# Action Taken Report on behalf of Uttarakhand Pollution Control Board

In matter of
Original Application no. 632 of 2022

V.K Tyagi
*v.*
State of Uttarakhand and Ors.


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**Date:** , May 2025
Place: Dehradun

**MUKESH VERMA**
Advocate for UKPCB
Chamber No. 50, Old Block,
Supreme Court of India, New Delhi

**Action Taken Report on behalf of Uttarakhand Pollution Control Board**

In matter of

Original Application no. 632 of 2022

V.K Tyagi

*v.*

State of Uttarakhand and Ors.

1. That the above-mentioned matter was listed for hearing on 30.04.2024 wherein the Hon'ble National Green Tribunal was pleased to issue the following directions:

"....

*16. In the peculiar facts and circumstances we consider it essential to constitute and accordingly constitute a Committee comprising nominees of Regional Officer, Integrated Regional Office, MOEF&CC, Dehradun; Secretary, Irrigation Department, Uttarakhand, and Principal Secretary, Irrigation and Water Resources Department, Uttar Pradesh, Member Secretaries, UKPCB and UPPCB, Engineer-in-Chief, Irrigation Department, Uttarakhand and Engineer-in-Chief, Irrigation and Water Resources Department, Uttar Pradesh, Director, National Institute of Hydrology, Roorkee, Mr. Raman Kant, President, Bhartiya Nadi Parishad, First Floor, Samrat Shopping Mall, Garh Road, Meerut, Uttar Pradesh (Non-Official) and Mr. Vineet Kashyap, Development Researcher, First Floor, A-154, Kalkaji, New Delhi (Non-Official) The Non-Official Members of the Committee will be paid honorarium of Rs. 50,000/- (one time) besides travelling and*

*boarding/lodging expenses. The expenses of the Committee for convening meetings, travelling, boarding/lodging etc., will be borne by the UKPCB and UPPCB in equal proportions out of environmental compensation amount lying deposited with them. UKPCB will be the nodal agency for co-ordination and compliance.*

....."

2. That further, the Hon'ble Tribunal was pleased to issue the following directions:

"....

*3. Further progress reports may be filed by State of U.P. and State of Uttarakhand within two months.*

....."

3. That in compliance to the aforementioned order, instant action taken report is being filed.
4. It is humbly submitted that the Member Secretary, Uttarakhand Pollution Control Board vide letter dated 28.02.2025 requested the Head of the Environment Hydrology Division at the National Institute of Hydrology, Jal Vigyan Bhawan, Roorkee to prepare and submit the report to the Hon'ble Tribunal in compliance to the order dated 25.02.2025. In this connection, a copy of the letter dated 28.02.2025 is being filed and marked as **Annexure no. 1**.
5. Consequently, the Head of the Environment Hydrology Division at the National Institute of Hydrology, Jal Vigyan Bhawan, Roorkee, vide email dated 14.05.2025, submitted the final report of the study

titled *"Preparation of NGT Joint Committee Report on Solani River Catchment"* to the Member Secretary, UKPCB, after incorporating the recommendations suggested during the meeting on the draft report. In this connection, a copy of the email dated 14.05.2025 and Joint Committee report are collectively being filed and marked as **Annexure no. 2**

6. That it is pertinent to mention that the Uttarakhand Pollution Control Board (UKPCB) is committed to ensure the compliance of the directions given by this Hon'ble Tribunal.
7. The above report is being presented for the consideration of Hon'ble NGT.

Dr. R. K Chaturvedi
Scientific Officer
UKPCB

Dated: 20 May, 2025

1677

मुख्यालय
उत्तराखण्ड प्रदूषण नियंत्रण बोर्ड
"गौरा देवी पर्यावरण भवन"
46बी, आई.टी. पार्क, सहस्त्रधारा रोड़, देहरादून
E-mail : ukpcblegalcell@gmail.com, दूरभाष : 0135-2607092

पत्रांक : यूकेपीसीबी/एच.ओ./सा0–183–631(II)/2025/1749,

दिनांक 28.02.2025
एन0जी0टी0 मैटर
अनुस्मारक–01

सेवा में,

डा0 वाई. आर. सत्याजी राव
वैज्ञानिक–जी
हेड इन्वारमेन्टल हाईडॉलोजी डिविजन
राष्ट्रीय जल विज्ञान संस्थान
जल विज्ञान भवन, रूड़की–2476647
जनपद–हरिद्वार, उत्तराखण्ड।

विषयः– मा0 एन0जी0टी0 में योजित मूल आवेदन सं0 632/2022 में सोलानी रिवर कैचमेंट संयुक्त आख्या तैयार करने के प्रस्ताव के सम्बन्ध में।

महोदय,

उपरोक्त विषयक बोर्ड के पत्रांक सं0 यूकेपीसीबी/एच.ओ./सा0–183–631/2024/1255 दिनांक 29.11.2024 का सन्दर्भ ग्रहण करना चाहें। जिसमें "Preparation of NGT Joint Report on Solani River Catchment" हेतु आपसे अनुबंध किया गया था। जिसके क्रम में आपसे आख्या तैयार कर इस कार्यालय को प्रेषित करना था जो कि वर्तमान तक अप्राप्त है।

मा0 एन0जी0टी0 में उक्त वाद पर दिनांक 25.02.2025 को सुनवाई हुई जिसमें मा0 एन0जी0टी0 के द्वारा निर्देशित किया गया है कि 02 माह के अन्तर्गत प्रगति रिपोर्ट दाखिल की जाये। उक्त के क्रम में आपसे अनुरोध है कि उक्त आख्या तैयार कर इस कार्यालय को प्रेषित करने का कष्ट करें। प्रकरण में अगली सुनवाई दिनांक 22.05.2025 को नियत है।

भवदीय

(डा0 पराग मधुकर धकाते)
सदस्य सचिव

प्रतिलिपिः–

1. जिलाधिकारी महोदय, हरिद्वार को सादर सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित।
2. डा0 राजेन्द्र सिंह, क्षेत्रीय अधिकारी, उत्तराखण्ड प्रदूषण नियंत्रण बोर्ड, क्षेत्रीय कार्यालय, रूड़की को इस आश्य के साथ कि डा0 वाई.आर. सत्याजी राव, को अपेक्षित अभिलेख उपलब्ध कराते हुए आख्या स–समय प्रेषित करने का कष्ट करें।

सदस्य सचिव

O/C
File

1678

Annexure-2

Gmail

**UKPCB LEGALCELL <ukpcblegalcell@gmail.com>**

## Fw: In compliance of order passed by the Hon'ble National Green Tribunal in the matter of O.A. No. 632 of 2022 - reg.

1 message

**Uttarakhand PCB** <msukpcb@yahoo.com> Thu, May 15, 2025 at 10:51 AM
To: UKPCB LEGALCELL <ukpcblegalcell@gmail.com>

**Office of the**
**Member Secretary**
**Uttarakhand Pollution Control Board**
**Dehradun**

----- Forwarded Message -----
**From:** Pradeep Sachan <pradeep4uonline@gmail.com>
**To:** "msukpcb@yahoo.com" <msukpcb@yahoo.com>
**Cc:** Yellamelli Ramji Satyaji Rao <yrsrao.nihr@gov.in>; Rajesh Singh <rsingh.nih@gmail.com>; Vinay Kumar Tyagi <vinayiitrp@gmail.com>
**Sent:** Wednesday, May 14, 2025 at 08:13:45 PM GMT+5:30
**Subject:** Re: In compliance of order passed by the Hon'ble National Green Tribunal in the matter of O.A. No. 632 of 2022 - reg.

Dear Sir,

Please find attached the Final Report of the study "Preparation of NGT Joint Committee Report on Solani River Catchment" after incorporating the recommendations as suggested during the meeting on presentation on the draft report.

With Regards,
Pradeep

On Fri, Jul 26, 2024 at 12:24 PM Yellamelli Ramji Satyaji Rao <yrsrao.nihr@gov.in> wrote:

---

**From:** "Sandeep Kumar" <dir.nihr@gov.in>
**To:** msukpcb@yahoo.com
**Cc:** "Yellamelli Ramji Satyaji Rao" <yrsrao.nihr@gov.in>, paragenetics@gmail.com, "jm roorkee" <jm.roorkee@gmail.com>, rorueppcb2013@gmail.com, sompals2@gmail.com
**Sent:** Thursday, July 25, 2024 5:56:51 PM
**Subject:** Re: In compliance of order passed by the Hon'ble National Green Tribunal in the matter of O.A. No. 632 of 2022 - reg.

Sir,

In response to your trailing mail on the above subject, I am directed to inform that the Director, NIH has nominated the following senior Scientist of this Institute. The contact details of the nominated officer are given below:

Dr. Y R S Rao, Scientist 'G', National Institute of Hydrology, Roorkee 247667
Phone No. 01332-249216;
Mob. No. 9490499694
Email ID: yrsrao.nihr@gov.in

With regards,

P.S. to Director, NIH

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**From:** msukpcb@yahoo.com
**To:** "pseuup irrig" <pseuup.irrig@nic.in>, "Sandeep Kumar" <dir.nihr@gov.in>, jlsharma108@gmail.com, "Akhilesh Kumar sachan" <einciduplu-up@nic.in>, engineerinchiefidup@gmail.com, "hodcamp id" <hodcamp.id@gmail.com>, "einc irrigation" <einc.irrigation@gmail.com>, "Dr Krishnendu Mondal" <krishnendu.mondal@gov.in>, romuzaffarnagar@uppcb.in, raman4neer@gmail.com, vineetkashyap01@gmail.com
**Cc:** paragenetics@gmail.com, "jm roorkee" <jm.roorkee@gmail.com>, rorueppcb2013@gmail.com, sompals2@gmail.com
**Sent:** Wednesday, July 24, 2024 4:53:25 PM
**Subject:** In compliance of order passed by the Hon'ble National Green Tribunal in the matter of O.A. No. 632 of 2022 - reg.

**NGT MATTER**

**From:**
**Uttarakhand Pollution Control Board**
**Dehradun**

**To,**

**1. Principal Secretary/Secretary,** Irrigation & Water Resource Department, Government of Uttar Pradesh, Secretariate, Lucknow (Uttar Pradesh). E-Mail: pseuup.irrig@nic.in
**2. Director,** National Institute of Hydrology, Roorkee, Distt. Haridwar - 247 667. E-Mail: dir.nihr@gov.in
**3. Shri J. L. Sharma,** Joint Secretary, Irrigation Department, Government of Uttarakhand, Dehradun. Email: jlsharma108@gmail.com
**4. Engineer-In-Chief, Irrigation** Department Uttar Pradesh, Sinchai Bhawan, Cantt Road, Udaiganj, Lucknow – 226001. E-mail: einciduplu-up@nic.in; engineerinchiefidup@gmail.com
**5. Engineer-In-Chief,** Irrigation Department Uttarakhand, Yamuna Colony, Dehradun. E-Mail: hodcamp.id@gmail.com
**6. Dr. Krishnendu Mondal,** Scientist "D", Integrated Regional Office, MOEF&CC, 25, Subhash Road, Dehradun. E-Mail: krishnendu.mondal@gov.in

***Final Report***

# PREPARATION OF NGT JOINT COMMITTEE REPORT ON SOLANI RIVER CATCHMENT

**Submitted to**

**Uttarakhand Pollution Control Board (UKPCB),**

**Dehradun, Uttarakhand**

**Submitted by**

**National Institute of Hydrology,**

**Jal Vigyan Bhawan, Roorkee (Uttarakhand) – 247667**

**March 2025**

# Constitution of the Joint Committee

**In compliance of order dated 30.04.2024 passed by the Hon'ble National Green Tribunal in the matter of O.A. No. 632 of2022 titled as "V.K. Tyagi Versus State of Uttarakhand & Ors"**

1. **Principal Secretary/Secretary,** Irrigation & Water Resource Department, Government of Uttar Pradesh, Secretariat, Lucknow (Uttar Pradesh)

2. **Director,** National Institute of Hydrology, Roorkee, Distt. Haridwar - 247 667

3. **Shri J. L. Sharma,** Joint Secretary, Irrigation Department, Government of Uttarakhand, Dehradun.Email: jlsharma108@gmail.com

4. **Engineer-In-Chief, Irrigation** Department Uttar Pradesh, Sinchai Bhawan, Cantt Road, Udaiganj,Lucknow – 226001. E-mail: eincididuplu-up@nic.in; engineerinchiefidup@gmail.com

5. **Engineer-In-Chief,** Irrigation Department Uttarakhand, Yamuna Colony, Dehradun. E-Mail:hodcamp.id@gmail.com

6. **Dr. Krishnendu Mondal,** Scientist "D", Integrated Regional Office, MOEF&CC, 25, Subhash Road,Dehradun. E-Mail: krishnendu.mondal@gov.in

7. **Shri Imran Ali,** Environment Engineer, Regional Office, Uttar Pradesh Pollution Control Board,Muzaffarnagar (U.P.) Email: romuzaffarnagar@uppcb.in

8. **Shri Raman Kant,** President, Bhartiya Nadi Parishad, Ist Floor Samrat Shopping Complex, GarhRoad, Meerut (UP).E-Mail: raman4neer@gmail.com

9. **Shri Vineet Kashyap,** Development Researcher, New Delhi. Email: vineetkashyap01@gmail.com

# STUDY TEAM

1. Dr. Y. R. S. Rao, Scientist ‘G’ & Head, Environmental Hydrology Division, NIH
2. Dr. Pradeep Kumar, Scientist ‘E’, Environmental Hydrology Division, NIH
3. Dr. Rajesh Singh, Scientist ‘E’, Environmental Hydrology Division, NIH
4. Dr. Vinay Kumar Tyagi, Scientist ‘D’, Environmental Hydrology Division, NIH
5. Dr. Shakti Suryavanshi, Scientist ‘C’, Environmental Hydrology Division, NIH
6. Dr. S. K. Kumre, Scientist ‘B’, Environmental Hydrology Division, NIH

## 1. BACKGROUND

In reference to the order dated 30.04.2024 passed by the Hon'ble National Green Tribunal in the matter of O.A. No. 632 of 2022 titled as "V.K. Tyagi Versus State of Uttarakhand & Ors, a review meeting was held with the members of Joint Committee constituted in this matter under the Chairmanship of Member Secretary, Uttarakhand Pollution Control Board on 26.07.2024. The Minutes of Meeting are enclosed as Annexure 7. The matter is related to encroachment in river Solani for cultivation purposes which is causing obstruction of river flow. Untreated sewage is also being discharged in river Solani. Subsequently, Uttarakhand Pollution Control Board (UKPCB) requested the National Institute of Hydrology (NIH) to prepare the report of the Joint Committee. Accordingly, the report has been prepared and submitted herewith by NIH.

## 2. SCOPE OF WORK

Hon'ble NGT constituted the Joint Committee for preparation of report pertaining to the Solani river covering the following issues:

a) Identification / demarcation of area of Solani River and its translation on GIS Map;
b) Rehabilitation and management of its catchment area;
c) Encroachments on the same and removal thereof;
d) Tapping of all drains discharging in river Solani by construction of STPs etc.;
e) Review of existing treatment facilities for treatment of industrial effluents and domestic sewage and improvements required to be made; and
f) Reuse of treated water from STPs/CETPs for irrigation by connecting the same to irrigation canals/channels and industrial purposes by laying down pipelines connecting the concerned industries.

These issues have been elaborated in the following sections:

## 3. IDENTIFICATION / DEMARCATION OF AREA OF SOLANI RIVER AND ITS TRANSLATION ON GIS MAP

### 3.1 Solani River Catchment

Solani River, which is a tributary of Ganga river – the largest river basin in India. It originates from Shivalik foothills and runs along the Biharigarh, Bhagwanpur, Roorkee, Laksar towns of the State of Uttarakhand before its confluence with river Banganga at upstream of Shukratal, Uttar Pradesh.

The Siwalik range is composed of a gentle northern slope and steeper southern slope. The plains are bordered by these ranges which is major characteristic feature of the watershed. The map of Solani river catchment presenting nearby areas in shown in Figure 1. The catchment area of Solani river is about 1300 $km^2$ with 115 km of river length. The catchment lies between between 78.03°E, 30.00°N and 77.48°E, 29.45°N. The elevation in the catchment varies from 200 m (lower flat agriculture lands) to 800 m (upper hilly area). The area is relatively flat with a maximum slope of 8.85 m/km, Min, slope 0.44 m/km and average slope 2.84 m/km and is mostly comprised of sandy loam soil having 70% sand, 20% silt, and 10% clay.

The Solani River is flowing over relatively flat land with significant meandering channel. The river width is also confined with bunds at various places and also it under passed by upper ganga canal through famous engineering marvel Solani Aquaduct at Roorkee. In Roorkee town, the minimum channel width is ~80 m and the maximum width is ~410 m with a mean channel width of ~248m.

The Solani River catchment experiences sub-tropical monsoon type of climate. Most of the rainfall occurs during the period June–September (Indian monsoon season) and annual precipitation varies from 1,200 to 1,500 mm. The surface winds in winter are westerly to northern-westerly. Average maximum temperature varies between 20–40°C and relative humidity varies from 35 to 97%. Around 65% of total annual rainfall occurs in the period from end of June to Mid of October.

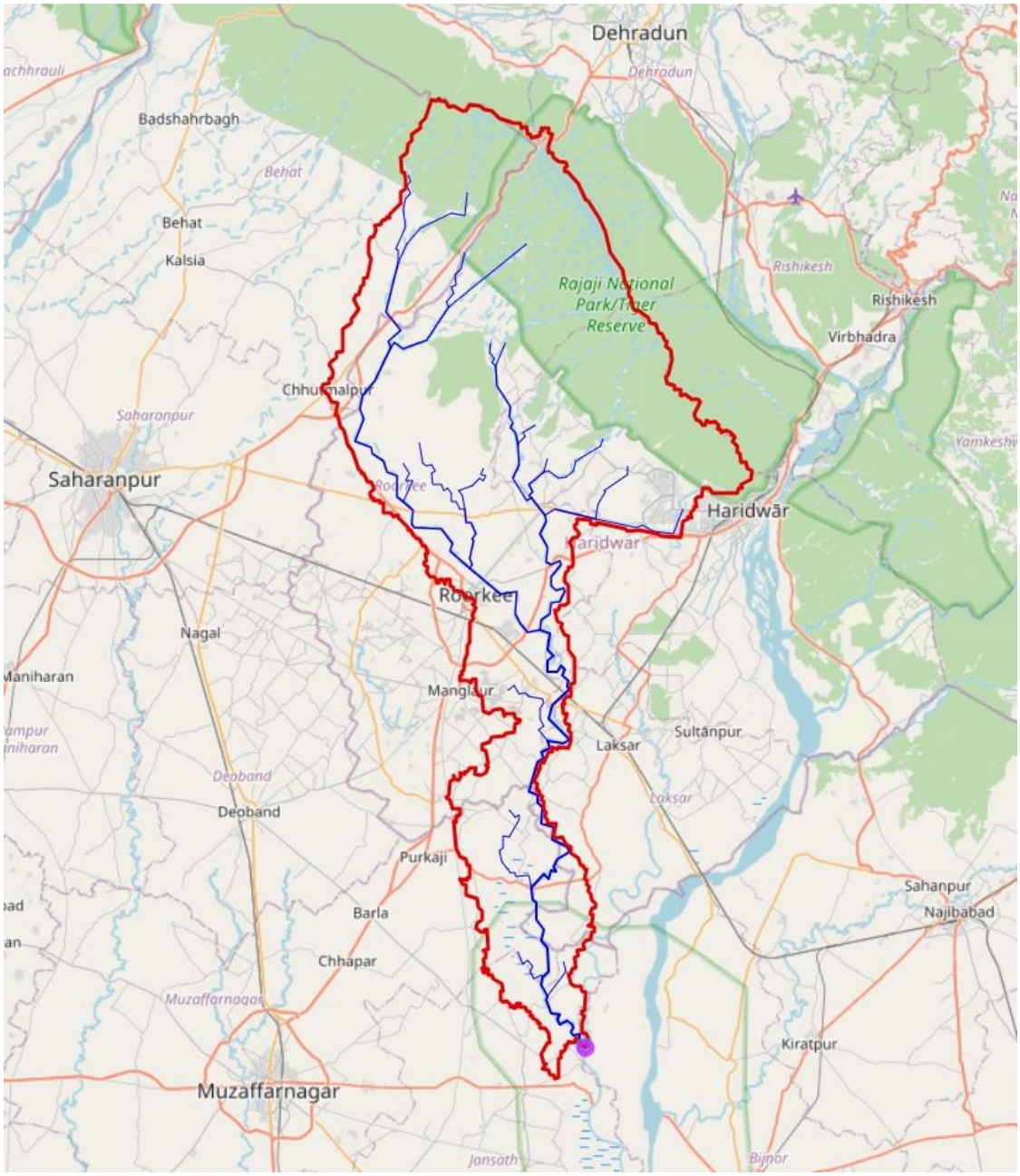



**Figure 1: Map of Solani river catchment**

### 3.2 Field Inspection of Solani River Catchment

In order to fulfil the mandate of the Committee, inspection of the Solani river catchment were conducted jointly by Shri Raman Kant, President, Bhartiya Nadi Parishad, Meerut and UKPCB officials. The report prepared by Shri Raman Kant is enclosed as Annexure 1.

The Solani River originating from the Shivalik hills of Saharanpur district, is formed by the confluence of two main streams, Khajnawar and Shahjahanpur, along with several smaller streams from these hills. Khajnawar and Shahjahanpur streams flow through the Shivalik forest about ten kilometers from the slopes of the Shivalik hills. According to the British Gazetteer, the name Solani River is first given to the stream formed by the confluence of Chilawala, Kania, Sukh, and Mohand Rao, which drains the sub-mountainous region up to the edge of Mohand Rao. Near Thapal Ismailpur, it joins Rajwa and Khandur Rao, carrying the combined waters of Khajnawar and Shahjahanpur Rao, as well as Hatni Hot and other streams. The entire river is then known as Solani, flowing southeast along the high bank marking the eastern boundary of the upland plain. After leaving the forest boundary, these streams converge approximately 10 kilometers downstream on the road from Dehradun to Sakumbhari near Saliyar Salahpur village. Before becoming the Solani River, it is joined by several other smaller streams. The Solani River flows gently, growing in size and importance. On the banks of the river in Saliyar Salahpur, there is a functioning stone crusher, while on the opposite side, a builder is constructing a colony on land adjacent to the river.

Just above the town of Roorkee on its left bank flows the Sipiya River, a long stream originating from the valleys of the Sakrauda plateau and fed solely by rainwater from numerous tributaries such as Haljaura, Jakhani, and Dhandora. The Solani Aqueduct, an important engineering marvel, was constructed in the 19th century under the supervision of Sir Proby Cautley. Built in 1846 over the Purani Ganga Canal (Old Upper Ganga Canal), it is a significant example of brick masonry construction, spanning 15 spans of 50 feet each. The aqueduct, 980 feet long, stands as a landmark in civil engineering, a testament to the advancements of its time. At Roorkee, the Solani Great Canal passes beneath the aqueduct, continuing southeast to the northern boundary of Mangalore, where it meets the Ratmau River.

For the past year, about 400 cusecs of water has been released into the Ratmau River through the old Roorkee canal at the Dhanouri dam. At this location, the old Roorkee canal directly meets the Ratmau River on the same level, with a canal built over the river. There is also a barrage here where the water falls approximately 50 feet. About 500 meters downstream, around 1000 cusecs of water is directed into

the Ratmau River through a canal of the new Roorkee canal. When the Ratmau River meets the Solani River northeast of Tod Kalyanpur and Sundhari villages below Roorkee city, the Solani River's water flow increases. However, during the monsoon, the Solani River carries much more water. Before joining the Solani River at Ratmau, it has already been joined by eight drains at various points. After the Ratmau River joins, the flow of the Solani River significantly increases, mixing the clean water with domestic effluents from 13 drains originating near Roorkee city. At this point, the Solani River appears clear and clean. This area is expansive, and during non-monsoon season, farmers practice temporary agriculture close to the river banks.

Moving forward, the Solani River enters Muzaffarnagar district. About one kilometer before the main bathing ghat of Shukratal, the Solani River merges with Banganga River (a distributary of Ganga River) flowing from the east. The Banganga River begins from a Ganga river stream near Katarpur Alipur village, Bahadarabad tehsil, Haridwar district, Uttarakhand, reaching Shukratal in Muzaffarnagar district, Uttar Pradesh. Here, after absorbing the Solani, it merges into the Ganga River basin at Haidarpur Wetland, on the west side of the Ganga Barrage in Bijnor.

Haidarpur Wetland, a Ramsar site, is crucial for its ecological significance, providing habitat to various bird species, aquatic life, and flora. The wetland plays a critical role in groundwater recharge, flood control, and maintaining ecological balance in the region. Banganga travels about 70 kilometers before again joining the Ganga River. Banganga is highly polluted due to receiving substantial drainage from Laksar near Idrishpur village, as well as untreated sewage from nearby villages like Mahatauli, Tanda, Mubarakpur, Chamrawal, Nehandpur Suthari, and Muzaffarpur Gujra Jadid. The main tributary of Banganga is Pathri, originating from Shivalik and passing through Hetampur Bahadarabad before joining Banganga. Banganga's flow is low initially but increases during the monsoon. At its source, Banganga relies solely on rainwater to maintain its flow. Currently, Banganga is fed by rainwater runoff, untreated sewage from towns/villages in its catchment area, domestic and industrial effluents via the Laksar drain, domestic sewage via the Sultanpur drain, and tributaries like the Pathri and Solani rivers.

### 3.3 Floodplain Zoning of Solani River and GIS Mapping

Floodplain zoning of Solani River and its major tributary Ratmau River in accordance of the Uttarakhand Flood Plain Zoning Act, 2012 has been carried out by the Hydraulic Circle, Bahadarabad (unit of Irrigation Research Institute, Roorkee), Department of Irrigation, Uttarakhand through M/s Visiontek Consultancy Services, Bhubaneshwar, Odisha. GIS map with demarcation of river Solani is now available and will be shared in KML format. In continuation of review meeting, Irrigation Department has forwarded the flood plain zoning report along with HFL points and GIS Map of river Solani-Ratmau to UKPCB. The details of floodplain zoning of Solani River are given in Annexure 2.

Initially the survey work of the flood plain was done by using DGPS, Total Station as well as Drone Survey. The appropriate Digital Elevation Model was also procured for use in Hydraulic model. The rainfall and discharge data was collected from respective sources. Due to non-availability of sufficient discharge data, the two rivers were treated as ungauged and the discharge calculation was done on the concept of Synthetic Unit Hydrograph. The maximum rainfalls have been obtained from PMP ATLAS and disaggregation of the data was done as per the defined process. The design discharge was obtained after performing critical sequencing of the rainfall. The discharge values were obtained for the 5-, 25-, 50- and 100-year return periods.

The hydrodynamic modelling is applied to the obtained design discharge. The HEC-RAS software is used to make the analysis. Both 1-D and 2-D modelling analysis is done to the given data. The cross-sections obtained at 50m interval, the DEM data, DGPS survey data are combined together for a hybrid DEM which remain the input for our model. The design discharge data remain the hydrologic input for the model. The local Manning's Constant (n) values are taken as per the river stretch configuration. The outputs in the form of flood lines corresponding to 5, 25, 50 and 100- year flood lines are obtained which are communicated to field staff for putting the marks at field at 50 m intervals. The same has been done in presence of field staff as well as the Survey team. The task of placing the flood lines in the Shajra

map is essential for finalising the flood inundation lines as well as fixing the flood zones i.e the restrictive, prohibitive and warning zones.

## 4. REHABILITATION AND MANAGEMENT OF ITS CATCHMENT AREA

### 4.1 Current State of Solani River

Based on field inspection of the Solani river catchment conducted jointly by Shri Raman Kant, President, Bhartiya Nadi Parishad, Meerut and UKPCB officials, a report on Solani River Rejuvenation Measures has been prepared and submitted by Shri Raman Kant (Annexure 1).

The Solani River plays a vital role in the region's hydrological dynamics. Originating and flowing through a diverse landscape, it interacts with various land cover types within its catchment. The catchment encompasses 10.21 square kilometers of water bodies, 194.43 square kilometers of built-up areas, 61.03 square kilometers of rangeland, and 540.44 square kilometers of tree-covered areas and 8.8 square kilometers of bare ground. The region includes almost 75% area dedicated to crops. This mosaic of land uses not only underscores the ecological diversity but also highlights the multifaceted interactions between natural and anthropogenic elements influencing the Solani River.

While there is no direct industrial pollution in the Solani River, it receives significant domestic wastewater discharge. Thirteen drains from Roorkee city discharge directly into the Solani River, resulting in polluted water at various points. A sewage treatment plant (STP) with a capacity of 33 MLD has been established in Saliar, Roorkee, supported financially by the Asian Development Bank and operated by KEC Company since April 30, 2019. At present, existing 33 MLD STP is not running in its full capacity and receiving only 6 to 7 MLD sewage flow due to inadequate drain connections. Several drains in Roorkee are situated on the eastern side of the canal, making connection to the STP nearly impossible. Consequently, these drains remain untreated. Moreover, sewage from a dozen villages/towns flows directly into the river. Farmers cultivate the riverbed and its catchment, and the wastewater through agricultural fields also join Solani River.

### 4.2 Regular Water Quality Monitoring of Solani River

Regular water quality monitoring of river Solani at upstream of Kuankhera village is being carried out by UKPCB on monthly basis. Water quality analysis data categorized the river Solani under Class "B" category as per CPCB classification. In this regard, water quality analysis data from January 2023 to June 2024 has been provided by UKPCB (Annexure 5) and summarized in Table 1.

### 4.3 Potential Factors Causing Degradation of Solani River

The potential causes for degradation of Solani River are as follows:

a) Urbanization: The rapid expansion of urban areas along the Solani River has led to increased pollution from domestic sewage, industrial effluents, and solid waste. Unplanned urban sprawl has also resulted in the encroachment of riverbanks, disrupting the natural flow and reducing the river's self-cleaning capacity.
b) Agricultural Runoff: The extensive use of chemical fertilizers and pesticides in agriculture has contributed to the pollution of the Solani River. Runoff from agricultural fields carries these harmful chemicals into the river, leading to eutrophication and the depletion of aquatic life.
c) Industrialization: Although, at present, there are mostly the pharmaceutical industries where medicines are not produced only packaging is being carried out and, hence, no industrial effluent is directly going into the river. Considering the urban expansion and potential of industrial development near Roorkee town, it may pose challenge for treating the industrial effluents.
d) Deforestation: The removal of vegetation along the riverbanks for agriculture and within the catchment for infrastructure development has led to increase in monsoon flows accelerating soil erosion, leading to decrease in non-monsoon flows and increased sedimentation in the river. This has reduced the river's depth and disrupted its ecological balance.
e) Climate Change: Changing rainfall patterns in the catchment area have further strained the already stressed Solani River, reducing its flow and exacerbating pollution levels during non-monsoon season.

**Table 1: Surface Water Quality of River Solani near U/s of Village Kuankhera, Haridwar from January 2023 to June, 2024**

| Month | Colour | Odour | Temperature (°C ) | pH | TDS (mg/l) | EC (µS/cm ) | DO (mg/l) | Chloride (mg/l) | Hardness (mg/l) | Calcium Hardness (mg/l) | Magnesium Hardness (mg/l) | Alkalinity (mg/l) | BOD (mg/l) 27°C for 3 days | COD (mg/l) | TC (MPN/100 ml) | FC (MPN/100 ml) | FS (MPN/100 ml) | Nitrate-N (mg/l) | Nitrite-N(mg/l) | Sulphate (mg/l) | Phosphate (mg/l) | Fluoride (mg/l) | Sodium (mg/l) | Potassium (mg/l) | SAR | Class of Water as per CPCB Designated Best Use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **02-Jan-23** | Colourless | Odourless | 13.4 | 7.71 | 561 | 878 | 7.2 | 35 | 237 | 199 | 38 | 218 | 2.2 | 12 | 84 | 25 | 14 | 0.53 | 0.01 | 29.22 | 0.26 | 0.97 | 30.3 | 7.9 | 0.86 | Class-B |
| **07-Feb-23** | Colourless | Odourless | 19.2 | 8.10 | 472 | 737 | 6.2 | 30 | 140 | 88 | 52 | 204 | 2.0 | 15 | 94 | 58 | 21 | 0.55 | 0.02 | 25.8 | 0.30 | 0.55 | 28.6 | 6.6 | 1.04 | Class-B |
| **03-Mar-23** | Colourless | Odourless | 22.7 | 7.95 | 324 | 506 | 6.2 | 24 | 266 | 152 | 114 | 252 | 1.8 | 10 | 110 | 63 | 33 | 1.01 | 0.64 | 22.48 | 0.12 | 0.68 | 35.4 | 10 | 0.94 | Class-B |
| **13-Apr-23** | Colourless | Odourless | 22.0 | 8.00 | 315 | 492 | 7.8 | 22.0 | 271 | 150 | 121 | 244 | 2.0 | 8.3 | 84 | 49 | 17 | 0.52 | 0.03 | 22.6 | 0.34 | 0.54 | 30.8 | 9.6 | 0.81 | Class-B |
| **12-May-23** | Colourless | Odourless | 25.4 | 7.68 | 308 | 481 | 7.4 | 18.0 | 186 | 56 | 130 | 110 | 2.4 | 7 | 79 | 26 | 17 | 0.49 | 0.31 | 35.98 | 0.59 | 0.55 | 9.1 | 2.6 | 0.29 | Class-B |
| **21-Jun-23** | Turbid | Odourless | 22.1 | 8.10 | 277 | 432 | 7.6 | 20 | 280 | 145 | 135 | 120 | 2.1 | 8.4 | 110 | 32 | 14 | 0.76 | 0.31 | 27.27 | 0.13 | 0.70 | 31.2 | 9.4 | 0.81 | Class-B |
| **04-Jul-23** | Turbid | Odourless | 32.3 | 7.79 | 513 | 802 | 5.8 | 18 | 92 | 52 | 40 | 142 | 2.8 | 16 | 170 | 79 | 63 | 0.34 | 0.18 | 36.45 | 0.36 | 0.29 | 33.2 | 13.3 | 1.50 | Class-B |
| **19-Aug-23** | Turbid | Odourless | 24 | 7.52 | 198 | 312 | 6.5 | 16 | 115 | 62 | 53 | 138 | 2.6 | 10 | 150 | 41 | 27 | 0.64 | 0.28 | 32.45 | 0.47 | 0.49 | 28.6 | 11.3 | 1.16 | Class-B |
| **05-Sep-23** | Turbid | Odourless | 28.0 | 7.67 | 512 | 800 | 7.6 | 10 | 196 | 114 | 82 | 130 | 2.0 | 9 | 130 | 43 | 22 | 0.32 | 0.12 | 35.9 | 0.27 | 0.25 | 27.9 | 6.0 | 0.86 | Class-B |
| **05-Oct-23** | Turbid | Odourless | 27.3 | 7.90 | 210 | 328 | 6.0 | 16 | 322 | 215 | 107 | 340 | 2.8 | 12 | 110 | 46 | 17 | 1.75 | 0.32 | 30.21 | 0.15 | 0.72 | 20.1 | 9.6 | 0.49 | Class-B |
| **01-Nov-23** | Turbid | Odourless | 24.7 | 7.21 | 201 | 315 | 6.8 | 14 | 197 | 124 | 73 | 219 | 2.2 | 10 | 94 | 70 | 9.3 | 0.59 | 0.32 | 35.66 | 0.51 | 0.62 | 25.0 | 16.0 | 0.77 | Class-B |
| **04-Dec-23** | Colourless | Odourless | 20.6 | 8.04 | 200 | 313 | 7.8 | 12 | 225 | 110 | 115 | 185 | 1.8 | 16 | 120 | 70 | 9.2 | 0.99 | 0.33 | 29.41 | 0.16 | 0.68 | 21.0 | 10.1 | 0.61 | Class-B |
| **02-Jan-24** | Colourless | Odourless | 20.4 | 7.10 | 455 | 712 | 7.9 | 13 | 189 | 93 | 96 | 167 | 1.2 | 16 | 120 | 94 | 14 | 0.59 | 0.22 | 32.89 | 0.29 | 0.43 | 17.8 | 4.5 | 0.56 | Class-B |
| **06-Feb-24** | Colourless | Odourless | 16.5 | 7.60 | 320 | 500 | 7.8 | 14 | 200 | 102 | 98 | 175 | 2.2 | 20 | 110 | 79 | 17 | 0.99 | 0.33 | 33.54 | 0.18 | 0.48 | 18.6 | 11.2 | 0.57 | Class-B |
| **04-Mar-24** | Turbid | Odourless | 20.6 | 8.10 | 307 | 480 | 7.6 | 11 | 206 | 98 | 108 | 209 | 2.0 | 9 | 150 | 94 | 14 | 0.69 | 0.37 | 38.54 | 0.58 | 0.58 | 18.1 | 9.3 | 0.55 | Class-B |
| **04-Apr-24** | Colourless | Odourless | 20.0 | 7.20 | 310 | 484 | 7.8 | 16 | 160 | 75 | 85 | 173 | 2.0 | 14 | 120 | 84 | 7.8 | 0.59 | 0.35 | 34.57 | 0.22 | 0.48 | 30.8 | 8.7 | 1.05 | Class-B |
| **06-May-24** | Colourless | Odourless | 22.0 | 7.30 | 250 | 390 | 7.6 | 13 | 160 | 78 | 82 | 188 | 2.4 | 16 | 170 | 79 | 9.3 | 0.58 | 0.38 | 35.57 | 0.62 | 0.58 | 25.8 | 12.7 | 0.88 | Class-B |
| **13-Jun-24** | Turbid | Odourless | 21.5 | 7.15 | 350 | 547 | 7.6 | 14 | 190 | 100 | 90 | 170 | 2.6 | 18 | 220 | 140 | 9.3 | 0.74 | 0.33 | 33.54 | 0.61 | 0.5 | 18.4 | 10.8 | 0.58 | Class-B |
| **Acceptable limits (AL)/** | | | | **(6.5-** | 500/2000 (mg/l) | | **5** | **250** | **200** | | | **200/** | **3** | | **500** | | | **(45** | | **200/4** | | **1.0/** | | | | |

### 4.4 Development of Restoration Plan for Solani River

To address the multifaceted issues plaguing the Solani River, a holistic and multi-pronged approach need to be adopted, involving governmental agencies, local communities, non-governmental organizations (NGOs), and environmental experts.

