over exploitation of ground and surface water.
- The project will ensure a saving of around Rs. 40.0 crores per year in due course being spent on construction of new tube wells, its power charges and maintenance.
- Additional revenue of Rs. 46.6 Crores will be generated from water supply per year.
- The project will create a 4 km long lake, which will be an attraction for the tourist.
- There will be a big scope of fisheries after completion of the project.

13.3. Revenue Generation and Financial Viability

The expected revenue generation from the project is given below in the following steps.

13.3.1. Projected Population

The projected population as explained in Chapter 2 Water Demand, Analysis and Planning is given below in Table 13-1**.**

Table 13-1: Projected Population

Sl No	**Year**	**PROJECTED POPULATION (Lakh)**			
		Population of Dehradun city	**Population of Suburban areas**	**Floating population (10% of city population**	**Total population**
1	2011	7.06	2.57	0.70	10.33

2	2018	7.89	2.84	0.78	11.52
3	2021	8.29	2.96	0.82	12.08
4	2031	9.84	3.35	0.98	14.17
5	2041	11.69	3.74	1.16	16.60
6	2051	13.86	4.13	1.38	19.38
7	2061	16.33	4.52	1.63	22.49
8	2071	19.12	4.91	1.91	25.95

13.3.2. Water Demand

The water demand as explain in Chapter-2 per projected population as per CPHEEO manual is given below in Table 13-2.

Table 13-2: Water Demand

			WATER DEMAND (MLD)			
year	Water requirement for urban area (@ 135 LPCD) in MLD	Water requirement for suburban area (@ 100 / 135 LPCD) in MLD	water requirement for floating population (@ 45 LPCD) in MLD	Industrial water demand	Net water Demand in MLD	Total water Demand in MLD
2011	95.33	25.71	3.18	25	149.21	175.55
2018	106.55	28.45	3.55	25	163.55	192.41
2021	111.99	29.62	3.73	25	170.34	200.40
2031	132.85	33.53	4.43	30	200.81	236.24
2041	157.90	44.00	5.26	30	237.81	279.01
2051	187.14	52.21	6.24	40	285.59	335.99
2061	220.58	61.11	7.35	40	329.59	387.10
2071	258.21	66.39	8.61	45	378.20	444.95

13.3.3. Water Supply

The situation of water supply in the project area is envisaged below in Table 13-3.

Table 13-3: Situation of Water Supply in the Project Area

	WATER SUPPLY FROM EXISTING SOURCE			SUPPLY FROM SONG DAM	
year	Net Supply From existing surface water resources (MLD)	Net Supply from Tube wells (MLD)	Net supply from existing resources (MLD)	Net availability for Water Supply	Net availability for any other use
				MLD	MLD
2011	23.8	127.5	151.3	Nil	Nil
2018	23.8	140.25	164.05	nil	Nil
2021	35.7	127.5	163.2	127.79	Nil
2031	35.7	127.5	163.2	127.79	Nil
2041	35.7	127.5	163.2	127.79	Nil
2051	35.7	127.5	163.2	127.79	Nil
2061	35.7	127.5	163.2	127.79	Nil

2071	35.7	127.5	163.2	127.79	Nil

13.3.4. Total Expenditure on Tube Wells (Without Song Dam)

The expected expenditure on Tube Wells for meeting water demand without existence of song Dam is given below in Table 13-4.

Table 13-4: Total Expenditure on Tube Wells (Without Song Dam)

Total expenditure in Tube Well (Without Song Dam Project)

Year	Total water demand (MLD)	Net Deficit (MLD) = Water Demand – Supply from Existing Source	No of existing tube well (as per jal Sansthan)	Requirement of new tube wells @ 0.6 MLD/Tube Well	Total tube wells needed	Cost of new tube-well (1 Cr. Each)	Period	Electricity charge of Tube wells (Cr.)	Maintenance charges of tube wells (Cr.) @10% of Electricity Charges
2011	175.55	24.25							
2018	192.41	28.36	248	-	248	-		-	-
2021	200.40	37.2	248	-	248	-	2018-21	-	-
2031	236.24	73.04	-	122	370	122	2021-31	185	18.5
2041	279.01	115.81	-	71	441	71	2031-41	220.5	22.05
2051	335.99	172.79	-	95	536	95	2041-51	268	26.8
2061	387.10	223.9	-	85	621	85	2051-61	310.5	31.05
2071	444.95	281.75	-	97	718	97	2061-71	359	35.9
	Total					**470**		**1343**	**134.3**
	Total Expenditure on Tube Wells					**Rs. 1947.3 Cr.**			

13.3.5. Total Expenditure on Tube Wells (With Song Dam)

The expected expenditure on Tube Wells for meeting water demand after implementation of Song Dam is given below in Table 13-5.

