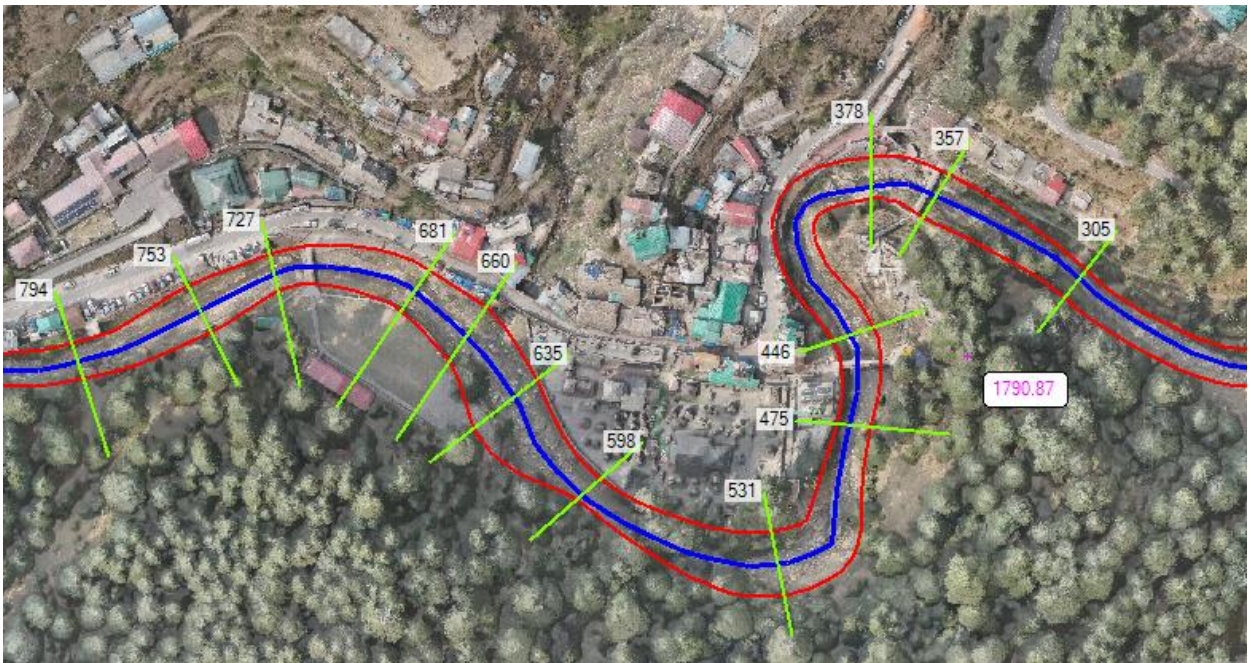


HYDROLOGY & HYDRAULICS STUDY FOR JATA GANGA RIVER AT JAGESHWAR DHAM



National Institute of Hydrology

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1 INTRODUCTION

The Government of Uttarakhand is committed to develop Jageshwar Temple (Part of Manas Khand) and its surrounding areas in a planned manner as per the vision of the Hon'ble Prime Minister to develop the Manas Khand circuit in the Kumaon region, For this purpose, the state government have appointed INI Design Studio, Ahmedabad as a master planning consultant. The consultant has developed the master plan, which comprises different components like temple illumination, Infrastructure facilities, parking facilities, streetscape development etc. Further to this, riverfront development for Jata ganga (which flows behind the temple complex) is also one of components of master plan. For this aspect, the Tourism department of Uttarakhand approached National Institute of Hydrology, Roorkee to carrying out hydrological and hydraulic studies to support the riverfront development plan by INI Design Studio (Annexure–I). This study is being carried out as in-house study of NIH, Roorkee.

2 OBJECTIVES AND SCOPE OF WORK

The scope of work of the study are as follows:

- a) Estimation of floods of various return periods viz. 25 year, 50 year and 100 year with corresponding water level.
- b) Estimation of water levels after incorporating the proposed riverfront for 25 year, 50 year and 100 year discharge.
- c) Evaluation of water retention strategy for the proposed riverfront

3 STUDY AREA AND DATA

The Jageshwar is a Hindu pilgrimage town near Almora in Almora district of the Uttarakhand. The site is protected and managed by the Archaeological Survey of India (ASI). Jageshwar is about 36 km northeast of Almora, in the Jataganga river valley near a Deodar forest. The temple clusters begin starting near the confluence of two streams Nandini and Surabhi after they flow down the hills in the narrow valley. The site is about 3.5 kilometres (2.2 mi) long along the Jataganga rivulet, is a narrow forested valley of oaks, deodara, rhododendrons and pines. The drone images of the

site provided by M/s INI Design Studio is shown in Figure 1. The INI Design Studio also provided the DEM of the concerned river reach.