The restoration plan for Solani River may be broadly categorized into the following areas:

#### (i) Pollution Control and Waste Management

- Sewage Treatment Plants (STPs): Establishing STPs along the major urban centers to ensure that domestic sewage is treated before being discharged into the river. These plants utilize advanced treatment technologies to remove contaminants and ensure the treated water meets environmental standards.
- Industrial Effluent Treatment: Enforcing stringent regulations for industries to treat their effluents before discharge. Industries are mandated to install Effluent Treatment Plants (ETPs) and comply with environmental norms.
- Solid Waste Management: Implementing comprehensive solid waste management systems in urban areas to prevent the dumping of waste into the river. This includes setting up waste segregation, collection, and disposal systems.

#### (ii) Ecosystem Restoration

- Afforestation and Riparian Buffer Zones: Planting native vegetation along the riverbanks to prevent soil erosion, enhance biodiversity, and create natural filtration systems. These riparian buffers help in stabilizing the banks and filtering pollutants before they enter the river.
- Wetland Creation and Restoration: Developing and restoring wetlands in the catchment area to act as natural water purifiers and provide habitat for wildlife. Wetlands help in sediment trapping, nutrient absorption, and maintaining the hydrological cycle.

- Bioremediation: Employing bioremediation techniques using specific plants, microbes, and fungi to degrade pollutants in the river water. This natural method helps in reducing chemical contaminants and restoring the ecological balance.

**(iii) Water Resource Management**

- Rainwater Harvesting: Encouraging the adoption of rainwater harvesting techniques in urban and rural areas to recharge groundwater levels and reduce surface runoff. This helps in maintaining the base flow of the river during dry periods.
- Check Dams and Reservoirs: Constructing check dams and small reservoirs in the catchment area to store rainwater, reduce surface runoff, and promote groundwater recharge. These structures help in regulating the flow of the river and ensuring water availability during lean periods.
- Efficient Irrigation Practices: Promoting water-efficient irrigation techniques such as drip and sprinkler irrigation among farmers to reduce water consumption and minimize agricultural runoff.

**(iv) Community Engagement and Awareness**

- Public Awareness Campaigns: Conducting awareness campaigns to educate the local population about the importance of river conservation and the steps they can take to reduce pollution. Schools, colleges, and community centers are actively involved in these campaigns.
- Community Participation: Encouraging local communities to participate in river monitoring, cleanup drives, and afforestation activities. Community-based organizations are empowered to take ownership of the river's health and actively contribute to its restoration.
- Sustainable Practices Promotion: Promoting sustainable agricultural practices, such as organic farming and integrated pest management, among farmers to reduce the impact of chemical runoff on the river.

**(v) Policy and Governance**

- Regulatory Framework: Strengthening the regulatory framework to enforce environmental laws and regulations related to water pollution. This includes regular monitoring and penalizing violators to ensure compliance.
- Inter-agency Coordination: Enhancing coordination between various governmental agencies, NGOs, and local bodies to ensure a unified and effective approach to river rejuvenation.
- Funding and Incentives: Securing funding from government bodies, international organizations, and private sector initiatives to support rejuvenation projects. Providing incentives for industries and communities adopting sustainable practices.

### 4.5 Implementation of Restoration Plan

The rejuvenation project may be divided into several phases to ensure systematic implementation and continuous monitoring:

**Phase I: Baseline Assessment and Planning**

- Conducting a comprehensive assessment of the river's current state, including water quality analysis, biodiversity surveys, and identification of pollution sources.
- Developing a detailed action plan outlining the specific interventions required and setting measurable targets.

**Phase II: Infrastructure Development**

- Constructing sewage treatment plants, effluent treatment plants, check dams, and rainwater harvesting structures.
- Initiating afforestation and wetland restoration projects.

**Phase III: Community Engagement and Implementation**

- Rolling out public awareness campaigns and involving local communities in river monitoring and cleanup activities.
- Implementing sustainable agricultural practices and promoting water-efficient irrigation techniques.

**Phase IV: Monitoring and Evaluation**

- Regularly monitoring water quality, biodiversity, and the effectiveness of

implemented interventions.

- Making necessary adjustments based on feedback and ongoing assessments.

## 5. ENCROACHMENTS ON THE SOLANI RIVER AND REMOVAL THEREOF

Executive Engineer, North Division Ganga Canat UP Irrigation Department, Roorkee has informed that there was no permanent encroachment in river Solani. Lease granted earlier for cultivation purposes have been cancelled and encroachment has been removed from river Solani. Copy of letter dated 02.08.2024 has been provided as Annexure 3.

## 6. TAPPING OF ALL DRAINS DISCHARGING IN RIVER SOLANI BY CONSTRUCTION OF STPs

Uttarakhand Peyjal Nigam has identified the drains joining the river Solani along with location for Interception and diversion of drains and Sewage Pumping Station (SPS) leading to STP, however, in absence of demarcation of HFL of the area, land could not be granted by UP Irrigation Department. Now, HFL data of Solani River is available with Uttarakhand Irrigation Department, the land issue would be shorted out at earliest. In this regard, copy of letter dated 27.07.2024 of UP Irrigation Department is enclosed as Annexure 4.

Roorkee city is the major town within the Solani River Catchment from where the largest contribution of sewage joins the Solani River. The database of drains, status of existing wasterwater disposal works and the proposed plan for tapping all these drains near Roorkee town have been elaborated in the following sub-sections:

### 6.1 Drains Discharging in Solani River near Roorkee town

There are 13 (Thirteen) major polluted nalas in the Roorkee town as mentioned earlier are majorly unlined. Further, being mostly open, choked, filled by solid waste and silted and thus, the drains are extremely inadequate to drain-out the storm water. The drains also pass through the thickly populated and congested localities and as such

are encroached by permanent and semi-permanent structures/buildings, significantly affecting the carrying capacity of the limited drainage channels in the town.

The final outfall for all the major drains is River Solani. Details of the Nalas flowing through the city and dropping into the river Solani are provided in the Table 2.

**Table 2: Details of Nala and Outfall points**

| S. No. | Name | Coordinates of Outfall | | Outfall of Nala |
|---|---|---|---|---|
| | | Latitude | Longitude | |
| 1 | Pathanpura Nala | 29°52'47.24"N | 77°53'52.18"E | Solani River |
| 2 | Adarsh Nagar Nala-1 | 29°52'35.65"N | 77°54'13.87"E | |
| 3 | Adarsh Nagar Nala-2 | 29°52'35.24"N | 77°54'14.38"E | |
| 4 | Khanjarpur Nala | 29°52'4.07"N | 77°54'40.72"E | |
| 5 | Dhobi Gaat Nala | 29°52'54.93"N | 77°53'38.71"E | |
| 6 | Sot Mohalla Nala-1 | 29°52'58.21"N | 77°53'37.26"E | |
| 7 | Sot Mohalla Nala-2 | 29°52'58.21"N | 77°53'37.26"E | |
| 8 | Rampur Chungi Nala | 29°53'18.41"N | 77°52'55.62"E | |
| 9 | Macchi Mohalla Nala | 29°53'12.44"N | 77°53'16.25"E | |
| 10 | Bandha Road Nala-1 | 29°53'8.44"N | 77°53'23.01"E | |
| 11 | Bandha Road Nala-2 | 29°53'8.44"N | 77°53'23.01"E | |
| 12 | Imli Road Nala-1 | 29°53'7.45"N | 77°53'24.77"E | |
| 13 | Imli Road Nala-2 | 29°53'7.45"N | 77°53'24.77"E | |

The flow of these Nalas/drains were measured and are summarized in Table 3. Water quality sampling was also conducted along with the measurement of flow in drains. The analysis was done to know the quality of the wastewater. The summary of the analytical results is given in Table 4.

**Table 3: Details of flow in Nalas/Drains**

| S. No. | Name of Nala | Average Discharge | |
|---|---|---|---|
| | | in MLD | in lps |
| 1 | Pathanpura Nala | 1.11 | 12.85 |
| 2 | Adarsh Nagar Nala-1 | 0.34 | 3.94 |
| 3 | Adarsh Nagar Nala-2 | 0.48 | 5.56 |
| 4 | Khanjarpur Nala | 8.80 | 101.85 |
| 5 | Dhobi Gaat Nala | 0.86 | 9.95 |
| 6 | Sot Mohalla Nala-1 * | 1.62 | 18.75 |
| 7 | Sot Mohalla Nala-2 | 1.66 | 19.21 |
| 8 | Rampur Chungi Nala | 0.37 | 4.28 |
| 9 | Macchi Mohalla Nala | 9.92 | 114.83 |
| 10 | Bandha Road Nala-1 | 0.85 | 9.84 |
| 11 | Bandha Road Nala-2 | 0.34 | 3.94 |
| 12 | Imli Road Nala-1 | 0.36 | 4.17 |
| 13 | Imli Road Nala-2 | 0.39 | 4.51 |

* The Sewage Pumping Station at Khanjarpur constructed in 1963-64 and rising main has already been completed their life. Due to defunct condition of rising main, at present the flow approx. 1.50 MLD pumped from Kanjarpur SPS directly discharging into Sot Mohalla Nala and contributing to pollution. So, the discharge of pumping through existing rising main deducted from Sot Mohalla Nala-1 and considered 1.62 MLD discharge for Sot Mohalla Nala-1.

**Table 4: Water Quality Characteristics of Nalas / drains**

| Parameter | Unit | Concentration | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | O/F 1 | O/F 2 | O/F 3 | O/F 4 | O/F 5 | O/F 6 | O/F 7 | O/F 8 | O/F 9 | O/F 10 | O/F 11 | O/F 12 | O/F 13 |
| pH | -- | 7.15 | 7.2 | 6.86 | 7.26 | 7.12 | 7.33 | 7.21 | 7.65 | 7.24 | 7.08 | 7.05 | 7.06 | 7.05 |
| TSS | mg/L | 870 | 360 | 320 | 180 | 127 | 369 | 562 | 121 | 224 | 840 | 911 | 715 | 528 |
| BOD (3 Days) | mg/L | 193.3 | 150 | 173.3 | 24 | 42.3 | 136.4 | 166.7 | 28 | 79 | 266.7 | 300 | 280 | 88 |
| COD | mg/L | 761.9 | 567.7 | 593.6 | 79.4 | 179.3 | 488 | 571.4 | 169.3 | 298.8 | 946.2 | 1075 | 962.2 | 297.6 |
| Ammonical Nitrogen (NH3-N) | mg/L | 6.2 | 6.2 | 6.2 | 3.6 | 4.2 | 5.4 | 5.1 | 3.2 | 4.6 | 5.8 | 0.2 | 5.5 | 2.9 |
| Total Phosphorus (as PO4) | mg/L | 3.9 | 4 | 4.1 | 1.7 | 2.1 | 3.2 | 2.9 | 1.8 | 2.0 | 3.3 | 3.9 | 3.3 | 2.8 |
| Total Nitrogen (as N) | mg/L | 11.8 | 12.2 | 11.4 | 5.4 | 8.6 | 10.2 | 9.8 | 6.9 | 8.2 | 10.4 | 10.3 | 10.4 | 5.4 |
| Faecal Coliforms | MPN / 100ml | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 |

## 6.2 Status of Existing Wastewater Disposal Works

The first sewerage scheme for Roorkee was introduced in 1963-64, excluding IIT Roorkee, CBRI and Cantonment area. The scheme comprised of laying of sewer line for a length of 22.0 Km and 02 nos sewage pumping stations along with rising main and sewage farm (150 acre) near Ibrahampur village.

The second sewerage scheme for Roorkee was executed in 1983-84 and thereafter the sewerage system was upgraded from time to time as and when required, but a comprehensive waste water management system has not been put in place for the complete town.

Sewerage Works in Phase-1 under ADB :- In Roorkee town, a sewerage system scheme was sanctioned by UUSDIP, Govt. of UK under ADB financial assistance programme. Under this scheme, only 12 wards out of 40 wards were fully covered and 8 wards were partially covered with sewerage network. Sewerage system comprising length of 78 km along with 02 nos sewage pumping stations and 33 MLD sewage treatment plant at Saliyar has been executed under this scheme. At present, existing

33 MLD STP is not running in its full capacity and receiving only 6 to 7 MLD sewage flow.

At present the open drains in the town act as the sewage carrier and in addition to this households and establishments on the bank of river Solani directly disposing their waste to the rivers.

The theoretical total sewage (DWF) generated in Roorkee is around 32.83 MLD for Year 2025. The increasing construction activities in the town has added to the degree of severity of the flow corridor and overflow of wastewater in open areas. The drains flow of the town ultimately reaches the river Ganga via the river Solani.

There are 13 (Thirteen) such major drainage channels which act as open sewer as well as to discharge the domestic wastewater and the surface runoff into the river Solani. No reliable updated database is currently available with Roorkee Nagar Nigam on the number of Domestic Units with toilets and corresponding informations on their connectivity to so called disposal system. As per the discussion with residents of the town, it is known that in the absence of complete structured sewerage system, septic tanks are the major form of treatment for the domestic sewage at source. Overflows from most of the septic tanks are connected to the open drains.

The 13 (Thirteen) Nalas flowing through the town carry the wastewater generated from residences as well as commercial establishments. The nalas ultimately flows through the channels constructed and discharge into the River Solani. This causes pollution in the river and enormous detrimental effect on overall aesthetic and hygiene condition of the town. This is further aggravated by indiscriminate disposal of solid wastes into the nalas. During the monsoons, roadside drains overflow and expose the populace to untreated sewage.

In absence of complete sewage collection and proper solid waste management system in town, the nalas are serving as the carrier of both sewage and solid waste generated from the town, which is finally carried to the River Solani.

### 6.3 Proposed Sewage Treatment Works

Roorkee is a fast growing urban body (Municipal Corporation), river side town and important institutional place in Uttarakhand State. The population of Roorkee has increased considerably in the past few years. However, the town is deprived of complete planned sewage management system. Therefore, a substantial quantum of wastewater generated in town and nearby area is being discharged in open or nearby nalas, which ultimately falls into river Solani, which is a tributary to River Ganga. Since the wastewater remains untreated till final disposal in river, it is adversely impacting the river water quality.

Lack of complete sewerage collection system in town possess dual threat: one in form of river water pollution due to incoming contaminated water through nalas and second overall hygiene condition of the town due to absence of sewage collection system in the town. At present the effect of discharge of untreated wastewater on river water quality is very minimal (due to high dilution factor); however, these problems are only going to worsen with time as the population of the town increases and town become more and more dense and also due to increased floating population.

The Sewage Pumping Station at Khanjarpur constructed in 1963-64 and rising main has already been completed their life. due to defunct condition of rising main, at present the flow pumped from Kanjarpur SPS directly discharging into Sot Mohalla Nala and contributing to pollution.

Therefore, there is a need to replace the existing rising main and repair and renovation of Khanjarpur SPS for immediate relief till the complete sewerage network system is in place in the city. In view of the above, replacement of the existing rising main and repair and renovation works of Khanjarpur SPS have been included in the DPR submitted by Uttarakhand Pey Jal Nigam (Annexure 8).

The above mentioned facts/shortcomings suggest the provision of new Scheme/Schemes with following components: -

- Outfall drains tapping with carrier / interceptor line to carry drains' flow towards STP / SPS, and
- Construction of STP / SPS for immediate complete abatement of pollution due to discharge of wastewater in river Ganga via the river Solani.

Following benefits are likely to be achieved:

- The expected project outcome is the reduction of pollution load from Roorkee town into river Ganga via river Solani along with the improvement in bio-diversity and eco-system of the river.
- River water quality improvement will result in improvement of ground water quality.
- Improvement in general hygiene and sanitation. It will also add to the overall aesthetics of the area.
- Reduction in pollution load on river Solani.

### 6.3.1 Interception and Diversion with STP (for Immediate Mitigation Measure to Curb River Pollution Caused at the Nala Outfalls)

As described in preceding sections at present nalas in town are acting as the ultimate sewage carrier in town before disposal to River Solani. So, there is an immediate requirement to curb this pollution load from falling into the river, in order to maintain its pristine nature. This will take place with immediate effect and will cover the time period from now to the time until implementation of comprehensive sewage collection network in town. Under this project Nala Interception and diversion (I&D) infrastructure will be developed along with wastewater treatment capacity to cater to the pollution load coming from the nalas. The I&D infrastructure thus proposed in this project will comprise of below given components with design horizon as mentioned:

**i) Nala tapping and interceptor/carrier line**

At present there are 13 nalas in town which carry wastewater along with surface run off directly to the river Solani. These nalas are the major concentrated point pollution loads coming to the river.

In order to effectively tap nalas and divert flow toward Collection Unit or Sewage Treatment Unit, it is proposed to strength existing nala section 10m before the tapping point, under this provision existing nala section will be constructed in RCC for the selected 10 m length at the outfall end of nala.

In order to effectively tap nalas and divert flow up to the inlet chamber of STP/SPS wet

well, it is proposed to construct Nala Tapping arrangements and lay interceptor/carrier line (DI K-7 Pipe) of 250 - 800 mm dia connected to nalas and wastewater outfalls from households directly falling into the river.

**ii) Sewage Pumping Station**

One sewage pumping station at Shamshan Ghaat, Mahigran is proposed to collect wastewater diverted from 09 nos of Nalas viz. Rampur Chungi Nala, Machchhi Mohalla Nala, Bandha Road Nala-1, Bandha Road Nala-2, Imli Road Nala-1, Imli Road Nala-2, Sot Mohalla Nala-1, Sot Mohalla Nala-2 & Dhobi Ghaat Nala.

At present, existing 33 MLD STP not running in its full capacity and receiving only 6 to 7 MLD sewage flow. Therefore, it is decided in joint meeting with Uttarakhand Jal Sansthan to divert flow from proposed SPS to existing 33 MLD STP.

**iii) Rising main**

Rising Main of DI K-9, 600 mm dia is proposed to divert the wastewater from sewage pumping station to existing 33 MLD Sewage Treatment Plant.

**iv) Sewage Treatment Plant**

Sewage Treatment Plant (STP) will be installed to treat the intercepted nala flow within the permissible limits set by NMCG (i.e. BOD:10 mg/l; Faecal Coliform: 100 mg/l; TSS: 10 mg/l)

One Sewage Treatment Plant near Shamshan Ghaat at Khanjarpur with capacity of 14.0 MLD will be installed to treat 04 nos of nala's flow, in future when complete sewer network will be in place the same STP can be utilized to cater the treatment of domestic wastewater generated from nearby residential and commercial areas. The treatment capacity if needed may be enhanced to cater domestic sewage generated up to the year 2041.

### v) Works for existing SPS and Rising Main at Khanjarpur

The Sewage Pumping Station at Khanjarpur constructed in 1963-64 and 350 mm dia rising main has already been completed their life. due to defunct condition of rising main, at present the flow pumped from Kanjarpur SPS directly discharging into Sot Mohalla Nala and contributing to pollution. Therefore, there is a need to replace the existing 350 mm dia rising main and repair and renovation of Khanjarpur SPS for immediate relief till the complete sewerage network system is in place in the city. In view of the above, replacement of the existing rising main and repair and renovation works of Khanjarpur SPS have been included in this DPR.

The details of proposed STP and SPS are summarized in Table 5 and depicted in Figure 2. The summary of proposed works is listed in Table 6.

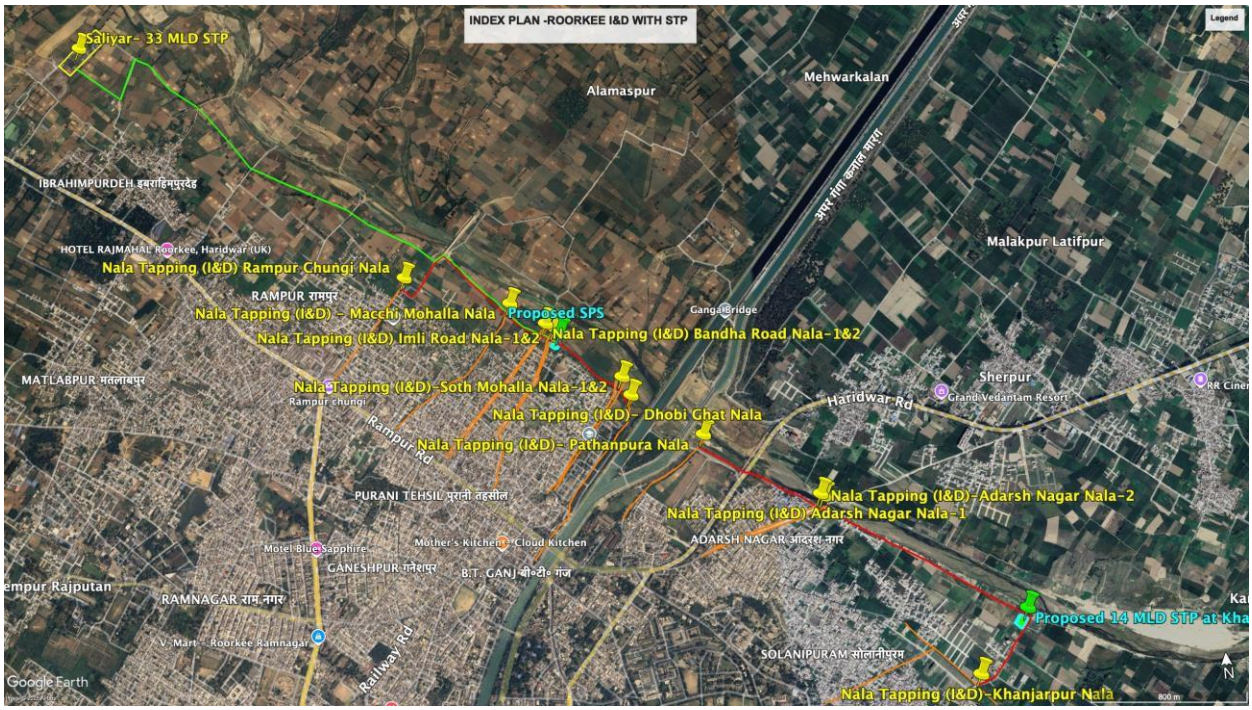



**Figure 2: Index map depicting interception / diversion of nalla and STPs**

## Table 5: Details of proposed STP & SPS

| S. No. | Collection Point | Description of source of Discharge | Avg. Flow for Base Year (2026) | Avg. Flow for STP Design Year (2041) | Capacity of STP (MLD) | Location of STP |
|---|---|---|---|---|---|---|
| **PART-A** | | | | | | |
| 1 | STP | Pathanpura Drain | 1.15 | 1.41 | **14.00** | Proposed Near Shamshan Ghat, Kanhapur, Khanjarpur |
| | | Adarsh Nagar Drain No -1 | 0.35 | 0.43 | | |
| | | Adarsh Nagar Drain No -2 | 0.50 | 0.61 | | |
| | | Khanjarpur Drain | 9.10 | 11.21 | | |
| | | **Sub Total** | **11.10** | **13.66** | | |
| **PART-B** | | | | | | |
| 2 | SPS near Shamshan Ghaat | Dhobi Ghat Nala | 0.89 | 1.10 | **SPS proposed & flow diverted from SPS to existing STP through Rising Main** | Existing 33.0 MLD STP, Saliyar |
| | | Sot Mohalla Nala-1 | 1.68 | 2.06 | | |
| | | Sot Mohalla Nala-2 | 1.72 | 2.11 | | |
| | | Emli Road Nala-1 | 0.38 | 0.47 | | |
| | | Emli Road Nala-2 | 10.26 | 12.64 | | |
| | | Bandha Road Nala-1 | 0.88 | 1.08 | | |
| | | Bandha Road Nala-2 | 0.35 | 0.43 | | |
| | | Machchhi Mohalla Nala | 0.37 | 0.46 | | |
| | | Rampur Chungi Nala | 0.40 | 0.50 | | |
| | | **Sub Total** | **16.93** | **20.85** | | |
| | | **Total (PART A + B)** | **28.03** | **34.51** | | |

**Table 6: Summary of Proposed Works**

| S. No. | Description of works | Qty. |
|---|---|---|
| **A.** | **Interception and Diversion Works** | |
| 1. | Nala Tapping Arrangements | 10 Nos |
| 2. | Interception/Carrier Line | 4.02 km |
| 3. | Sewage Pumping Station | 01 No. |
| 4. | Rising Main | 3.20 km |
| **B.** | **Sewage Treatment Plant** | |
| 1. | 14.0 MLD Capacity | 01 No |
| 2. | Upgradation of existing 33 MLD STP | 01 Job |
| **C.** | **Works for existing SPS & Rising Main at Khanjarpur** | 728 Nos |
| 1. | Repairs & Renovation of existing SPS | 01 Job |
| 2. | Replacement of existing rising main | 2.68 km |

## 7. REVIEW OF EXISTING TREATMENT FACILITIES FOR TREATMENT OF INDUSTRIAL EFFLUENTS AND DOMESTIC SEWAGE AND IMPROVEMENTS REQUIRED TO BE MADE

The industries located in the catchment of river Solani do not discharge wastewater in to river Solani, therefore, there is no requirement of CETP. However, regular surveillance will be carried out by the UKPCB ensuring that no wastewater is discharge in to river, illegally.

The performance monitoring of STP located at Saliyar is being carried out by UKPCBon monthly basis. The water quality characteristics of inlet sewage to STP and Outlet discharge from January, 2023 to June, 2024 is summarized in Table 7 (as per Annexure 6 of Status Report submitted by UKPCB). The data presented in the table shows that, most of the time, the water quality parameters of treated water followed the Prescribed Outlet Standards as per MoEF&CC under E(P) Rules, 1986 except at couple of occasions in case of Fecal Coliform only. However, the water quality

parameters of treated water did not follow the Prescribed Outlet Standards as per Hon'ble NGT almost 50% of time for all the water quality parameters.

**Table 7: Performance monitoring of data of 33 MLD capacity STP located at Saliyar (Roorkee) from January, 2023 to June, 2024**

| Month | INLET | | | OUTLET | | | |
|---|---|---|---|---|---|---|---|
| | pH | BOD (mg/L) | TSS (mg/L) | pH | BOD (mg/L) | TSS (mg/L) | Fecal Coliform (MPN/100 ml) |
| **Jan-23** | 7.70 | 225 | 206 | 7.60 | 86 | 96 | >1600 |
| **Feb-23** | 7.56 | 175 | 265 | 7.76 | 24 | 52 | 110 |
| **Mar-23** | 7.31 | 255 | 280 | 7.62 | 10 | 50 | 220 |
| **Apr-23** | 7.49 | 255 | 295 | 7.67 | 22 | 78 | 170 |
| **May-23** | 7.90 | 235 | 210 | 7.98 | 12 | 20 | 110 |
| **Jun-23** | 7.53 | 275 | 250 | 7.81 | 40 | 62 | 920 |
| **Jul-23** | 7.64 | 220 | 240 | 7.82 | 24 | 30 | 920 |
| **Aug-23** | 7.23 | 170 | 320 | 7.56 | 26 | 20 | 280 |
| **Sep-23** | 7.32 | 210 | 220 | 7.88 | 14 | 26 | 84 |
| **Sep-23** | 7.12 | 120 | 360 | 7.58 | 16 | 20 | 220 |
| | **Joint monitoring with Uttarakhand Jal Sansthan** | | | | | | |
| **Oct-23** | 7.23 | 255 | 260 | 7.68 | 28 | 30 | 1600 |
| **Nov-23** | 7.39 | 180 | 210 | 7.68 | 12 | 16 | 280 |
| **Dec-23** | 6.59 | 170 | 210 | 7.28 | 18.0 | 28.0 | 220 |
| **Jan-24** | 7.19 | 160 | 190 | 7.66 | 12.0 | 20.0 | 170 |
| **Feb-24** | 7.15 | 160 | 120 | 7.66 | 10.0 | 10.0 | 220 |
| **Mar-24** | 7.20 | 160 | 180 | 7.60 | 8.0 | 9.0 | 280 |
| **Apr-24** | 6.70 | 180 | 140 | 7.70 | 10.0 | 10.0 | 540 |
| **May-24** | 7.27 | 170 | 160 | 7.40 | 10.0 | 9.0 | 350 |
| **Jun-24** | 7.03 | 160 | 140 | 7.56 | 9.6 | 8.0 | 280 |
| **Prescribed Outlet Standards as per Hon'ble NGT** | | | | **5.5-9.0** | **<10** | **<20** | **<230** |
| **Prescribed Outlet Standards as per MoEF&CC under E(P) Rules, 1986** | | | | **6.5-9.0** | **<30** | **<100** | **<1000** |

## 8. REUSE OF TREATED WATER FROM STPS/CETPS FOR IRRIGATION BY CONNECTING THE SAME TO IRRIGATION CANALS/CHANNELS AND INDUSTRIAL PURPOSES BY LAYING DOWN PIPELINES CONNECTING THE CONCERNED INDUSTRIES

At present, no reuse of treated water from existing only STP at Saliyar is being carried out. During the time, the proposed plan for upgradation of sewage interception / diversion and treatment submitted by Uttarakhand Pey Jal Nigam is approved and executed, the plan for reuse of treated water for irrigation / industrial purposes from both the STPs (existing and proposed) may be prepared and submitted for approval and execution.

## 9. RECOMMENDATIONS

The following recommendations are made after detailed discussions among the members of Joint Committee:

1. Regular water quality monitoring of Solani River and the existing STP are being conducted by UKPCB on monthly basis. The water quality monitoring of Solani River upstream and downstream of major towns/peri-urban clusters and the existing STP should also be carried out on quarterly basis by the third party i.e. national level institutes with NABL accredited Labs.
2. The existing STP at Saliyar, Roorkee with the design capacity of 33 MLD is underutilized as only 6-7 MLD sewage is coming to the STP. The proposal for retrofitting for existing STP at Saliyar, Roorkee and for construction of new STP has been proposed by Uttarakhand Pey Jal Nigam (as Annexure 8). After execution of these works, it is expected that both the issues of under-utilization of existing STP and other sewage loads may be addressed significantly. There is need to execute this work as soon as possible detailing the milestones/deadlines for various steps.
3. UKPCB has reported that the existing industries do not discharge their effluents in the Solani River. However, considering the ongoing and expected future industrial developments in the Solani River Catchment especially near Bhagwanpur, Roorkee and Laksar, it is recommended that the upcoming

industrial units should set up Effluent Treatment Plant (ETP) alongwith recycling options to the maximum extent possible in their premises. The UKPCB should monitor on regular basis and ensure that no untreated industrial effluents may meet the Solani River.

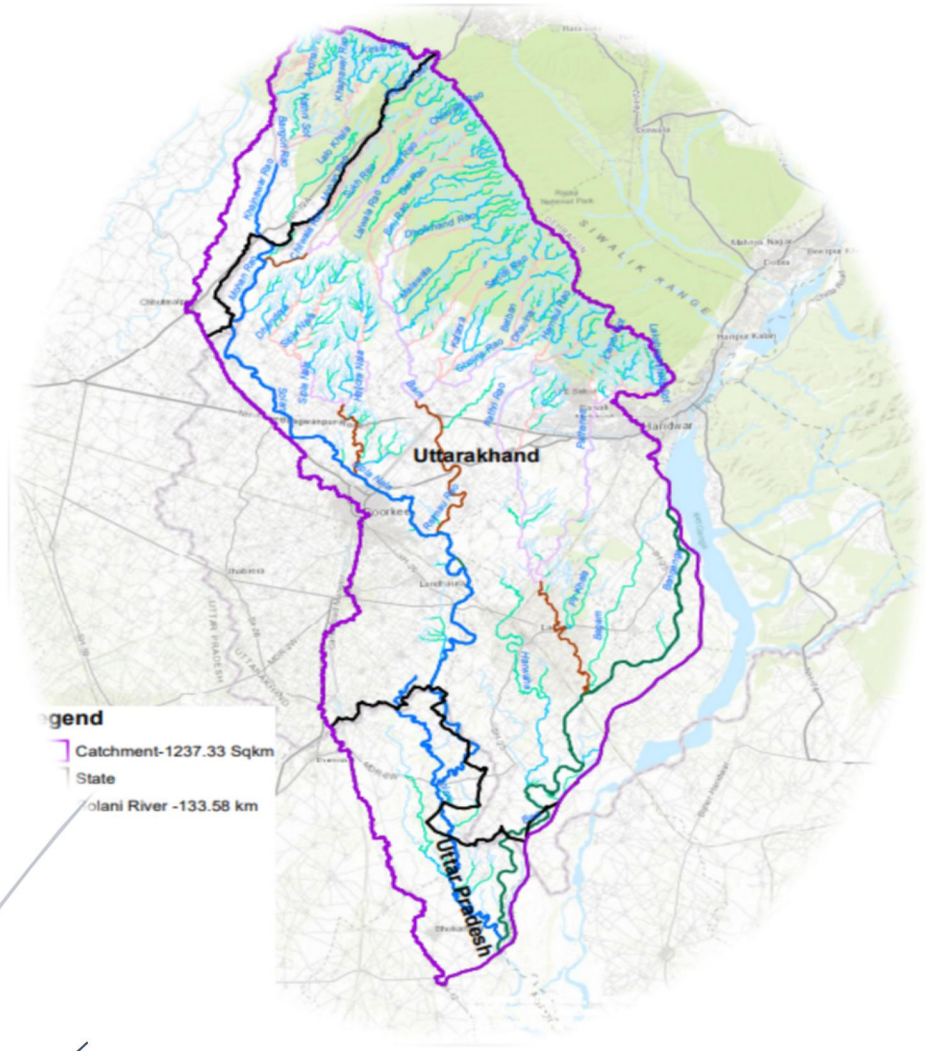
4. Considering the diminishing non-monsoon flows in Solani River affecting the river ecosystem, the detailed plan for rejuvenation of Solani river should be prepared engaging the national level institutes with proven expertise on the same.

***

Annexure No. 1

# SOLANI RIVER

## Rejuvenation Measures




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भारतीय नदी परिषद

# Solani River Survey

In the application number 632/2022 regarding Solani river filed by Shri VK Tyagi in the main bench of Hon'ble NGT, I (Raman Kant, President of Bhartiya Nadi Parishad) was included in the committee constituted by the division bench of Hon'ble Judge Shri Arun Kumar Tyagi and Hon'ble Expert Member Dr. Afroz Ahmed on 30th April, 2024.

In compliance with the instructions of Hon'ble NGT, on 18th and 19th June, I along with the team of Uttarakhand Pollution Control Board inspected the river from the origin of Solani river in Saharanpur to Haridwar district. During this, I saw all the major places of the river and all its aspects. During this, officials of Forest Department, Shivalik and Uttarakhand Jal Jal Sansthan were also present. On June 26, 2024, I, along with the team of Pollution Control Board, Muzaffarnagar, inspected the Solani river from its merger with Banganga at Sukhtirth to its merger with Ganga at Haiderpur Wetland.