Table 13-5: Total Expenditure on Tube Wells (With Song Dam)

Year	Total water demand (MLD)	Net Deficit (MLD) = Water Demand – Supply from Existing Source	No of existing tube well	Requirements of new tube wells	Total tube wells needed	Cost of new tube-well (1 Cr. Each)	Period	Electricity charge of Tube wells (Cr.)	Maintenance charges of tube wells (Cr.)
2011	-	24.25	-	-	-	-	-	-	-
2018	197.13	28.36	248	-	-	-	-	-	-
2021	223.31	37.2	248	-	248	-	2018-23	-	-
2031	267.43	-	248	-	248	-	2023-31	124	12.4
2041	283.6	-	248	-	248	-	2031-41	124	12.4
2051	283.6	45.0	248	75	323	75	2041-51	161.5	16.16

2061	283.6	96.11	323	85	408	85	2051-61	204	20.4
2071	302.61	153.96	408	97	505	97	2061-71	252.5	25.25
	Total					**257.0**		**866.0**	**86.6**
	Total Expenditure on tube-wells					**Rs. 1209.6 Cr.**			
	Net benefit by savings in expenditure on tube-well if song dam project is commissioned					1947.3 - 1209.6 **= 737.7 Cr.**			

13.3.6. Revenue Gain from Song Dam

The expected revenue gain from Song Dam project is given below in Table 13-6**.**

Table 13-6: Revenue Gain from Song Dam Project

Year	Total Water Demand (MLD)	Net Water Supply (MLD)	Rate of drinking water @10 Rs /KL	Revenue Collection (Cr.)	
		From Song dam		Time Period	Total
2011	175.55	-	-		
2018	192.41	-	-		
2021	200.40	127.79	10	2021-23	Nil
2031	236.24	127.79	10	2023-31	373.15
2041	249.01	127.79	10	2031-41	466.43
2051	335.99	127.79	10	2041-51	466.43
2061	387.10	127.79	10	2051-61	466.43
2071	444.95	127.79	10	2061-71	466.43
				Total	**2238.87**

13.3.7. Financial Benefit from Song Dam

The expected financial benefits from Song Dam Drinking water project is given below in Table 13-7.

Table 13-7: Financial Benefit from Song Dam

	Financial Benefit from song dam	
a	Savings from expenditure on tube well up to 2071	737.7
b	Revenue for water supply upto 2071	2238.87
	Total	**2976.57**
c	Cost of the project	1408.66

	Hence Benefit Cost Ratio	**2.113:1**	
	Yearly financial benefits at present cost (cr.)	**87**	

Hence the project cost is likely to be recovered till year 2039 i.e. in 16 yrs @ 87 Cr./ year

13.4. Conclusion and Recommendation

Based on above benefits, it can be concluded that implementation of project is very crucial for meeting the drinking water requirement of Dehradun city and suburban areas.

As determined above, based on Benefit Cost Ratio, the project is financially viable and recommended for implementation.

14. INFRASTRUCTURE FACILITIES

Dehradun is the capital city in the State of Uttarakhand and is on the Tourist map of the Country. The population of the city is 5,74,840 (2011) within the Municipal Corporation boundaries and it is continuously increasing. The tourists who visit Mussoorie and the pilgrims who visit the Shrines of Badrinath, Kedarnath, Gangotri and Yamunotri - halt at Dehradun. This has put a tremendous pressure for necessary amenities to be provided to the Public. Dehradun is already facing shortage of water supply and the situation becomes more grave during summers when the discharge at the sources of water supply reduces. There is a demand for Song storage reservoir to meet the drinking water requirement and ground/subsurface water source augmentation in the vicinity of Dehradun.

It is anticipated that this shortfall will go up continuously over the coming years. Keeping this in view, it is proposed to store surplus water during monsoon by constructing a dam across river song to solve the problem of domestic water requirement for the city of Dehradun and adjoining suburban areas.

Irrigation department, Uttarakhand has proposed a dam on river Song, to cater the domestic water demand of Dehradun city and its suburban areas. The project envisages construction of a dam 130.6 meters height. A part of stored water shall be released into the existing Kalanga Canal. The share for drinking water shall be released to proposed treatment plant near pacific Golf (Sahastradhara road) thereafter to distribution system. The project will be helpful in supplying the water through gravity and so the huge expenditure involved in pumping the water will be saved. By construction of the dam some of the water will seep into the ground and will supplement the ground water table which, in turn, will enhance the output of tube wells in the vicinity and Storage of water will help in recharging the ground water and augmentation of natural water sources in downstream. Rivers like Riana, Bindal and other small streams may get recharged and ground water level in vicinity of Dehradun will also be increased. Tourism and Fisheries may also be developed.