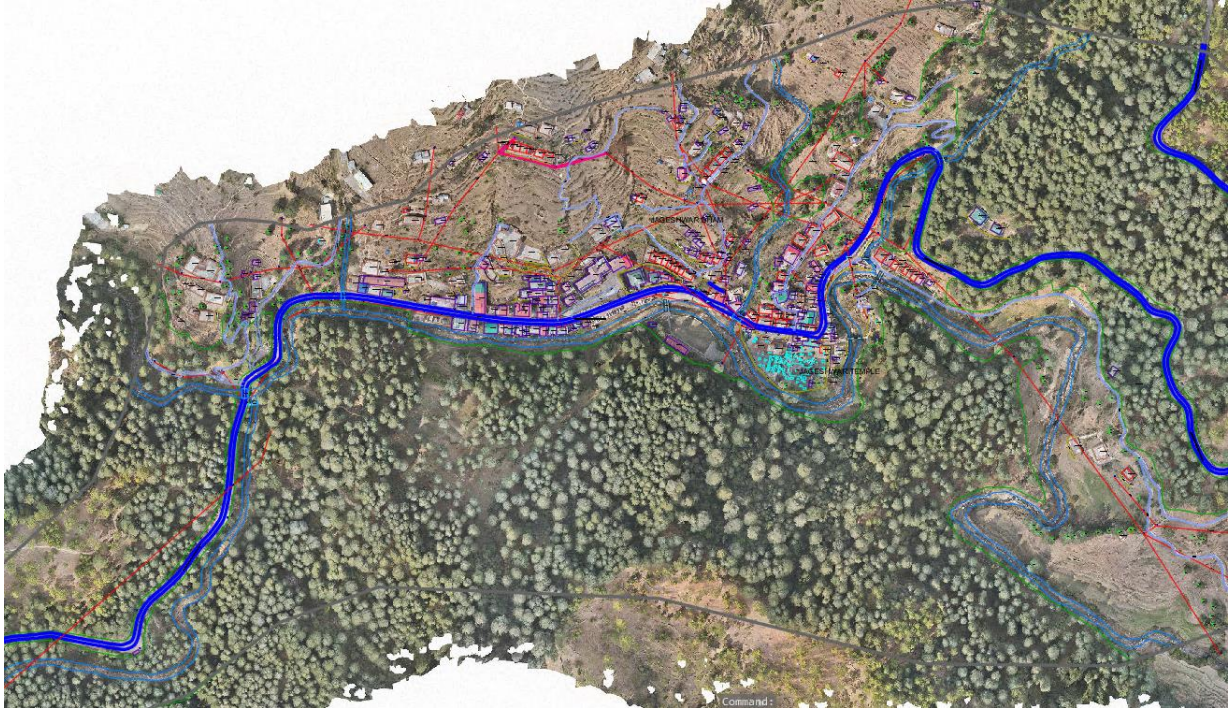


Figure 1: Index Map of the Study Area

3.1 Field Investigations

The NIH team discussed about the area with INI team through video conference and visit to the study area was made during 28 April 2024. The photographs during field visit are shown in Figure 2. During the field visit it was observed that the earlier constructed soil conservation structures (check dam/ weir) have been filled with sediment. The flow was also very less. The INI team informed that there is no observation of discharge or water level in the area. However, INI team shared the photographs (Figure 3) of flood during 2024. It can be seen that the flood water has overtopped the bridge.



Figure 2: Photographs of field visit



Figure 3: Flood of 2024 (as share by INI)

3.2 Topography and River Cross-section

The DEM of study area is provided by M/s INI Design Studio in TIF format as shown in Figure 4. Other AutoCad drawings are also provided for reference. The clipped DEM in the river reach is shown in Figure 5. It is observed that the various bridges/culverts and tree canopy are not removed from the DEM, which is essentially a Digital Surface Model (DSM). However, for river flood modelling a Digital Terrain Model (DTM) is essential. The INI is asked to provide river cross-section for pre and post project condition. However, here further analysis and HEC-RAS modelling, this DSM with *EPSG:32644 - WGS 84 / UTM zone 44N* coordinate system is used for extraction of river cross-section.

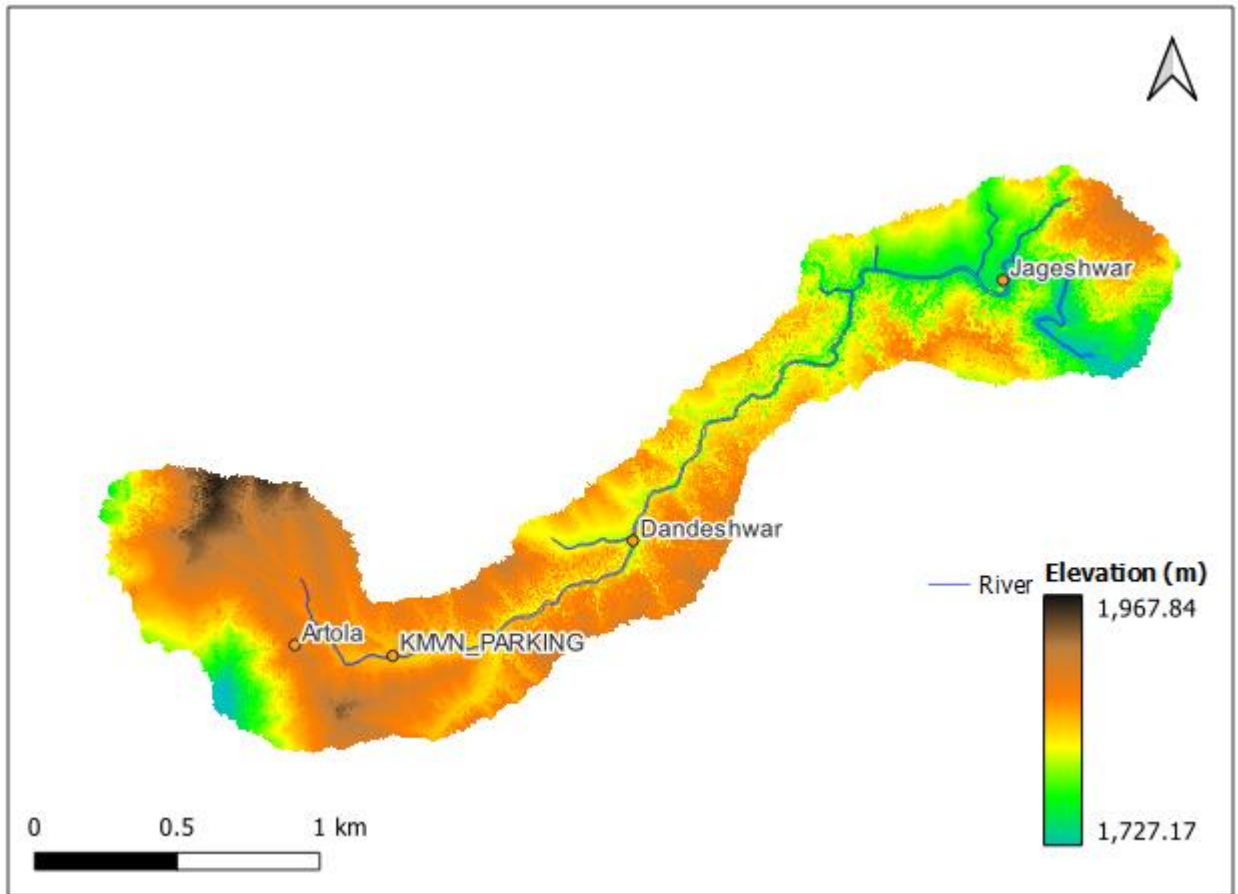


Figure 4: DEM of the study area

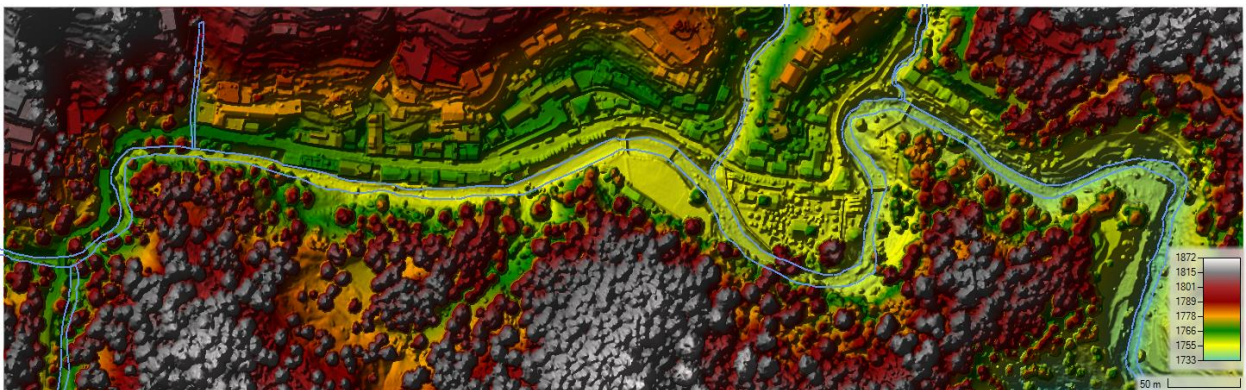


Figure 5: DEM for the river reach

4 DESIN FLOOD ESTIMATION

4.1 Catchment Delineation

The Digital Elevation Model of the study area is developed from the CARTO DEM V3 data. The DEM (Figure 6) is available at 30 m horizontal resolutions. 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 7. The estimated value of catchment characteristics are given in Table 1. It is to be noted that the catchment and sub catchment area are very small. Hence, SUH is not derived and rational formula is used for computation of discharge. The Time of Concentration is estimated by Kirpich, Kerby and California formula and average value is reported.