In these three days, after talking to all the stakeholders related to the river and conducting a field inspection, I thoroughly examined the current problems of the river and prepared a framework for solution based on my experiences of river rejuvenation in the last 22 years.

## Contents

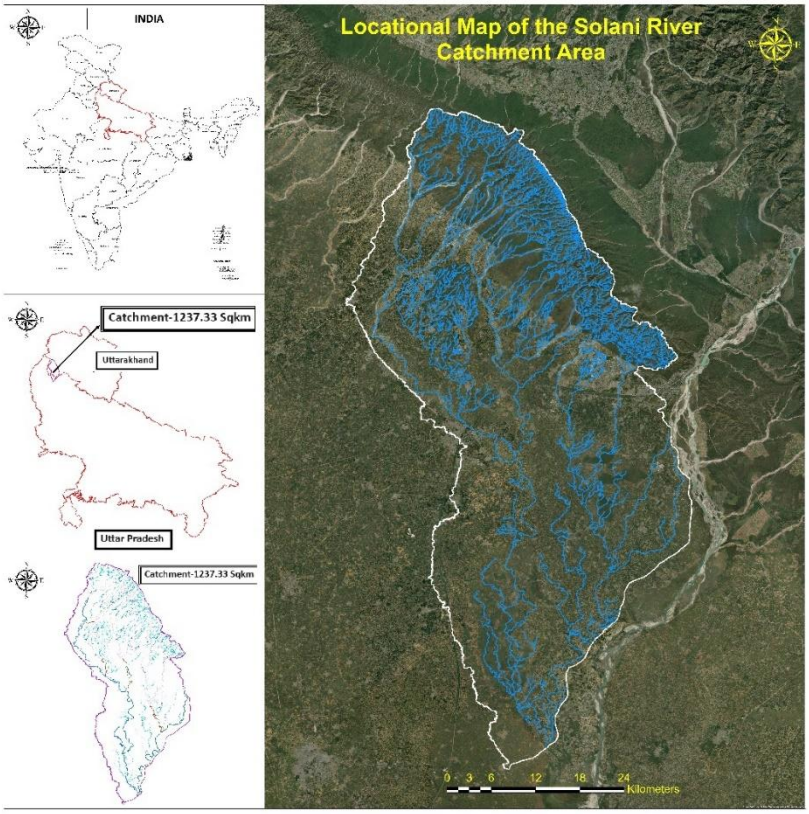
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# Introduction

The Solani River, a vital waterway in the northern Indian states of Uttarakhand and Uttar Pradesh, has long served as a crucial source of water for agriculture, drinking, and various domestic purposes for the communities living along its banks.

The Solani River originates from Saharanpur district in Uttar Pradesh and flows through Roorkee city in Haridwar district of Uttarakhand, then re-enters Muzaffarnagar district, Uttar Pradesh, reaching the historical and religious city of Sukhtirth, where it merges with Banganga. After originating, the Solani River covers a distance of approximately 145 kilometers passing through towns like Biharigarh, Bhagwanpur, Roorkee, and Laksar. It is a rain-fed river, almost dry during winter but prone to flooding during the monsoon, causing significant damage to low-lying areas along its banks. The Solani River has made its basin fertile for agriculture.

The Solani River originates in the Shivalik hills of Saharanpur district, formed by the confluence of two main streams, Khajnawar and Shahjahanpur, along with several smaller streams from these hills. Khajnawar and Shahjahanpur streams flow through the Shivalik forest about ten kilometers from the slopes of the Shivalik hills. After leaving the forest boundary, these streams converge approximately 10 kilometers downstream on the road from Dehradun to Sakumbhari near Saliyar Salahpur village. Before becoming the Solani River, it is joined by several other smaller streams. The Solani River flows gently, growing in size and importance. On the banks of the river in Saliyar Salahpur, there is a functioning stone crusher, while on the opposite side, a builder is constructing a colony on land adjacent to the river.



According to the British Gazetteer, the name Solani River is first given to the stream formed by the confluence of Chilawala, Kania, Sukh, and Mohand Rao, which drains the sub-mountainous region up to the edge of Mohand Rao. Near Thapal Ismailpur, it joins Rajwa and Khandur Rao, carrying the combined waters of Khajnawar and Shahjahanpur Rao, as well as Hatni Hot and other streams. The entire river is then known as Solani, flowing southeast along the high bank marking the eastern boundary of the upland plain.



Just above the town of Roorkee on its left bank flows the Sipiya River, a long stream originating from the valleys of the Sakrauda plateau and fed solely by rainwater from numerous tributaries such as Haljaura, Jakhani, and Dhandora. The Solani Aqueduct, an important engineering marvel, was constructed in the 19th century under the supervision of Sir Proby Cautley. Built in 1846 over the Purani Ganga Canal (Old Upper Ganga Canal), it is a significant example of brick masonry construction, spanning 15 spans of 50 feet each. The aqueduct, 980 feet long, stands as a landmark in civil engineering, a testament to the advancements of its time. At Roorkee, the Solani Great Canal passes beneath the aqueduct, continuing southeast to the northern boundary of Mangalore, where it meets the Ratmau River.

For the past year, about 400 cusecs of water has been released into the Ratmau River through the old Roorkee canal at the Dhanouri dam. At this location, the old Roorkee canal directly meets the Ratmau River on the same level, with a canal built over the river. There is also a barrage here where the water falls approximately 50 feet. About 500 meters downstream, around 1000 cusecs of water is directed into the Ratmau River through a canal of the new Roorkee canal. When the Ratmau River meets the Solani River northeast of Tod Kalyanpur and Sundhari villages below Roorkee city, the Solani River's water flow increases. However, during the monsoon, the Solani River carries much more water. Before joining the Solani River at Ratmau, it has already been joined by eight drains at various points. After the Ratmau River joins, the flow of the Solani River significantly increases, mixing the

clean water with domestic effluents from 14 drains originating in Roorkee city. At this point, the Solani River appears clear and clean. This area is expansive, and after rainfall, farmers practice temporary agriculture within the river.



Moving forward, the Solani River enters Muzaffarnagar district. In Muzaffarnagar, the Solani River reaches the historic and religious city of Sukhtirth.

About one kilometer before the main bathing ghat of Sukhtirth, Ghantaghar, the Solani River merges with Banganga flowing from the east. The Banganga River begins from a Ganga river stream near Katarpur Alipur village, Bahadarabad tehsil, Haridwar district, Uttarakhand, reaching Sukhtirth in Muzaffarnagar district, Uttar Pradesh. Here, after absorbing the Solani, it merges into the Ganga River basin at Haidarpur Wetland, on the west side of the Ganga Barrage in Bijnor.

Haidarpur Wetland, a Ramsar site, is crucial for its ecological significance, providing habitat to various bird species, aquatic life, and flora. The wetland plays a critical role in groundwater recharge, flood control, and maintaining ecological balance in the region. Banganga travels about 70 kilometers before joining the Ganga River.

Banganga is highly polluted due to receiving substantial drainage from Laksar near Idrishpur village, as well as untreated sewage from nearby villages like Mahatauli, Tanda, Mubarakpur, Chamrawal, Nehandpur Suthari, and Muzaffarpur Gujra Jadid. The main tributary of Banganga is Pathri, originating from Shivalik and passing through Hetampur Bahadarabad before joining Banganga.




Banganga's flow is low initially but increases during the monsoon. At its source, Banganga relies solely on rainwater to maintain its flow. Currently, Banganga is fed by rainwater runoff, untreated sewage from towns/villages in its catchment area, domestic and industrial effluents via the Laksar drain, domestic sewage via the Sultanpur drain, and tributaries like the Pathri and Solani rivers.




30°12'06.6"N 77°49'31.4"E

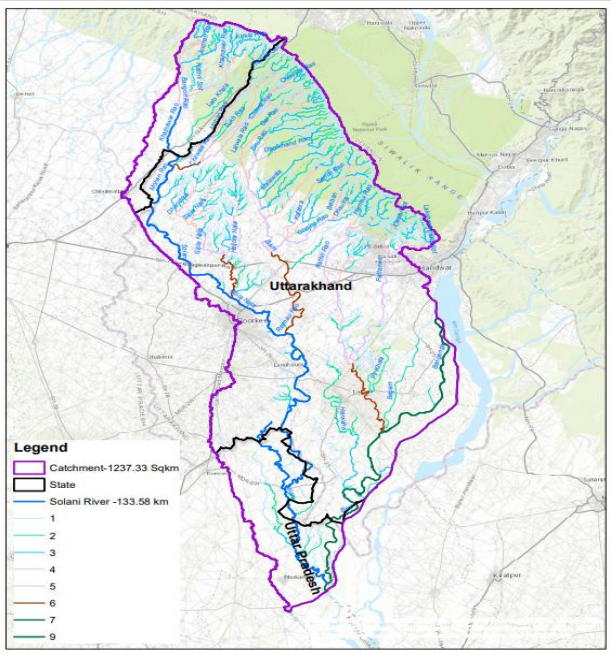
# Historical Background

Historically, the river has been revered not just for its ecological significance but also for its cultural and spiritual importance. However, over the past few decades, the Solani River has faced severe ecological degradation due to rapid urbanization, industrialization, and unsustainable agricultural practices. This report delves into the comprehensive rejuvenation efforts undertaken to restore the river, detailing the methods employed and the outcomes achieved.





# Current State of the Solani River




The Solani River, stretching 133.58 kilometers, plays a vital role in the region's hydrological dynamics. Originating and flowing through a diverse landscape, it interacts with various land cover types within its catchment area of 1237.33 square kilometers. The catchment encompasses 10.21 square kilometers of water bodies, 194.43 square kilometers of built-up areas, and 8.8 square kilometers of bare ground. Additionally, the region includes 1145.21 square kilometers dedicated to crops, 0.01 square kilometers of flooded vegetation, 61.03 square kilometers of rangeland, and 540.44 square kilometers of tree-covered areas. This mosaic of land uses not only underscores the ecological diversity but also highlights the multifaceted interactions between natural and anthropogenic elements influencing the Solani River.

| S.No. | Layer Name | Area SqKm and Length in km |
|---|---|---|
| 1 | Catchment Area | 1237.33 Sqkm |
| 2 | Waterbodies | 10.21 Sqkm |
| 3 | Built Area | 194.43 Sqkm |
| 4 | Bare ground | 8.8 Sqkm |
| 5 | Crops | 1145.21 Sqkm |
| 6 | Flooded vegetation | 0.01 Sqkm |
| 7 | Rangeland | 61.03 Sqkm |
| 8 | Trees/Vegetation | 540.44 Sqkm |
| 11 | Lineament | 135.58 km |
| 12 | Solani River | 133.58 km |

**Work to be Done for Solani River**

From my three-day river survey, extensive river research, and my river rejuvenation experience, I have identified the Solani River as a living river. It has sustained millions in Uttar Pradesh and Uttarakhand and is a major tributary of the Ganga.

**Presently, the Solani River faces three main challenges:**

- Water scarcity post-rainfall
- Encroachment
- Pollution

While there is no direct industrial pollution in the Solani River, it receives significant domestic wastewater discharge. Fourteen drains from Roorkee city discharge directly into the Solani River, resulting in polluted water at various points. A sewage treatment plant (STP) with a capacity of 33 MLD has been established in Salier, Roorkee, supported financially by the Asian Development Bank and operated by KEC Company since April 30, 2019. Currently, only 5 to 6 MLD of sewage reaches the plant due to inadequate drain connections. The sewage reaching the plant is not adequately treated due to the absence of a dedicated electricity supply, although it was planned to have one. Presently, the plant operates intermittently using generators. Several drains in Roorkee are situated on the eastern side of the canal, making connection to the STP nearly impossible. Consequently, these drains remain untreated. Moreover, sewage from approximately a dozen villages/towns flows directly into the river. Farmers cultivate the riverbed and its catchment, and the river has been encroached upon for various purposes in numerous locations.

# Causes of Degradation

1. **Urbanization**: The rapid expansion of urban areas along the Solani River has led to increased pollution from domestic sewage, industrial effluents, and solid waste. Unplanned urban sprawl has also resulted in the encroachment of riverbanks, disrupting the natural flow and reducing the river's capacity to self-cleanse.
2. **Agricultural Runoff**: The extensive use of chemical fertilizers and pesticides in agriculture has contributed to the pollution of the Solani River. Runoff from agricultural fields carries these harmful chemicals into the river, leading to eutrophication and the depletion of aquatic life.
3. **Industrialization**: The establishment of numerous industries in the region, particularly in Roorkee and its surrounding areas, has been a significant source of industrial pollutants entering the river. Effluents from these industries, often discharged without proper treatment, have severely contaminated the water quality.
4. **Deforestation**: The removal of vegetation along the riverbanks for agriculture and urban development has exacerbated soil erosion, leading to increased sedimentation in the river. This has reduced the river's depth and disrupted its ecological balance.
5. **Climate Change**: Changing weather patterns and reduced rainfall in the catchment area have further strained the already stressed Solani River, reducing its flow and exacerbating pollution levels.

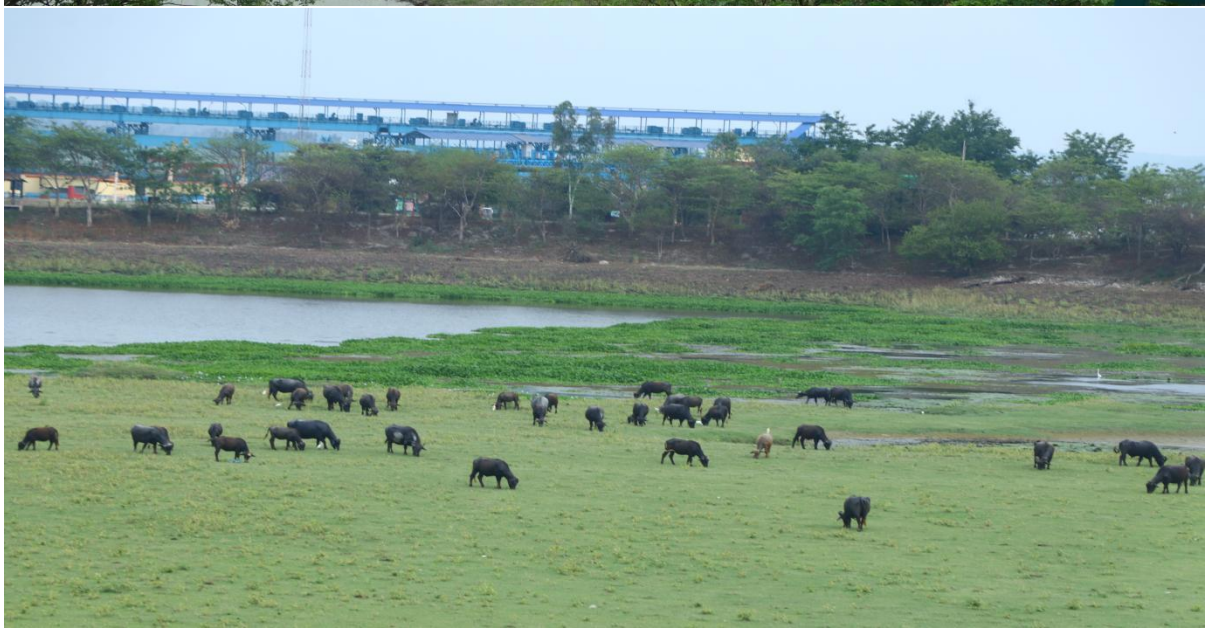












# Rejuvenation Methods

To address the multifaceted issues plaguing the Solani River, a holistic and multi-pronged approach need to be adopted, involving governmental agencies, local communities, non-governmental organizations (NGOs), and environmental experts.

Initially a Solani River Council need to be formed which can carry out the supervision of rejuvenation process and monitoring of Sonali River after it is revived.

**Solani River Council**

Solani River Council is a group that will take all the social decisions regarding the arrangement of clean and uninterrupted flow of Solani and its tributary rivers. It will not be a constitutional organization but a social organization formed at the level of society. This organization will worry about its river and will also take decisions for its betterment. All decisions will be under Indian rules and regulations and will be taken without any discrimination. The decisions taken by Solani River Council regarding Solani River will be informed in writing to the District Magistrate / Chief Development Officer of the concerned district out of all the seven districts of the river flow at the administrative level and it will be necessary to get their consent in the works under the authority of the administration. Solani River Council will be provided technical support by the Bhartiya Nadi Parishad and GIZ India.

**Structure of Solani River Council**

The Solani River Council will be formed by the Pradhans and Secretaries of the villages situated on the banks of the river in both the districts of the river flow area. Out of all these Pradhans, one will be elected as the President, Vice-President and Secretary of the Council on the basis of majority. The President and Vice-President will be elected from among the Pradhans, while the Secretary will be elected from among the village secretaries. The Solani River flows through three districts of two states, Saharanpur, Roorkee and Muzaffarnagar, in such a situation, separate councils can also be formed in the three districts. By doing this, there will be no problem in working from administrative point of view. Along with this, the tributary rivers of Solani will also be a part of Solani River Council. ?

**Village Committee**

Solani River Council will include the Pradhans of the villages along the river flow. It will be the responsibility of the Pradhan of each village to form a committee of ten or more members of such aware people under his chairmanship in his village, which will do the work of river improvement in that part of the village. The village secretary will be the secretary of this committee. The village Pradhan will appoint an aware person as the vice-president on the basis of majority. The meeting of the village committee will be held on the 2nd of every month at the place and time decided by the consent of the Pradhan and the secretary. In the meeting, the old works will be reviewed and the outline of new works will be made. The work of writing down the agenda of the meeting and the decisions taken during the meeting will be the collective work of the vice-president and the secretary. A register will be made for

this. Although this village committee will also be a part of Solani River Council, but only the village Pradhan and the village secretary will participate in the meetings of the council.

**Functioning of Solani River Council**

The Solani River Council will meet on the first of every month at a fixed place (the place will be a village on the river bank) and time with the consent of the Chairman and Secretary. In the meeting, the previous works will be reviewed and plans for future works will be made. The work of writing down the agenda of the meeting and the decisions taken during the meeting will be the collective work of the Vice Chairman and the Secretary. If the cooperation of the administration is also taken in making plans for the decisions taken in the meeting and in implementing those works, then the work will be completed in a better way.

**Rights of Solani River Council to take decisions:**

Solani River Council will have the following rights to take decisions-

- Related to cleaning the river.
- Related to plantation of trees on the river bank.
- Related to revival of ponds on the river bank or in the villages on the river bank.
- Related to stop liquid and solid waste in the river.
- Related to public awareness in the villages on the river bank.
- Related to making dams in the river.

Apart from this, Solani River Council will be able to take any decision regarding the betterment of the river under the administrative rules and regulations. The Secretary of Solani River Council will be responsible for bringing all the decisions and works related to Solani River Council to the notice of the Chief Development Officer of the district, correspondence and approval of those works etc.

**Publicity**

A WhatsApp group of the members of Solani River Council will be formed. All the members of Solani River Council will be included in it. Apart from this, people participating in the river improvement works in the village can also be included with the consent of the Chairman of the Council. From time to time, news related to the river works and decisions of the meeting can also be given to the local newspapers with the consent of the Council Chairman. Apart from this, for publicity of the works being done for the river, mediums like creating a website, creating a Facebook page and creating a Twitter handle etc. can also be used.

## Solani River Council & Saharanpur, Roorkee and Muzaffarnagar District

| SN | Pradhan Name | Father/Husband | Position | Age | Education | Occupation | Village | Block | Contact |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | President | | | | | | |
| 2 | | | Secretary | | | | | | |
| 3 | | | Vice-President | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4 | | | Member | | | | | | |
| 5 | | | Member | | | | | | |
| 6 | | | Member | | | | | | |
| 7 | | | Member | | | | | | |
| 8 | | | Member | | | | | | |
| 9 | | | Member | | | | | | |
| 10 | | | Member | | | | | | |
| 11 | | | Member | | | | | | |
| 12 | | | Member | | | | | | |
| 13 | | | Member | | | | | | |
| 14 | | | Member | | | | | | |
| 15 | | | Member | | | | | | |
| 16 | | | Member | | | | | | |
| 17 | | | Member | | | | | | |
| 18 | | | Member | | | | | | |
| 19 | | | Member | | | | | | |
| 20 | | | Member | | | | | | |

The rejuvenation methods can be broadly categorized into the following areas:

1. **Pollution Control and Waste Management**
    - **Sewage Treatment Plants (STPs)**: Establishing STPs along the major urban centers to ensure that domestic sewage is treated before being discharged into the river. These plants utilize advanced treatment technologies to remove contaminants and ensure the treated water meets environmental standards.
    - **Industrial Effluent Treatment**: Enforcing stringent regulations for industries to treat their effluents before discharge. Industries are mandated to install Effluent Treatment Plants (ETPs) and comply with environmental norms.
    - **Solid Waste Management**: Implementing comprehensive solid waste management systems in urban areas to prevent the dumping of waste into the river. This includes setting up waste segregation, collection, and disposal systems.
2. **Ecosystem Restoration**
    - **Afforestation and Riparian Buffer Zones**: Planting native vegetation along the riverbanks to prevent soil erosion, enhance biodiversity, and create natural filtration systems. These riparian buffers help in stabilizing the banks and filtering pollutants before they enter the river.
    - **Wetland Creation and Restoration**: Developing and restoring wetlands in the catchment area to act as natural water purifiers and provide habitat for wildlife. Wetlands help in sediment trapping, nutrient absorption, and maintaining the hydrological cycle.

   - **Bioremediation**: Employing bioremediation techniques using specific plants, microbes, and fungi to degrade pollutants in the river water. This natural method helps in reducing chemical contaminants and restoring the ecological balance.
3. **Water Resource Management**
   - **Rainwater Harvesting**: Encouraging the adoption of rainwater harvesting techniques in urban and rural areas to recharge groundwater levels and reduce surface runoff. This helps in maintaining the base flow of the river during dry periods.
   - **Check Dams and Reservoirs**: Constructing check dams and small reservoirs in the catchment area to store rainwater, reduce surface runoff, and promote groundwater recharge. These structures help in regulating the flow of the river and ensuring water availability during lean periods.
   - **Efficient Irrigation Practices**: Promoting water-efficient irrigation techniques such as drip and sprinkler irrigation among farmers to reduce water consumption and minimize agricultural runoff.
4. **Community Engagement and Awareness**
   - **Public Awareness Campaigns**: Conducting awareness campaigns to educate the local population about the importance of river conservation and the steps they can take to reduce pollution. Schools, colleges, and community centers are actively involved in these campaigns.
   - **Community Participation**: Encouraging local communities to participate in river monitoring, cleanup drives, and afforestation activities. Community-based organizations are empowered to take ownership of the river's health and actively contribute to its restoration.
   - **Sustainable Practices Promotion**: Promoting sustainable agricultural practices, such as organic farming and integrated pest management, among farmers to reduce the impact of chemical runoff on the river.
5. **Policy and Governance**
   - **Regulatory Framework**: Strengthening the regulatory framework to enforce environmental laws and regulations related to water pollution. This includes regular monitoring and penalizing violators to ensure compliance.
   - **Inter-agency Coordination**: Enhancing coordination between various governmental agencies, NGOs, and local bodies to ensure a unified and effective approach to river rejuvenation.
   - **Funding and Incentives**: Securing funding from government bodies, international organizations, and private sector initiatives to support rejuvenation projects. Providing incentives for industries and communities adopting sustainable practices.

**Recommendations for the Permanent Revival of the Solani River**

1. The name of the Solani River should be officially corrected from "Sonali" to "Solani" in NGT proceedings, aligning with historical and governmental documents.

2. Check dams and reservoirs should be constructed at the river's origin to retain rainwater, ensuring a consistent flow throughout the year, and providing water to wildlife.

3. Check dams should be built every five kilometres along the river's course below the Shivalik.

4. All the streams coming from Shivalik including the streams of Solani, Hindon etc., have been bringing a large amount of stones and debris for a long time, which has accumulated up to ten to fifteen feet in the flow of the stream below. In such a situation, the depth of all the streams including Solani in this area should also be increased.

5. Embankments should be constructed to prevent excessive spreading of the river in the Shivalik region.

6. The streams from Shivalik, including Solani and Hindon, have deposited considerable stones and debris over time, raising their bed levels by ten to fifteen feet. It is necessary to deepen these streams, utilizing the excavated debris for embankments and check dams. Increased depth will facilitate better water retention in these streams.

7. Immediate arrangements should be made to divert city sewage to the Roorkee STP.

8. Electricity supply to the STP should be ensured for regular operation.

9. For drains on the eastern side of the Roorkee canal, either a separate treatment plant should be constructed or natural treatment methods should be implemented. Various effective models exist across the country.

10. Natural methods should be adopted for treating sewage from villages and towns flowing directly into the river.

11. Riverbank demarcation should be implemented, and encroachments on river land should be removed. Permanent markers should be installed to prevent future encroachments.

12. Afforestation should be promoted in the vacant areas of the river basin.

13. Villages within one kilometre of both riverbanks should be considered part of the river basin. Ponds and lakes in these villages should be revitalized.

14. Solani River Councils should be established under village leadership in communities located within one kilometre of the riverbanks, involving them in river conservation efforts and public awareness campaigns.

15. Farmers should be encouraged to adopt chemical-free farming practices in these villages, with incentives for cultivating diverse fruit orchards on their land.

16. Agricultural activities within the river stream and its basin should be prohibited to prevent contamination from chemical fertilizers and pesticides.

17. Comprehensive river mapping should be conducted, including identification of fractured zones, to facilitate effective river management.

### Implementation and Phases

The rejuvenation project was divided into several phases to ensure systematic implementation and continuous monitoring:

1. **Phase I: Baseline Assessment and Planning**
    - Conducting a comprehensive assessment of the river's current state, including water quality analysis, biodiversity surveys, and identification of pollution sources.
    - Developing a detailed action plan outlining the specific interventions required and setting measurable targets.
2. **Phase II: Infrastructure Development**
    - Constructing sewage treatment plants, effluent treatment plants, check dams, and rainwater harvesting structures.
    - Initiating afforestation and wetland restoration projects.
3. **Phase III: Community Engagement and Implementation**
    - Rolling out public awareness campaigns and involving local communities in river monitoring and cleanup activities.
    - Implementing sustainable agricultural practices and promoting water-efficient irrigation techniques.
4. **Phase IV: Monitoring and Evaluation**
    - Regularly monitoring water quality, biodiversity, and the effectiveness of implemented interventions.
    - Making necessary adjustments based on feedback and ongoing assessments.

# Outcomes and Impact

The rejuvenation efforts will yield significant positive outcomes, contributing to the restoration of the Solani River's ecological health and improving the quality of life for the communities dependent on it:

1. **Improved Water Quality**: The establishment of sewage and effluent treatment plants can lead to a substantial reduction in the levels of pollutants in the river. Regular water quality monitoring will indicate a marked improvement in key parameters such as Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), and levels of heavy metals and toxic substances.
2. **Enhanced Biodiversity**: Afforestation and wetland restoration projects will contribute to the revival of biodiversity along the river. Native plant species will be reintroduced, providing habitat for various wildlife species. Aquatic life, including fish and amphibians, has shown signs of recovery, indicating the restoration of ecological balance.
3. **Increased Groundwater Levels**: Rainwater harvesting and the construction of check dams may help in recharging groundwater levels, ensuring a steady

flow of water in the river even during dry periods. This will alleviate water scarcity issues for the local communities and improved agricultural productivity.

4. **Community Empowerment and Participation**: The active involvement of local communities in the rejuvenation efforts can foster a sense of ownership and responsibility towards the river. Community-led initiatives will play a crucial role in sustaining the project's momentum and ensuring its long-term success.
5. **Sustainable Agricultural Practices**: The promotion of sustainable farming techniques will reduce the reliance on chemical fertilizers and pesticides, leading to a decrease in agricultural runoff and its associated pollution. Farmers will report improved soil health and crop yields, demonstrating the benefits of environmentally friendly practices.
6. **Policy and Governance Reforms**: The strengthened regulatory framework and inter-agency coordination can ensure effective implementation and enforcement of environmental laws. Regular monitoring and penalties for non-compliance may create a deterrent effect, encouraging adherence to pollution control measures.

# Conclusion

The rejuvenation of the Solani River stands as a testament to the power of collective action and the importance of adopting a holistic approach to environmental restoration. Through a combination of pollution control measures, ecosystem restoration, water resource management, community engagement, and policy reforms, the project can be successfully revived a vital waterway and improved the quality of life for the communities dependent on it. The positive outcomes might be achieved which can underscore the need for continued efforts to sustain the river's health and serve as a model for similar initiatives worldwide. As we move forward, it is imperative to build on the lessons learned and further strengthen our commitment to preserving and restoring our natural ecosystems for future generations.
















Haiderpur Wetland
FIELD MAP
Haiderpur Wetland Western Road
Northern Road
Canal Side Road
PARKING ENTRY GATE
CAR PARKING AREA
TOILET COMPLEX
GARDEN
ACTIVITY AREA
INTERPRETATION CENTRES
Birds View Area
Private Land
01. Wetland Entry Gate
02. Watchman Hut
03. Car Parking Area
04. Ticket Counter & Shopes
05. Canteen
06. Nature Camp
07. Interpretation Center
08. Toilet Complex
09. Northern Watch tower 1
10. Northan Wooden Watch tower 2
11. Western Wooden Watch tower 3
12. Petroling Watch tower
13. Natural Trail
14. Birds View Area
15. Private Land
16. Patrolling Boat
Bluethroat
Grey Lag Goose
Grebe
Greenshank
Greyheaded Lapwing
Gull
Rudy Shelduck
Warbler




# ANNEXURE 1:

## LIST OF VILLAGES IN THE CATCHMENT OF SOLANI RIVER

| S.No. | Village name | subdistric | district | state | lgd_vill |
|---|---|---|---|---|---|
| 1 | Rampur | Roorkee | Haridwar | Uttarakhand | 56502 |
| 2 | Ibrahimpurdeh | Roorkee | Haridwar | Uttarakhand | 56492 |
| 3 | Mohd Pur Bazurg Aht | Laksar | Haridwar | Uttarakhand | 56795 |
| 4 | Abdipur | Laksar | Haridwar | Uttarakhand | 56902 |
| 5 | Kuwan Khera Aht | Laksar | Haridwar | Uttarakhand | 56798 |
| 6 | Karaundi | Roorkee | Haridwar | Uttarakhand | 56403 |
| 7 | Kuwan Khera Must | Laksar | Haridwar | Uttarakhand | 56797 |
| 8 | Bhainsarhedi Ah | Narsan | Haridwar | Uttarakhand | 56532 |
| 9 | Alampur | Laksar | Haridwar | Uttarakhand | 56915 |
| 10 | Dhadhekidhana Majahidpur Aht | Laksar | Haridwar | Uttarakhand | 56804 |
| 11 | Jalalpur Mu | Roorkee | Haridwar | Uttarakhand | 56505 |
| 12 | Bhainsarhedi Mu | Narsan | Haridwar | Uttarakhand | 56527 |
| 13 | Shikarpur | Narsan | Haridwar | Uttarakhand | 56592 |
| 14 | Uleheri | Narsan | Haridwar | Uttarakhand | 56531 |
| 15 | Mandawar | Bhagwanpur | Haridwar | Uttarakhand | 56347 |
| 16 | Sisauna | Bhagwanpur | Haridwar | Uttarakhand | 56352 |
| 17 | Kishanpur Jamalpur | Roorkee | Haridwar | Uttarakhand | 56404 |
| 18 | Saliyer Salhapur | Roorkee | Haridwar | Uttarakhand | 56406 |
| 19 | Hazzarpur Ah | Narsan | Haridwar | Uttarakhand | 56594 |

| | | | | | |
|---|---|---|---|---|---|
| 20 | Sikanderpur | Laksar | Haridwar | Uttarakhand | 56901 |
| 21 | Hasanpur Madanpur M | Bhagwanpur | Haridwar | Uttarakhand | 56345 |
| 22 | Kagwali | Narsan | Haridwar | Uttarakhand | 56624 |
| 23 | Mukeempur Ah | Narsan | Haridwar | Uttarakhand | 56611 |
| 24 | Shahpur CT | Bhagwanpur | Haridwar | Uttarakhand | 56627 |
| 25 | Sikandarpur Mawal | Narsan | Haridwar | Uttarakhand | 56619 |
| 26 | Khanjarpur CT | Roorkee | Haridwar | Uttarakhand | 56634 |
| 27 | Lawwa | Bhagwanpur | Haridwar | Uttarakhand | 56350 |
| 28 | Naqibpur Ghosipura | Narsan | Haridwar | Uttarakhand | 56615 |
| 29 | Bheekar Gospur | Narsan | Haridwar | Uttarakhand | 56616 |
| 30 | Lodiwala | Bhagwanpur | Haridwar | Uttarakhand | 56338 |
| 31 | Toda Kalyanpur Ah | Roorkee | Haridwar | Uttarakhand | 56508 |
| 32 | Aurangzeb Pur | Bhagwanpur | Haridwar | Uttarakhand | 56337 |
| 33 | Ahamadpur Khedi | Bhagwanpur | Haridwar | Uttarakhand | 56342 |
| 34 | Dhadheki Dhana Majamidpur Must | Laksar | Haridwar | Uttarakhand | 56803 |
| 35 | Kanhapur M | Roorkee | Haridwar | Uttarakhand | 56433 |
| 36 | Makanpur Mahmood Alampur | Bhagwanpur | Haridwar | Uttarakhand | 56354 |
| 37 | Gin Mohd Shaheed Pur | Bhagwanpur | Haridwar | Uttarakhand | 56351 |
| 38 | Bhagwanpur CT | Bhagwanpur | Haridwar | Uttarakhand | 56628 |
| 39 | Puhana | Roorkee | Haridwar | Uttarakhand | 56405 |
| 40 | Chauli Shahbuddin Pur | Bhagwanpur | Haridwar | Uttarakhand | 56348 |
| 41 | Malakpur Latifpur | Roorkee | Haridwar | Uttarakhand | 56503 |
| 42 | Thoi | Narsan | Haridwar | Uttarakhand | 56625 |
| 43 | Madarpur | Laksar | Haridwar | Uttarakhand | 56913 |
| 44 | Jalalpur Ah | Roorkee | Haridwar | Uttarakhand | 56507 |
| 45 | Bangherimahabatpur Must CT | Roorkee | Haridwar | Uttarakhand | 56635 |
| 46 | Aamkheri | Narsan | Haridwar | Uttarakhand | 56614 |
| 47 | Khedi Shikohpur | Bhagwanpur | Haridwar | Uttarakhand | 56341 |
| 48 | Latifpur Khubban Pur | Bhagwanpur | Haridwar | Uttarakhand | 56349 |
| 49 | Sundhari | Narsan | Haridwar | Uttarakhand | 56526 |
| 50 | Hasanawala | Bhagwanpur | Haridwar | Uttarakhand | 56336 |
| 51 | Roorkee Npp | Roorkee | Haridwar | Uttarakhand | 247848 |
| 52 | Yahayyapur | Laksar | Haridwar | Uttarakhand | 56903 |
| 53 | Mundalana | Narsan | Haridwar | Uttarakhand | 56613 |
| 54 | Hazzarpur Mu | Narsan | Haridwar | Uttarakhand | 56593 |
| 55 | Zaurasi Mu | Narsan | Haridwar | Uttarakhand | 56534 |
| 56 | Zaurasi Ah | Narsan | Haridwar | Uttarakhand | 56533 |
| 57 | Abul Hasanpur Urf Ghisarpadi M | Narsan | Haridwar | Uttarakhand | 56608 |
| 58 | Abul Hasanpur Urf Ghisarpadi A | Narsan | Haridwar | Uttarakhand | 56609 |
| 59 | Mominpur | Hardwar | Haridwar | Uttarakhand | 56696 |
| 60 | Majri Akbarpur | Laksar | Haridwar | Uttarakhand | 56788 |
| 61 | Jogawala | Laksar | Haridwar | Uttarakhand | 56945 |

| | | | | | |
|---|---|---|---|---|---|
| 62 | Bhadoli | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110882 |
| 63 | Nanupur | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110879 |
| 64 | Damaatpatti | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110877 |
| 65 | Razkallapur | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110890 |
| 66 | Faridpur | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110905 |
| 67 | Hajipur Jahangirpur | Jansath | Muzaffarnagar | Uttar Pradesh | 111327 |
| 68 | Bulakipur | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110876 |
| 69 | Mandanwala | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110894 |
| 70 | Nurnagar | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110865 |
| 71 | Majlishpur | Jansath | Muzaffarnagar | Uttar Pradesh | 111323 |
| 72 | Bhadola | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110881 |
| 73 | Sherpur | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110891 |
| 74 | Almawala | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110897 |
| 75 | Firozpur Khadar | Jansath | Muzaffarnagar | Uttar Pradesh | 111330 |
| 76 | Sukertari | Jansath | Muzaffarnagar | Uttar Pradesh | 111329 |
| 77 | Kherki | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110887 |
| 78 | Farakhpur | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110889 |
| 79 | Baikunthpur | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110886 |
| 80 | Chamrawala | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110895 |
| 81 | Dadupur | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110880 |
| 82 | Panchli | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110888 |
| 83 | Suheli | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110909 |
| 84 | Marakpur | Muzaffarnagar | Muzaffarnagar | Uttar Pradesh | 110883 |
| 85 | Sikari | Jansath | Muzaffarnagar | Uttar Pradesh | 111319 |
| 86 | Badshahpur | Behat | Saharanpur | Uttar Pradesh | 109071 |
| 87 | Khushalipur | Behat | Saharanpur | Uttar Pradesh | 109070 |
| 88 | Thappel Ismailpur | Behat | Saharanpur | Uttar Pradesh | 109072 |





Annexure No. 2

# CONSULTANCY WORK FOR FLOOD PLAIN ZONING IN ACCORDANCE WITH UTTARAKHAND FLOOD PLAIN ZONING ACT-2012 FOR SOLANI-RATMAU RIVER

## CLIENT

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| 18 | 12 Hour bell distribution of rainfall | 36 |
| 19 | Hourly Distribution of Rainfall | 36 |
| 20 | Critical sequencing for Effective hourly rainfall | 37 |
| 21 | 50yr Return Period flood for Solani River | 38 |
| 22 | 50 yr Design Flood Hydrograph for Solani River | 39 |
| 23 | RP rainfall depth for 12-hour bells | 40 |
| 24 | 12 Hour bell distribution of rainfall | 40 |
| 25 | Hourly Distribution of Rainfall | 41 |
| 26 | Critical sequencing for Effective hourly rainfall | 42 |
| 27 | 25yr Return Period flood for Solani River | 43 |
| 28 | 25 Year Design Flood Hydrograph for Solani River | 44 |
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| | | |
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## List of Abbreviation

| S.No. | Abbreviation | Description |
|---|---|---|
| 1 | CWC | Central Water Commission |
| 2 | DEM | Digital Elevation Model |
| 3 | DTM | Digital Terrain Model |
| 4 | DGPS | Differential Global Positioning System |
| 5 | HFL | Highest Flood Level |
| 6 | GCP | Ground Control Points |
| 7 | PMP | Probable Maximum Precipitation |
| 8 | SUH | Synthetic Unit Hydrograph |
| 9 | LULC | Land Use land Cover |
| 10 | NDMA | National Disaster Management Authority |
| 11 | FPZ | Flood Plain Zoning |
| 12 | FFA | Flood Frequency Analysis |

## Abstract: -

India as a country has much of its concern towards natural calamities due to its location, topography, hydro-meteorological conditions. Out of many numbers of natural calamities flood constitutes one of the major national calamities faced almost every year resulting in substantial loss of life, large scale damage to property, disruption of community lifelines besides entailing untold misery to the millions. Concerted efforts have been made over the years to reduce the damage due to floods and mitigate the sufferings of the people. Various structural flood control measures were taken-up in the past including construction of reservoirs, embankments, drainage channels, etc. It is however, now realised that absolute and permanent protection to all flood prone areas and for all magnitudes of floods by structural measures alone is impossible due to constraints of time, money and land. So the emphasis will be on non-structural measures like Flood Plain Zoning and regulation, flood risk mapping, flood forecasting etc. to effectively supplement the structural measures for providing sustainable protection to flood affected areas.