14.1. Facilities Already Available

14.1.1 Road & Connectivity

The Project site can be reached from Capital city of Dehradun via metalled road upto Maldeota (important place in between) via all weather metalled road. Maldeota, is very well connected to Dehradun and other important parts of the state via metalled road. The distance from Dehradun to Maldeota is approximately 12 km.

After Maldeota to Dam site, the road connectivity is via an un-metalled seasonal motorable road which is in very bad condition. Distance from Maldeota to Song dam site is approximately 10.0 km.

14.1.2 Railhead

The proposed site is located at the boundary of district Dehradun and Tehri Garhwal near village Sondhana at a distance of about 22 kilometers from Dehradun Railway Station.

14.1.3 Air Service

Jolly Grant Airport is the nearest airport from Dehradun City- approximately 25 kms.

14.1.4 Telecommunication

The telecommunication services in and around the project area are in a poor condition and needs improvement. Some special operators like BSNL provides little or small coverage in the area while other operators are not playing in the area due to low population. Hence, it is advised that while and after construction of the project, the authorities may have to develop their own communication system

14.1.5 Medical Facitlity

The nearest Government Hospital – Dun Hospital is approximately 22km away from the site. However, there is a government dispensary with inadequate arrangements at Village Ragar Gaon which is about 4.0km in the upstream of the dam axis.

14.1.6 Schools

The area has in sufficient numbers of schools. The children's has to travel to kms to reach the nearest Government School which is at Hilans valley village or at Ragar Gaon which are both at a distance of 3-4km from the Dam area.

14.1.7 Electric Power

Presently the area has a supply of 11KV line which is sufficient for household purposes only.

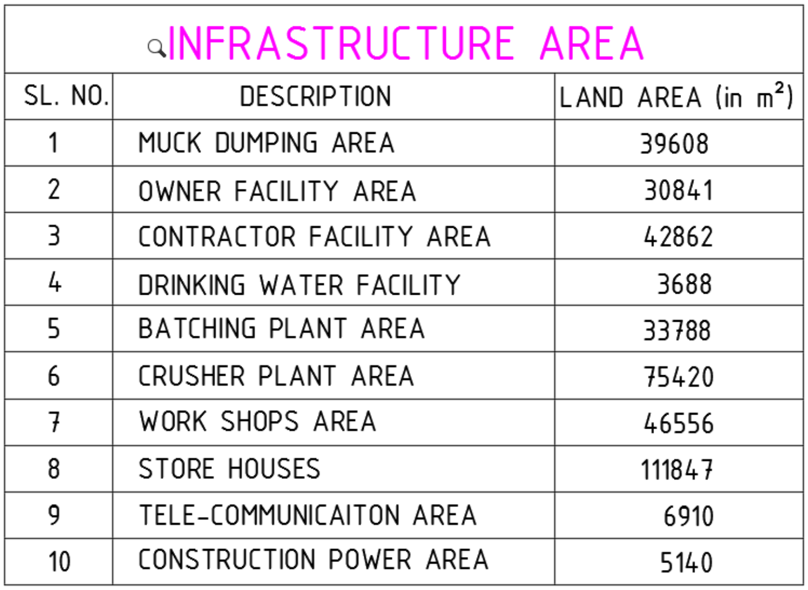
14.2. Facilities to be Developed

The facilities to be developed for the proper and timely implementation for the project must include:

1. Roads within the Project area
2. Muck Dumping Area
3. Owners Facility
4. Contractor Facility
5. Drinking Water
6. Batching Plant Area
7. Crusher Plant Area
8. Workshops
9. Store Houses
10. Telecommunication Facilities
11. Construction Power

The tentative area identified for the above mentioned facilities has been identified on ground is given below and all the heads are explained in the subsequent sections and subsections.

Approximately 396660m² area for all the facilities mentioned above has been identified.



INFRASTRUCTURE AREA

SL. NO.	DESCRIPTION	LAND AREA (in m^2)
1	MUCK DUMPING AREA	39608
2	OWNER FACILITY AREA	30841
3	CONTRACTOR FACILITY AREA	42862
4	DRINKING WATER FACILITY	3688
5	BATCHING PLANT AREA	33788
6	CRUSHER PLANT AREA	75420
7	WORK SHOPS AREA	46556
8	STORE HOUSES	111847
9	TELE-COMMUNICAITON AREA	6910
10	CONSTRUCTION POWER AREA	5140

14.1.8 Roads within the Project Area

The Project site is reachable from Capital city of Dehradun via metalled road. The proposed site is located at the boundary of district Dehradun and Tehri Garhwal near village Sondhana at a distance of about 22 kilometers from Dehradun Railway Station.

Nearest important landmark to reach the dam site from dehradun is Maldeota Temple. Distance from Dehradun to Maldeota is approximately 12 km. Maldeota is very well connected to Dehradun and other important parts of the state via metalled road.