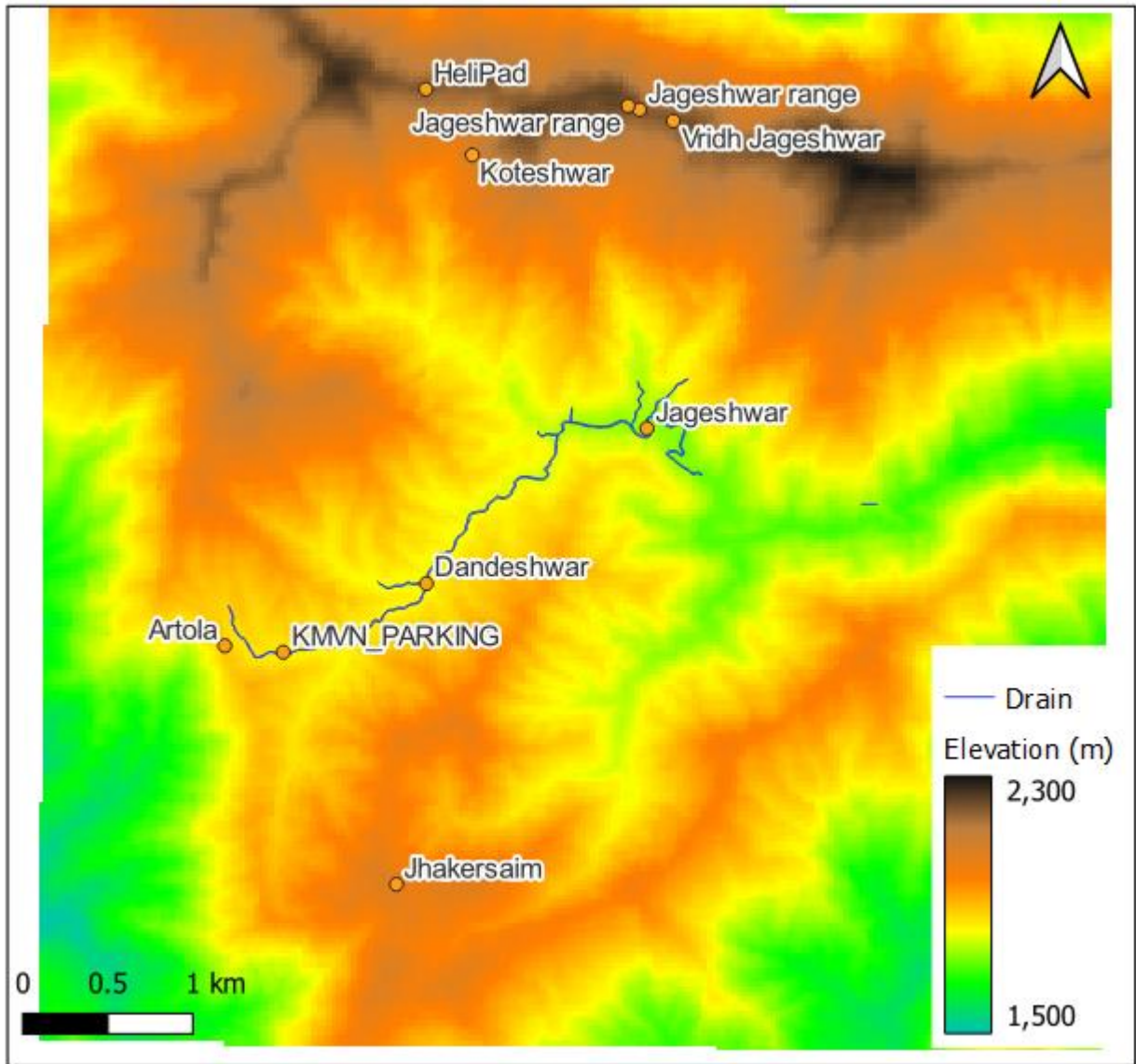


Figure 6: Carto DEM of the catchment area

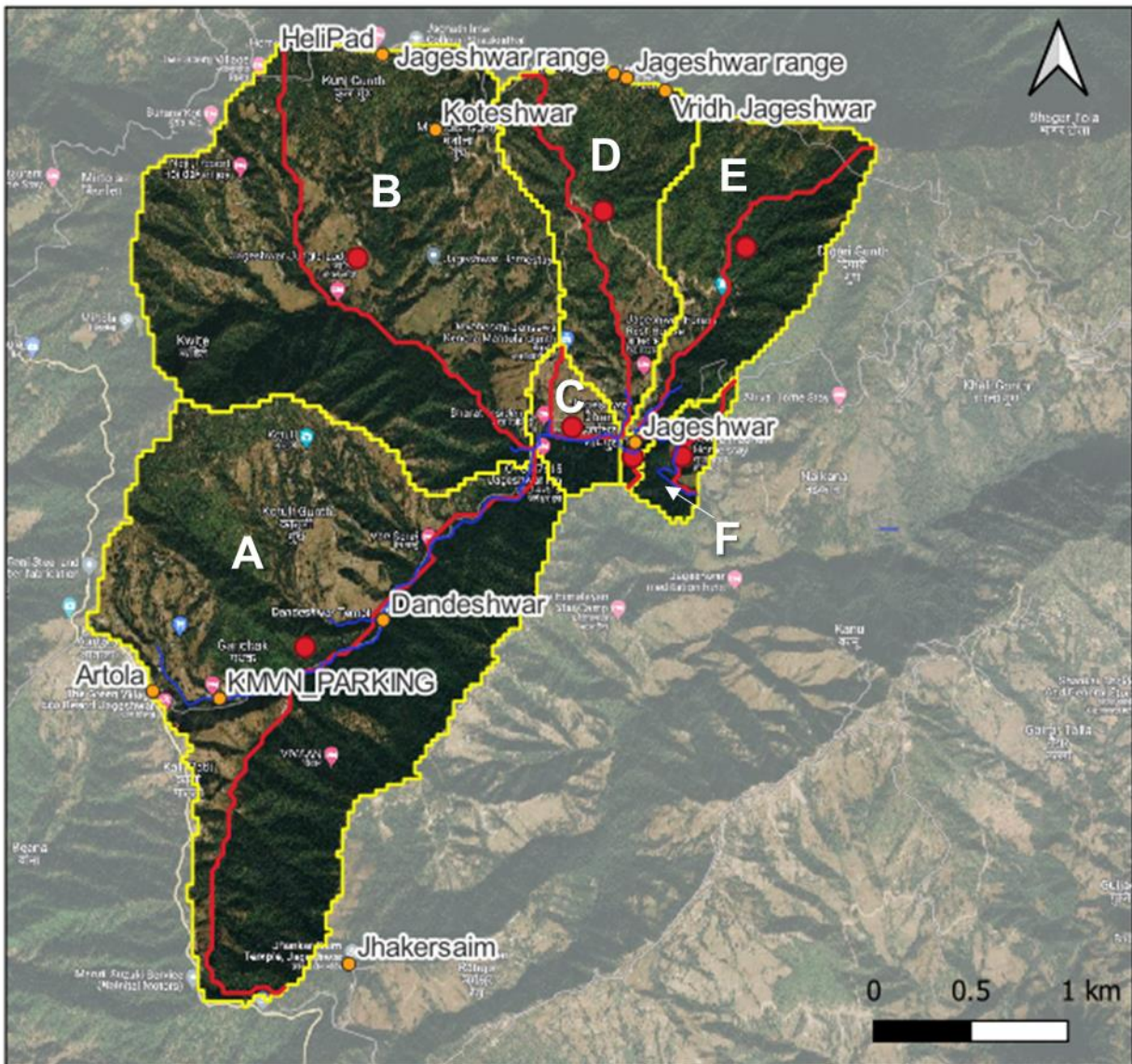


Figure 7: Delineated catchments with catchment characteristics

Table 1: Catchment characteristics

Characteristics	Catchment					
	A	B	C	D	E	F
A: Area of the catchment (km ²)	4.182	3.662	0.285	1.164	1.112	0.186
L: Longest Flow path (km)	4.155	2.922	0.822	2.3	2.258	0.816
Tc: Time of Concentration (min)	70	38	18	30	29	16

4.2 Design Rainfall

The nearest rain gauge station is at Almora. The 1-day highest rainfall is 223 mm in 29/09/1924 (CWC, 2015). The 1 day annual maximum return period rainfall for various return periods at Almora is shown in Figure 8. Further the time distribution coefficients as per the CWC sub basin 401A is adopted to compute hourly and smaller time steps. The estimated rainfall intensity for various sub catchments a

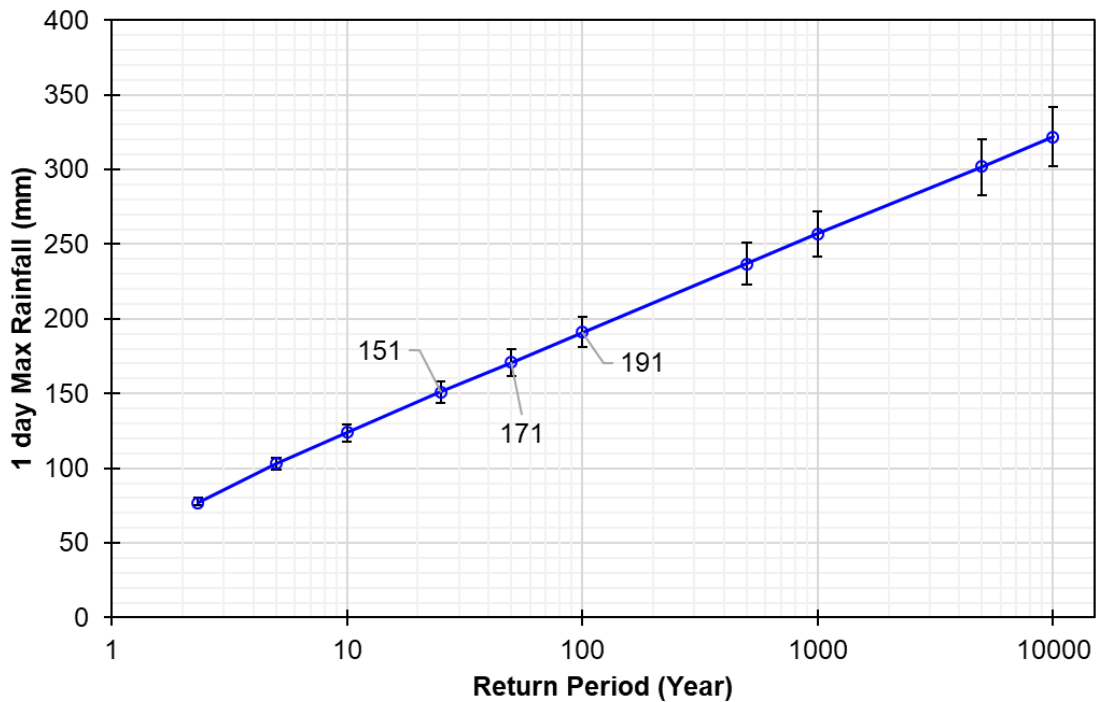


Figure 8: 1-day annual maximum rainfall for various return period

Table 2: Design Rainfall Intensity (mm/h) for various return period

Sub catchment	Return period (Year)			
	2.33	25	50	100
A	16.48	32.31	36.59	40.87
B	20.44	40.08	45.38	50.69
C	20.72	40.64	46.02	51.40
D	21.35	41.88	47.42	52.97
E	20.60	40.40	45.75	51.10