Uttarakhand is an Indian Himalayan State known for its rich spiritual and religious tourism, ecological richness & diversity, and cultural ethos rooted in traditions, but it is also known for growing frequency and intensity of natural disasters and for its fragility of ecological and geological systems. Consisting mostly of uplifted sedimentary & metamorphic rocks and tectonically very active, the region is vulnerable to natural disasters. Due to its geo-climatic, ecological and socio- economic settings, Uttarakhand is one of the most disaster-prone States of the country.

Floods of varying magnitude, affect low lying areas and river valleys in Uttarakhand, due to variability in the monsoonal rainfall. However, the rapid increase of population and developmental activities in this hilly state aggravated the situation.

Cloudburst and related floods during August 1998 at Ukhimath (Rudraprayag) and Malpa (Pithoragarh), August 2001 at Phata (Rudraprayag), August 2002 at Burakedar (Tehri), August, 2012 in Asi Ganga (Uttarkashi), September, 2012 at Ukhimath (Rudraprayag) and June 2013 at Kedarnath (Rudraprayag), Feb 2021 in Rishi ganga and Dhauliganga are some of the examples of recent floods. Out of all the disasters the Kedarnath flood remain the worst.

## Executive Summary: -

Flood as a natural disaster is a sensitive issue for the Himalayan state like Uttarakhand. The magnitude and frequency of the flood are increasing from year to year. There are number of occasions of such flood disasters that happened over near past are of Kedarnath flood of 2013, Joshimath flood of 2021, and the flood over most part of Uttarakhand during 2023. A huge number of life & properties is lost during the disasters which is creating a socio-economic imbalance in the state. July 2023 saw 201.4 mm of rain, which is 14% more than the normal of 176.8 mm which was observed one the heaviest rainfall in past few years

There are number of measures to mitigate the effect of flood like Structural and Non-structural measures. Due to the involvement higher cost, time and land requirements the structural measures are scarcely used whereas due to easy implementation processes the non-structural measures like flood plain zoning, flood risk mapping, flood warning/forecasting are largely implemented. While flood plain zoning is a proven technique for reducing the flood damages, the state of Uttarakhand has adopted this in principle to delineate the flood plain zoning lines in order to demarcate the areas along the flood plains according to the effect of flood damages as per NDMA guidelines.

The entire rivers selected for flood plain zoning are divided in three lots. The rivers Solani and Ratmau falls in Lot number 3. Initially the survey work of the flood plain is done by using DGPS, Total Station as well as Drone Survey. The appropriate Digital Elevation Model is also procured for use in Hydraulic model. The rainfall and discharge data is collected from respective sources. Due to non-availability of sufficient discharge data, the two rivers are treated as ungauged and the discharge calculation is done on the concept of Synthetic Unit Hydrograph. The maximum rainfalls have been obtained from PMP ATLAS and disaggregation of the data is done as per the defined process. The design discharge is obtained after performing critical sequencing of the rainfall. The discharge values are obtained for the 5-, 25-, 50- and 100-year return periods.

The hydrodynamic modelling is applied to the obtained design discharge. The HEC-RAS software is used to make the analysis. Both 1-D and 2-D modelling analysis is done to the given data. The cross-sections obtained at 50m interval, the DEM data, DGPS survey data are combined together

for a hybrid DEM which remain the input for our model. The design discharge data remain the hydrologic input for the model. The local Manning's Constant (n) values are taken as per the river stretch configuration. The outputs in the form of flood lines corresponding to 5, 25, 50 and 100-year flood lines are obtained which are communicated to field staff for putting the marks at field at 50 m intervals. The same has been done in presence of field staff as well as the Survey team.

The task of placing the flood lines in the Shajra map is essential for finalising the flood inundation lines as well as fixing the flood zones i.e the restrictive, prohibitive and warning zones. The same has also been done and submitted to appropriate authority. Mean time two workshops were held at Irrigation department Seminar Hall, one on 7$^{th}$ Oct. 2023 where the discussion on study area and approach & methodologies were discussed and in the second workshop on 12$^{th}$ March, 2024, the outcomes of the analysis basically the flood lines and implementations are discussed. The remarks and suggestions for improvements/corrections were gladly accepted and rectified in the present report.

The flood plain zoning work is highly essential for the rivers as the utility of flood plain is important due to the land constraints. Further the frequency of flood and climate change driven floods are more frequent now. So, in one hand the safety of life and property and in other the increasing the utility of land have to be balanced. In that context, making flood plain zoning for sensitive rivers is the foremost step.

This study regarding flood plain zoning completes all the scopes assigned to the specific problem.

Expecting a healthy co-operation from all

Warm Regards

**VISIONTEK CONSULTANCY SERVICES PVT LTD**
**BHUBANESWAR**

# 1. Introduction

The floods are usual phenomena at Uttarakhand state. The network of rivers coming from hills, passing through a tough terrain and finally reaching at plains and the high slope encountered during their travel makes the scenario difficult when a high intense rainfall continues for a significant duration. Many damages and loss of lives and properties are recorded during past and few of them of recent times are presented.

## 1.1 Kedarnath Flood (June 16-17,2013)

Over Sunday and Monday, June 16-17, 2013, when a series of cloudbursts wreaked havoc in 5 districts of Rudraprayag, Uttarkashi, Chamoli, Pithoragarh and Tehri, there were nearly 12,000 people at Kedarnath and Gaurikund the stretch that bore the brunt of the deluge. Ten days later, about 6,000 had been rescued from Kedarnath. More than 800 bodies were recovered in and around Kedarnath. Hundreds were reported missing.



**Fig-1:- Flood at Rishikesh:-**

The cloudbursts led to flash floods that swept away mountainsides, villages, people, animals, houses, trucks, cars, roads... nothing escaped. Nothing survived, it had no hope of surviving. The first of the cloudbursts-signalled by something that sounded like a sudden explosion that shook most of the houses--at Kedarnath took place around 7.30 pm on June 16. The check dam behind the temple crumbled and water gushed towards the temple. A second cloudburst on the morning of June 17 made the Chorabari Tal breach its walls. The massive amount of water released from the lake, combined with that of the incessant rain, flowed down and brought with it a massive

mudslide that dislodged boulders and brought them down. All those structures that had withstood the previous night's onslaught perished under the sheer speed and weight of the water.

The floodwaters weren't content with ravaging the town of Kedarnath. As it flowed downhill towards flat land, it went through nearly 200 villages with such terrifying speed that the villagers had little or no time to escape. The result: houses, two-three storey buildings came crashing down as the floodwaters washed away the earth they were standing on, people and livestock were no exceptions. Roads and bridges soon became part of the debris the water was carrying with it.

## 1.2 Flood of Year 2021: -

On Sunday morning of 7th February 2021 at 10:08Hrs, a massive flash flood took place along Rishi Ganga River valley of Chamoli district. As per the official records, among 204 died people only 80 dead bodies retrieved and 124 people's bodies still missing which were later declared dead after long search operation. In this flood, Rishiganga Hydropower project and under construction Tapovan Vishnugad Hydropower project were also extremely damaged. In addition, flood also dismantled a bridge near the confluence of Dhauliganga and the Rishiganga (1985m.a.s.l.). Several disturbing live footages recorded by eyewitness were surfaced online through news channels and social media platforms. In the immediate aftermath of the event, based on the recorded videos, it was speculated that the flood was most probably triggered by

Glacial Lake Outburst Flood (GLOF) event. However, early aerial surveys and available satellite imagery data confirmed that the flash flood was triggered by failure of a massive rockslide just below Ronti peak in the Nanda Devi massif.(Singh et.al.2022)

Among the places most severely hit by the floods are Joshimath, Rini, Nanda Devi National Park, Tapovan Vishnugad Hydropower Plant and Sridhar.

The disaster left over 200 killed or missing. As of May 2021, "83 bodies and 36 human body parts out of a total of 204 people missing have been recovered so far. Of the missing and dead, 140 were workers at the Tapovan Hydropower Plant site.

## 1.3 Flood Plain Zoning

The basic concept of flood plain management is to regulate the land use in the flood plains in order to restrict the damage due to floods, while deriving maximum benefits from the same. This is done by determining the locations and the extent of areas likely to be affected by floods of different magnitudes/ frequencies and to develop those areas in such a fashion that the resulting damage is minimum in case the floods do occur. Flood Plain Zoning, therefore aims at disseminating, such 'potential loss' information on a wider basis so as to regulate indiscriminate and unplanned development in flood plains and is relevant both for unprotected as well as protected areas.

Flood Plain Zoning recognises the basic fact that the flood plains are essentially the domain of the river, and as such all developmental activities in flood plains must be compatible with the flood risk involved. Heavy encroachment of flood plains has been responsible for increasing trend of damage over the years. The need for Flood Plain Zoning has received recognition at various fora in the past also.

As far back as 1973-74, the Central Water Commission (CWC) had prepared guidelines 18 for Flood Plain Zoning which were approved by the Central Flood Control Board. Since the implementation of these guidelines needed statutory backing, CWC also prepared a model draft bill which was circulated in 1975 by the then Ministry of Irrigation, Government of India, to all the States advising them for enactment of a suitable legislation. In pursuance of the provisions of clause (3) of Article 348 of the constitution of India, the Uttarakhand Government passed the Uttarakhand Flood Plain Zoning Act 2012. The aftermath of 2013 Kedarnath flood, the Honourable Supreme Court and the Honourable National Green Tribunal (N.G.T.) has taken a serious note of that and in the lights of the directions passed by Honourable Supreme Court and subsequently by the Honourable N.G.T., it becomes imperative to decide the limiting boundary for rivers/streams in Uttarakhand. For regulating land use in different flood zones, the National Disaster Management Authority (N.D.M.A.) has classified following priorities in respect of construction of buildings and other utility services (Table 1).

## 1.4 Objective of Study

Flood-plain zoning is a concept for flood plain management. It recognizes the basic fact that the flood plain of a river is essentially its domain and any intrusion into or developmental activity

therein must recognize the river's 'right of way'. Flood plain zoning measures aim at demarcating zones or areas likely to be affected by floods of different magnitudes or frequencies and probability levels, and specify the types of permissible developments in these zones. The objective is to document flood plain boundaries based on channel configuration, geometry, bed form and profile characteristics of the identified major rivers of Uttarakhand together with their hydraulic characteristics and to identify areas/stretches where the stream flow is likely to have adverse impact on human interests during spells of high discharge caused by flood or flash flood. It will include flood plain Zoning based on the modelling results for the characteristic discharges calculated for the said streams (flood frequencies of say 5 years, 25 years, 50 years, and 100 years return period). The study is also intended to provide detailed account/database for engineering design and others, of the various flood control/mitigation measures and channel improvement measures near habitations along the river course so as to reduce the impact of the flood disaster on human life, property and adjoining habitation.

## 1.5 Scope of Works

The scope of work in the light of objectives discussed above shall include stipulated tasks under following heads which shall be completed as per NDMA guidelines.

1. Preparation of Digital /Survey maps of the streams as mentioned above, showing all the major cities, towns, semi urban development using satellite imageries or suitable latest techniques.

2. Preparation of Detailed Maps showing habitation around the rivers.

3. Calculation of Characteristic flood discharges of all the major streams based on flood frequency analysis.

4. Defining the streams in the sensitive reaches based on the results found as per para 4 above.

5. The prime objective of this assignment is to restrict/prohibit the human activities in the river flood plains. Since the reserve forests/national parks are already protected by law hence the river reaches falling in these areas will be excluded from the study. However civil lands having forest cover will be included.

6. Tabulation of flood plain boundary limit in various cities /towns villages, in general depending on desired waterway to pass the characteristic discharge.

7. Preparation of digital /GIS map showing the defined prohibitive, regulating, and warning zone as per NDMA flood plain zoning guidelines.

8. Preparation of digital GIS maps showing flood plain boundaries for floods of return periods and the map will be prepared showing the defined zone boundary.

9. To estimate water surface profiles employing hydro-dynamic river flow model.

10. All survey work & data acquisition from different agencies will be done by the consultant.

11. Consultant shall assist the department to clarify the methodology and other technical issues related to the task, before the Govt., Honorable N.G.T. or any other court if required.

12. River Cross-section Interval in habitations the cross-section interval should not be more than 50 m c/c. In other habitable reaches this interval should not be more than 500m. In hilly/forest areas the cross-section interval may be chosen suitably for the required level of accuracy.

### 1.6 NDMA Guidelines

The scope of work provided above and the expected deliverables are inline to meet the guidelines provided by national Disaster Management Act Jan 2008. Below are the guidelines from the NDMA document: In the regulation of land use in flood plains, different types of buildings and utility services can be grouped under three priorities from the point of view of the damage likely to occur and the flood plain zone in which they are to be located:

**Table 1: NDMA guidelines for Flood Plain & Land Utilization**

| Priority | Reach |
|---|---|
| **Priority 1** | • Defence installations,<br>• Industries,<br>• Public utilities like hospitals, electricity installations, water supply, telephone exchanges, aerodromes, railway stations, commercial centres, etc.<br>Buildings should be located in such a fashion that they are above the levels corresponding to a 100-year frequency or the maximum observed flood levels. Similarly, they should also be above the levels corresponding to a 50-year rainfall and the likely submersion due to drainage congestion. |
| **Priority 2** | • Public institutions,<br>• Government offices, universities, public libraries and residential areas. -Buildings should be above a level corresponding to a 25-year flood or a 10-year rainfall with stipulation that all buildings in vulnerable zones should be constructed on columns or stilts as indicated above. |
| **Priority 3** | • Parks and playgrounds. -Infrastructure such as playgrounds and parks can be located in areas vulnerable to frequent floods.<br>• Since every city needs some open areas and gardens, by restricting building activity in a vulnerable area, it will be possible to develop parks and play grounds, which would provide a proper environment for the growth of the city. |

## 1.7 Methodology: -

Besides the gauged locations the other locations where scanty or intermittent flow data are available does not give a clear scenario of the flow pattern. At ungauged locations, determining the discharge is always a challenge for doing subsequent hydrological analyses. Simultaneously it is also difficult to put the gauges at all salient locations. Numbers of techniques are used in resolving the problems of data availability at ungauged locations such as:

One of the most frequently used events in hydrology is the relation between rainfall and runoff. It determines the runoff signal which leaves the watershed from the rainfall signal received by the

basin. In it, a part of the hydrological cycle has been studied to express the runoff from the catchment as a function of the rainfall and other catchment characteristics. It helps to extend stream flow time series both spatially and temporally to estimate management strategies and catchment response to climate. There are various popular flood hydrograph modeling techniques for ungauged basins, like the synthetic unit hydrograph (SUH). The SUH models are grouped into four main classes, as follows: (a) conceptual models (b) traditional or empirical models (c) probabilistic models (d) geomorphologic models. The unit hydrograph (UH) theory is a potentially powerful tool in watershed hydrology similar to the unit-impulse response function in fields such as electrical, electronics and telecommunication or and structural engineering (Gavahne and Londhe, 2021).

The Synthetic Unit Hydrograph approach is used in many studies in order to find the design floods of different ungauged catchments. The parameters related to physiographic as well as hydrometeorology based on the regionalization property has been well defined by CWC. Accordingly, CWC divided entire India in to 7 hydro-meteorological zones and 26 sub zones as mentioned in the diagram below:

Whenever we are going for the flood Plain zoning works so in that case, we have two types of catchments first one is gauged catchment and the other one is ungauged catchment so the discharge calculation will depend on the type of catchment weather it is gauged or ungauged. Here we will mention the discharge preparation steps for different return period and modeling steps for gage catchment and engagement catchment separately.

**For Gauged Catchment:**

To estimate the design flood using flood frequency approach, the following procedures shall be adopted:

(a) The flood peak series shall be checked for randomness, homogeneity, trend, jump, outliers etc using appropriate statistical methods.

(b) Flood frequency analysis shall be carried out using time series of instantaneous annual flood peak. Based on the hourly gauge data the observed annual flood peak shall be converted into instantaneous flood peak.

(c) Using the instantaneous annual flood peak time series, the flood frequency analysis shall be carried out using standard frequency distributions such as Gumbel, log Pearson type-III and Log Normal distributions etc. to estimate the desired return period flood.

(d) Goodness of fit test for the frequency distribution shall be carried out using standard statistical tests such as Chi Square, D-Index etc. to assess the appropriate frequency distribution for the data set and decide the appropriate design flood.

**a) Normal Distribution**

Analysis by using the Normal distribution uses the formula as below:

$Q_T = \bar{Q} + K_T\sigma$

Where:

$Q_T$ = the probable discharge with a return period of T years

$\bar{Q}$ =mean flood (for n years)

$K_T$= frequency factor

$\sigma$ = Standard deviation of data

The tables presented below summarize calculated discharges for different return period based on the Normal distribution.

**b) Log-Normal Distribution**

The formula used for estimation of discharges for any return period in the method is written as:

$$\log Q_T = \log(Q)_{avg} + K_T\sigma$$

Where:

$Q_T$ = the probable discharge with a return period of T years

log(Q)avg. = average of the log Q discharge values

$K_T$= frequency factor (referred from for return period)

σ = the standard deviation of the log Q values

**c) Log Pearson Type III Distribution**

The formula used for estimation of discharges for any return period in the method is written as:

$$logQ_T = \log(\overline{Q}) + K_T\sigma$$

Where:

$Q_T$ = the probable discharge with a return period of T years

$\log(\overline{Q})$ = average of the log Q discharge values

$K_T$= frequency factor (referred from standard table based on skewness coefficient Cs and return period)

σ = the standard deviation of the log Q values

**d) Gumbel Extreme Value Type 1 Distribution (GEVT – 1)**

The formula used for estimation of discharges for any return period in the method is written as:

$$Q_T = \bar{Q} + K_T\sigma$$

Where:

$Q_T$= the probable discharge with a return period of T years

$\bar{Q}$ = mean flood (for n years)

$K_T$= frequency factor = $(Y_T - Y_n)/ \sigma_n$

$\sigma_n$ = Standard deviation of data

$Y_T$ = - Ln (Ln (T/T- 1))

$Y_n$, $\sigma_n$ = expected mean and standard deviations of reduced extremes to be found from Gumbel's table based on number of year of data available.

Here also mentioning below the flow chart which explains the holistic approach for flood plain zoning works for Gauged catchments

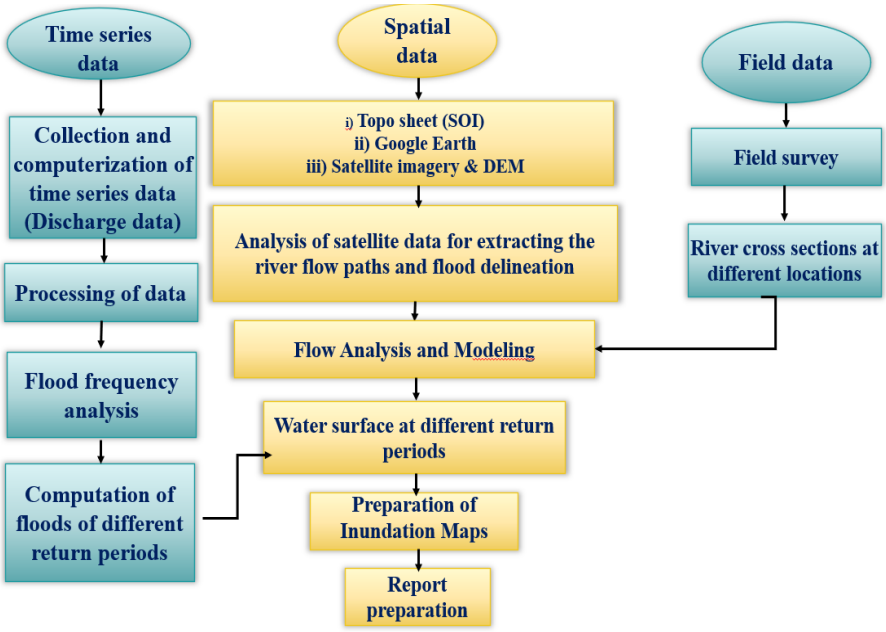



**Fig.2 Flowchart of methodology of Flood Plain Zoning**

**For Ungauged Catchment**

The availability of historical discharge data is the prime information required to proceed for Flood Plain Zoning (FPZ) analysis. The major sites sensitive to FPZ are not within the vicinity of the gauged site. So the analysis for ungauged analysis is to be taken care of. Besides the gauged locations the other locations where scanty or intermittent flow data are available does not give a clear scenario of the flow pattern. At ungauged locations, determining the discharge is always a challenge for doing subsequent hydrological analyses. Simultaneously it is also difficult to put the gauges at all salient locations. Numbers of techniques are used in resolving the problems of data availability at ungauged locations such as:

One of the most frequently used events in hydrology is the relation between rainfall and runoff. It determines the runoff which leaves the watershed from the rainfall received by the basin. In it, a part of the hydrological cycle has been studied to express the process of runoff from the catchment as a function of the rainfall and other catchment characteristics. It helps to extend stream flow time series both spatially and temporally to estimate management strategies and catchment response to climate. There are various popular flood hydrograph modelling techniques for ungauged basins,

like the synthetic unit hydrograph (SUH). The SUH models are grouped into four main classes, as follows:

(a) Conceptual models

(b) Traditional or empirical models

(c) Probabilistic models

(d) Geomorphologic models.

The unit hydrograph (UH) theory is a potentially powerful tool in watershed hydrology similar to the unit-impulse response function in fields such as electrical, electronics and telecommunication or and structural engineering (Gavahne and Londhe, 2021).

The Synthetic Unit Hydrograph approach is used in many studies in order to find the design floods of different ungauged catchments. The parameters related to physiographic as well as hydrometeorology based on the regionalization property has been well defined by CWC. Accordingly, CWC divided entire India in to 7 hydro-meteorological zones and 26 sub zones as mentioned in the Figure-3 below:

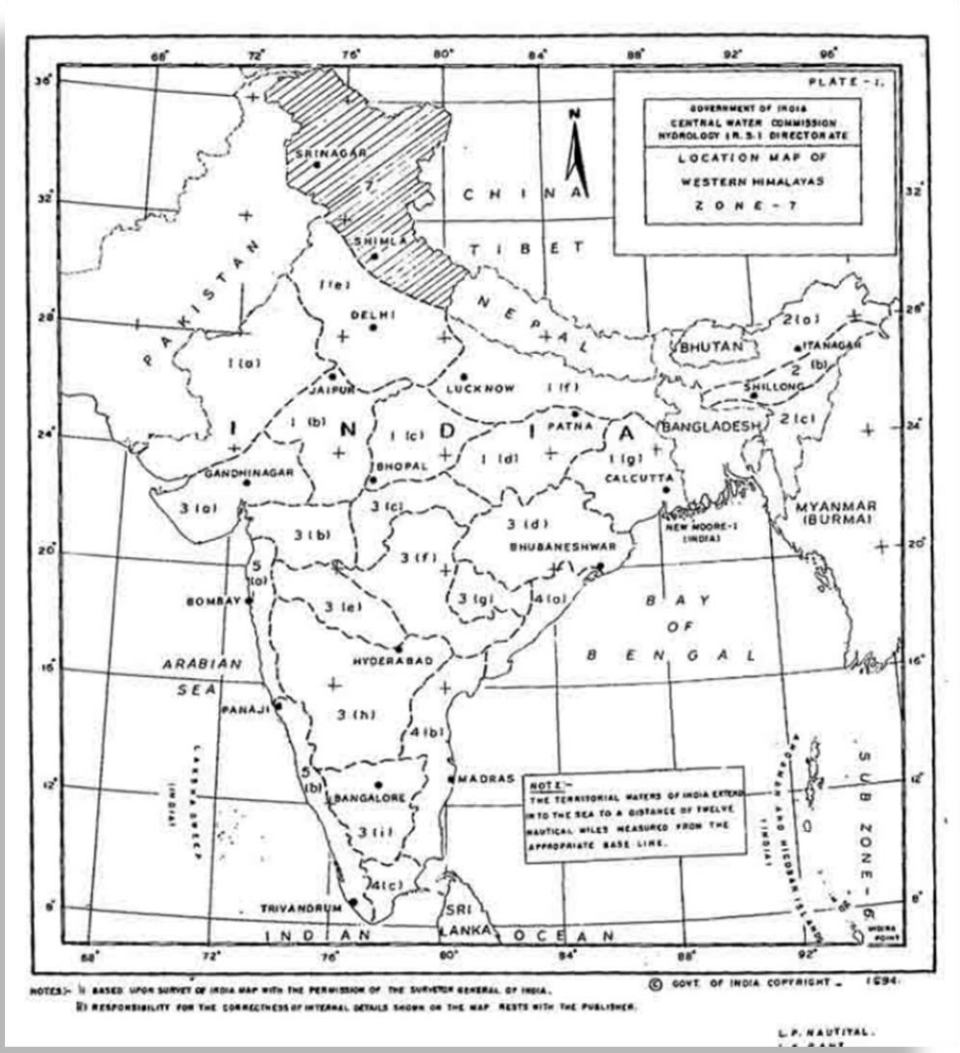



**Fig. 3 Hydro-meteorological sub-divisions of India**

As our study area, falls under Western Himalayas it comes at Zone-7. The equations for developing the Synthetic Unit Hydrograph have to be followed by the guidelines provided by CWC. The steps to be followed regarding the calculation of parameters for individual ungauged sites are shown in Fig. 4, Fig.5 and the parameters are calculated through the equations mentioned in Table 2.

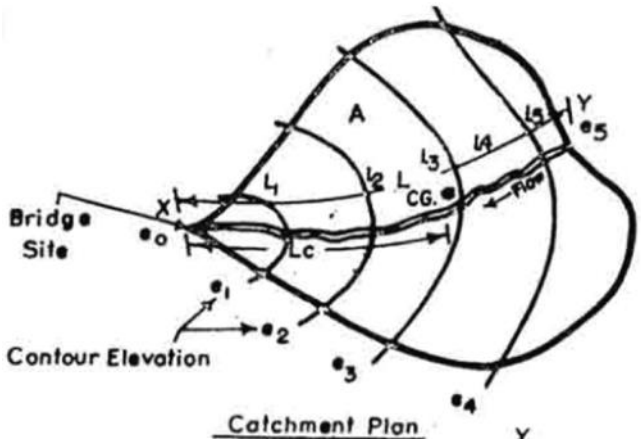



**Fig.-4 Catchment plan for ungauged sites**

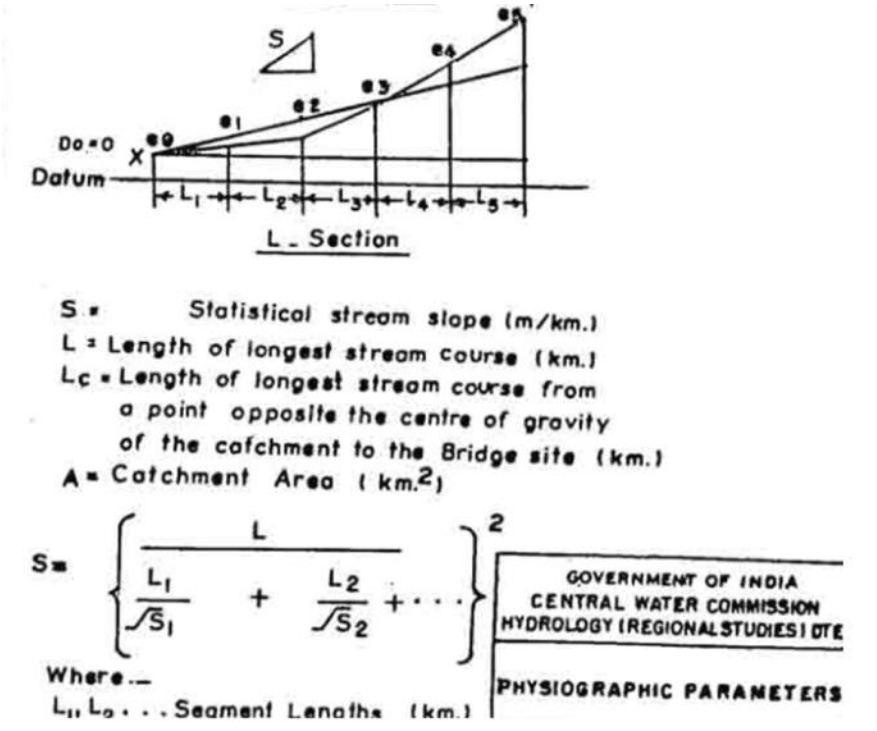



**Fig.-5 Slope and other physiographic parameter calculation**

| Table 2: Parameter calculation according to the equation for Western Himalayan Zone-7 |
|---|
| Time from the centre of effective rainfall duration to the UH peak $t_p = 2.498*(L*L_c/S)^{0.156}$ |
| Peak discharge of unit hydrograph per unit area $qp = 1.048*(tp)^{-0.178}$ |
| Width of the UH measured at 50% of peak discharge ordinate $W_{50} = 1.954*(L*L_c/S)^{0.099}$ |
| Width of the UH measured at 75% of peak discharge ordinate $W_{75} = 0.972*(L*L_c/S)^{0.124}$ |
| Width of the rising limb of UH measured at 50% of peak discharge ordinate $W_{R50} = 0.189(W_{50})^{1.769}$ |
| Width of the rising limb of UH measured at 75% of peak discharge ordinate $W_{R75} = 0.419(W_{75})^{1.246}$ |
| Base width of UH $T_B = 7.845*(t_p)^{0.453}$ |
| Peak Discharge of UH $Q_p = q_p$ x A |
| Unit duration of unit hydrograph $t_r$ |
| Time from the start of rise to the peak of the UH $Tm=t_p+t_r /2$ |
| $Q_{theoretical} = A*d/0.36*t_r$ here d= 1 cm depth and $t_r$ = 1 hr |

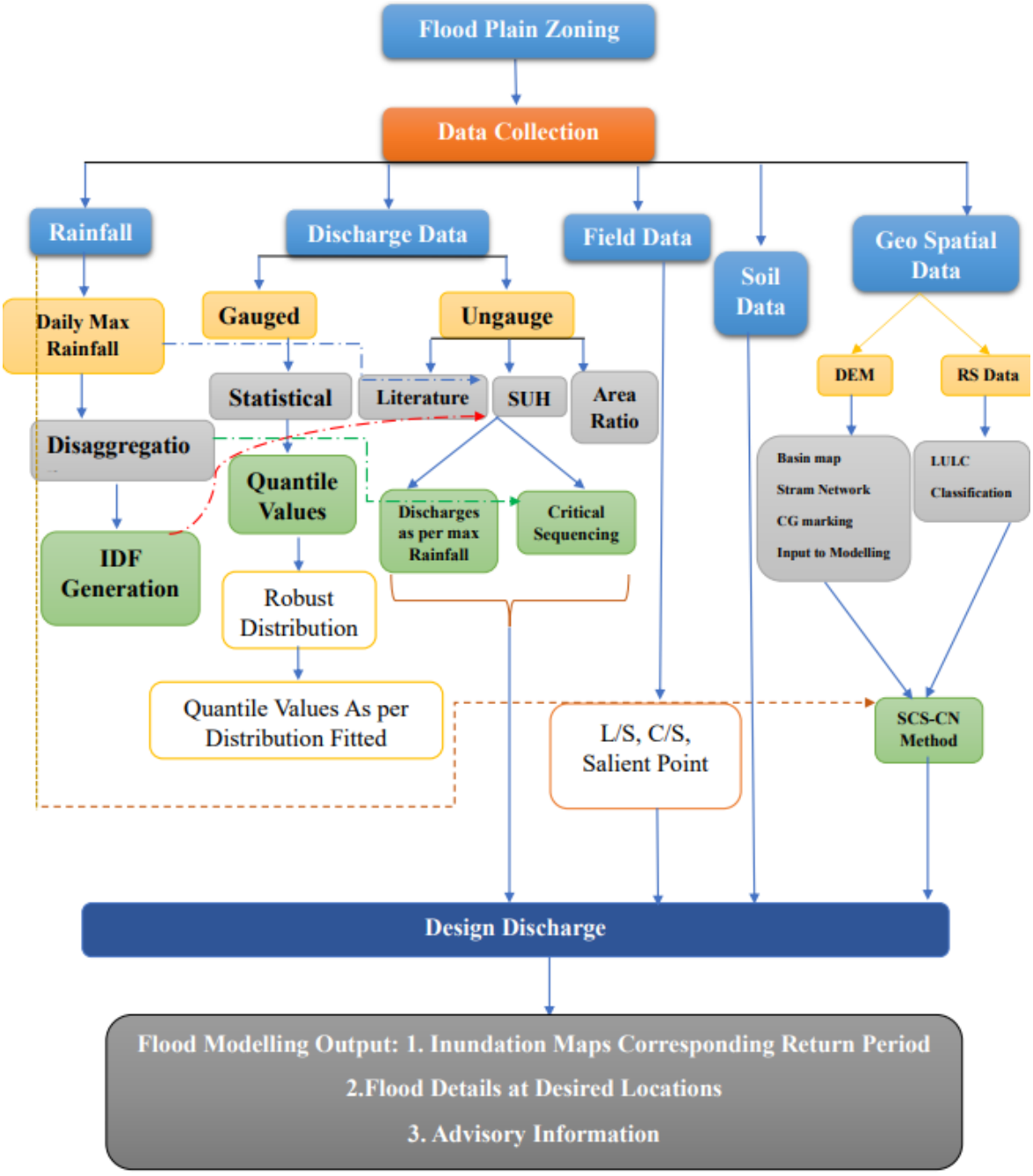



**Fig.-6 Steps for Design Discharge calculations and subsequent modelling**

## 1.8 Hydraulic Modelling

Hydraulic characteristics like Water Surface Elevation have great importance to study the behavior of Flood Plain zone in response to flow hydrograph. A hydrodynamic model is a tool to describe or represent the motion of water. Before the advent of widely available computer systems, a hydrodynamic model could in fact be a physical model built to scale. However, virtually all hydrodynamic models in use today are computational numerical models. Here, HEC-RAS has been employed to study the hydrodynamics of the river. Hydraulic Models Simulating the fluvial hydraulics of a reach of river, including the channel and over bank, can be performed using a variety of mathematical computer models depending on the type of study and model the user wants to employ.