Maldeota to Song dam site is approximately 10.0 km and both are connected by an un-metalled seasonal motorable road which needs to be developed as a motorable all season road. The connectivity within the project area is not adequate and shall require improvement by construction of new roads or improvement of the existing roads by means of metalling and widening.

It is observed that few village lies on the upstream of the dam which has its road connectivity from Dehradun through the dam, lying near to the bed level. Once the dam is under construction / constructed the road connectivity to these village will be disconnected. Therefore, alternate connectivity to the upstream villages of dam is required to be made prior to start of construction. Thus, a new road is proposed to be connected to the upstream catchment area villages. The layout plan of this new proposed road alignment is shown in **Drawing No P.012745-W-20302-003**.

It is proposed to construct the access road to the various project components. The visualised length of the internal roads, as propose dis tabulated below in Table 14-1.

Table 14-1: Approach Roads in the Project Area

Sl. No	Description	Unit	Quantity
1	Ring road around the Reservoir	km	10.50
2	Construction of haul road for various project components (Two Lane) Stage I on Right Bank	km	4.0 km
2	Construction of haul road for various project components (Two Lane) Stage I on Left Bank	km	6.0 km

Sl. No	Description	Unit	Quantity
3	Widening and Strengthening of approach road from Maldeota to Project site (Two Lane)	km	10.0
		Total	**30.5**

It is proposed to construct two lane 70 T capacity Maldeota Bridge for carriage of construction materials. It is also proposed to construct a 42 m span bridge for connecting Gurshal Gaon to Ragad Gaon. Two lane 70 T capacity bridge of 60 m span is also proposed to be constructed on Song river near Shodhana.

14.1.9 Muck Dumping Area

Muck Dumping areas has been identified and it is apprehended that 800,000m³ of muck shall be excavated from the project components. Accordingly 39,608m² of land has already been identified in the downstream of Dam on the right bank of river. The area has been chosen in a way so that proper disposal of muck can be done in an eco-friendly and systematic manner. The layout plan showing the area identified for muck disposal (indexed as 1) in drawing is appended as **Drawing No P.012745-W-20302-004** named as Infrastructure Facilities.

The muck generated from the below construction activities are required to be disposed off:

- Dam Excavation
- Top weathered layer of Quarry
- Other construction activities for development of infrastructure

It is also suggested to use the muck in widening of the roads, i.e. laying the muck on the downstream side of the road and widening the road width up to 15 m. It will solve two purposes at the same time, first is muck disposal and secondly widening of road which will enhance the project activities with the appropriate movement of the haulage vehicles without any traffic congestion.

14.1.10 Owners Facility

Residential and official buildings will be required to house staff working during and post the construction of the project and subsequently for the operational staff at the dam site. Permanent buildings may be considered only if these are required in the post construction period also.

This Permanent colony at dam marked as 2 having an area of 30841m² shall have a well equipped Dispensary, Club, Community hall, Field hostel, School, Nursery and Sewerage treatment plant. This colony shall have following facilities:

- Potable Water Supply arrangements.
- Sanitation and sewage disposal arrangements.
- Drainage arrangements.
- Internal roads and cross-drainage works.
- Electrical supply.
- Fencing and Security.

It is proposed to provide one office complex at suitable topographic location near Dam site on the right bank of river.

The layout plan showing the area identified for Owner Facility (indexed as 2) in drawing is appended as **Drawing No P.012745-W-20302-004** named as Infrastructure Facilities. The details of proposed Residential and non residential buildings to be developed are tabulated below in Table 14-2 and Table 14-3 respectively.

Table 14-2: Details of Residential Buildings – Permanent

Sl. No	Designation	Type of Quarters			
		I	II	III	IV
1	GM (Project Head)	1	-	-	-
2	DGM	-	2	-	-
3	AGM	-	6	-	-
4	DM	-	11	-	-
5	Engineer	-	-	11	-
6	Assistant Engineer	-	-	11	-
7	Medical Officer	-	2	-	-
8	Nurses & Compounders	-	-	-	4
9	Security Officer	-	1	-	-
10	Assistant Security Officer	-	-	2	-
11	Accounts Officer	-	2	-	-
12	Accounts Assistants	-	-	8	-
13	Electrician	-	-	-	5
14	Car Drivers	-	-	-	3
15	Administrative Assistants	-	-	9	-
16	Peons & Messengers	-	-	-	10
17	Work Charge/Maintenance Staff	-	-	-	20

Table 14-3: Details of Non Residential Buildings – Permanent

Sl. No.	Description	Area (m²)
1	Administration block & site office	1500
2	Field hostel / Guest House	500
3	Parking Area	500
4	Store	500
5	Primary school	1000
6	Post office, Police Station & Bank	300
7	Dispensary	500
8	Club/recreation	1000
9	Community hall with parking	500
10	Fire Station	300
11	Taxi & Bus stand	1000
	Total	**7600**

14.1.11 Contractor Facility

Contractor's colony and Labour Colonies will be placed at respective location near to the dam site area. This will include temporary residential colony near to the dam complex area. Labour colonies will be near to the dam complex location. Non-Residential buildings include project administrative building and other facilities at the location near to Dam complex.