F	20.24	39.69	44.95	50.20

4.3 Design Flood

The Rational equation is the simplest method to determine peak discharge from drainage basin runoff. As a conservative approach, the Runoff Coefficient of 0.9 is

used. The computed runoff for various return period and for cloud burst condition (intensity = 10 cm/h) are given in Table 3.

Table 3: Design runoff (m³/s) for various return periods

Sub catchment	Return period (Year)				Intensity = 10 cm/h
	2.33	25	50	100	
A	17.23	33.78	38.26	42.73	104.55
B	18.71	36.69	41.55	46.41	91.55
C	1.48	2.90	3.28	3.66	7.13
D	6.21	12.19	13.80	15.41	29.10
E	5.73	11.23	12.72	14.21	27.80
F	0.94	1.85	2.09	2.33	4.65

4.4 Global Precipitation Measurement (GPM) Data

The 30 minute temporal resolution GPM rainfall data was also obtained for the period 2000 to 2023. The annual maximum rainfall intensity of various durations are shown in Figure 9. Rainfall frequency analysis is carried out using L-moments approach for development of Intensity Duration Frequency Curve (IDF) as shown in Figure 10. The comparison of estimated design runoff (Figure 11) shows that the flood values for cloud burst condition (Intensity = 10 cm/h) is higher and adopted for further hydraulic analysis as conservative approach.