The United States and many other developed countries utilize hydraulic modelling as a tool to gain an in-depth perspective of hydraulic systems so that they can more effectively develop different mitigation measures at the time of flood, planning for bridges, embankment, levees and dams. Numerical hydraulic modelling involves the use of mathematical equations representing the fundamental physics of how water moves in order to gain a better understanding of the hydraulic system's behaviour. It takes into account more than just the topography of the land and the amount of water in the system. Hydraulic modelling takes into account time, land use/land cover, conveyance area, basic physics of water behaviour, and water volume to portray the effects a river can have on the surrounding community.

## 1.9 HECRAS 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.

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

Y, Z, V, α, he, 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 HEC-GeoRAS (Arc-GIS extension) and these data then transferred to 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 Center (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 5.0.3 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.

Two dimensional HEC-RAS takes into account mass conservation using the continuity equation and momentum conservation using variations of the momentum equation called the Saint Venant equations, based on Newton's second law of motion and assuming incompressible flow. The area being two-dimensionally modelled is divided into a grid where each cell is treated as a control volume. Each cell is a polygonal prism with irregular terrain on the bottom, developed from the topography data. The lateral flows are calculated in the x and y direction using the Saint Venant equations, which account for internal and external forces on the fluid, specifically hydrostatic

pressure, turbulence, and friction. Then using the continuity equation, the lateral flows in and out of every side of the cell, expressed as velocities, are used to calculate the volume of water in the cell and area of each cell face, as a function of water surface elevation.

Both one-dimensional and two-dimensional models were considered plausible options for the project and desired outcomes because HEC-RAS one dimensional and two-dimensional models are on the Federal Emergency Management Agency's (FEMA) list of nationally accepted hydraulic models for developing flood mitigation measures. The most significant challenge in developing hydraulic models for India is that many of the country's rivers are not gauged and hydrologic/hydraulic data are not widely collected. Moreover, the data that are collected are not easily accessible and not always of the quality preferred for hydraulic model development The Hydrologic Engineering Center – River Analysis System (HEC-RAS), is a hydraulic modelling software widely accepted and used because it has proven to be reliable software and is freely available making it easily used by countries with limited resources (US Army Corps of Engineers). Both one-dimensional and two-dimensional version were chosen for the work described in this report. HEC-RAS 5.0.3, which includes two-dimensional capabilities, was recently released and is expected to become as prominent as the one-dimensional version (Brunner, HEC-RAS River Analysis System, 2D Modelling User's Manual Version 5.0.3).

The general data required to build a hydraulic model are

1.) Surface roughness values typically derived from land use/land cover (LULC) data

2.) A digital elevation model (DEM) derived from topographic data, and observed hydraulic data (discharge and stage).

The surface roughness values can be estimated from satellite imagery if LULC datasets are not available. The DEM forms the conveyance area of the model, and thus, can greatly affect the output of hydraulic models.

## 1.10 Data Needed for Model Development

There are three main data inputs required to build a model. First is the discharge or flow of water entering and exiting the model. The discharge flowing into or out of the model and the corresponding locations along the outer perimeter of the flow area are referred to as boundary

conditions. Second is the Manning's "n" roughness coefficients representing the land's frictional resistance to flow derived from land use data. Third is the topography of the model area in the form of a digital elevation model (DEM), used to derive the irregular terrain on the bottom of the flow area grid.

HEC-RAS models do not account for infiltration or evaporation so those data are not needed. It is preferred to have data for at least two flood events for the hydraulic system of interest, one to calibrate the model and the other to validate the calibrated model. The calibration of a HEC-RAS model entails making sure the geometry and discharge, flow in and out, are correctly representing the true hydraulic system and then adjusting the Manning's "n" values, and maybe other parameters, to fine-tune the simulated water surface elevations (stage) to match observed water surface elevations (measured stage) from the event. The validation of a HEC-RAS model requires observed data for a different event. It entails running the calibrated model using discharge data from the validation event to see if the simulated water surface elevations match up to the observed water surface elevations for that event. If the stages match up, the model is validated, but if they do not, further adjustment to the model is needed. The validation proves the model is trustworthy and accurately portraying the hydraulic system of interest by producing correct results for a different flood event. The topography data are usually best representative of the hydraulic system if it consists of surveyed cross-sections. The surveyed cross-sections are preferably measured at reasonable intervals to capture the general topography and channel bathymetry. The DEM did not capture the general conveyance area because it did not have a well-defined channel.

## 1.8 Mannings N Value Assignment

The local manning's N values are applied during modeling for different section and mostly it varied in within the range depending upon the bed of the River reach

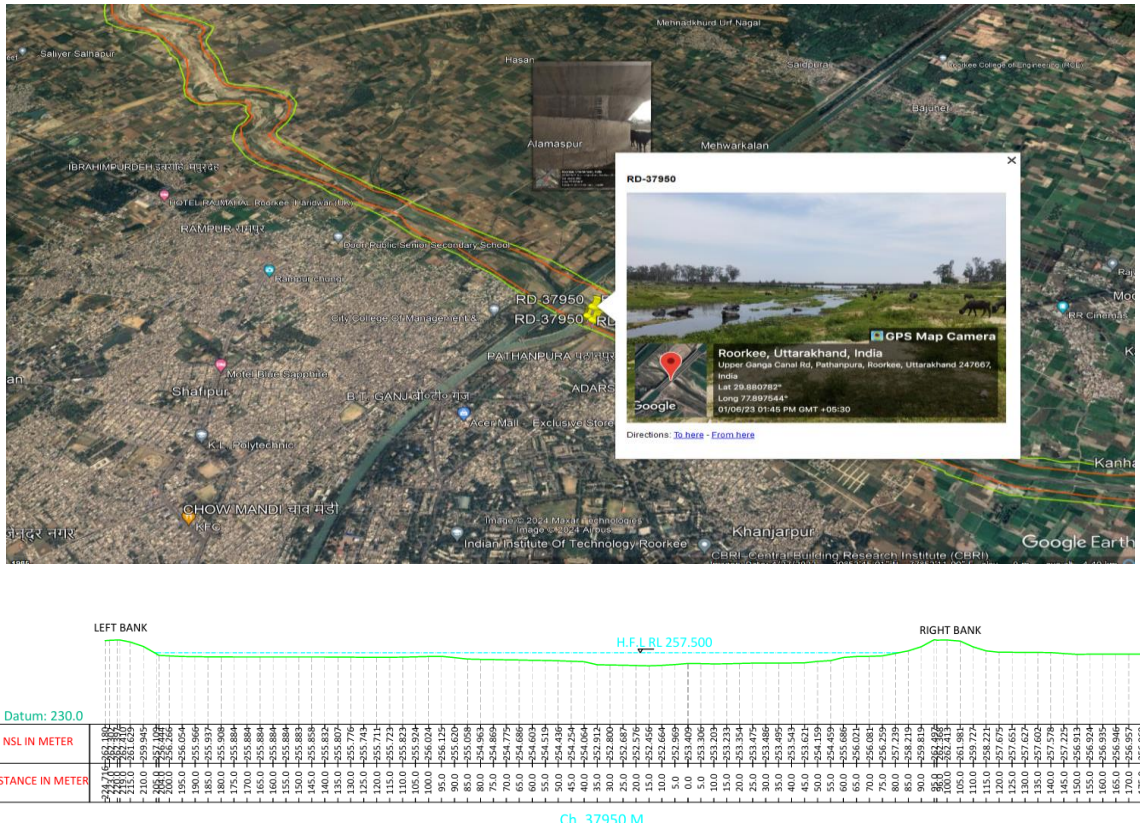
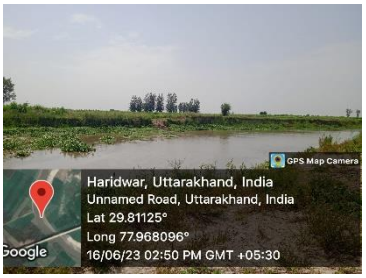


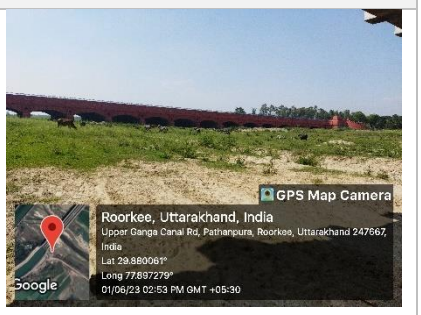




Fig. 7 Geotagged photos over the cross section for assigning the Manning's N & surveyed cross Section

**Table 3: Manning's N at Different Reach**

| Reference | Location | River Chainage | Description | Mannings N Value | Reference Photograph |
|---|---|---|---|---|---|
| USGS, 1987 & Chow Table | Damodrabad | 50 | clean, straight, full stage, no rifts or deep pools | 0.033 |  |
| USGS, 1987 & Chow Table | Ladpur kalan | 39250 | very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush | 0.1 |   |
| USGS, 1987 & Chow Table | Bhagwanpur | 24200 | Main Channel is clean, winding, some pools and shoals | 0.040 |  |
| USGS, 1987 & Chow Table | Bhainsarhedi | 43450 | Cultivated Areas: mature row crops | 0.035 |  |

| | | | | | |
|---|---|---|---|---|---|
| USGS, 1987 & Chow Table | Kanhapur, Roorkee | 39350 | The bed consists of sand and gravel, and has light cover of brush in some places | 0.030 |  |
| USGS, 1987 & Chow Table | Roorkee, Upper Ganga Canal | 38700 | The bed consists of sand and gravel, and has light cover of brush in some places | 0.03 |  |

## 2. Geomorphic Description of the Study Reach

The study area belongs to the catchment of the river Solani a tributary of the river Ganges in and around Roorkee town between 78.03°E, 30.00°N and 77.48°E, 29.45°N. The area is relatively flat with a maximum slope of 8.85 m/km, Min, slope 0.44 m/km and average slope 2.84 m/km and is mostly comprised of sandy loam soil having 70% sand, 20% silt, and 10% clay.

**Table 4: Geometric Description of Solani River**

| S. No. | Lot No. | Reach | Length of Reach (Km) |
|---|---|---|---|
| 1 | 3 | Solani River (Damodrabad to State Border with UP) | 71 |

The start of the autumn season had a fairly good rainfall with relative humidity of 65 to 70%. At this time, the area was covered with mixed vegetation consisting of grassland, sugarcane, cherry, and rice. Crops were at their mature stage, which led to the variation in both surface roughness and the amount of moisture in the field. The end of the spring season had a meagre rainfall with a relative humidity of less than 50%. The beginning of the summer season had effectively no rainfall and humidity was less than 40%. The spring and summer seasons were dominated by three vegetation classes, namely, grassland, sugarcane, and wheat.

The watershed receives the rain under the influence of southwest monsoon. The northeast monsoon mainly contributes to the rainfall in the area. Most of the precipitation occurs in the monsoon season that causes flooding. The southwest monsoon rainfall is highly erratic, and Geomorphology of the study area is important for the assessment of floods because flooding is largely based on the topography. Low lying areas near to the channel are frequently flooded and such area is defined as an active floodplain. The floodplain covers channel belt and low-lying areas on either side of the river banks. Furthermore, the channel belt covers the active channel, secondary channel, chute channel and bars. Large floods often cause erosion and deposition in channel belt as well as in adjoining floodplain. Therefore, geomorphic processes (erosion or deposition) perverse footprints of large floods for many years in the virgin reaches of the river. The areas lying, between active

floodplain and valley margins are called as older floodplain which gets inundated at high magnitude floods (e.g., 100-year return period floods).

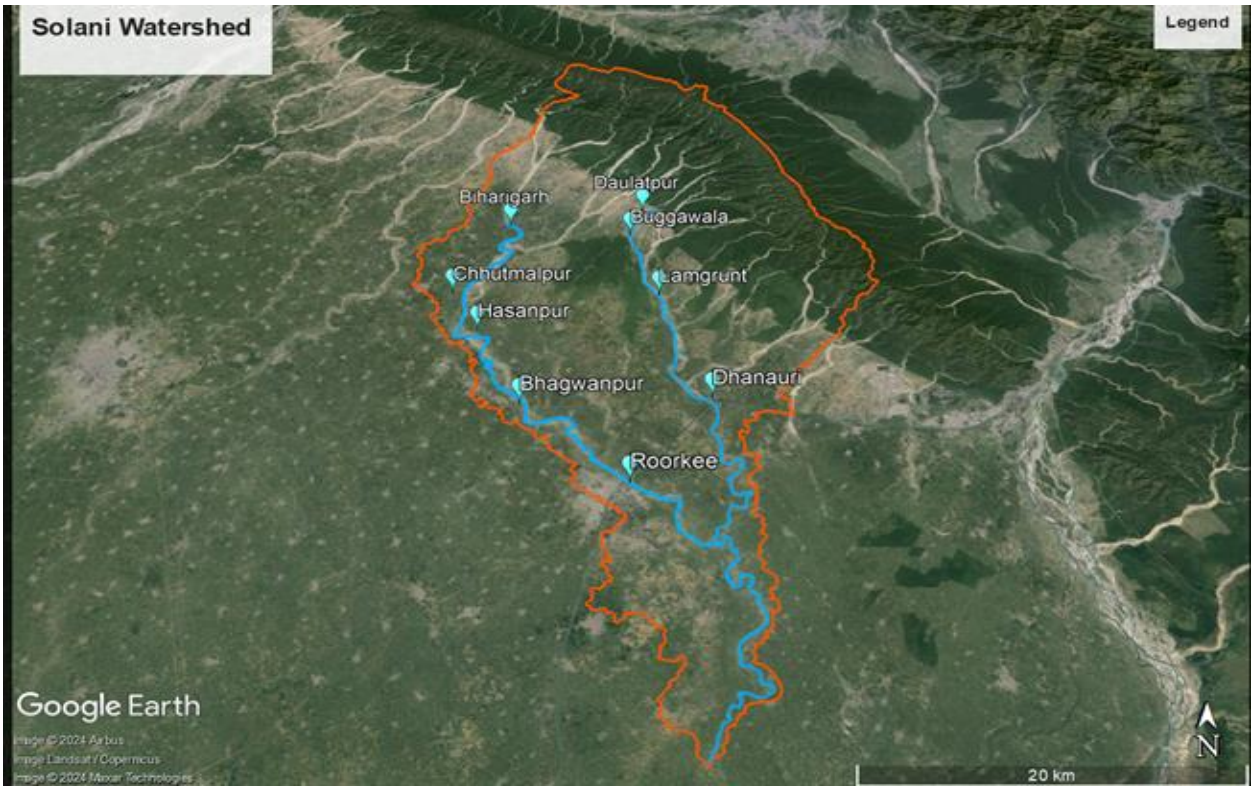



**Fig. 8 Location Map of Solani Watershed**

## 3. River Morphology

The length of Solani River is 71 km with an average slope of 2.84 m/ km. The maximum river width (~402.2 m) is found near downstream area while the minimum width (~110 m) is at 1 km at Biharigarh. The Solani River is flowing over relatively flat land with significant meandering channel. The River width is also confined with bunds at various places and also it under passed by upper ganga canal. In Roorkee town, the minimum channel width is ~80 m and the maximum width is ~410 m with a mean channel width of ~248m. Floodplain is covered by agricultural land, vegetation, and settlements. Sand, loamy and Clay deposits and floodplain materials. Such geomorphic study helped us to determine the transverse and longitudinal cross-sections for the HEC RAS modelling of the floodplain at 5, 25, 50, and 100-year return periods.

## 4. Input Data Base

The following data (Table 5) was procured and analyzed:

**Table 5: List of input database in the present study.**

| S. No. | Input Data | Source | Remarks |
|---|---|---|---|
| 1 | Satellite Imagery | NRSC (National Remote Sensing Centre, Hyderabad) | |
| 2 | Rainfall Data | IMD (Indian Meteorological Department, Pune) | Year 1901-2016 |
| 3 | Topographic Survey Sheet | SOI (Survey of India, Dehradun) | |
| 4 | Soil Map | NBSS-LUP (National Bureau of Soil Science & Land Use Planning, Nagpur) | One for Complete State |
| 5 | Annual Peak Flow & Associated Gauge Levels | Central Water Commission / Irrigation Department Uttarakhand | Peak Annual Discharges from 2019-2022 |
| 6 | Hydrographic Cross-Sections | Total Station | |
| 7 | Global Control Points | DGPS (Digital Global Positioning System) | |
| 8 | Field Based Records | Interaction with Local Residents | For Recent Flood Events |

# 5. Design Flood Estimation for Solani Watershed

## Solani River

**Physiographic parameters**:

The physiographic parameters of the river catchment at project site have been estimated by GIS processing. The elevation along the longest flow path of the river varies from about 350m to 237m. The estimated parameters of the river catchment at project site are given in Table.

**Table 6 Physiographic parameters of Solani catchment**

| Catchment Area ($km^2$) | L (km) | Lc (km) | Equivalent stream slope (m/km) |
|---|---|---|---|
| 1001 | 71.45 | 25 | 7.30 |

**Assessment of Unit Hydrograph**

In absence of short interval observed discharge and concurrent rainfall data; the unit hydrograph of one-hour duration has been derived using Flood Estimation Report for Western Himalaya Zone-7 The estimated UH parameters are given at Table-2. The unit hydrograph ordinates as assessed for the unit hydrograph of catchment are given at Table-4.

**Table 7: Unit Hydrograph Parameters:**

| Parameter | Unit | Value |
|---|---|---|
| Time from the centre of effective rainfall duration to the UH peak tp = $2.498*(L*Lc/S)^{0.156}$ | hr | 5.89 |
| Peak discharge of unit hydrograph per unit area qp = $1.048*(tp)^{-0.178}$ | m 3 /sec/sq. km | 0.76 |
| Width of the UH measured at 50% of peak discharge ordinate W50 = $1.954*(L*Lc/S)^{0.099}$ | hr | 3.37 |
| Width of the UH measured at 75% of peak discharge ordinate W75 = $0.972*(L*Lc/S)^{0.124}$ | hr | 1.92 |
| Width of the rising limb of UH measured at 50% of peak discharge ordinate WR50 = $0.189(W50)^{1.769}$ | hr | 1.62 |
| Width of the rising limb of UH measured at 75% of peak discharge ordinate WR75 = $0.419(W75)^{1.246}$ | hr | 0.95 |
| Base width of UH TB = $7.845*(tp)^{0.453}$ | hr | 17.52 |
| Peak Discharge of UH Qp = qp x A | m 3 /sec | 721.50 |
| Unit duration of unit hydrograph tr | hr | 1 |
| Time from the start of rise to the peak of the UH Tm=tp+tr /2 | hr | 6.39 |
| Q theoretical = A*d/0.36*tr here d= 1 cm depth and tr = 1 hr | m 3 /sec | 2622.22 |

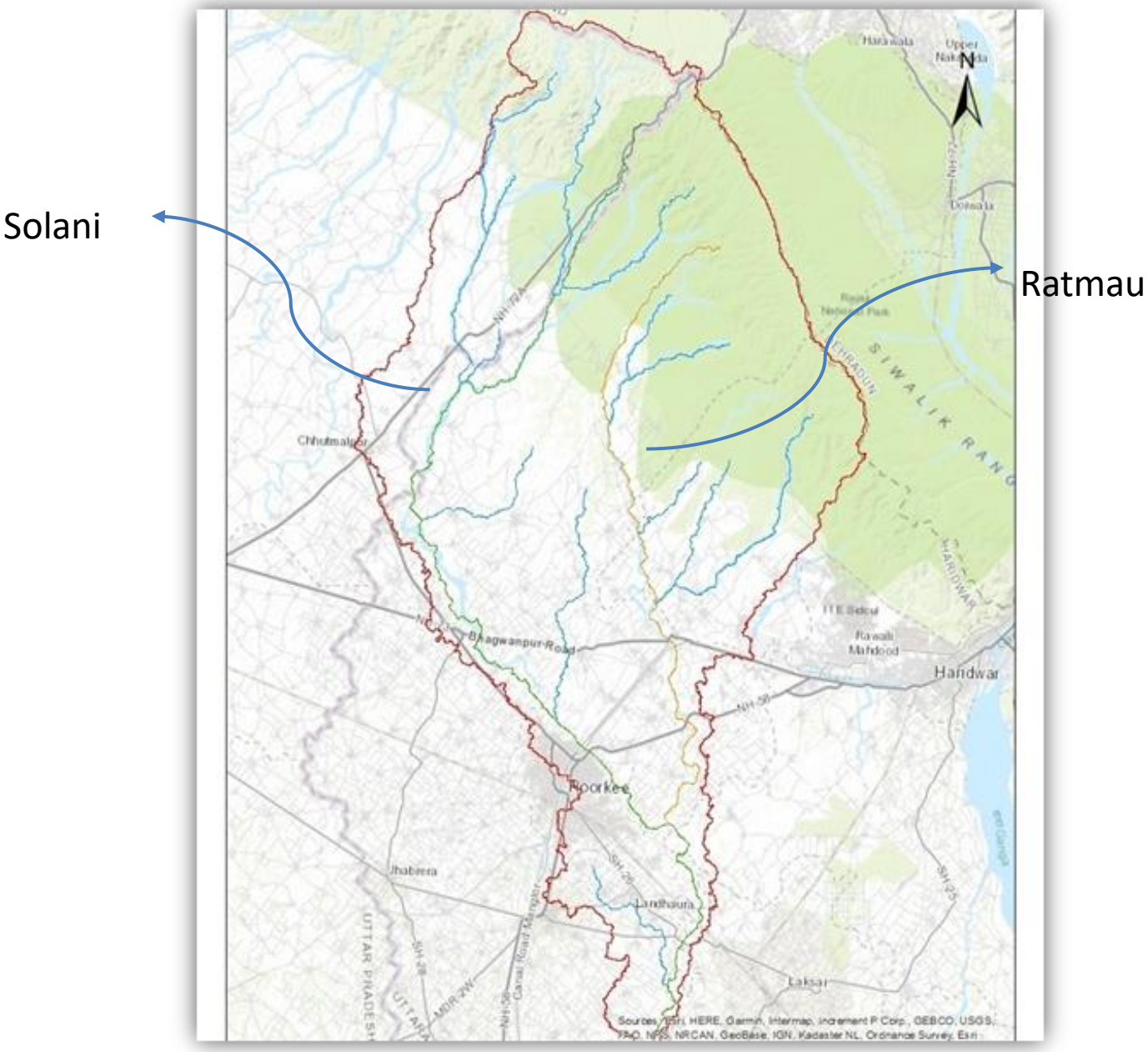



**Fig. 9. Map of Solani watershed**

**Table 8: Rainfall for Different Return Period**

By obtaining the rain gauge station from PMP atlas, Thiessen polygon is prepared and weighted average rainfall is derived for basin of different return period as mentioned in the table given below.

| Return Period | 5 | 10 | 25 | 50 | 100 |
|---|---|---|---|---|---|
| Rainfall (mm) | 135.00 | 165.32 | 202.63 | 230.95 | 259.10 |
| Rainfall (cm) | 13.50 | 16.53 | 20.26 | 23.09 | 25.91 |

**Table 9: Unit Hydrograph Ordinates**

After deriving the peak and ordinates at 50% and 75% of the peak, UH for 1 hr unit depth is traced at graph paper then hydrograph is smoothened as mentioned below in the Table.

| Unit Hydrograph | |
|---|---|
| T | Q |
| 0 | 0 |
| 1 | 13 |
| 2 | 36 |
| 3 | 56 |
| 4 | 90 |
| 5 | 137 |
| 6 | 214 |
| 7 | 337 |
| 8 | 721 |
| 9 | 313 |
| 10 | 182 |
| 11 | 142 |
| 12 | 109 |
| 13 | 85 |
| 14 | 66 |
| 15 | 45 |
| 16 | 33 |
| 17 | 23 |
| 18 | 9 |
| 19 | 6 |

Fig. 6 1Hr UH for Solani Watershed

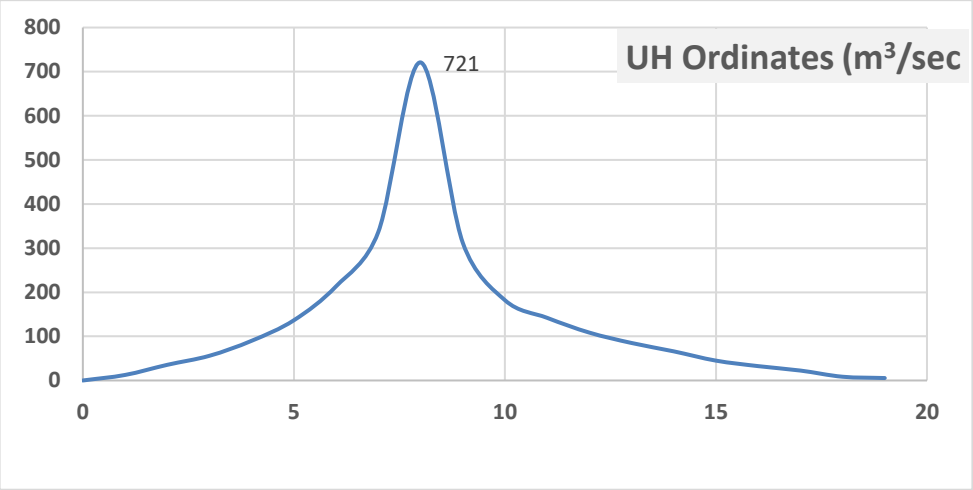



**Fig.- 10: Synthetic Unit Hydrograph for Solani River**

## A. 100 Year Return Period Flood Estimation

A design loss rate of 0 to 0 .6 cm /hr as recommended in CWC FER of Western Himalayan Zone-7 report for has been adopted for design flood computation.

As recommended by CWC Western Himalayan Zone-7 report following base flow rate has been adopted:

Base flow / km2 of drainage area = 0.10 (max)

Using the above formula, the computed base flow for the catchment area is 0.61 $m^3$ /sec.

**Time Distribution of Rainfall:**

For hourly distribution of rainfall, normalized distribution coefficient has been worked out for bell of 12 hour each using the hourly distribution coefficient of 24-hour rainfall from PMP Atlas of Ganga River Basins.

The hourly distribution coefficient of 24-hour rainfall and normalized distribution coefficient for 12-hour bell are given in **Table 10: Distribution Coefficient**

| Time | Distribution coefficient for 24 hour rainfall (%) | Normalised Distribution coefficient for 12 hour bell |
|---|---|---|
| 1 | 0.17 | 0.202 |
| 2 | 0.27 | 0.341 |
| 3 | 0.36 | 0.452 |
| 4 | 0.43 | 0.544 |
| 5 | 0.48 | 0.631 |
| 6 | 0.53 | 0.7 |
| 7 | 0.58 | 0.768 |
| 8 | 0.63 | 0.831 |
| 9 | 0.66 | 0.882 |
| 10 | 0.7 | 0.928 |
| 11 | 0.73 | 0.971 |
| 12 | 0.76 | 1 |
| 13 | 0.79 | |
| 14 | 0.82 | |
| 15 | 0.84 | |
| 16 | 0.86 | |
| 17 | 0.88 | |
| 18 | 0.9 | |
| 19 | 0.92 | |
| 20 | 0.94 | |
| 21 | 0.96 | |
| 22 | 0.98 | |
| 23 | 0.99 | |
| 24 | 1 | |

**Table 11: RP rainfall depth for 12-hour bells**

After getting rainfall distribution for 24 hrs, rainfall is further distributed in the sets of 12hr based on the previous table.

| Catchment | 100yr RP Rainfall | 24 hr Max ( 1.15* col(1) | 1st Bell 76% of col. (1) B1 | 2nd Bell 24% of col. (1) B2 |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Solani | 134.70 | 154.90 | 102.37 | 32.33 |

**Table 12: 12 Hour bell distribution of rainfall**

Two bells on based on its fraction are prepared i.e. 1st 12hr Bell & 2nd 12hr Bell.

| Bell | Rainfall PMP Depth |
|---|---|
| 1st 12Hr Bell | 102.4 |
| 2nd 12Hr Bell | 32.3 |

**Table 13: Hourly Distribution of Rainfall**

After preparing 12hr bells, cumulative rainfall depth, incremental rainfall depth & effective rainfall are calculated by subtracting the losses.

| Time | Dis. Coeff. | Nor. Dis. Coeff. | Cumulative Rainfall Depth | | Incremental Rainfall Depth | | | Effective Rainfall Depth | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1st 12 hr Bell Distribution | 2nd 12 Hr Bell Distribution | Incremental Rainfall 1st Bell | Incremental Rainfall 2nd Bell | Loss | Eff. Inc. Rainfall Depth 1st Bell | Eff. Inc. Rainfall Depth 2nd Bell |
| Hr | % | % | (mm) | (mm) | (mm) | (mm) | mm/ hr | (mm) | (mm) |
| | | | | | | | | | |
| 1 | 0.17 | 0.202 | 22.90 | 6.53 | 22.90 | 6.53 | 0.6 | 22.30 | 5.93 |
| 2 | 0.27 | 0.341 | 36.37 | 11.02 | 13.47 | 4.49 | 0.6 | 12.87 | 3.89 |
| 3 | 0.36 | 0.452 | 48.49 | 14.61 | 12.12 | 3.59 | 0.6 | 11.52 | 2.99 |
| 4 | 0.43 | 0.544 | 57.92 | 17.59 | 9.43 | 2.97 | 0.6 | 8.83 | 2.37 |
| 5 | 0.48 | 0.631 | 64.66 | 20.40 | 6.73 | 2.81 | 0.6 | 6.13 | 2.21 |
| 6 | 0.53 | 0.7 | 71.39 | 22.63 | 6.73 | 2.23 | 0.6 | 6.13 | 1.63 |
| 7 | 0.58 | 0.768 | 78.12 | 24.83 | 6.73 | 2.20 | 0.6 | 6.13 | 1.60 |
| 8 | 0.63 | 0.831 | 84.86 | 26.86 | 6.73 | 2.04 | 0.6 | 6.13 | 1.44 |
| 9 | 0.66 | 0.882 | 88.90 | 28.51 | 4.04 | 1.65 | 0.6 | 3.44 | 1.05 |
| 10 | 0.7 | 0.928 | 94.29 | 30.00 | 5.39 | 1.49 | 0.6 | 4.79 | 0.89 |
| 11 | 0.73 | 0.971 | 98.33 | 31.39 | 4.04 | 1.39 | 0.6 | 3.44 | 0.79 |
| 12 | 0.76 | 1 | 102.37 | 32.33 | 4.04 | 0.94 | 0.6 | 3.44 | 0.34 |

**Table 14: Critical sequencing for Effective hourly rainfall**

After getting the effective rainfall depth, for both bell, critical sequencing and reverse critical sequencing is done for rainfall & corresponding to its UH ordinates. Then rain convolution for both the bell are obtained, which is further to be used for designing the flood hydrograph for different return period floods.

| Time | UH ordinate | Critical Sequence of Hourly Rainfall Depth | | Reverse Critical Sequence | | Conv. Rainfall B2-B1 |
|---|---|---|---|---|---|---|
| | | 1st 12 Hr bell | 2nd 12 Hr bell | 1st 12 Hr bell | 2nd 12 Hr bell | |
| Hr | cumec | (mm) | (mm) | (mm) | (mm) | (mm) |
| 0 | 0 | | | | | |
| 1 | 16 | | | | | 3.4 |
| 2 | 36 | | | | | 4.8 |
| 3 | 62 | 3.4 | 0.3 | | | 6.1 |
| 4 | 95 | 3.4 | 1.0 | | | 6.1 |
| 5 | 146 | 6.1 | 1.6 | 3.4 | 0.8 | 6.1 |
| 6 | 230 | 8.8 | 2.4 | 4.8 | 0.9 | 11.5 |
| 7 | 360 | 12.9 | 3.9 | 6.1 | 1.4 | 22.3 |
| 8 | 722 | 22.3 | 5.9 | 6.1 | 1.6 | 12.9 |
| 9 | 335 | 11.5 | 3.0 | 6.1 | 2.2 | 8.8 |
| 10 | 195 | 6.1 | 2.2 | 11.5 | 3.0 | 6.1 |
| 11 | 153 | 6.1 | 1.6 | 22.3 | 5.9 | 3.4 |
| 12 | 120 | 6.1 | 1.4 | 12.9 | 3.9 | 3.4 |
| 13 | 93 | 4.8 | 0.9 | 8.8 | 2.4 | 0.8 |
| 14 | 72 | 3.4 | 0.8 | 6.1 | 1.6 | 0.9 |
| 15 | 54 | | | 3.4 | 1.0 | 1.4 |
| 16 | 41 | | | 3.4 | 0.3 | 1.6 |
| 17 | 26 | | | | | 2.2 |
| 18 | 15 | | | | | 3.0 |
| 19 | 7 | | | | | 5.9 |
| 20 | 0 | | | | | 3.9 |
| 21 | | | | | | 2.4 |
| 22 | | | | | | 1.6 |
| 23 | | | | | | 1.0 |
| 24 | | | | | | 0.3 |

**Design Flood Estimation** By using convoluted rainfall and UH ordinate, design flood is derived for specific return period.