This Permanent/Temporary colony at dam marked as 3 having an area of 42862m² have a well equipped Dispensary, Club, Community hall, Field hostel, School and Sewerage treatment plant. This colony shall have following facilities:

- Potable Water Supply arrangements.
- Sanitation and sewage disposal arrangements.
- Drainage arrangements.
- Internal roads and cross-drainage works.
- Electrical supply.
- Fencing and Security.

It is proposed to provide one office complex at suitable topographic location near Dam site.

The layout plan showing the area identified for Contractor Facility (indexed as 3) in drawing is appended as **Drawing No P.012745-W-20302-004** named as Infrastructure Facilities.

The facility development for non-residential buildings are provided below in Table 14-4.

Table 14-4: Details of Non Residential Buildings – Temporary

Sl. No.	Description	Development Area (m²)
1	Administration block & site office	1500
2	Workshop building	500
4	Petrol pump with service station	300
5	Explosive magazine 2 nos. 20 T capacity	200
6	Sewerage treatment plant	500
7	Water pumping station	100
8	Stores	1000
	Total	**4100**

14.1.12 Drinking Water Facilities

The requirement of water for drinking purpose of all the staff and contractor will be fulfilled from the right bank tributary of River Song i.e. Chipaldi Stream meeting Song river in the downstream of Dam Axis on right bank. The storage and clear water tanks will be far away from the camps and other structures. The area to be covered by this facility is approximately 3688m². The water from this facility shall be pumped to the residential areas/camps/offices etc. Water for drinking purpose at various non-residential as well as residential complexes will be treated as per IS specifications.

The layout plan showing the area identified for Drinking Water Facility (indexed as 4) in drawing is appended as **Drawing No P.012745-W-20302-004** named as Infrastructure Facilities.

14.1.13 Batching Plant Area

Batching plant area has been identified near to the Dam area in the downstream side. Approximately 33788m² area has been identified for batching plant area. This facility is on the left bank of the river having best connectivity to dam area so that concreting can be done without any hindrance.

The layout plan showing the area identified for Batching Plant Facility (indexed as 5) in drawing is appended as **Drawing No P.012745-W-20302-004** named as Infrastructure Facilities.

14.1.14 Crusher Plant Area

Crusher plant area has been identified 1.5 km away from the Dam area in the downstream side on the left bank of Song river. Approximately 75420m² area has been identified for crushing plant area. This facility is on the left bank of the river having best connectivity to batching plant and stores so that aggregates can be transported to batching plant without any hindrance.

The layout plan showing the area identified for Crusher Plant Facility (indexed as 6) in drawing is appended as **Drawing No P.012745-W-20302-004** named as Infrastructure Facilities.

14.1.15 Workshops

It is necessary to provide workshops i.e. electrical, mechanical etc for repairing and maintenance of the machinery and other construction equipments timely. For this facility area has been identified 1.2 km away from the Dam area in the downstream side on the left bank of Song river adjacent to Crusher plant area. Approximately 46556m² area has been identified for this facility.

The layout plan showing the area identified for Workshops Facility (indexed as 7) in drawing is appended as **Drawing No P.012745-W-20302-00** named as Infrastructure Facilities.

14.1.16 Store Houses

It is necessary to provide Storehouses which acts as reserves and buffers while adverse conditions so that construction activities may not stop due to lack of cement, steel, explosives, fuels, spare parts etc. For this facility area has been identified 2.0 km away from the Dam area in the downstream side on the left bank of Song river adjacent to Workshop area. Approximately 111847m² area has been identified for this facility.

The layout plan showing the area identified for Store houses Facility (indexed as 8) in drawing is appended as **Drawing No P.012745-W-20302-004** named as Infrastructure Facilities.

14.1.17 Telecommunication Facilities

In order to ensure efficient execution of works at different work sites of the project offices, stores, laboratories, workshop and residences would be connected through a reliable telecommunication network is necessary. VSAT has been proposed for the project site. It is also proposed to provide VHF wireless link between various project component sites. Video/Teleconferencing facilities are proposed to monitor the site progress from corporate office. Approximately 6910m² area has been identified for this facility which is adjacent to Storehouse area.

The layout plan showing the area identified for Telecommunicaiton Facility (indexed as 9) in drawing is appended as **Drawing No P.012745-W-20302-004** named as Infrastructure Facilities.

14.1.18 Construction Power

The construction power is required for construction and facilities for the following works:

- Main works of Dam, Intake, water conductor pipe and ancillary structures.
- Power requirement for support and maintenance of the construction work such as crushing plants, workshops, laboratories and site offices.
- Construction power is also required for infrastructure works such as site illumination, camps etc.