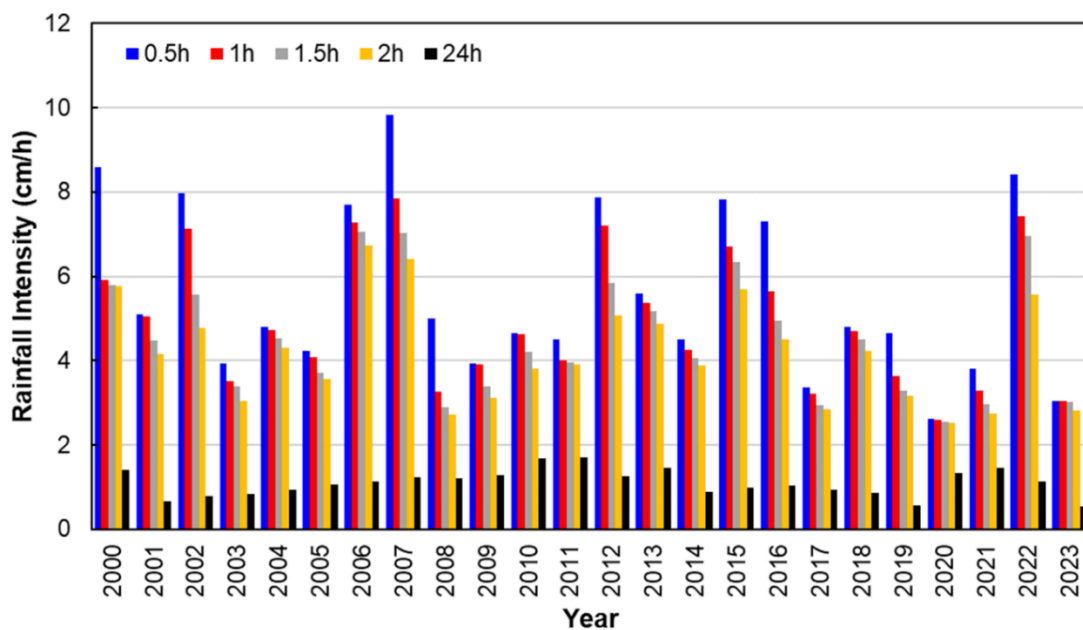


Figure 9: Annual maximum rainfall intensity (GPM data)

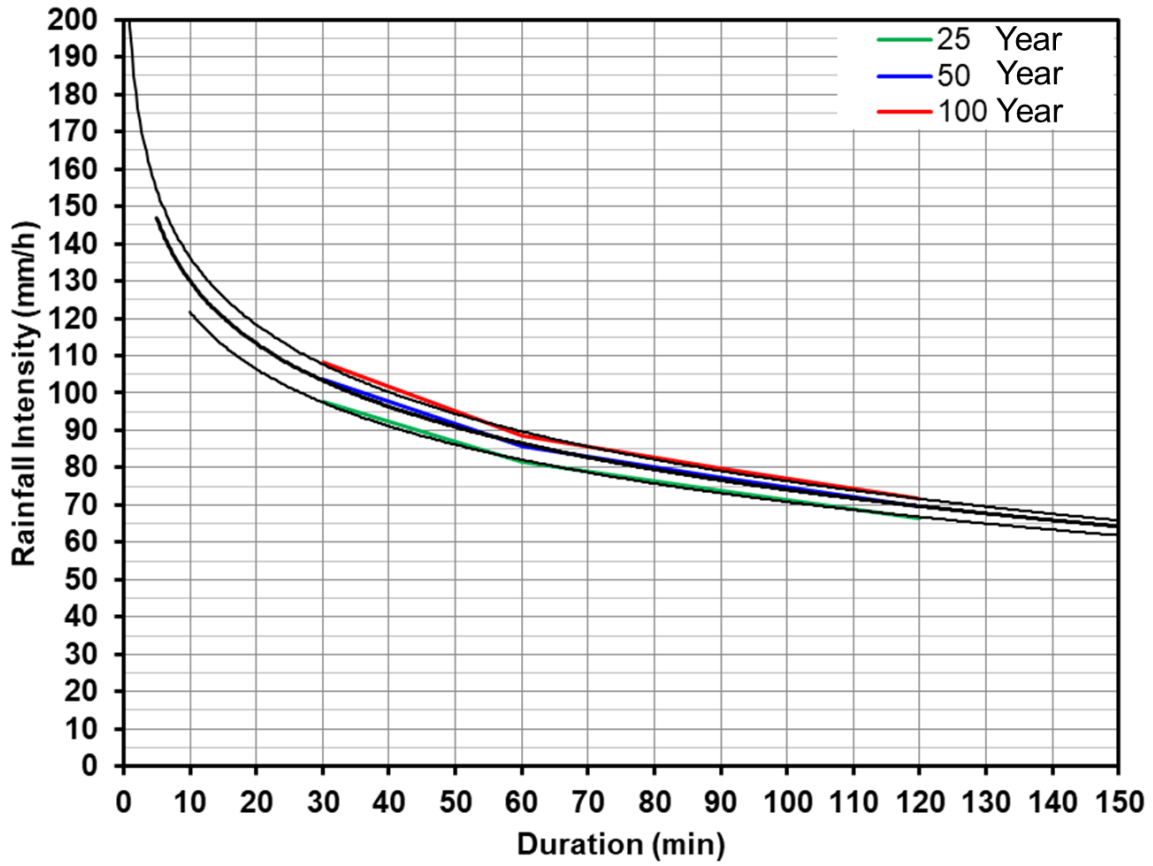


Figure 10: Intensity Duration Frequency Curve

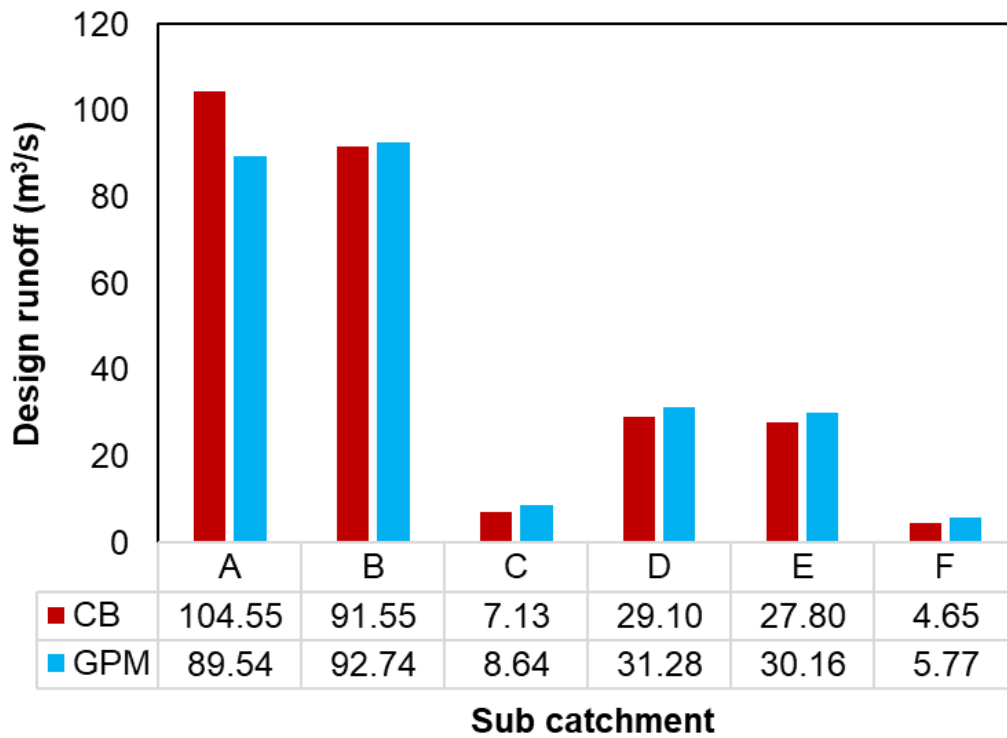


Figure 11: Comparison of Design runoff

5 HYDRAULIC MODELLING

5.1 HEC-RAS Model

HEC-RAS, a hydraulic model developed by the USACE, is extensively applied in calculating the hydraulic characteristics of rivers. It is an integrated program and uses the following energy equation for calculating water surface profiles:

$$Y_2 + Z_2 + \frac{\alpha_2 V_2^2}{2g} = Y_1 + Z_1 + \frac{\alpha_1 V_1^2}{2g} + h_e$$

Where Y , Z , V , α , h_e , and g represent water depth, channel elevation, average velocity, velocity weighting coefficient, energy head loss, and gravitational acceleration; and subscripts 1 and 2, respectively, show cross sections 1 and 2. This program provides user to input data, data correction, to receive output display and analysis. HEC-RAS model needs details of river cross sections and upstream flow rate. The water depth and mean velocity are calculated for a given cross section using the energy conservation equation HEC-RAS calculates the water levels' variation along the channel and the water level values are overlaid on a digital elevation model (DEM) of the area to get the extent and flood depth using GIS. Spatial data like cross section, river reach, stream network, flow paths, and others have been obtained using RAS mapper of HEC-RAS.

The U. S. Army Corps of Engineers (USACE) developed HEC-RAS, and it is the latest product of 90 years of hydraulic modelling experience in the United States. Hydraulic modelling development began in the United States after a major flood event on the Mississippi River in 1927 prompting the USACE to begin exploring options to prevent flooding. The Hydrologic Engineering Centre (HEC) is a branch of the USACE that was established for the purpose of researching and developing new techniques to deal with the effects of floods (US Army Corps of Engineers). HEC originally began developing physical models to simulate river flow, but as technology progressed, computer programs that could simulate floods were developed. The computer models were then used to predict water surface profiles in response to potential future flood events and better prepare. The latest update on the program, HEC-RAS 6.2 includes capabilities to model the hydraulics of a river both one and two dimensionally. The

three governing equations of hydraulics are the energy equation, the momentum equation, and the continuity equation. One-dimensional HEC-RAS uses a variation of the energy equation in a procedure called the standard step method to calculate the water surface elevation corresponding to different discharges flowing through the hydraulic system being modelled.

5.1.1 Geometric data

The cross-sections along the study reach of 1.1 km are extracted from the DEM provided to INI. The geometric layout of cross-sections of study area is shown in Figure 12. It is requested to INI to provided pre-project and post-project river cross-section for comparison and updating the study. The manning's n value of 0.04 and 0.06 are have been used for main river channel and over banks considering it as a mountain stream.

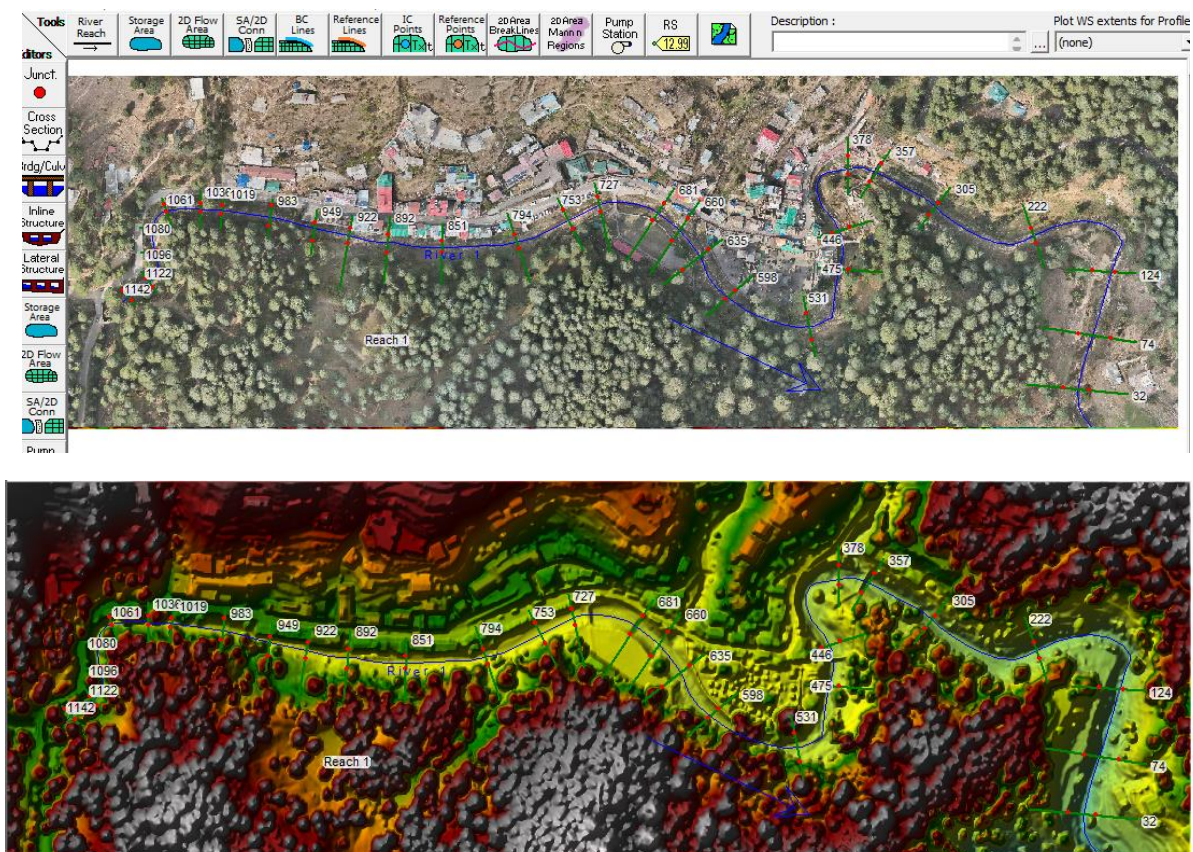


Figure 12: Geometric layout of cross-sections in HEC-RAS

5.1.2 HEC-RAS Simulation Results

Steady flow simulation is carried out for design discharge of various return periods viz. 25, 50 and 100 year return period respectively. The longitudinal water surface profile for different return period floods for the study reach is shown in Figure 13. The simulated water surface profile for 100 year return for pre-project scenario is shown in Figure 10. The simulated water level for pre-project and post project scenario for 100 year return period flood is given in Table 4.