## Table 15: 100yr Return Period flood for Solani River

| Time | UH ord. | Rainfall Excess (cm) | | | | | | | | | | | | | | | | | | | | | | | DRH | Base Flow | 100yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| hr | cumec | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | cumec | cumec | Return |
| | | 0.34 | 0.48 | 0.61 | 0.61 | 0.61 | 1.15 | 2.23 | 1.29 | 0.88 | 0.61 | 0.34 | 0.34 | 0.08 | 0.09 | 0.14 | 0.16 | 0.22 | 0.30 | 0.59 | 0.39 | 0.24 | 0.16 | 0.10 | 0.03 | | | Period |
| 0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 1 | 1.0 |
| 1 | 12.5 | 4.3 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | 4.3 | 1 | 5.3 |
| 2 | 35.5 | 12.2 | 6.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | 18.2 | 1 | 19.2 |
| 3 | 56.0 | 19.3 | 17.0 | 7.7 | 0.0 | | | | | | | | | | | | | | | | | | | | | 43.9 | 1 | 44.9 |
| 4 | 90.0 | 31.0 | 26.8 | 21.8 | 7.7 | 0.0 | | | | | | | | | | | | | | | | | | | | 87.2 | 1 | 88.2 |
| 5 | 136.5 | 47.0 | 43.1 | 34.4 | 21.8 | 7.7 | 0.0 | | | | | | | | | | | | | | | | | | | 153.9 | 1 | 154.9 |
| 6 | 213.5 | 73.5 | 65.4 | 55.2 | 34.4 | 21.8 | 14.4 | 0.0 | | | | | | | | | | | | | | | | | | 264.6 | 1 | 265.6 |
| 7 | 336.5 | 115.8 | 102.2 | 83.7 | 55.2 | 34.4 | 40.9 | 27.9 | 0.0 | | | | | | | | | | | | | | | | | 460.1 | 1 | 461.1 |
| 8 | 721.0 | 248.1 | 161.1 | 131.0 | 83.7 | 55.2 | 64.5 | 79.2 | 16.1 | 0.0 | | | | | | | | | | | | | | | | 838.9 | 1 | 839.9 |
| 9 | 312.5 | 107.5 | 345.2 | 206.4 | 131.0 | 83.7 | 103.7 | 124.9 | 45.7 | 11.0 | 0.0 | | | | | | | | | | | | | | | 1159.2 | 1 | 1160.2 |
| 10 | 182.0 | 62.6 | 149.6 | 442.3 | 206.4 | 131.0 | 157.3 | 200.7 | 72.1 | 31.3 | 7.7 | 0.0 | | | | | | | | | | | | | | 1461.0 | 1 | 1462.0 |
| 11 | 142.0 | 48.9 | 87.1 | 191.7 | 442.3 | 206.4 | 246.0 | 304.4 | 115.8 | 49.4 | 21.8 | 4.3 | 0.0 | | | | | | | | | | | | | 1718.2 | 1 | 1719.2 |
| 12 | 108.5 | 37.3 | 68.0 | 111.7 | 191.7 | 442.3 | 387.7 | 476.1 | 175.7 | 79.5 | 34.4 | 12.2 | 4.3 | 0.0 | | | | | | | | | | | | 2020.8 | 1 | 2021.8 |
| 13 | 85.0 | 29.2 | 51.9 | 87.1 | 111.7 | 191.7 | 830.8 | 750.3 | 274.8 | 120.5 | 55.2 | 19.3 | 12.2 | 1.0 | 0.0 | | | | | | | | | | | 2535.8 | 1 | 2536.8 |
| 14 | 66.0 | 22.7 | 40.7 | 66.6 | 87.1 | 111.7 | 360.1 | 1607.7 | 433.1 | 188.5 | 83.7 | 31.0 | 19.3 | 2.8 | 1.1 | 0.0 | | | | | | | | | | 3056.0 | 1 | 3057.0 |
| 15 | 45.0 | 15.5 | 31.6 | 52.1 | 66.6 | 87.1 | 209.7 | 696.8 | 927.9 | 297.1 | 131.0 | 47.0 | 31.0 | 4.4 | 3.1 | 1.8 | 0.0 | | | | | | | | | 2602.7 | 1 | 2603.7 |
| 16 | 32.5 | 11.2 | 21.5 | 40.5 | 52.1 | 66.6 | 163.6 | 405.8 | 402.2 | 636.6 | 206.4 | 73.5 | 47.0 | 7.1 | 5.0 | 5.1 | 2.0 | 0.0 | | | | | | | | 2146.2 | 1 | 2147.2 |
| 17 | 22.5 | 7.7 | 15.6 | 27.6 | 40.5 | 52.1 | 125.0 | 316.6 | 234.2 | 275.9 | 442.3 | 115.8 | 73.5 | 10.8 | 8.0 | 8.0 | 5.8 | 2.8 | 0.0 | | | | | | | 1762.3 | 1 | 1763.3 |
| 18 | 8.5 | 2.9 | 10.8 | 19.9 | 27.6 | 40.5 | 97.9 | 241.9 | 182.8 | 160.7 | 191.7 | 248.1 | 115.8 | 16.9 | 12.1 | 12.9 | 9.1 | 7.9 | 3.7 | 0.0 | | | | | | 1403.3 | 1 | 1404.3 |
| 19 | 5.5 | 1.9 | 4.1 | 13.8 | 19.9 | 27.6 | 76.1 | 189.5 | 139.6 | 125.4 | 111.7 | 107.5 | 248.1 | 26.6 | 18.9 | 19.6 | 14.7 | 12.4 | 10.6 | 7.4 | 0.0 | | | | | 1175.4 | 1 | 1176.4 |
| 20 | 0.0 | 0.0 | 2.6 | 5.2 | 13.8 | 19.9 | 51.9 | 147.2 | 109.4 | 95.8 | 87.1 | 62.6 | 107.5 | 57.0 | 29.8 | 30.7 | 22.3 | 19.9 | 16.7 | 21.1 | 4.9 | 0.0 | | | | 905.4 | 1 | 906.4 |
| 21 | | | 0.0 | 3.4 | 5.2 | 13.8 | 37.4 | 100.3 | 84.9 | 75.0 | 66.6 | 48.9 | 62.6 | 24.7 | 64.0 | 48.3 | 34.8 | 30.2 | 26.9 | 33.2 | 13.8 | 3.0 | 0.0 | | | 777.1 | 1 | 778.1 |
| 22 | | | | 0.0 | 3.4 | 5.2 | 25.9 | 72.5 | 57.9 | 58.3 | 52.1 | 37.3 | 48.9 | 14.4 | 27.7 | 103.6 | 54.9 | 47.2 | 40.8 | 53.4 | 21.8 | 8.4 | 2.0 | 0.0 | | 735.7 | 1 | 736.7 |
| 23 | | | | | 0.0 | 3.4 | 9.8 | 50.2 | 41.8 | 39.7 | 40.5 | 29.2 | 37.3 | 11.2 | 16.1 | 44.9 | 117.6 | 74.5 | 63.8 | 80.9 | 35.0 | 13.3 | 5.7 | 1.3 | 0.0 | 716.3 | 1 | 717.3 |
| 24 | | | | | | 0.0 | 6.3 | 19.0 | 29.0 | 28.7 | 27.6 | 22.7 | 29.2 | 8.6 | 12.6 | 26.1 | 51.0 | 159.5 | 100.6 | 126.6 | 53.1 | 21.4 | 9.0 | 3.7 | 0.4 | 734.7 | 1 | 735.7 |
| 25 | | | | | | | 0.0 | 12.3 | 10.9 | 19.9 | 19.9 | 15.5 | 22.7 | 6.7 | 9.6 | 20.4 | 29.7 | 69.1 | 215.5 | 199.5 | 83.1 | 32.4 | 14.4 | 5.9 | 1.2 | 787.6 | 1 | 788.6 |
| 26 | | | | | | | | 0.0 | 7.1 | 7.5 | 13.8 | 11.2 | 15.5 | 5.2 | 7.5 | 15.6 | 23.2 | 40.3 | 93.4 | 427.6 | 131.0 | 50.7 | 21.8 | 9.4 | 1.9 | 880.7 | 1 | 881.7 |
| 27 | | | | | | | | | 0.0 | 4.9 | 5.2 | 7.7 | 11.2 | 3.6 | 5.9 | 12.2 | 17.7 | 31.4 | 54.4 | 185.3 | 280.7 | 79.9 | 34.1 | 14.3 | 3.0 | 748.5 | 1 | 749.5 |
| 28 | | | | | | | | | | 0.0 | 3.4 | 2.9 | 7.7 | 2.6 | 4.0 | 9.5 | 13.9 | 24.0 | 42.4 | 107.9 | 121.7 | 171.2 | 53.8 | 22.4 | 4.6 | 587.3 | 1 | 588.3 |
| 29 | | | | | | | | | | | 0.0 | 1.9 | 2.9 | 1.8 | 2.9 | 6.5 | 10.8 | 18.8 | 32.4 | 84.2 | 70.9 | 74.2 | 115.2 | 35.3 | 7.2 | 457.7 | 1 | 458.7 |
| 30 | | | | | | | | | | | | 0.0 | 1.9 | 0.7 | 2.0 | 4.7 | 7.3 | 14.6 | 25.4 | 64.3 | 55.3 | 43.2 | 49.9 | 75.6 | 11.4 | 345.0 | 1 | 346.0 |
| 31 | | | | | | | | | | | | | 0.0 | 0.4 | 0.8 | 3.2 | 5.3 | 10.0 | 19.7 | 50.4 | 42.2 | 33.7 | 29.1 | 32.8 | 24.3 | 227.6 | 1 | 228.6 |
| 32 | | | | | | | | | | | | | | 0.0 | 0.5 | 1.2 | 3.7 | 7.2 | 13.4 | 39.1 | 33.1 | 25.8 | 22.7 | 19.1 | 10.5 | 165.8 | 1 | 166.8 |
| 33 | | | | | | | | | | | | | | | 0.0 | 0.8 | 1.4 | 5.0 | 9.7 | 26.7 | 25.7 | 20.2 | 17.3 | 14.9 | 6.1 | 121.7 | 1 | 122.7 |
| 34 | | | | | | | | | | | | | | | | 0.0 | 0.9 | 1.9 | 6.7 | 19.3 | 17.5 | 15.7 | 13.6 | 11.4 | 4.8 | 86.9 | 1 | 87.9 |
| 35 | | | | | | | | | | | | | | | | | 0.0 | 1.2 | 2.5 | 13.3 | 12.7 | 10.7 | 10.5 | 8.9 | 3.7 | 59.9 | 1 | 60.9 |
| 36 | | | | | | | | | | | | | | | | | | 0.0 | 1.6 | 5.0 | 8.8 | 7.7 | 7.2 | 6.9 | 2.9 | 37.3 | 1 | 38.3 |
| 37 | | | | | | | | | | | | | | | | | | | 0.0 | 3.3 | 3.3 | 5.3 | 5.2 | 4.7 | 2.2 | 21.8 | 1 | 22.8 |
| 38 | | | | | | | | | | | | | | | | | | | | 0.0 | 2.1 | 2.0 | 3.6 | 3.4 | 1.5 | 11.2 | 1 | 12.2 |
| 39 | | | | | | | | | | | | | | | | | | | | | 0.0 | 1.3 | 1.4 | 2.4 | 1.1 | 5.0 | 1 | 6.0 |
| 40 | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.9 | 0.9 | 0.8 | 1.8 | 1 | 2.8 |
| 41 | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.6 | 0.3 | 0.6 | 1 | 1.6 |
| 42 | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0.2 | 0.0 | 1 | 1.0 |
| 43 | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | 1 | 1.0 |

**Design Flood Hydrograph:**

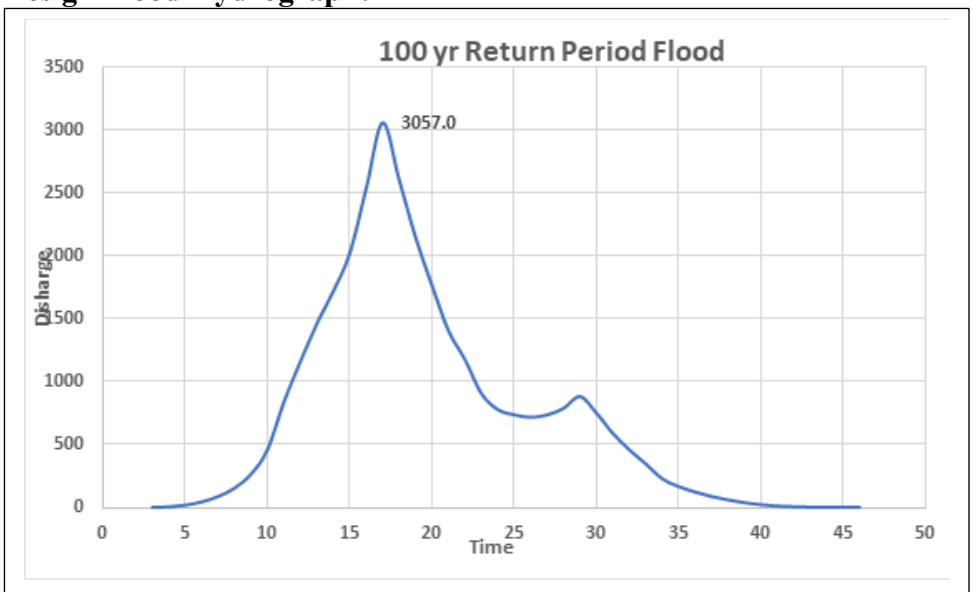



**Fig.11: Design Flood Hydrograph for 100yr Return Period**

**Table 16: 100 yr Design Flood Hydrograph for Solani River:**

| Time (hr) | Design Flood Ordinates (cumec) | Time (hr) | Design Flood Ordinates (cumec) |
|---|---|---|---|
| 0 | 1 | 22 | 737 |
| 1 | 5 | 23 | 717 |
| 2 | 19 | 24 | 736 |
| 3 | 45 | 25 | 789 |
| 4 | 88 | 26 | 882 |
| 5 | 155 | 27 | 749 |
| 6 | 266 | 28 | 588 |
| 7 | 461 | 29 | 459 |
| 8 | 840 | 30 | 346 |
| 9 | 1160 | 31 | 229 |
| 10 | 1462 | 32 | 167 |
| 11 | 1719 | 33 | 123 |
| 12 | 2022 | 34 | 88 |
| 13 | 2537 | 35 | 61 |
| 14 | **3057** | 36 | 38 |
| 15 | 2604 | 37 | 23 |
| 16 | 2147 | 38 | 12 |
| 17 | 1763 | 39 | 6 |
| 18 | 1404 | 40 | 3 |
| 19 | 1176 | 41 | 2 |
| 20 | 906 | 42 | 1 |
| 21 | 778 | 43 | 1 |

**50 Year Return Period Flood Estimation**

A design loss rate of 0 to 0 .6 cm /hr as recommended in CWC FER of Western Himalayan Zone-7 report for has been adopted for design flood computation.

As recommended by CWC Western Himalayan Zone-7 report following base flow rate has been adopted:

Base flow / km2 of drainage area = 0.10 (max)

Using the above formula, the computed base flow for the catchment area is 0.61.0 $m^3$ /sec.

**Time Distribution of Rainfall:**

For hourly distribution of rainfall, normalized distribution coefficient has been worked out for bell of 12 hour each using the hourly distribution coefficient of 24-hour rainfall from PMP Atlas of Ganga River Basins. The hourly distribution coefficient of 24-hour rainfall and normalized distribution coefficient for 12-hour bell are given in previously mentioned table no. 8

**Table 17: PMP depth for 12-hour bells**

After getting rainfall distribution for 24 hrs, rainfall is further bifurcated in the sets of 12hr based on the previous table.

| Catchment | 100yr RP Rainfall | 24 hr Max ( 1.15* col(1) | 1st Bell 76% of col. (1) B1 | 2nd Bell 24 % of col. (1) B2 |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Solani | 120.19 | 138.22 | 91.34 | 28.85 |

**Table 18: 12 Hour bell distribution of rainfall**

Two bells on based on its fraction are prepared i.e. 1st 12hr Bell & 2nd 12hr Bell.

| Bell | Rainfall PMP Depth |
|---|---|
| 1st 12Hr Bell | 91.3 |
| 2nd 12Hr Bell | 28.8 |

**Table 19: Hourly Distribution of Rainfall**

After preparing 12hr bells, cumulative rainfall depth, incremental rainfall depth & effective rainfall are calculated by subtracting the losses.

| Time | Dis. Coeff. | Nor. Dis. Coeff. | Cumulative Rainfall Depth | | Incremental Rainfall Depth | | Loss | Effective Rainfall Depth | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1st 12 hr Bell Distribution | 2nd 12 Hr Bell Distribution | Incremental Rainfall 1st Bell | Incremental Rainfall 2nd Bell | | Eff. Inc. Rainfall Depth 1st Bell | Eff. Inc. Rainfall Depth 2nd Bell |
| Hr | % | % | (mm) | (mm) | (mm) | (mm) | mm/hr | (mm) | (mm) |
| | | | | | | | | | |
| 1 | 0.17 | 0.202 | 20.43 | 5.83 | 20.43 | 5.83 | 0.6 | 19.83 | 5.23 |
| 2 | 0.27 | 0.341 | 32.45 | 9.84 | 12.02 | 4.01 | 0.6 | 11.42 | 3.41 |
| 3 | 0.36 | 0.452 | 43.27 | 13.04 | 10.82 | 3.20 | 0.6 | 10.22 | 2.60 |
| 4 | 0.43 | 0.544 | 51.68 | 15.69 | 8.41 | 2.65 | 0.6 | 7.81 | 2.05 |
| 5 | 0.48 | 0.631 | 57.69 | 18.20 | 6.01 | 2.51 | 0.6 | 5.41 | 1.91 |
| 6 | 0.53 | 0.7 | 63.70 | 20.19 | 6.01 | 1.99 | 0.6 | 5.41 | 1.39 |
| 7 | 0.58 | 0.768 | 69.71 | 22.15 | 6.01 | 1.96 | 0.6 | 5.41 | 1.36 |
| 8 | 0.63 | 0.831 | 75.72 | 23.97 | 6.01 | 1.82 | 0.6 | 5.41 | 1.22 |
| 9 | 0.67 | 0.882 | 80.53 | 25.44 | 4.81 | 1.47 | 0.6 | 4.21 | 0.87 |
| 10 | 0.7 | 0.928 | 84.13 | 26.77 | 3.61 | 1.33 | 0.6 | 3.01 | 0.73 |
| 11 | 0.73 | 0.971 | 87.74 | 28.01 | 3.61 | 1.24 | 0.6 | 3.01 | 0.64 |
| 12 | 0.76 | 1 | 91.34 | 28.85 | 3.61 | 0.84 | 0.6 | 3.01 | 0.24 |

**Table 20: Critical sequencing for Effective hourly rainfall**

After getting the effective rainfall depth, for both bell, critical sequencing and reverse critical sequencing is done for rainfall & corresponding to its UH ordinates. Then rain convolution for both the bell are obtained, which is further to be used for designing the flood hydrograph for different return period floods

| Time | UH ordinate | Critical Sequence of Hourly Rainfall Depth | | Reverse Critical Sequence | | Conv. Rainfall B2-B1 |
|---|---|---|---|---|---|---|
| | | 1st 12 Hr bell | 2nd 12 Hr bell | 1st 12 Hr bell | 2nd 12 Hr bell | |
| Hr | cumec | (mm) | (mm) | (mm) | (mm) | (mm) |
| 0 | 0 | | | | | |
| 1 | 16 | | | | | 3.0 |
| 2 | 36 | | | | | 3.0 |
| 3 | 62 | 3.0 | 0.2 | | | 5.4 |
| 4 | 95 | 4.2 | 0.9 | | | 5.4 |
| 5 | 146 | 5.4 | 1.4 | 3.0 | 0.6 | 5.4 |
| 6 | 230 | 7.8 | 2.1 | 3.0 | 0.7 | 10.2 |
| 7 | 360 | 11.4 | 3.4 | 5.4 | 1.2 | 19.8 |
| 8 | 722 | 19.8 | 5.2 | 5.4 | 1.4 | 11.4 |
| 9 | 335 | 10.2 | 2.6 | 5.4 | 1.9 | 7.8 |
| 10 | 195 | 5.4 | 1.9 | 10.2 | 2.6 | 5.4 |
| 11 | 153 | 5.4 | 1.4 | 19.8 | 5.2 | 4.2 |
| 12 | 120 | 5.4 | 1.2 | 11.4 | 3.4 | 3.0 |
| 13 | 93 | 3.0 | 0.7 | 7.8 | 2.1 | 0.6 |
| 14 | 72 | 3.0 | 0.6 | 5.4 | 1.4 | 0.7 |
| 15 | 54 | | | 4.2 | 0.9 | 1.2 |
| 16 | 41 | | | 3.0 | 0.2 | 1.4 |
| 17 | 26 | | | | | 1.9 |
| 18 | 15 | | | | | 2.6 |
| 19 | 7 | | | | | 5.2 |
| 20 | 0 | | | | | 3.4 |
| 21 | | | | | | 2.1 |
| 22 | | | | | | 1.4 |
| 23 | | | | | | 0.9 |
| 24 | | | | | | 0.2 |

## Table 21: 50yr Return Period flood for Solani River:

| Time | UH ord. | Rainfall Excess (cm) | | | | | | | | | | | | | | | | | | | | | | | DRH | Base Flow | 100yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| hr | cumec | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | cumec | cumec | Return |
| | | 0.30 | 0.30 | 0.54 | 0.54 | 0.54 | 1.02 | 1.98 | 1.14 | 0.78 | 0.54 | 0.42 | 0.30 | 0.06 | 0.07 | 0.12 | 0.14 | 0.19 | 0.26 | 0.52 | 0.34 | 0.21 | 0.14 | 0.09 | 0.02 | | | Period |
| 0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 1 | 1.0 |
| 1 | 15.8 | 4.7 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | 4.7 | 1 | 5.7 |
| 2 | 36.2 | 10.9 | 4.7 | 0.0 | | | | | | | | | | | | | | | | | | | | | | 15.6 | 1 | 16.6 |
| 3 | 61.8 | 18.6 | 10.9 | 8.5 | 0.0 | | | | | | | | | | | | | | | | | | | | | 38.0 | 1 | 39.0 |
| 4 | 95.1 | 28.6 | 18.6 | 19.6 | 8.5 | 0.0 | | | | | | | | | | | | | | | | | | | | 75.3 | 1 | 76.3 |
| 5 | 145.9 | 43.8 | 28.6 | 33.5 | 19.6 | 8.5 | 0.0 | | | | | | | | | | | | | | | | | | | 134.0 | 1 | 135.0 |
| 6 | 230.0 | 69.1 | 43.8 | 51.4 | 33.5 | 19.6 | 16.1 | 0.0 | | | | | | | | | | | | | | | | | | 233.5 | 1 | 234.5 |
| 7 | 360.0 | 108.2 | 69.1 | 78.9 | 51.4 | 33.5 | 37.0 | 31.2 | 0.0 | | | | | | | | | | | | | | | | | 409.3 | 1 | 410.3 |
| 8 | 722.0 | 217.0 | 108.2 | 124.4 | 78.9 | 51.4 | 63.2 | 71.7 | 18.0 | 0.0 | | | | | | | | | | | | | | | | 732.9 | 1 | 733.9 |
| 9 | 335.5 | 100.8 | 217.0 | 194.7 | 124.4 | 78.9 | 97.2 | 122.6 | 41.3 | 12.3 | 0.0 | | | | | | | | | | | | | | | 989.3 | 1 | 990.3 |
| 10 | 195.4 | 58.7 | 100.8 | 390.6 | 194.7 | 124.4 | 149.0 | 188.6 | 70.6 | 28.3 | 8.5 | 0.0 | | | | | | | | | | | | | | 1314.3 | 1 | 1315.3 |
| 11 | 153.0 | 46.0 | 58.7 | 181.5 | 390.6 | 194.7 | 235.0 | 289.3 | 108.6 | 48.3 | 19.6 | 6.6 | 0.0 | | | | | | | | | | | | | 1578.8 | 1 | 1579.8 |
| 12 | 119.6 | 35.9 | 46.0 | 105.7 | 181.5 | 390.6 | 367.8 | 456.1 | 166.5 | 74.3 | 33.5 | 15.2 | 4.7 | 0.0 | | | | | | | | | | | | 1877.9 | 1 | 1878.9 |
| 13 | 93.3 | 28.1 | 35.9 | 82.8 | 105.7 | 181.5 | 737.7 | 714.0 | 262.6 | 114.0 | 51.4 | 26.0 | 10.9 | 1.0 | 0.0 | | | | | | | | | | | 2351.5 | 1 | 2352.5 |
| 14 | 72.3 | 21.7 | 28.1 | 64.7 | 82.8 | 105.7 | 342.7 | 1431.9 | 411.1 | 179.7 | 78.9 | 40.0 | 18.6 | 2.3 | 1.1 | 0.0 | | | | | | | | | | 2809.3 | 1 | 2810.3 |
| 15 | 54.3 | 16.3 | 21.7 | 50.5 | 64.7 | 82.8 | 199.7 | 665.3 | 824.4 | 281.3 | 124.4 | 61.4 | 28.6 | 4.0 | 2.6 | 1.9 | 0.0 | | | | | | | | | 2429.6 | 1 | 2430.6 |
| 16 | 40.8 | 12.3 | 16.3 | 39.1 | 50.5 | 64.7 | 156.3 | 387.6 | 383.1 | 564.1 | 194.7 | 96.8 | 43.8 | 6.1 | 4.5 | 4.4 | 2.2 | 0.0 | | | | | | | | 2026.5 | 1 | 2027.5 |
| 17 | 26.3 | 7.9 | 12.3 | 29.4 | 39.1 | 50.5 | 122.2 | 303.4 | 223.2 | 262.1 | 390.6 | 151.5 | 69.1 | 9.3 | 6.9 | 7.5 | 5.0 | 3.0 | 0.0 | | | | | | | 1693.0 | 1 | 1694.0 |
| 18 | 14.6 | 4.4 | 7.9 | 22.1 | 29.4 | 39.1 | 95.4 | 237.2 | 174.7 | 152.7 | 181.5 | 303.8 | 108.2 | 14.7 | 10.6 | 11.6 | 8.6 | 6.9 | 4.1 | 0.0 | | | | | | 1412.8 | 1 | 1413.8 |
| 19 | 7.0 | 2.1 | 4.4 | 14.2 | 22.1 | 29.4 | 73.9 | 185.1 | 136.6 | 119.5 | 105.7 | 141.1 | 217.0 | 23.1 | 16.7 | 17.8 | 13.2 | 11.8 | 9.4 | 8.2 | 0.0 | | | | | 1149.3 | 1 | 1150.3 |
| 20 | 0.0 | 0.0 | 2.1 | 7.9 | 14.2 | 22.1 | 55.4 | 143.5 | 106.6 | 93.4 | 82.8 | 82.2 | 100.8 | 46.2 | 26.2 | 28.0 | 20.3 | 18.2 | 16.1 | 18.9 | 5.4 | 0.0 | | | | 888.2 | 1 | 889.2 |
| 21 | | | 0.0 | 3.8 | 7.9 | 14.2 | 41.7 | 107.6 | 82.6 | 72.9 | 64.7 | 64.4 | 58.7 | 21.5 | 52.5 | 43.8 | 32.0 | 27.9 | 24.7 | 32.3 | 12.3 | 3.2 | 0.0 | | | 765.0 | 1 | 766.0 |
| 22 | | | | 0.0 | 3.8 | 7.9 | 26.8 | 81.0 | 62.0 | 56.5 | 50.5 | 50.3 | 46.0 | 12.5 | 24.4 | 87.9 | 50.1 | 43.9 | 37.9 | 49.7 | 21.1 | 7.4 | 2.1 | 0.0 | | 718.1 | 1 | 719.1 |
| 23 | | | | | 0.0 | 3.8 | 14.9 | 52.1 | 46.6 | 42.4 | 39.1 | 39.3 | 35.9 | 9.8 | 14.2 | 40.8 | 100.4 | 68.7 | 59.8 | 76.2 | 32.4 | 12.7 | 4.9 | 1.4 | 0.0 | 691.8 | 1 | 692.8 |
| 24 | | | | | | 0.0 | 7.2 | 28.9 | 30.0 | 31.9 | 29.4 | 30.4 | 28.1 | 7.7 | 11.1 | 23.8 | 46.6 | 137.9 | 93.7 | 120.2 | 49.7 | 19.5 | 8.4 | 3.2 | 0.4 | 700.8 | 1 | 701.8 |
| 25 | | | | | | | 0.0 | 13.9 | 16.7 | 20.5 | 22.1 | 22.8 | 21.7 | 6.0 | 8.7 | 18.6 | 27.2 | 64.1 | 187.9 | 188.2 | 78.4 | 30.0 | 12.9 | 5.4 | 0.9 | 731.9 | 1 | 732.9 |
| 26 | | | | | | | | 0.0 | 8.0 | 11.4 | 14.2 | 17.2 | 16.3 | 4.6 | 6.8 | 14.6 | 21.3 | 37.3 | 87.3 | 377.4 | 122.7 | 47.2 | 19.9 | 8.3 | 1.5 | 807.9 | 1 | 808.9 |
| 27 | | | | | | | | | 0.0 | 5.5 | 7.9 | 11.0 | 12.3 | 3.5 | 5.3 | 11.4 | 16.6 | 29.2 | 50.9 | 175.3 | 246.2 | 73.9 | 31.3 | 12.7 | 2.2 | 689.7 | 1 | 690.7 |
| 28 | | | | | | | | | | 0.0 | 3.8 | 6.1 | 7.9 | 2.6 | 3.9 | 8.8 | 13.0 | 22.8 | 39.8 | 102.2 | 114.4 | 148.3 | 49.0 | 20.0 | 3.4 | 542.3 | 1 | 543.3 |
| 29 | | | | | | | | | | | 0.0 | 2.9 | 4.4 | 1.7 | 3.0 | 6.6 | 10.1 | 17.8 | 31.1 | 80.0 | 66.6 | 68.9 | 98.3 | 31.4 | 5.4 | 425.2 | 1 | 426.2 |
| 30 | | | | | | | | | | | | 0.0 | 2.1 | 0.9 | 1.9 | 5.0 | 7.5 | 13.8 | 24.3 | 62.5 | 52.2 | 40.1 | 45.7 | 62.9 | 8.5 | 325.4 | 1 | 326.4 |
| 31 | | | | | | | | | | | | | 0.0 | 0.4 | 1.1 | 3.2 | 5.7 | 10.4 | 18.8 | 48.8 | 40.8 | 31.4 | 26.6 | 29.2 | 17.1 | 233.0 | 1 | 234.0 |
| 32 | | | | | | | | | | | | | | 0.0 | 0.5 | 1.8 | 3.7 | 7.8 | 14.1 | 37.8 | 31.8 | 24.6 | 20.8 | 17.0 | 7.9 | 167.3 | 1 | 168.3 |
| 33 | | | | | | | | | | | | | | | 0.0 | 0.9 | 2.0 | 5.0 | 10.6 | 28.4 | 24.7 | 19.2 | 16.3 | 13.3 | 4.6 | 124.1 | 1 | 125.1 |
| 34 | | | | | | | | | | | | | | | | 0.0 | 1.0 | 2.8 | 6.8 | 21.3 | 18.5 | 14.9 | 12.7 | 10.4 | 3.6 | 91.1 | 1 | 92.1 |
| 35 | | | | | | | | | | | | | | | | | 0.0 | 1.3 | 3.8 | 13.7 | 13.9 | 11.1 | 9.8 | 8.1 | 2.8 | 63.4 | 1 | 64.4 |
| 36 | | | | | | | | | | | | | | | | | | 0.0 | 1.8 | 7.6 | 9.0 | 8.4 | 7.4 | 6.3 | 2.2 | 40.9 | 1 | 41.9 |
| 37 | | | | | | | | | | | | | | | | | | | 0.0 | 3.7 | 5.0 | 5.4 | 5.6 | 4.7 | 1.7 | 22.4 | 1 | 23.4 |
| 38 | | | | | | | | | | | | | | | | | | | | 0.0 | 2.4 | 3.0 | 3.6 | 3.6 | 1.3 | 11.4 | 1 | 12.4 |
| 39 | | | | | | | | | | | | | | | | | | | | | 0.0 | 1.4 | 2.0 | 2.3 | 1.0 | 5.2 | 1 | 6.2 |
| 40 | | | | | | | | | | | | | | | | | | | | | | 0.0 | 1.0 | 1.3 | 0.6 | 1.9 | 1 | 2.9 |
| 41 | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.6 | 0.3 | 0.3 | 1 | 1.3 |
| 42 | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0.2 | 0.2 | 1 | 1.2 |
| 43 | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | 1 | 1.0 |

## Design Flood Hydrograph

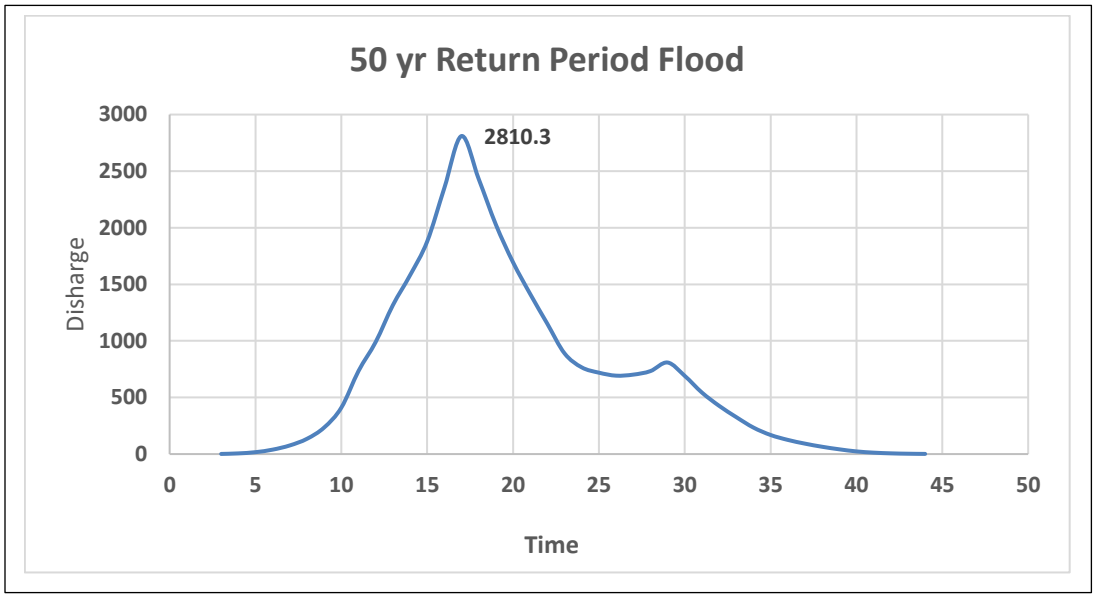



**Fig.12: Design Flood Hydrograph for 50yr Return Period**

**Table 22: 50 yr Design Flood Hydrograph for Solani River**

| Time (hr) | Design Flood Ordinates (cumec) | Time (hr) | Design Flood Ordinates (cumec) |
|---|---|---|---|
| 0 | 1 | 22 | 719 |
| 1 | 6 | 23 | 693 |
| 2 | 17 | 24 | 702 |
| 3 | 39 | 25 | 733 |
| 4 | 76 | 26 | 809 |
| 5 | 135 | 27 | 691 |
| 6 | 235 | 28 | 543 |
| 7 | 410 | 29 | 426 |
| 8 | 734 | 30 | 326 |
| 9 | 990 | 31 | 234 |
| 10 | 1315 | 32 | 168 |
| 11 | 1580 | 33 | 125 |
| 12 | 1879 | 34 | 92 |
| 13 | 2353 | 35 | 64 |
| 14 | **2810** | 36 | 42 |
| 15 | 2431 | 37 | 23 |
| 16 | 2028 | 38 | 12 |
| 17 | 1694 | 39 | 6 |
| 18 | 1414 | 40 | 3 |
| 19 | 1150 | 41 | 1 |
| 20 | 889 | 42 | 1 |
| 21 | 766 | 43 | 1 |

**C. 25 Year Return Period Flood Estimation**

A design loss rate of 0 to 0 .6 cm /hr as recommended in CWC FER of Western Himalayan Zone-7 report for has been adopted for design flood computation.

As recommended by CWC Western Himalayan Zone-7 report following base flow rate has been adopted:

Base flow / km2 of drainage area = 0.10 (max)

Using the above formula, the computed base flow for the catchment area is 0.61.0 $m^3$ /sec.

**Time Distribution of Rainfall:**

For hourly distribution of rainfall, normalized distribution coefficient has been worked out for bell of 12 hour each using the hourly distribution coefficient of 24-hour rainfall from PMP Atlas of Ganga River Basins. The hourly distribution coefficient of 24-hour rainfall and normalized distribution coefficient for 12-hour bell are mentioned in table no.8.

After getting rainfall distribution for 24 hrs, rainfall is further bifurcated in the sets of 12hr based on the previous table.

**Table 23: RP rainfall depth for 12-hour bells**

| Catchment | RP Rainfall | 24 hr Max ( 1.15* col(1) | 1st Bell 76% of col. (1) B1 | 2nd Bell 24 % of col. (1) B2 |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| Solani | 105.45 | 121.27 | 80.14 | 25.31 |

Two bells on based on its fraction are prepared i.e. 1st 12hr Bell & 2nd 12hr Bell.

**Table 24: 12 Hour bell distribution of rainfall**

| Bell | Rainfall PMP Depth |
|---|---|
| 1st 12Hr Bell | 80.1 |
| 2nd 12Hr Bell | 25.3 |

After preparing 12hr bells, cumulative rainfall depth, incremental rainfall depth & effective rainfall are calculated by subtracting the losses.