In order to ensure efficient execution of works at different work sites of the project offices, stores, laboratories, workshop and residences, proper and regular supply of electrical power must be ensured. In absence of the power from the Grid this power has to be produced by means of Diesel Generator sets (DGs).

Area for placing DGs has been identified 0.5 km away from the Dam area in the downstream side on the left bank of Song river near to Batching plant area. Approximately 5140 m² area has been identified for this facility.

The layout plan showing the area identified for Construction power Facility (indexed as 10) in drawing is appended as **Drawing No P.012745-W-20302-004** named as Infrastructure Facilities.

A. Construction Power Requirement

The construction power requirement has been worked out based on the proposed power driven equipments for construction of the project, site facilities and development of infrastructure at all locations of the project. The envisaged list of power driven equipment/facility and location wise construction power requirement is provided in **Annexure I** and **Annexure II.** The location wise breakup of construction power load is tabulated below in Table 14-5.

Table 14-5: Location wise Breakup of Construction Power load

Sl. No.	Location	Power Requirement in kW	Power Requirement in kVA
1	Dam Complex (Diversion, Dam and Intake)	350.00	437.50
2	Water Conductor Pipe (5 locations)	1150.00	1437.50
3	Central Work shop & laboratory	110.00	137.50
4	Crusher Plant	580.00	725.00
5	Colony, laboratory and Office	55.00	68.75
	Total	**2255.00**	**2806.25**

B. Construction Power Arrangement

The following arrangements have been considered to meet the construction power requirement for the project. Nearest grid sub-station of 33 kV is to be assessed for construction power of the project.

Power from 33 kV voltage level may be drawn to project site for requirement of power during construction. 33 kV overhead lines to dam site shall be drawn and distribution line 11kV shall be laid to various load centres. 33 kV voltage level shall be suitably stepped down to 11kV/415V by means of a step down transformer. Necessary sub-stations shall be installed at following strategic locations:

- Dam site
- Along Water conductor pipe (5 locations)
- Project Colony and various facilities.

The above grid supply work will be done by relevant authorities as a deposit work. The main scope of construction power works is detailed below in Table 14-6.

Table 14-6: Main scope of works for construction power

SI. No.	Description
1	Construction of 33/11kV substation near Dam complex with 2 Nos. Transformers each of capacity 2 × 2.5 MVA) with provision for incoming 33kV lines from nearby sub-station)
2	Construction of 11kV/0.415kV substation at Dam site with 2 transformers each of capacity 1.7 MVA
3	Construction of 11 kV / 0.415 kV substations at Colony with 2 nos. Transformers each of 750 kVA capacity.
4	HT/LT switchgears.
5	Associated civil work.

For supply of reliable construction power as described above, it is proposed to install two transformers (11/0.415 kV) each of 1.7 MVA capacity at dam site for catering to requirement of dam site, crusher plant, two transformers each of 1.0 MVA at suitable place along water conductor system for catering to requirements of construction power supply for water conductor system, central workshop and laboratory. In order to ensure reliable power supply at the 3rd location to project colony & other facilities it is proposed to install two transformers (11/0.415kV) each of 750 kVA capacity in the Sub Station. Breakers/ Switchgears, LT panels and cabling will be provided for further distribution of power supply to the construction equipments. Same arrangement will be kept for back-up supply project operation after commissioning of the project.

C. Construction Power with DG Sets

DG sets are proposed to install at all locations of the project for smooth functioning of various construction activities as a back-up supply. The location wise construction power requirement and total requirement of DG sets envisages for construction of the project is annexed as **Annexure II**. The total requirement of DG sets and location wise DG set requirement envisages for construction of the project is provided below in Table 14-7 and Table 14-8 respectively.

Table 14-7: DG Sets Requirement for Construction of Project

SI. No.	Total DG Sets requirement	Number of DG Sets
1	DG 500 KVA	1
2	DG 320 KVA	7
3	DG 125 KVA	3
4	DG 25 KVA	1
	Total Number of DG sets	**12**

Table 14-8: DG sets requirement for different component of the project

Sl. No.	Location	DG Set capacity (KVA)	No. of DG Set	Power requirement as per DG Set (KVA)
1	Dam Complex (Diversion, Dam and Intake)	320 & 125	1 – For 320 1 – For 125	445
2	Water Conductor Pipe	320	5 no.	1600
3	Central Workshop & laboratory	125 & 25	1 – For 125 1 – For 25	150
4	Crusher Plant	500 & 320	1 – For 500 1 – For 320	820
5	Colony and Office	125	1 no.	125
	Total Power availability (as per DG set)			**3140**

The tariff of DG Generation is calculated as Rs. 15.21 / kWh and provided as **Annexure III**.