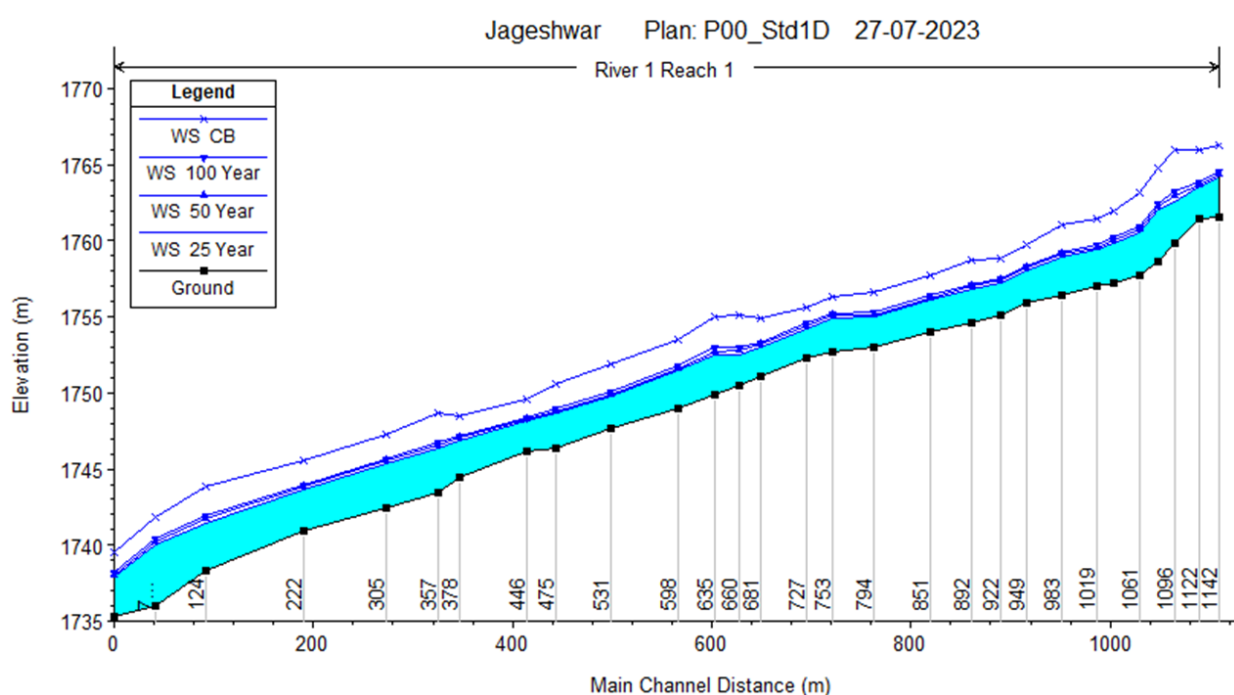


Figure 13: Simulated longitudinal water surface profile for different return period floods along the study reach

Table 4: Water surface profile for various return period floods.

River Sta	Min Ch El (m)	Maximum water surface elevation (m)			
		25 Year	50 Year	100 Year	CB
1142	1761.53	1764.2	1764.38	1764.55	1766.3
1122	1761.43	1763.53	1763.7	1763.86	1765.97
1096	1759.84	1762.58	1762.93	1763.28	1765.99
1080	1758.63	1762.09	1762.29	1762.48	1764.75
1061	1757.73	1760.51	1760.73	1760.94	1763.12
1036	1757.25	1759.88	1760.07	1760.26	1761.91
1019	1757	1759.39	1759.57	1759.76	1761.43
983	1756.38	1758.89	1759.09	1759.29	1761.08
949	1755.89	1758.02	1758.19	1758.35	1759.79
922	1755.12	1757.25	1757.4	1757.53	1758.8

892	1754.65	1756.83	1757.02	1757.17	1758.73
851	1753.97	1756.09	1756.22	1756.39	1757.69
794	1752.98	1754.99	1755.12	1755.27	1756.58
753	1752.73	1754.95	1755.09	1755.21	1756.33
727	1752.33	1754.19	1754.44	1754.59	1755.65
681	1751.08	1753.05	1753.17	1753.3	1754.91
660	1750.45	1752.55	1752.78	1753.01	1755.07
635	1749.93	1752.51	1752.74	1752.97	1755.05
598	1748.94	1751.47	1751.64	1751.81	1753.55
531	1747.68	1749.74	1749.92	1750.1	1751.91
475	1746.41	1748.66	1748.82	1748.98	1750.61
446	1746.18	1748.14	1748.27	1748.41	1749.61
378	1744.49	1746.89	1747.05	1747.19	1748.5
357	1743.48	1746.38	1746.57	1746.77	1748.71
305	1742.41	1745.35	1745.54	1745.71	1747.22
222	1740.9	1743.67	1743.83	1744	1745.53
124	1738.27	1741.48	1741.7	1741.9	1743.81
74	1735.96	1740.08	1740.27	1740.45	1741.88
32	1735.31	1737.91	1738.07	1738.22	1739.55

CB= rainfall intensity of 10 cm/h

6 DEVELOPMENT PLAN

The proposed masterplan of Jageshwar Dham and Jata Ganga Formation Plan explained by INI in video conference on 21st August 2024 are shown in Figure 14 and Figure 15. As discussed, earlier flow is very less during lean seasons. Hence at about six locations weirs/water retention structures can be constructed for making water available during lean season. It is recommended that appropriate provision should be made to pass the flood water during monsoon seasons uninterruptedly (KT weir, Inflatable Weirsetc.). Any restriction in flow and subsequent reduction in flow velocity will not only rise the maximum water level in the river but also may lead to rise in river bed level due to sedimentation. As evident from Table 4, limited de-silting activity can also be performed as to maintain a flow depth of about 3.3 m the road level shall be maintained at 5.25m above the river bed level.