**Table 25: Hourly Distribution of Rainfall**

| Time | Dis. Coeff. | Nor. Dis. Coeff. | Cumulative Rainfall Depth | | Incremental Rainfall Depth | | Loss | Effective Rainfall Depth | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1st 12 hr Bell Distribution | 2nd 12 Hr Bell Distribution | Incremental Rainfall 1st Bell | Incremental Rainfall 2nd Bell | | Eff. Inc. Rainfall Depth 1st Bell | Eff. Inc. Rainfall Depth 2nd Bell |
| Hr | % | % | (mm) | (mm) | (mm) | (mm) | mm/ hr | (mm) | (mm) |
| | | | | | | | | | |
| 1 | 0.17 | 0.202 | 17.93 | 5.11 | 17.93 | 5.11 | 0.6 | 17.33 | 4.51 |
| 2 | 0.27 | 0.341 | 28.47 | 8.63 | 10.55 | 3.52 | 0.6 | 9.95 | 2.92 |
| 3 | 0.36 | 0.452 | 37.96 | 11.44 | 9.49 | 2.81 | 0.6 | 8.89 | 2.21 |
| 4 | 0.43 | 0.544 | 45.34 | 13.77 | 7.38 | 2.33 | 0.6 | 6.78 | 1.73 |
| 5 | 0.48 | 0.631 | 50.62 | 15.97 | 5.27 | 2.20 | 0.6 | 4.67 | 1.60 |
| 6 | 0.53 | 0.7 | 55.89 | 17.72 | 5.27 | 1.75 | 0.6 | 4.67 | 1.15 |
| 7 | 0.58 | 0.768 | 61.16 | 19.44 | 5.27 | 1.72 | 0.6 | 4.67 | 1.12 |
| 8 | 0.63 | 0.831 | 66.44 | 21.03 | 5.27 | 1.59 | 0.6 | 4.67 | 0.99 |
| 9 | 0.67 | 0.882 | 70.65 | 22.32 | 4.22 | 1.29 | 0.6 | 3.62 | 0.69 |
| 10 | 0.7 | 0.928 | 73.82 | 23.49 | 3.16 | 1.16 | 0.6 | 2.56 | 0.56 |
| 11 | 0.73 | 0.971 | 76.98 | 24.57 | 3.16 | 1.09 | 0.6 | 2.56 | 0.49 |
| 12 | 0.76 | 1 | 80.14 | 25.31 | 3.16 | 0.73 | 0.6 | 2.56 | 0.13 |

After getting the effective rainfall depth, for both bell, critical sequencing and reverse critical sequencing (Table 21) is done for rainfall & corresponding to its UH ordinates. Then rain convolution for both the bell are obtained, which is further to be used for designing the flood hydrograph for different return period floods.

**Table 26: Critical sequencing for Effective hourly rainfall**

| Time | UH ordinate | Critical Sequence of Hourly Rainfall Depth | | Reverse Critical Sequence | | Conv. Rainfall B2-B1 |
|---|---|---|---|---|---|---|
| | | 1st 12 Hr bell | 2nd 12 Hr bell | 1st 12 Hr bell | 2nd 12 Hr bell | |
| Hr | cumec | (mm) | (mm) | (mm) | (mm) | (mm) |
| 0 | 0 | | | | | |
| 1 | 16 | | | | | 2.6 |
| 2 | 36 | | | | | 2.6 |
| 3 | 62 | 2.6 | 0.1 | | | 4.7 |
| 4 | 95 | 3.6 | 0.7 | | | 4.7 |
| 5 | 146 | 4.7 | 1.1 | 2.6 | 0.5 | 4.7 |
| 6 | 230 | 6.8 | 1.7 | 2.6 | 0.6 | 8.9 |
| 7 | 360 | 9.9 | 2.9 | 4.7 | 1.0 | 17.3 |
| 8 | 722 | 17.3 | 4.5 | 4.7 | 1.1 | 9.9 |
| 9 | 335 | 8.9 | 2.2 | 4.7 | 1.6 | 6.8 |
| 10 | 195 | 4.7 | 1.6 | 8.9 | 2.2 | 4.7 |
| 11 | 153 | 4.7 | 1.1 | 17.3 | 4.5 | 3.6 |
| 12 | 120 | 4.7 | 1.0 | 9.9 | 2.9 | 2.6 |
| 13 | 93 | 2.6 | 0.6 | 6.8 | 1.7 | 0.5 |
| 14 | 72 | 2.6 | 0.5 | 4.7 | 1.1 | 0.6 |
| 15 | 54 | | | 3.6 | 0.7 | 1.0 |
| 16 | 41 | | | 2.6 | 0.1 | 1.1 |
| 17 | 26 | | | | | 1.6 |
| 18 | 15 | | | | | 2.2 |
| 19 | 7 | | | | | 4.5 |
| 20 | 0 | | | | | 2.9 |
| 21 | | | | | | 1.7 |
| 22 | | | | | | 1.1 |
| 23 | | | | | | 0.7 |
| 24 | | | | | | 0.1 |

## Table 27: 25yr Return Period flood for Solani River

| Time | UH ord. | Rainfall Excess (cm) | | | | | | | | | | | | | | | | | | | | | | | | DRH | Base Flow | 100yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| hr | cumec | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | cumec | cumec | Return Period |
| | | 0.26 | 0.26 | 0.47 | 0.47 | 0.47 | 0.89 | 1.73 | 0.99 | 0.68 | 0.47 | 0.36 | 0.26 | 0.05 | 0.06 | 0.10 | 0.11 | 0.16 | 0.22 | 0.45 | 0.29 | 0.17 | 0.11 | 0.07 | 0.01 | | | |
| 0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 1 | 1.0 |
| 1 | 15.8 | 4.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | 4.0 | 1 | 5.0 |
| 2 | 36.2 | 9.3 | 4.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | 13.3 | 1 | 14.3 |
| 3 | 61.8 | 15.9 | 9.3 | 7.4 | 0.0 | | | | | | | | | | | | | | | | | | | | | 32.5 | 1 | 33.5 |
| 4 | 95.1 | 24.4 | 15.9 | 16.9 | 7.4 | 0.0 | | | | | | | | | | | | | | | | | | | | 64.5 | 1 | 65.5 |
| 5 | 145.9 | 37.4 | 24.4 | 28.9 | 16.9 | 7.4 | 0.0 | | | | | | | | | | | | | | | | | | | 114.9 | 1 | 115.9 |
| 6 | 230.0 | 59.0 | 37.4 | 44.4 | 28.9 | 16.9 | 14.0 | 0.0 | | | | | | | | | | | | | | | | | | 200.6 | 1 | 201.6 |
| 7 | 360.0 | 92.3 | 59.0 | 68.2 | 44.4 | 28.9 | 32.2 | 27.3 | 0.0 | | | | | | | | | | | | | | | | | 352.2 | 1 | 353.2 |
| 8 | 722.0 | 185.1 | 92.3 | 107.5 | 68.2 | 44.4 | 55.0 | 62.7 | 15.7 | 0.0 | | | | | | | | | | | | | | | | 630.8 | 1 | 631.8 |
| 9 | 335.5 | 86.0 | 185.1 | 168.2 | 107.5 | 68.2 | 84.5 | 107.2 | 36.0 | 10.7 | 0.0 | | | | | | | | | | | | | | | 853.3 | 1 | 854.3 |
| 10 | 195.4 | 50.1 | 86.0 | 337.4 | 168.2 | 107.5 | 129.7 | 164.8 | 61.5 | 24.5 | 7.4 | 0.0 | | | | | | | | | | | | | | 1137.0 | 1 | 1138.0 |
| 11 | 153.0 | 39.2 | 50.1 | 156.8 | 337.4 | 168.2 | 204.5 | 252.7 | 94.6 | 41.9 | 16.9 | 5.7 | 0.0 | | | | | | | | | | | | | 1368.0 | 1 | 1369.0 |
| 12 | 119.6 | 30.7 | 39.2 | 91.3 | 156.8 | 337.4 | 320.1 | 398.5 | 145.1 | 64.5 | 28.9 | 13.1 | 4.0 | 0.0 | | | | | | | | | | | | 1629.5 | 1 | 1630.5 |
| 13 | 93.3 | 23.9 | 30.7 | 71.5 | 91.3 | 156.8 | 641.9 | 623.8 | 228.7 | 98.9 | 44.4 | 22.4 | 9.3 | 0.8 | 0.0 | | | | | | | | | | | 2044.3 | 1 | 2045.3 |
| 14 | 72.3 | 18.5 | 23.9 | 55.9 | 71.5 | 91.3 | 298.3 | 1251.0 | 358.0 | 156.0 | 68.2 | 34.4 | 15.9 | 1.8 | 0.9 | 0.0 | | | | | | | | | | 2445.5 | 1 | 2446.5 |
| 15 | 54.3 | 13.9 | 18.5 | 43.6 | 55.9 | 71.5 | 173.8 | 581.3 | 718.0 | 244.1 | 107.5 | 52.8 | 24.4 | 3.0 | 2.0 | 1.6 | 0.0 | | | | | | | | | 2111.9 | 1 | 2112.9 |
| 16 | 40.8 | 10.5 | 13.9 | 33.8 | 43.6 | 55.9 | 136.0 | 338.6 | 333.6 | 489.6 | 168.2 | 83.2 | 37.4 | 4.6 | 3.5 | 3.6 | 1.8 | 0.0 | | | | | | | | 1758.0 | 1 | 1759.0 |
| 17 | 26.3 | 6.7 | 10.5 | 25.4 | 33.8 | 43.6 | 106.3 | 265.1 | 194.4 | 227.5 | 337.4 | 130.3 | 59.0 | 7.1 | 5.4 | 6.1 | 4.1 | 2.5 | 0.0 | | | | | | | 1465.2 | 1 | 1466.2 |
| 18 | 14.6 | 3.7 | 6.7 | 19.1 | 25.4 | 33.8 | 83.0 | 207.2 | 152.2 | 132.5 | 156.8 | 261.2 | 92.3 | 11.2 | 8.2 | 9.5 | 7.1 | 5.8 | 3.5 | 0.0 | | | | | | 1219.2 | 1 | 1220.2 |
| 19 | 7.0 | 1.8 | 3.7 | 12.3 | 19.1 | 25.4 | 64.3 | 161.7 | 118.9 | 103.8 | 91.3 | 121.4 | 185.1 | 17.6 | 13.0 | 14.5 | 10.9 | 9.9 | 8.0 | 7.1 | 0.0 | | | | | 989.8 | 1 | 990.8 |
| 20 | 0.0 | 0.0 | 1.8 | 6.8 | 12.3 | 19.1 | 48.2 | 125.3 | 92.8 | 81.1 | 71.5 | 70.7 | 86.0 | 35.3 | 20.3 | 22.9 | 16.7 | 15.2 | 13.7 | 16.3 | 4.6 | 0.0 | | | | 760.7 | 1 | 761.7 |
| 21 | | | 0.0 | 3.3 | 6.8 | 12.3 | 36.3 | 94.0 | 71.9 | 63.3 | 55.9 | 55.4 | 50.1 | 16.4 | 40.7 | 35.8 | 26.4 | 23.4 | 21.0 | 27.9 | 10.6 | 2.7 | 0.0 | | | 654.1 | 1 | 655.1 |
| 22 | | | | 0.0 | 3.3 | 6.8 | 23.3 | 70.8 | 54.0 | 49.1 | 43.6 | 43.3 | 39.2 | 9.5 | 18.9 | 71.8 | 41.3 | 36.8 | 32.2 | 42.9 | 18.0 | 6.3 | 1.8 | 0.0 | | 612.9 | 1 | 613.9 |
| 23 | | | | | 0.0 | 3.3 | 13.0 | 45.5 | 40.6 | 36.8 | 33.8 | 33.8 | 30.7 | 7.5 | 11.0 | 33.4 | 82.8 | 57.7 | 50.8 | 65.8 | 27.7 | 10.7 | 4.1 | 1.1 | 0.0 | 589.9 | 1 | 590.9 |
| 24 | | | | | | 0.0 | 6.2 | 25.3 | 26.1 | 27.7 | 25.4 | 26.2 | 23.9 | 5.8 | 8.6 | 19.4 | 38.5 | 115.7 | 79.5 | 103.8 | 42.6 | 16.4 | 6.9 | 2.5 | 0.2 | 600.7 | 1 | 601.7 |
| 25 | | | | | | | 0.0 | 12.1 | 14.5 | 17.8 | 19.1 | 19.6 | 18.5 | 4.6 | 6.7 | 15.2 | 22.4 | 53.7 | 159.5 | 162.4 | 67.1 | 25.2 | 10.7 | 4.3 | 0.5 | 634.1 | 1 | 635.1 |
| 26 | | | | | | | | 0.0 | 7.0 | 9.9 | 12.3 | 14.8 | 13.9 | 3.5 | 5.3 | 11.9 | 17.5 | 31.3 | 74.1 | 325.8 | 105.0 | 39.8 | 16.4 | 6.6 | 0.8 | 695.8 | 1 | 696.8 |
| 27 | | | | | | | | | 0.0 | 4.7 | 6.8 | 9.5 | 10.5 | 2.6 | 4.1 | 9.3 | 13.7 | 24.5 | 43.2 | 151.4 | 210.7 | 62.2 | 25.8 | 10.1 | 1.3 | 590.3 | 1 | 591.3 |
| 28 | | | | | | | | | | 0.0 | 3.3 | 5.3 | 6.7 | 2.0 | 3.1 | 7.2 | 10.7 | 19.2 | 33.8 | 88.2 | 97.9 | 124.8 | 40.4 | 15.9 | 2.0 | 460.3 | 1 | 461.3 |
| 29 | | | | | | | | | | | 0.0 | 2.5 | 3.7 | 1.3 | 2.3 | 5.4 | 8.3 | 15.0 | 26.4 | 69.0 | 57.0 | 58.0 | 80.9 | 24.9 | 3.1 | 357.9 | 1 | 358.9 |
| 30 | | | | | | | | | | | | 0.0 | 1.8 | 0.7 | 1.5 | 4.1 | 6.2 | 11.6 | 20.6 | 54.0 | 44.6 | 33.8 | 37.6 | 49.9 | 4.8 | 271.2 | 1 | 272.2 |
| 31 | | | | | | | | | | | | | 0.0 | 0.3 | 0.8 | 2.6 | 4.7 | 8.7 | 16.0 | 42.1 | 34.9 | 26.4 | 21.9 | 23.2 | 9.7 | 191.3 | 1 | 192.3 |
| 32 | | | | | | | | | | | | | | 0.0 | 0.4 | 1.5 | 3.0 | 6.5 | 12.0 | 32.6 | 27.2 | 20.7 | 17.2 | 13.5 | 4.5 | 139.1 | 1 | 140.1 |
| 33 | | | | | | | | | | | | | | | 0.0 | 0.7 | 1.7 | 4.2 | 9.0 | 24.5 | 21.1 | 16.1 | 13.4 | 10.6 | 2.6 | 103.9 | 1 | 104.9 |
| 34 | | | | | | | | | | | | | | | | 0.0 | 0.8 | 2.3 | 5.8 | 18.4 | 15.8 | 12.5 | 10.5 | 8.3 | 2.0 | 76.5 | 1 | 77.5 |
| 35 | | | | | | | | | | | | | | | | | 0.0 | 1.1 | 3.2 | 11.8 | 11.9 | 9.4 | 8.1 | 6.4 | 1.6 | 53.6 | 1 | 54.6 |
| 36 | | | | | | | | | | | | | | | | | | 0.0 | 1.5 | 6.6 | 7.7 | 7.1 | 6.1 | 5.0 | 1.3 | 35.2 | 1 | 36.2 |
| 37 | | | | | | | | | | | | | | | | | | | 0.0 | 3.2 | 4.3 | 4.5 | 4.6 | 3.7 | 1.0 | 21.2 | 1 | 22.2 |
| 38 | | | | | | | | | | | | | | | | | | | | 0.0 | 2.0 | 2.5 | 2.9 | 2.8 | 0.7 | 11.1 | 1 | 12.1 |
| 39 | | | | | | | | | | | | | | | | | | | | | 0.0 | 1.2 | 1.6 | 1.8 | 0.5 | 5.2 | 1 | 6.2 |
| 40 | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.8 | 1.0 | 0.4 | 2.1 | 1 | 3.1 |
| 41 | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.5 | 0.2 | 0.7 | 1 | 1.7 |
| 42 | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0.1 | 0.1 | 1 | 1.1 |
| 43 | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | 1 | 1.0 |

**Design flood Hydrograph; -**

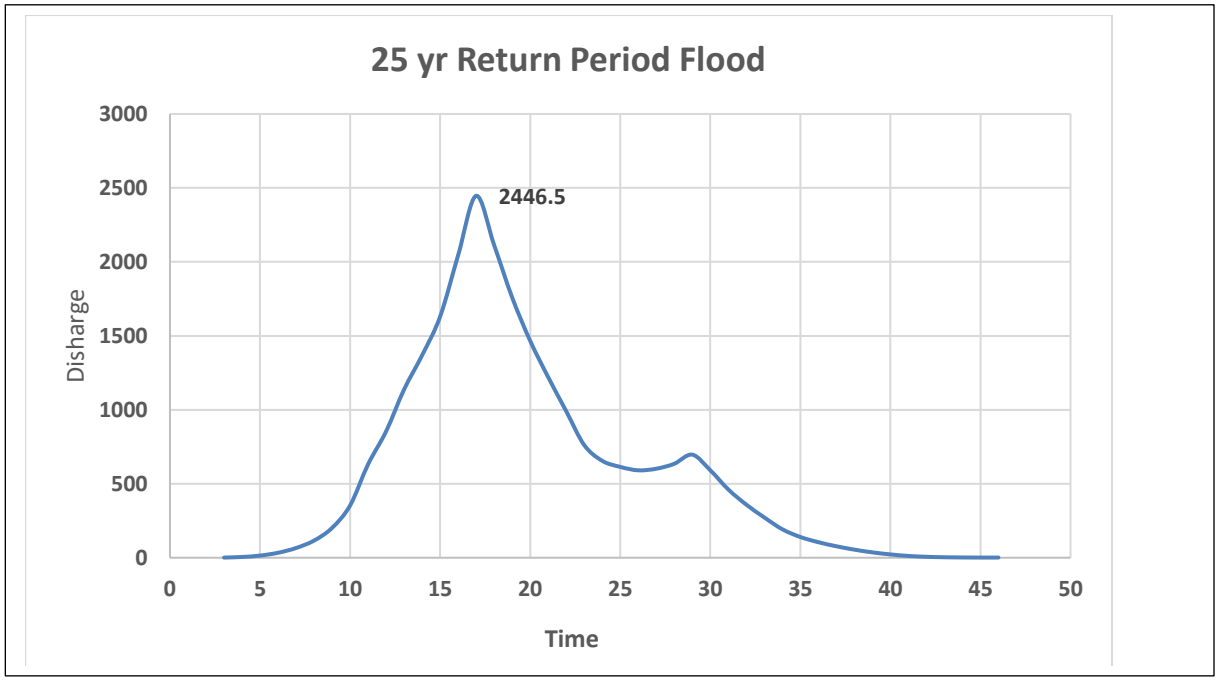



**Fig. 13: Design Flood Hydrograph for 25yr Return Period**

**Table 28: 25 Year Design Flood Hydrograph for Solani River**

| Time (hr) | Design Flood Ordinates (cumec) | Time (hr) | Design Flood Ordinates (cumec) |
|---|---|---|---|
| 0 | 1 | 22 | 614 |
| 1 | 5 | 23 | 591 |
| 2 | 14 | 24 | 602 |
| 3 | 33 | 25 | 635 |
| 4 | 65 | 26 | 697 |
| 5 | 116 | 27 | 591 |
| 6 | 202 | 28 | 461 |
| 7 | 353 | 29 | 359 |
| 8 | 632 | 30 | 272 |
| 9 | 854 | 31 | 192 |
| 10 | 1138 | 32 | 140 |
| 11 | 1369 | 33 | 105 |
| 12 | 1630 | 34 | 77 |
| 13 | 2045 | 35 | 55 |
| 14 | **2447** | 36 | 36 |
| 15 | 2113 | 37 | 22 |
| 16 | 1759 | 38 | 12 |
| 17 | 1466 | 39 | 6 |
| 18 | 1220 | 40 | 3 |
| 19 | 991 | 41 | 2 |
| 20 | 762 | 42 | 1 |
| 21 | 655 | 43 | 1 |

**C. 5 Year Return Period Flood Estimation**

A design loss rate of 0 to 0 .6 cm /hr as recommended in CWC FER of Western Himalayan Zone-7 report for has been adopted for design flood computation.

As recommended by CWC Western Himalayan Zone-7 report following base flow rate has been adopted:

Base flow / km2 of drainage area = 0.10 (max)

Using the above formula, the computed base flow for the catchment area is 0.61 $m^3$ /sec.

**Time Distribution of Rainfall:**

For hourly distribution of rainfall, normalized distribution coefficient has been worked out for bell of 12 hour each using the hourly distribution coefficient of 24-hour rainfall from PMP Atlas of Ganga River Basins. The hourly distribution coefficient of 24-hour rainfall and normalized distribution coefficient for 12-hour bell are mentioned in table no. 8.

After getting rainfall distribution for 24 hrs, rainfall is further bifurcated in the sets of 12hr based on the previous Table 25.

**Table 29: RP rainfall depth for 12-hour bells**

| Catchment | RP Rainfall | 24 hr Max ( 1.15* col(1) | 1st Bell 76% of col. (1) B1 | 2nd Bell 24 % of col. (1) B2 |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| 70.26 | 80.79 | 53.39 | 16.86 | 70.26 |

Two bells on based on its fraction are prepared i.e. 1st 12hr Bell & 2nd 12hr Bell.

**Table 30: 12 Hour bell distribution of rainfall**

| Bell | Rainfall Depth |
|---|---|
| 1st 12Hr Bell | 53.4 |
| 2nd 12Hr Bell | 16.9 |

After preparing 12hr bells, cumulative rainfall depth, incremental rainfall depth & effective rainfall is calculated by subtracting the losses.

**Table 31: Hourly Distribution of Rainfall**

| Time | Dis. Coeff. | Nor. Dis. Coeff. | Cumulative Rainfall Depth | | Incremental Rainfall Depth | | Loss | Effective Rainfall Depth | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1st 12 hr Bell Distribution | 2nd 12 Hr Bell Distribution | Incremental Rainfall 1st Bell | Incremental Rainfall 2nd Bell | | Eff. Inc. Rainfall Depth 1st Bell | Eff. Inc. Rainfall Depth 2nd Bell |
| Hr | % | % | (mm) | (mm) | (mm) | (mm) | mm/hr | (mm) | (mm) |
| | | | | | | | | | |
| 1 | 0.17 | 0.202 | 11.94 | 3.41 | 11.94 | 3.41 | 0.6 | 11.34 | 2.81 |
| 2 | 0.27 | 0.341 | 18.97 | 5.75 | 7.03 | 2.34 | 0.6 | 6.43 | 1.74 |
| 3 | 0.36 | 0.452 | 25.29 | 7.62 | 6.32 | 1.87 | 0.6 | 5.72 | 1.27 |
| 4 | 0.43 | 0.544 | 30.21 | 9.17 | 4.92 | 1.55 | 0.6 | 4.32 | 0.95 |
| 5 | 0.48 | 0.631 | 33.72 | 10.64 | 3.51 | 1.47 | 0.6 | 2.91 | 0.87 |
| 6 | 0.53 | 0.7 | 37.24 | 11.80 | 3.51 | 1.16 | 0.6 | 2.91 | 0.56 |
| 7 | 0.58 | 0.768 | 40.75 | 12.95 | 3.51 | 1.15 | 0.6 | 2.91 | 0.55 |
| 8 | 0.63 | 0.831 | 44.26 | 14.01 | 3.51 | 1.06 | 0.6 | 2.91 | 0.46 |
| 9 | 0.67 | 0.882 | 47.07 | 14.87 | 2.81 | 0.86 | 0.6 | 2.21 | 0.26 |
| 10 | 0.7 | 0.928 | 49.18 | 15.65 | 2.11 | 0.78 | 0.6 | 1.51 | 0.18 |
| 11 | 0.73 | 0.971 | 51.29 | 16.37 | 2.11 | 0.73 | 0.6 | 1.51 | 0.13 |
| 12 | 0.76 | 1 | 53.39 | 16.86 | 2.11 | 0.49 | 0.6 | 1.51 | 0.01 |

**Table 32: Critical sequencing for Effective hourly rainfall**

After getting the effective rainfall depth, for both bell, critical sequencing and reverse critical sequencing is done for rainfall & corresponding to its UH ordinates. Then rain convolution for both the bell are obtained, which is further to be used for designing the flood hydrograph for different return period floods

| Time | UH ordinate | Critical Sequence of Hourly Rainfall Depth | | Reverse Critical Sequence | | Conv. Rainfall B2-B1 |
|---|---|---|---|---|---|---|
| | | 1st 12 Hr bell | 2nd 12 Hr bell | 1st 12 Hr bell | 2nd 12 Hr bell | |
| Hr | cumec | (mm) | (mm) | (mm) | (mm) | (mm) |
| 0 | 0 | | | | | |
| 1 | 16 | | | | | 1.5 |
| 2 | 36 | | | | | 1.5 |
| 3 | 62 | 1.5 | 0.0 | | | 2.9 |
| 4 | 95 | 2.2 | 0.3 | | | 2.9 |
| 5 | 146 | 2.9 | 0.5 | 1.5 | 0.1 | 2.9 |
| 6 | 230 | 4.3 | 1.0 | 1.5 | 0.2 | 5.7 |
| 7 | 360 | 6.4 | 1.7 | 2.9 | 0.5 | 11.3 |
| 8 | 722 | 11.3 | 2.8 | 2.9 | 0.6 | 6.4 |
| 9 | 335 | 5.7 | 1.3 | 2.9 | 0.9 | 4.3 |
| 10 | 195 | 2.9 | 0.9 | 5.7 | 1.3 | 2.9 |
| 11 | 153 | 2.9 | 0.6 | 11.3 | 2.8 | 2.2 |
| 12 | 120 | 2.9 | 0.5 | 6.4 | 1.7 | 1.5 |
| 13 | 93 | 1.5 | 0.2 | 4.3 | 1.0 | 0.1 |
| 14 | 72 | 1.5 | 0.1 | 2.9 | 0.5 | 0.2 |
| 15 | 54 | | | 2.2 | 0.3 | 0.5 |
| 16 | 41 | | | 1.5 | 0.0 | 0.6 |
| 17 | 26 | | | | | 0.9 |
| 18 | 15 | | | | | 1.3 |
| 19 | 7 | | | | | 2.8 |
| 20 | 0 | | | | | 1.7 |
| 21 | | | | | | 1.0 |
| 22 | | | | | | 0.5 |
| 23 | | | | | | 0.3 |
| 24 | | | | | | 0.0 |

## Table 33: 5-Year Return Period flood for Solani River

| Time | UH ord. | Rainfall Excess (cm) | | | | | | | | | | | | | | | | | | | | | | | DRH | Base Flow | 100yr Return Period |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| hr | cumec | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | cumec | cumec | |
| | | 0.15 | 0.15 | 0.29 | 0.29 | 0.29 | 0.57 | 1.13 | 0.64 | 0.43 | 0.29 | 0.22 | 0.15 | 0.01 | 0.02 | 0.05 | 0.06 | 0.09 | 0.13 | 0.28 | 0.17 | 0.10 | 0.05 | 0.03 | 0.00 | | | |
| 0 | 0.0 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 1 | 1.0 |
| 1 | 15.8 | 2.4 | 0.0 | | | | | | | | | | | | | | | | | | | | | | | 2.4 | 1 | 3.4 |
| 2 | 36.2 | 5.5 | 2.4 | 0.0 | | | | | | | | | | | | | | | | | | | | | | 7.8 | 1 | 8.8 |
| 3 | 61.8 | 9.3 | 5.5 | 4.6 | 0.0 | | | | | | | | | | | | | | | | | | | | | 19.4 | 1 | 20.4 |
| 4 | 95.1 | 14.3 | 9.3 | 10.5 | 4.6 | 0.0 | | | | | | | | | | | | | | | | | | | | 38.8 | 1 | 39.8 |
| 5 | 145.9 | 22.0 | 14.3 | 18.0 | 10.5 | 4.6 | 0.0 | | | | | | | | | | | | | | | | | | | 69.5 | 1 | 70.5 |
| 6 | 230.0 | 34.7 | 22.0 | 27.7 | 18.0 | 10.5 | 9.0 | 0.0 | | | | | | | | | | | | | | | | | | 121.9 | 1 | 122.9 |
| 7 | 360.0 | 54.3 | 34.7 | 42.5 | 27.7 | 18.0 | 20.7 | 17.9 | 0.0 | | | | | | | | | | | | | | | | | 215.7 | 1 | 216.7 |
| 8 | 722.0 | 108.9 | 54.3 | 67.0 | 42.5 | 27.7 | 35.4 | 41.0 | 10.1 | 0.0 | | | | | | | | | | | | | | | | 386.9 | 1 | 387.9 |
| 9 | 335.5 | 50.6 | 108.9 | 104.9 | 67.0 | 42.5 | 54.4 | 70.2 | 23.2 | 6.8 | 0.0 | | | | | | | | | | | | | | | 528.4 | 1 | 529.4 |
| 10 | 195.4 | 29.5 | 50.6 | 210.3 | 104.9 | 67.0 | 83.5 | 107.9 | 39.7 | 15.6 | 4.6 | 0.0 | | | | | | | | | | | | | | 713.5 | 1 | 714.5 |
| 11 | 153.0 | 23.1 | 29.5 | 97.7 | 210.3 | 104.9 | 131.6 | 165.5 | 61.1 | 26.7 | 10.5 | 3.5 | 0.0 | | | | | | | | | | | | | 864.3 | 1 | 865.3 |
| 12 | 119.6 | 18.0 | 23.1 | 56.9 | 97.7 | 210.3 | 206.0 | 260.9 | 93.7 | 41.1 | 18.0 | 8.0 | 2.4 | 0.0 | | | | | | | | | | | | 1036.1 | 1 | 1037.1 |
| 13 | 93.3 | 14.1 | 18.0 | 44.6 | 56.9 | 97.7 | 413.2 | 408.4 | 147.8 | 63.0 | 27.7 | 13.7 | 5.5 | 0.2 | 0.0 | | | | | | | | | | | 1310.7 | 1 | 1311.7 |
| 14 | 72.3 | 10.9 | 14.1 | 34.8 | 44.6 | 56.9 | 192.0 | 819.0 | 231.3 | 99.3 | 42.5 | 21.0 | 9.3 | 0.5 | 0.3 | 0.0 | | | | | | | | | | 1576.5 | 1 | 1577.5 |
| 15 | 54.3 | 8.2 | 10.9 | 27.2 | 34.8 | 44.6 | 111.9 | 380.5 | 463.9 | 155.4 | 67.0 | 32.2 | 14.3 | 0.8 | 0.6 | 0.7 | 0.0 | | | | | | | | | 1353.2 | 1 | 1354.2 |
| 16 | 40.8 | 6.2 | 8.2 | 21.1 | 27.2 | 34.8 | 87.6 | 221.7 | 215.6 | 311.8 | 104.9 | 50.8 | 22.0 | 1.2 | 1.1 | 1.7 | 0.9 | 0.0 | | | | | | | | 1116.5 | 1 | 1117.5 |
| 17 | 26.3 | 4.0 | 6.2 | 15.8 | 21.1 | 27.2 | 68.4 | 173.6 | 125.6 | 144.9 | 210.3 | 79.6 | 34.7 | 1.8 | 1.7 | 2.9 | 2.0 | 1.4 | 0.0 | | | | | | | 920.9 | 1 | 921.9 |
| 18 | 14.6 | 2.2 | 4.0 | 11.9 | 15.8 | 21.1 | 53.4 | 135.7 | 98.3 | 84.4 | 97.7 | 159.6 | 54.3 | 2.9 | 2.6 | 4.4 | 3.5 | 3.1 | 2.0 | 0.0 | | | | | | 756.8 | 1 | 757.8 |
| 19 | 7.0 | 1.1 | 2.2 | 7.6 | 11.9 | 15.8 | 41.4 | 105.9 | 76.9 | 66.1 | 56.9 | 74.1 | 108.9 | 4.5 | 4.0 | 6.7 | 5.4 | 5.4 | 4.6 | 4.4 | 0.0 | | | | | 602.7 | 1 | 603.7 |
| 20 | 0.0 | 0.0 | 1.1 | 4.2 | 7.6 | 11.9 | 31.1 | 82.1 | 60.0 | 51.6 | 44.6 | 43.2 | 50.6 | 9.0 | 6.3 | 10.6 | 8.2 | 8.2 | 7.9 | 10.1 | 2.7 | 0.0 | | | | 450.1 | 1 | 451.1 |
| 21 | | | 0.0 | 2.0 | 4.2 | 7.6 | 23.4 | 61.5 | 46.5 | 40.3 | 34.8 | 33.8 | 29.5 | 4.2 | 12.7 | 16.6 | 13.0 | 12.6 | 12.1 | 17.4 | 6.3 | 1.5 | 0.0 | | | 378.1 | 1 | 379.1 |
| 22 | | | | 0.0 | 2.0 | 4.2 | 15.0 | 46.3 | 34.9 | 31.2 | 27.2 | 26.4 | 23.1 | 2.4 | 5.9 | 33.4 | 20.3 | 19.9 | 18.5 | 26.7 | 10.8 | 3.4 | 0.9 | 0.0 | | 350.6 | 1 | 351.6 |
| 23 | | | | | 0.0 | 2.0 | 8.3 | 29.8 | 26.2 | 23.4 | 21.1 | 20.6 | 18.0 | 1.9 | 3.4 | 15.5 | 40.7 | 31.2 | 29.2 | 40.9 | 16.6 | 5.9 | 2.0 | 0.4 | 0.0 | 335.3 | 1 | 336.3 |
| 24 | | | | | | 0.0 | 4.0 | 16.5 | 16.9 | 17.6 | 15.8 | 16.0 | 14.1 | 1.5 | 2.7 | 9.0 | 18.9 | 62.6 | 45.8 | 64.5 | 25.4 | 9.0 | 3.4 | 0.9 | 0.0 | 340.8 | 1 | 341.8 |
| 25 | | | | | | | 0.0 | 7.9 | 9.4 | 11.3 | 11.9 | 12.0 | 10.9 | 1.2 | 2.1 | 7.1 | 11.0 | 29.1 | 91.8 | 101.0 | 40.1 | 13.9 | 5.2 | 1.6 | 0.0 | 359.6 | 1 | 360.6 |
| 26 | | | | | | | | 0.0 | 4.5 | 6.3 | 7.6 | 9.0 | 8.2 | 0.9 | 1.6 | 5.5 | 8.6 | 16.9 | 42.7 | 202.6 | 62.8 | 21.9 | 8.0 | 2.5 | 0.1 | 405.2 | 1 | 406.2 |
| 27 | | | | | | | | | 0.0 | 3.0 | 4.2 | 5.8 | 6.2 | 0.7 | 1.3 | 4.3 | 6.7 | 13.3 | 24.9 | 94.1 | 125.9 | 34.2 | 12.6 | 3.8 | 0.1 | 338.1 | 1 | 339.1 |
| 28 | | | | | | | | | | 0.0 | 2.0 | 3.2 | 4.0 | 0.5 | 1.0 | 3.3 | 5.3 | 10.4 | 19.5 | 54.8 | 58.5 | 68.7 | 19.7 | 6.0 | 0.1 | 254.9 | 1 | 255.9 |
| 29 | | | | | | | | | | | 0.0 | 1.5 | 2.2 | 0.3 | 0.7 | 2.5 | 4.1 | 8.1 | 15.2 | 42.9 | 34.1 | 31.9 | 39.5 | 9.4 | 0.2 | 191.1 | 1 | 192.1 |
| 30 | | | | | | | | | | | | 0.0 | 1.1 | 0.2 | 0.5 | 1.9 | 3.1 | 6.3 | 11.9 | 33.6 | 26.7 | 18.6 | 18.3 | 18.8 | 0.4 | 140.0 | 1 | 141.0 |
| 31 | | | | | | | | | | | | | 0.0 | 0.1 | 0.3 | 1.2 | 2.3 | 4.7 | 9.2 | 26.2 | 20.9 | 14.6 | 10.7 | 8.7 | 0.7 | 99.4 | 1 | 100.4 |
| 32 | | | | | | | | | | | | | | 0.0 | 0.1 | 0.7 | 1.5 | 3.5 | 6.9 | 20.3 | 16.3 | 11.4 | 8.4 | 5.1 | 0.3 | 74.3 | 1 | 75.3 |
| 33 | | | | | | | | | | | | | | | 0.0 | 0.3 | 0.8 | 2.3 | 5.2 | 15.2 | 12.6 | 8.9 | 6.5 | 4.0 | 0.2 | 55.7 | 1 | 56.7 |
| 34 | | | | | | | | | | | | | | | | 0.0 | 0.4 | 1.3 | 3.3 | 11.5 | 9.5 | 6.9 | 5.1 | 3.1 | 0.2 | 40.8 | 1 | 41.8 |
| 35 | | | | | | | | | | | | | | | | | 0.0 | 0.6 | 1.9 | 7.4 | 7.1 | 5.2 | 4.0 | 2.4 | 0.1 | 28.0 | 1 | 29.0 |
| 36 | | | | | | | | | | | | | | | | | | 0.0 | 0.9 | 4.1 | 4.6 | 3.9 | 3.0 | 1.9 | 0.1 | 17.5 | 1 | 18.5 |
| 37 | | | | | | | | | | | | | | | | | | | 0.0 | 2.0 | 2.5 | 2.5 | 2.2 | 1.4 | 0.1 | 8.8 | 1 | 9.8 |
| 38 | | | | | | | | | | | | | | | | | | | | 0.0 | 1.2 | 1.4 | 1.4 | 1.1 | 0.1 | 3.9 | 1 | 4.9 |
| 39 | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.7 | 0.8 | 0.7 | 0.0 | 1.5 | 1 | 2.5 |
| 40 | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.4 | 0.4 | 0.0 | 0.4 | 1 | 1.4 |
| 41 | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.2 | 0.0 | 0.0 | 1 | 1.0 |
| 42 | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0.0 | 0.0 | 1 | 1.0 |
| 43 | | | | | | | | | | | | | | | | | | | | | | | | | 0.0 | 0.0 | 1 | 1.0 |

**Design Flood Hydrograph**

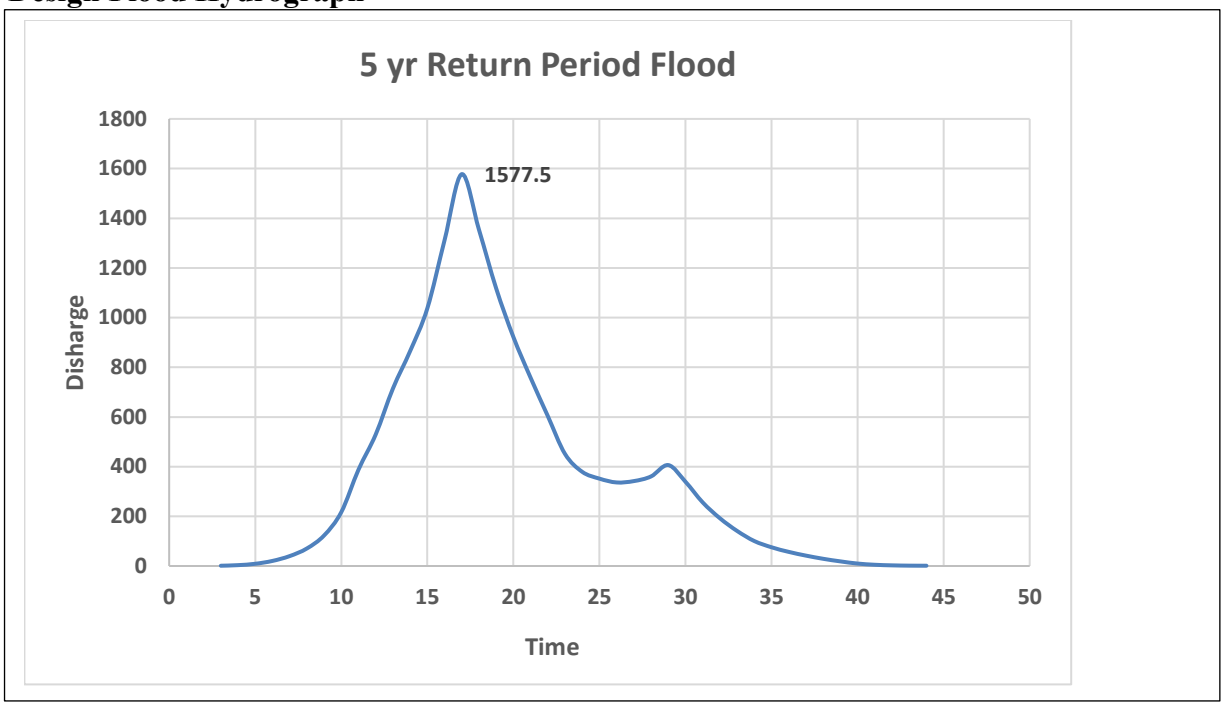



Fig.14: Design Flood Hydrograph for 5yr Return Period

**Table 34: 5-Year Design Flood Hydrograph for Solani River**

| Time (hr) | Design Flood Ordinates (cumec) | Time (hr) | Design Flood Ordinates (cumec) |
|---|---|---|---|
| 0 | 1 | 22 | 352 |
| 1 | 3 | 23 | 336 |
| 2 | 9 | 24 | 342 |
| 3 | 20 | 25 | 361 |
| 4 | 40 | 26 | 406 |
| 5 | 70 | 27 | 339 |
| 6 | 123 | 28 | 256 |
| 7 | 217 | 29 | 192 |
| 8 | 388 | 30 | 141 |
| 9 | 529 | 31 | 100 |
| 10 | 714 | 32 | 75 |
| 11 | 865 | 33 | 57 |
| 12 | 1037 | 34 | 42 |
| 13 | 1312 | 35 | 29 |
| 14 | **1577** | 36 | 18 |
| 15 | 1354 | 37 | 10 |
| 16 | 1118 | 38 | 5 |
| 17 | 922 | 39 | 3 |
| 18 | 758 | 40 | 1 |
| 19 | 604 | 41 | 1 |
| 20 | 451 | 42 | 1 |
| 21 | 379 | 43 | 1 |

At various key locations for specific return period flows are back routed as mentioned in the table given below.