The tariff from the grid is considered as Rs. 6.95/kWh. The weighted average cost of electricity for construction power works out to be Rs. 11.08 /kWh, as given below in Table 14-9.

Table 14-9: Calculation of weighted average tariff

Sl. No.	Source of electric supply	Unit Rate
1	From DG set	Rs. 15.21
2	Power availability from DG set	50%
3	From Grid	Rs. 6.95
4	Power availability from grid	50%
5	Weighted average tariff from electricity consumption during construction (Rs/Kwh)	Rs. 11.08

Annexure I: List of Power driven Equipment/facility

Sl No.	Details of Equipment	Nos.	Unit Load (KW)	Total Load (KW)
1	Dam Complex (Diversion, Dam, Intake- Open works)			
	Illumination			10
	Site office			20
	Batching Plant (90 cum/hr)	2	90	180
	Shotcrete machine (6 cum/hr)	1	20	20
	Compressor (1000cfm)	1	60	60
	Dewatering Pumps (20HP-2)	2		29.84
	Welding machine	1	10	10
	Bar cutting machine	2	1	2
	Bar bending machine	2	1	2
	Grout Pump	1	10	10
		Total		350
2	Water Conductor Pipe (5 Locations)			

	Welding Rectifier (400 Amps)	10	50	500
	Winch (5-T, 10T etc.)	10	20	200
	Concrete Pump	10	40	400
	Fabrication yard complete	5	10	50
	Total			1150
3	Central fabrication shop			
	Plate bending machine	1		22.38
	Welding machine	2	10	20
	Lathe machine	2	5	10
	Bench Grinder	2	5	10
	Hand grinder	3	1	3
	Crimpling machine	2	1	2
	Threading machine	2	0.5	1
	Bench drill machine	2	0.5	1
	Hand drill machine	2	0.5	1
	Shaping machine (3HP)	1	2	2
	Power saw (3HP)	2	2	4
	Total			80
4	Crushing Plant			
	Illumination			10
	Site office			20
	Aggregate processing Plant (200TPH)	2	200	400
	Sand Sieving Plant	1	150	150
	Total			580
5	Testing Laboratories			
	Illumination			5
	Site office			5
	CTM (cube testing machine)	1		20
	Cement mortar cube casting machine	1		
	Aggregate abbresion machine	1		
	Oven	1		
	Hot Plate	1		
	gradation (sand and aggregate)	1		
	UTM (computerised Reinforcement testing machine)	1		
	Core cutting machine	1		
	Humidity chamber	1		
	Total			30
6	Common			
	Illumination at colony			10
	Main Colony			25
	Weigh bridge	1		20
	Total			55
	Total load in kW		Kw	2245
	Total load in KVA= kW/0.8		Kva	2806.25

Annexure II: Location wise Construction power requirement

S.No.	Location	Power Requirement (kW)	Power Requirement (KVA)	DG Set capacity (KVA)	No. of DG Set	Power as per DG Set (Kva)
1	Dam Complex (Diversion, Dam and Intake)	350	437.5	320 + 125	2	445
2	Water Conductor Pipe (5 Locations)	1150	1437.5	320 x 5	5	1600
3	Central Workshop & laboratory	110	137.5	125 x 1 + 25	2	150
4	Crusher Plant	580	725	500+320	2	820
5	Colony and Office	55	68.75	125	1	125
	Total	2245	2806.25		12	3140

Total DG Sets requirement	Nos.
DG 500 kVA	1
DG 320 kVA	7
DG 125 kVA	3
DG 25 kVA	1

Annexure III: Unit rate of electricity produced by DG

A	Equipment Cost	Units	Quantity	Rate (Rs)	Amount (Rs)
1	Cost of DG sets with 415V, 3 phase comprising of engine 415V alternator, common based frame, duly coupled along with fuel tank, control panels etc.				
a	500 Kva	Set	1	3600000	3600000
b	320 Kva	Set	7	2640000	18480000
c	125 Kva	Set	3	960000	2880000
d	25 Kva	Set	1	400000	400000
	Sum				25360000
	CED @ 12 % ; educational CESS @ 3 % on CED; CST @ 1 %	Rs			3388096
	Grand Total	Rs	12		28748096
2	Switch gear (LT, 415 V, 2-incoming, 5-outgoing)	LS			6000000
3	LT cable	m	500	100	50000
4	Cost of foundation and shed	Rs	12	100000	1200000
5	Mandatory spares	@	3% of item 1,2,3		1043943
6	Total cost of material including spares	Rs			37042039
7	Octroi, entry Taxes, transportation, handling, insurance etc	Rs	6% of Item No. 6		2222522
	TOTAL	Rs			39264561
B	Depreciation Value				
1	Life of plant in years	Year			10
2	Life of plant in hours	Hrs.			2500
3	Lifetime repair provision	Hrs.			120
4	No. of shifts	Nos.			3
5	Annual scheduled production hour	Hrs.			3000
6	Depreciation charges with ref. to life in hours	Rs.			1963228