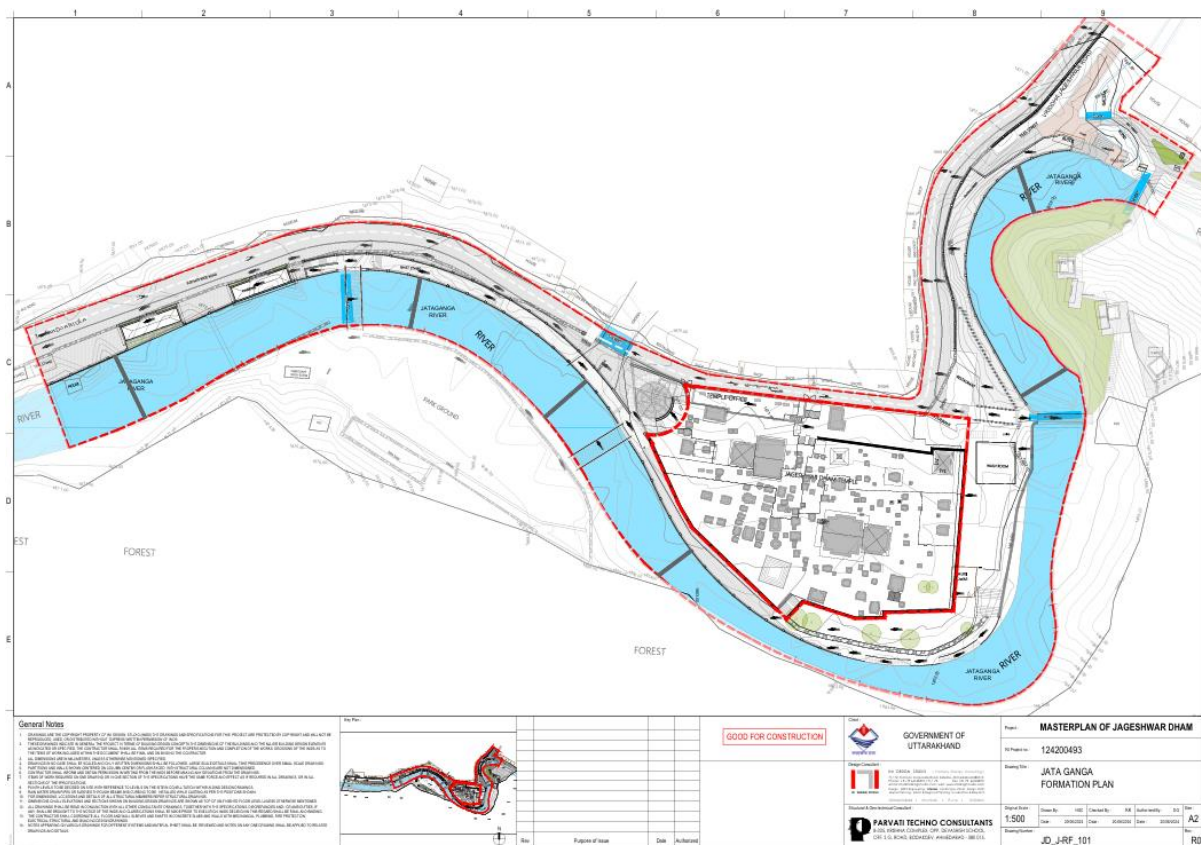


Figure 14: Masterplan of Jageshwar Dham and Jata Ganga Formation Plan

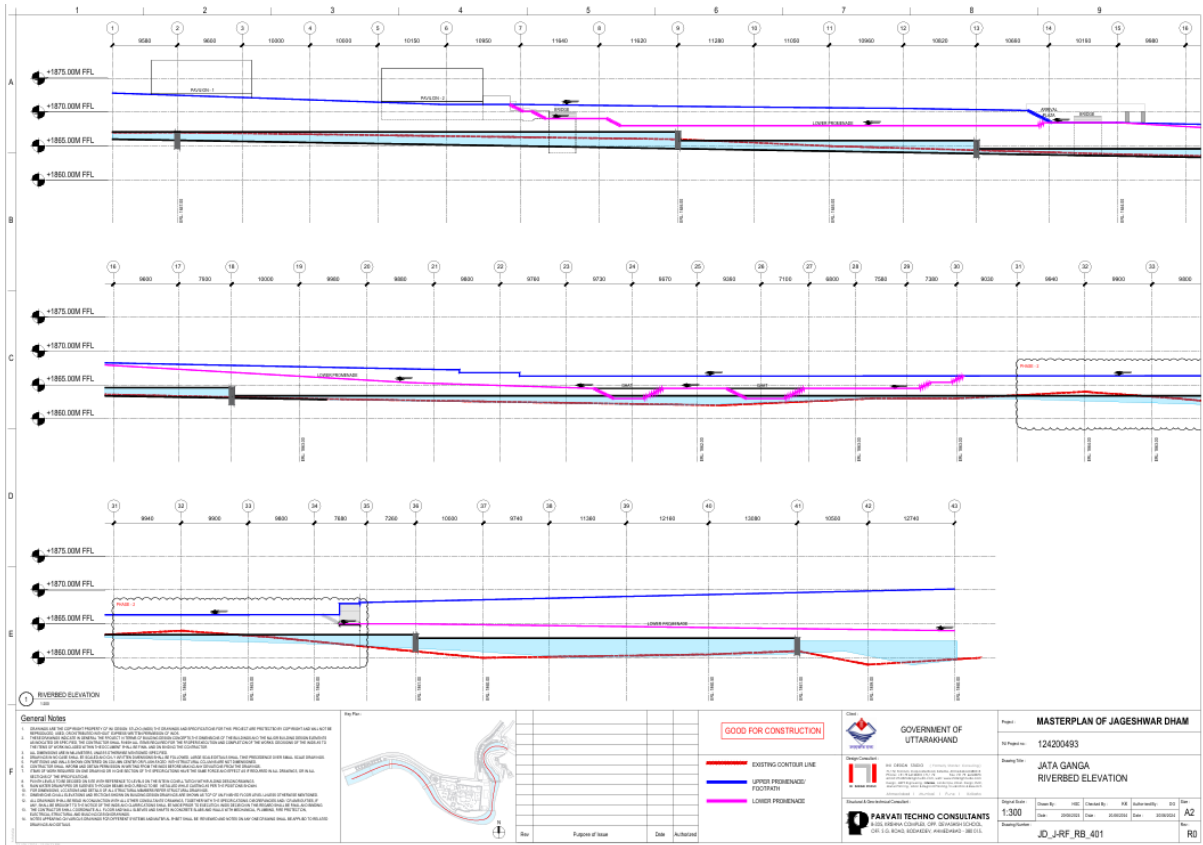


Figure 15: Proposed longitudinal profile of Jata Ganga river

Sachin S. Kurve, IAS
Secretary



Tourism Department
No.: 2595 /Secy/PS/2023
Dated : 20 July, 2023

Sub: Hydrology & Hydraulics study for Jata Ganga river at Jageshwar Dham, Almora, Uttarakhand.

Dear Shri Sudhir ji

The state government is committed to developing Jageshwar Temple (Part of Manas Khand) and its surrounding areas in a planned manner as per the vision of the Hon'ble Prime Minister to develop the Manas Khand circuit in the Kumaon region. For this purpose, the state government have appointed INI Design Studio, Ahmedabad as a master planning consultant.

The consultant has developed the master plan which comprises different components like temple illumination, Infrastructure facilities, parking facilities, streetscape development etc. Further to this, riverfront development for Jataganga(which flows behind the temple complex)is also one of components of master plan. For this aspect, we would require your expertise in carrying out hydrological and hydraulic studies which must contain the following, but are not limited to this:

- 25-yr 50-yr 100-yr flood discharge with HFL
- HFL after incorporating the proposed riverfront for 25-yr 50-yr 100-yr flood discharge
- Water retention strategy for the proposed riverfront

You are requested to kindly look into this matter urgently and provide us your valued inputs by 31.07.2023.

Yours sincerely

(Sachin Kurve)

Director
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Roorkee - 247667
Uttarakhand, India.