7	Depreciation charges with ref. to years	Rs.			1963228
8	Average depreciation with reference yearly	Rs.			1963228
9	Average depreciation with reference hourly	Rs.			785.29
	Therefore cost of equipment including repair and maintanance charges (@ 100% of cost of equipment/hour) per hour	Rs.			785.29
C	P.O.L. charges				
1	Fuel consumption per hour for DG sets at 90% load in lts.:-				
a	500 Kva (1 Nos.)	lts.	90	360	732
b	320 Kva (7 Nos.)	lts.	57.5	345	
c	125 Kva (3 Nos.)	lts.	22.5	22.5	
d	25 Kva (1 No.)	lts.	4.5	4.5	
6	Price of disel per litre	Rs.			58.16
7	Cost of HSD per hour				42573.12
8	Lube oil consumption per hour for DG sets at 0.22gms/BHP (in kg).:-				
9	500 Kva (0.3 gms/BHP= 0.3 x 617 BHP)	1	0.1851	0.1851	1.16543
10	320 Kva (0.3 gms/BHP= 0.3 x 408 BHP)	7	0.1224	0.8568	
11	125 Kva (0.22 gms/BHP= 0.22 x 172.5 BHP)	3	0.03795	0.11385	
12	25 Kva (0.22 gms/BHP= 0.22 x 44 BHP)	1	0.00968	0.00968	
13	Price of lube oil	Rs.			255
14	Cost of lube oil per hour				297.18
	Total P.O.L. charges per hour				42870.30

D	Labour Charges		Rate/Month	No.	Amount
1	Regular category-				
a	Mechanic	Rs	14196.6	8	113572.8
b	Electrician	Rs	13992	8	111936
2	Casual category-				
a	Operator	Rs	13992	10	139920
b	Helper	Rs	4373.6	12	52483.2
3	Total crew charges/month	Rs			417912
	Hourly crew charges	Rs			803.68
	Sundries and misc. supplies @ 15% of (B) above	Rs.			117.79
	Hourly use rate of DG sets	Rs.			44577.07
	Total electricity production per hour (KW per hour) considering 90% loading as per manufacturer guidelines of total 3140 kVA capacity of DG sets				2930.4
	Unit rate of electricity produced by DG sets	Rs/kwh			15.21

15. CONCLUSION AND RECOMMENDATION

15.1. General

The project involves construction of conventional civil structures as per details given below;

- River diversion Pipe and Upstream Coffer Dam
- Roller Compacted Concrete Dam of about 130.6 m height
- Intake Structure
- Water conductor system of 1.5 m diameter pipe of about 14.7 km length
- Valve House
- Related Hydro-mechanical Works

The project is intended to ensure water supply in Dehradun city and Sub-Urban area

15.2. Preliminary and Pre-construction Works

To ensure timely completion of project, it is essential to initially accomplish the following activities including obtaining all clearances before start of main civil works;

- Acquisition of Land
- Completion of detailed design and specifications
- Firming up of Financial Resources for the project
- Tender and award of main Civil and Hydro-mechanical works
- Deploying Forerunner contractors / departmental work for the following activities;
    - Construction of Project Access and Internal roads
    - Office and Residential Buildings
    - Strengthening of Access road and Bridges

15.3. Civil and Hydro-mechanical Works

Song Dam Drinking water project is proposed to be completed in a period of 48 months. Preparation of Tender Document including finalisation is proposed to be completed in a period of 6 months. Tendering and Award of Contract is likely to be finalized in a period of about 3 months. Project Infrastructure & mobilization is proposed in a period of about 3 months and main civil and Hydro-mechanical activities are planned in a period of 36 months.

The construction of the project is planned to be constructed through awarding single package on EPC (Engineering Procurement Construction) contract. The contract packages proposed is as follows:

EPC Contract for Civil and Hydro-mechanical Works

15.4. Benefits

Based on benefits of the project determined in Chapter 13, the savings from expenditure on tube well up to year 2071 is estimated as Rs. 737.7 Crores and revenue for water supply up to years 2071 is estimated as Rs. 2238.87 crores. Thus total benefits are estimated as Rs. 2976.57 crores.

15.5. Project Cost

Total cost of the project including GST @ 12% on Civil works works out to Rs. 1408.66 Crores. The details are given in chapter 11 of the report.

15.6. Recommendation

Based on above benefits, it can be concluded that implementation of project is very crucial for meeting the drinking water requirement of Dehradun city and suburban areas.

As determined above, based on Benefit Cost Ratio of about 2.113, the project is financially viable and recommended for implementation.

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