**Table 35: Discharges at Different Key Location:**

| Identification Name | Catchment Area | Return Period(Year) | | | |
|---|---|---|---|---|---|
| | | 5 | 25 | 50 | 100 |
| Kheri | 232 | 387 | 600 | 689 | 750 |
| Hasanpur | 267 | 446 | 691 | 794 | 864 |
| Shahpur | 411 | 686 | 1065 | 1223 | 1331 |
| Roorkee | 518 | 865 | 1342 | 1542 | 1677 |
| Solani Ratmau Conf. | 884 | 1476 | 2290 | 2631 | 2862 |
| Outlet | 944 | 1576 | 2446 | 2809 | 3056 |

| Identification Name | Catchment Area ($km^2$) | Return Period (Year) Flow (cumec) | | | |
|---|---|---|---|---|---|
| | | 5 | 25 | 50 | 100 |
| Kurkawala | 28.87 | 61 | 83 | 93 | 103 |
| Lam Grunt | 85.82 | 183 | 246 | 276 | 306 |
| Sohalpur Sikrodha | 180.00 | 383 | 515 | 579 | 643 |
| Dhanauri | 296.69 | 632 | 850 | 954 | 1059 |
| Outlet | 337.00 | 718 | 965 | 1084 | 1203 |

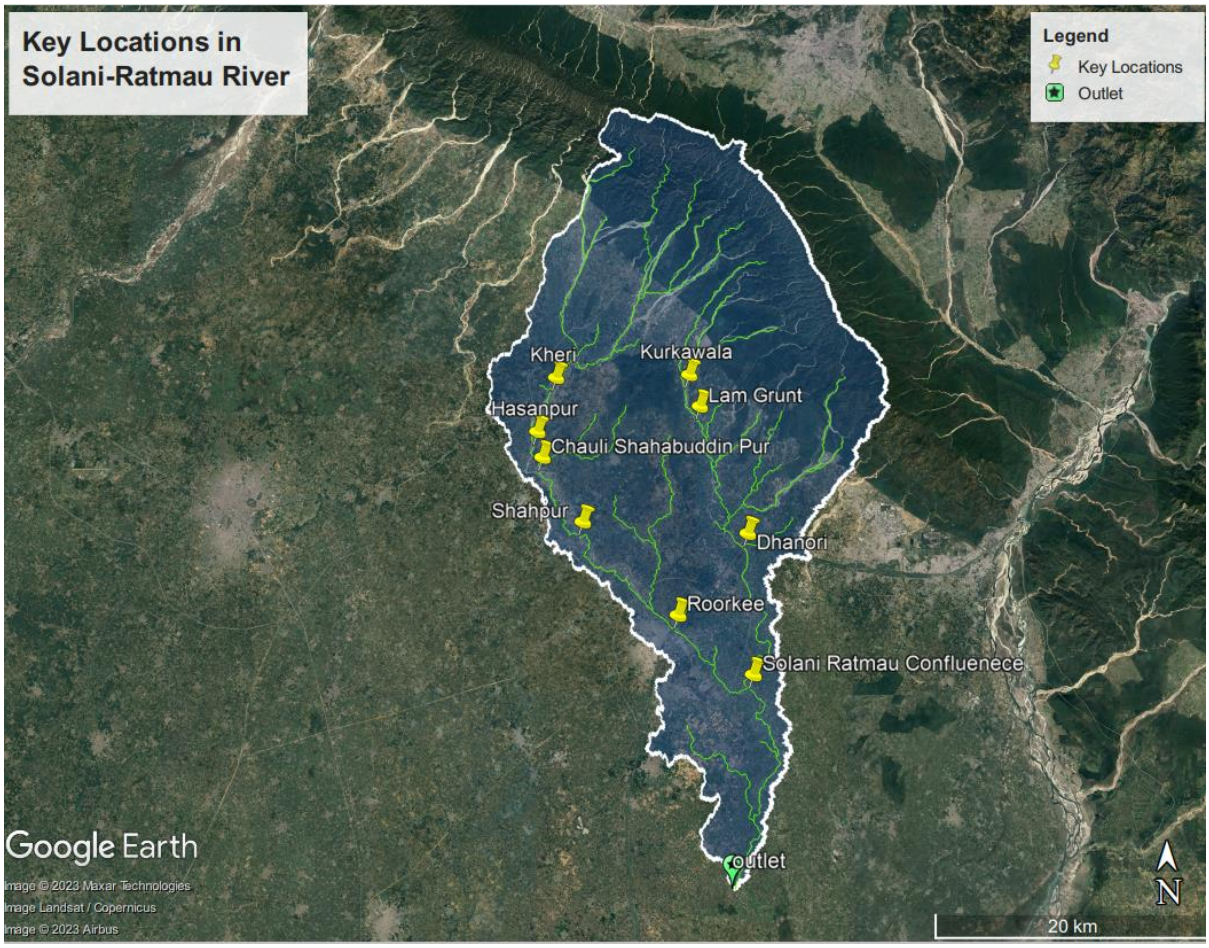



**Fig 15. Key Location of Solani-Ratmau Basin**

## Table 36: Estimated discharges for Different ungauged watershed

Major Ungauged watersheds are identified and flows are calculated for specific return period as mentioned the table given below.

| Watershed Id | Catchment Area (Sq. km. | Return Period(Year) | | | |
|---|---|---|---|---|---|
| | | 5 | 25 | 50 | 100 |
| 1 | 277 | 463 | 718 | 824 | 897 |
| 2 | 124 | 207 | 321 | 369 | 401 |
| 3 | 122 | 204 | 316 | 363 | 395 |
| 4 | 52 | 87 | 135 | 155 | 168 |
| 5 | 59 | 99 | 153 | 176 | 191 |

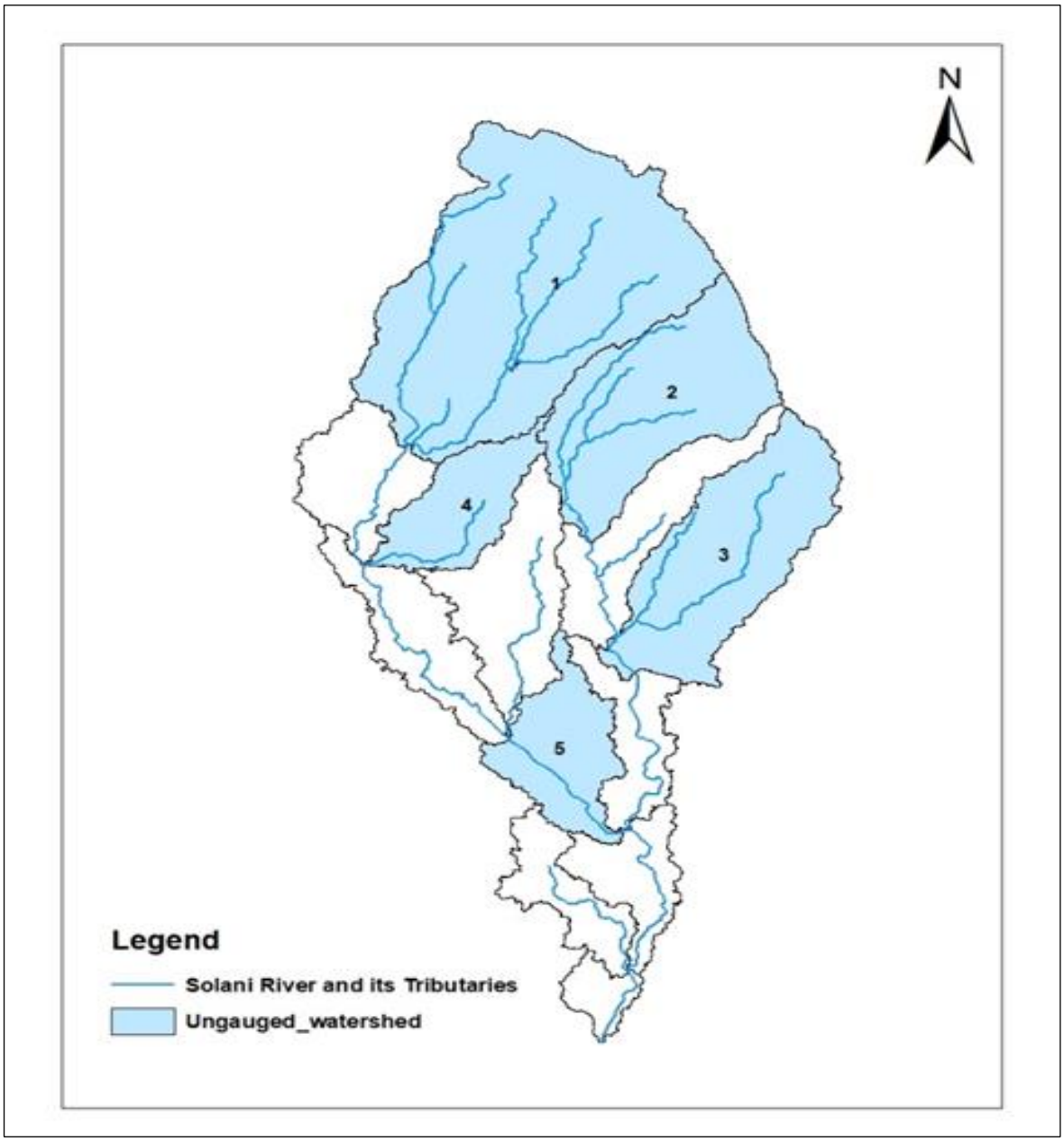



**Fig. 16: Ungauged watersheds contributing water to the Solani River. The Label ID denotes the numbering of watersheds**

## 5.2 DEVELOPMENT OF REGIONAL FLOOD FREQUENCY RELATIONSHIP USING L-MOMENTS APPROACH FOR UNGAUGED CATCHMENTS:

For development of regional flood frequency relationships for ungauged catchments, the regional flood frequency relationships developed for gauged catchments have been coupled with the regional relationships between mean annual peak floods and catchment areas of the respective Zones. In this manner the following form of regional flood frequency relationships have been developed for ungauged catchments.

For estimation of floods of commonly used returns periods for an ungauged catchment for a given catchment area the value of flood estimates may be directly obtained from the fig. mentioned below for western Zone-7 which is adopted from Regional Flood Frequency Estimation in India (Rakesh Kumar, 2011).

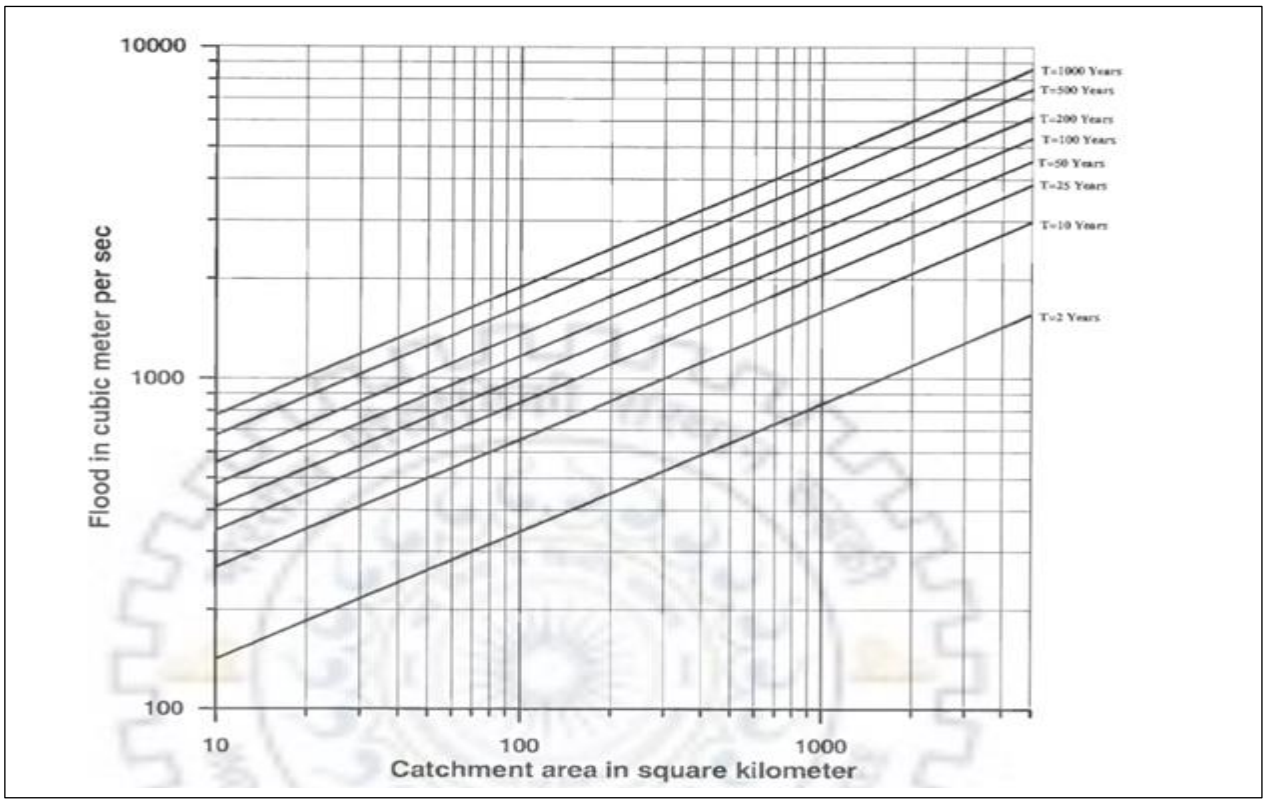



**Fig. 17 Variation of floods of Various return periods with catchment area based on L-moments for Sub-Himalayan region Zone-7**

## Design Flood Peak from Different Method:

Based on the above-mentioned envelope derived by L-moments return period flood peak values are compared with the design values obtained by SUH (synthetic unit hydrograph).

**Table 37: Design flood peak comparison at Solani River**

| Return Period | Solani River | |
|---|---|---|
| | SUH | L Moments |
| 5 | 1576 | 900 |
| 25 | 2446 | 2100 |
| 50 | 2809 | 2400 |
| 100 | 3056 | 2900 |

| Return Period | Ratmau River | |
|---|---|---|
| | SUH | L Moments |
| 5 | 718 | 475 |
| 25 | 965 | 1500 |
| 50 | 1084 | 1650 |
| 100 | 1203 | 1850 |

## 7. River Geometry Creation in RAS Mapper: -

In the RAS tab of HEC-RAS, the projection and datum (UTM Zone 43 N, WGS 84) have been defined. The Cartosat DEM and Google Earth images have been added to define the river geometry for 1D flow modeling. River geometry (channel central line, bank lines, flow paths, transverse cross-sections, and levee) has been created using Cartosat digital elevation model (DEM) and geomorphological map. Manning's N values for built-up areas, barren land, forest, river bed, scrub and arable land on a transverse cross- section has been taken from Chow (1959) and Syme (2008). The maximum LU/LC category on a cross-section is 20. In other words, on a cross-section, HECRAS can plot a maximum of 20 Manning's N values.

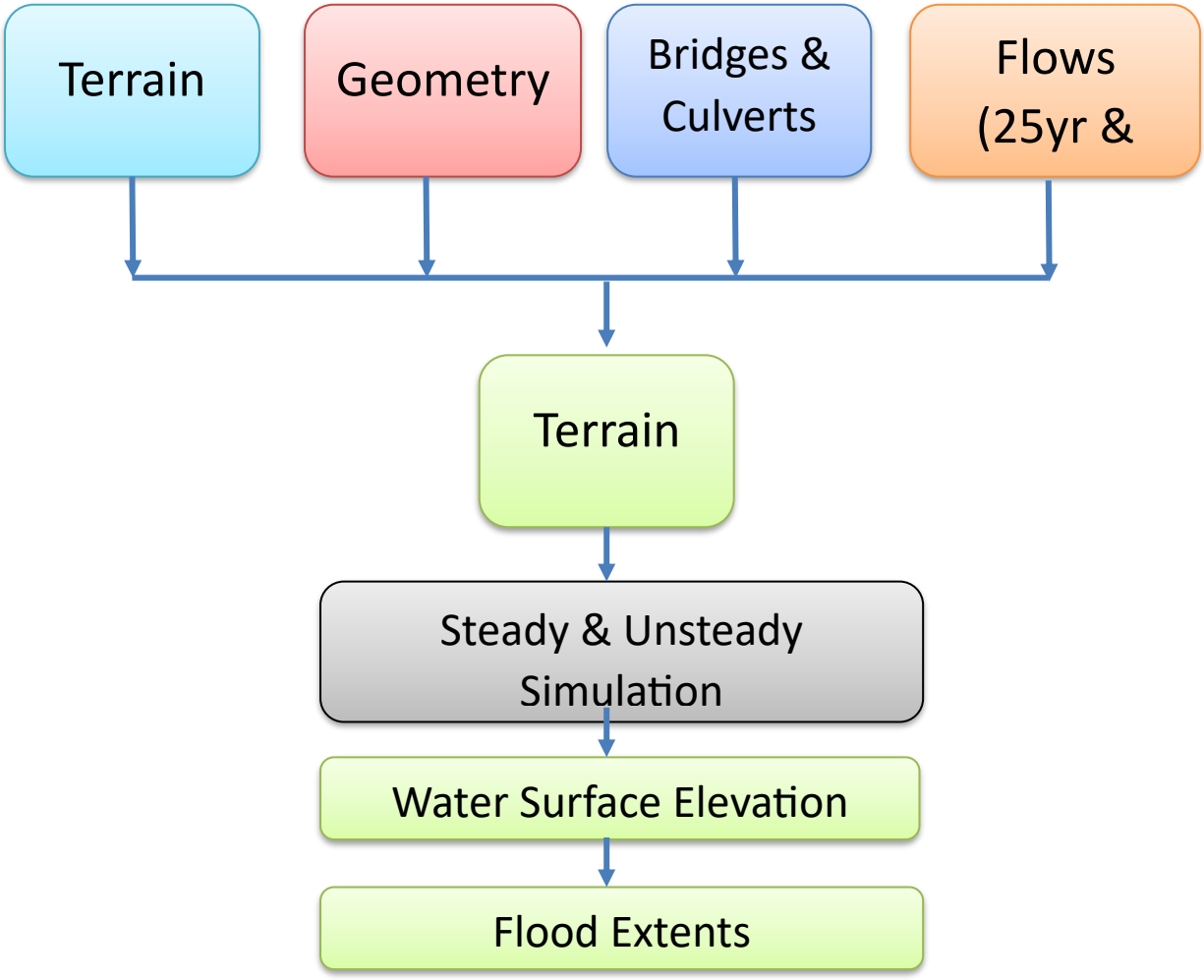



**Fig. 18: Flow chart for modelling steps**

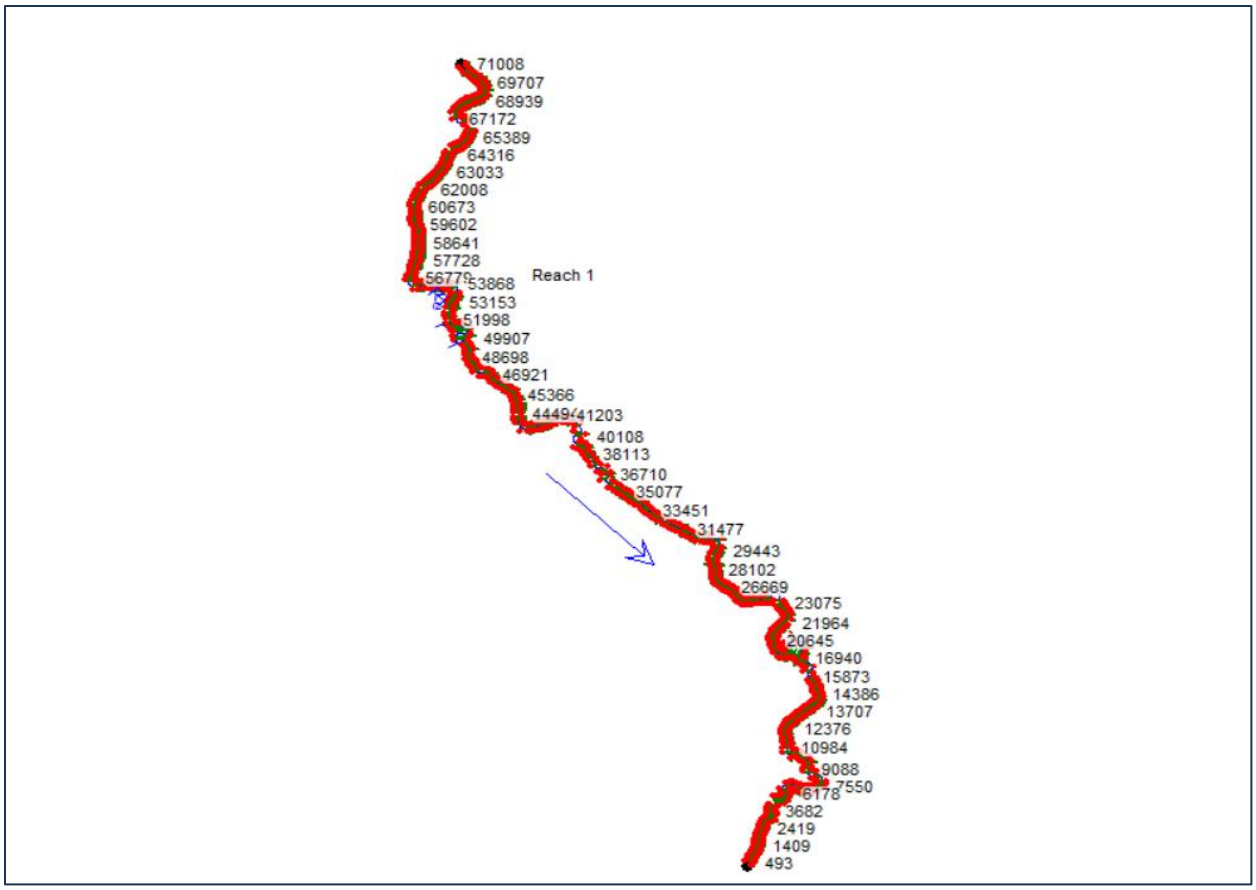



**Fig. 19: River geometry with cross section.**

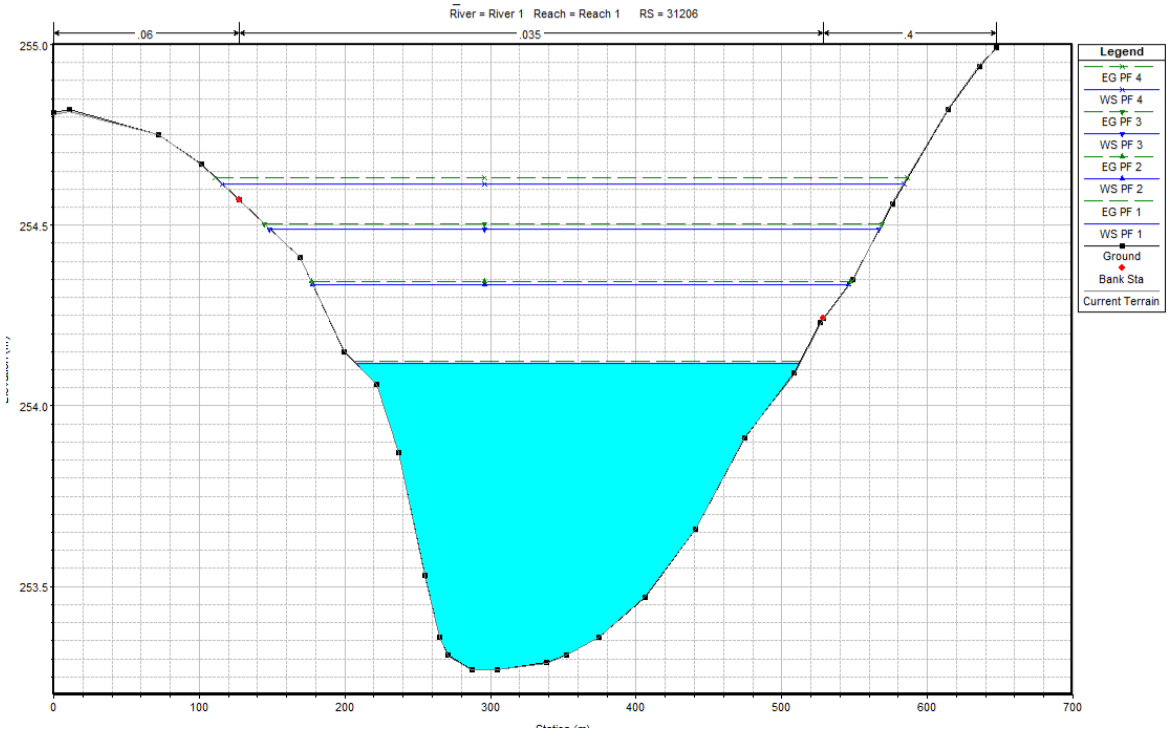



**Fig. 20 Transverse cross-section at Roorkee showing N values.**

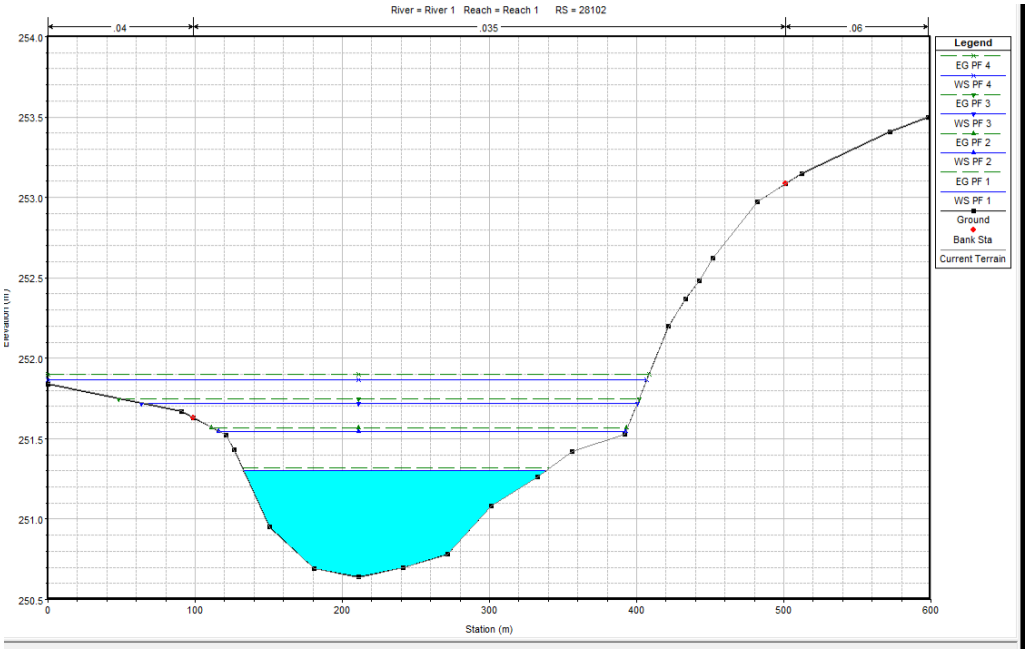



**Fig. 21: Transverse cross-section at Roorkee showing N values.**

## 8. RAS Geometry used in HEC-RAS 1D Flow Modelling & Flood Plain Zoning

In HEC RAS, the boundary conditions at downstream cross-sections have been defined on the basis of normal depth. The normal depth method utilizes an energy slope (average bed slope in m/m) to compute flood depth using Manning's N values. The estimated discharges at different return periods (5, 25, 50 and 100 years) for each ungauged watershed have been considered in HEC RAS by adding flow change location from upstream to downstream. Based on the input data (Manning's N values, normal depth, and discharges), the HEC-RAS computed rating curves for entire cross- sections. A sum of 701 cross-sections was drawn for 1D flow modeling. In other words, six cross-sections per kilometer have been made on the basis of channel curvature.

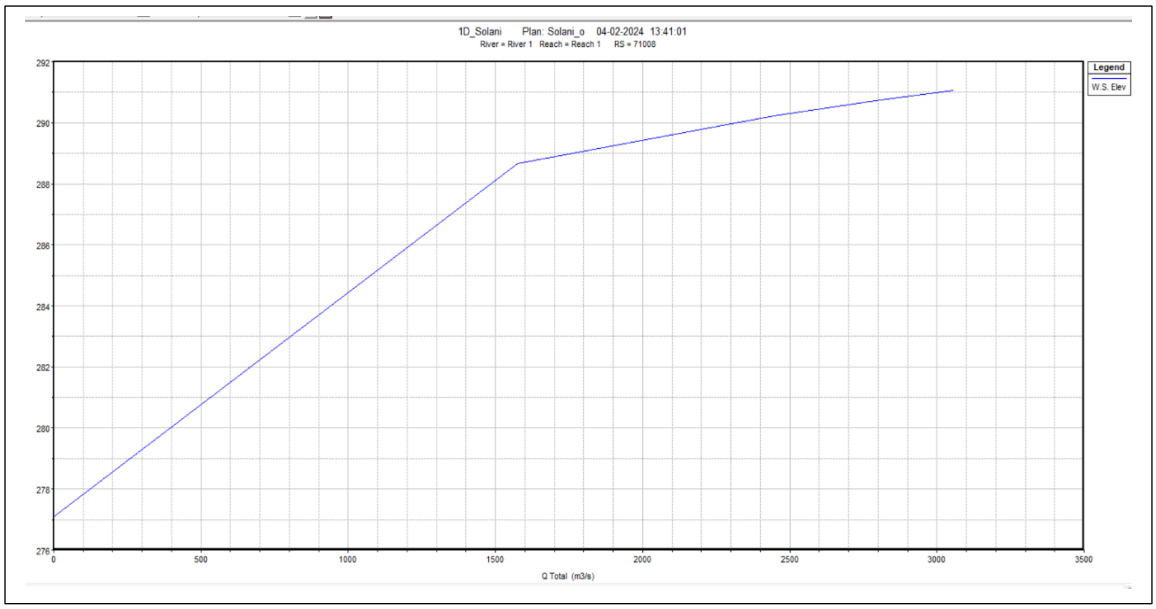



**Fig. 22: Rating Curve of Solani River.**

**Table 38:** Discharges (in $m^3$/sec) at different return periods considered at flow change location in HEC-RAS steady flow modeling.

| Identification Name | Catchment Area of Drain($km^2$) | Catchment Area ($km^2$) | Return Period(Year) Flow (cumec) | | | |
|---|---|---|---|---|---|---|
| | | | 5 | 25 | 50 | 100 |
| Kheri | 232 | 232 | 387 | 600 | 689 | 750 |
| Hasanpur | 35 | 267 | 446 | 691 | 794 | 864 |
| Shahpur | 144 | 411 | 686 | 1065 | 1223 | 1331 |
| Roorkee | 107 | 518 | 865 | 1342 | 1542 | 1677 |
| Solani Ratmau Conf. | 366 | 884 | 1476 | 2290 | 2631 | 2862 |
| Outlet | 117 | 1001 | 1576 | 2446 | 2809 | 3056 |

**Table 39:** Cross-section wise flood level (m) above mean sea level at different return periods at some prominent location.

| XS | Location | 25 | 50 | 100 |
|---|---|---|---|---|
| 1 | Biharigarh | 304.62 | 305.12 | 305.49 |
| 2 | Aurangzeb Pur | 300.29 | 300.70 | 301.09 |
| 3 | Kheri | 290.71 | 291.12 | 291.46 |
| 4 | Chhutmalpur | 286.04 | 286.35 | 286.87 |
| 5 | Hasanpur | 280.17 | 280.68 | 281.02 |
| 6 | Latifpur | 277.31 | 277.79 | 278.25 |
| 7 | Saidpur | 273.78 | 274.01 | 274.36 |
| 8 | Bhagwanpur | 267.77 | 268.05 | 268.66 |
| 9 | Roorkee | 256.5 | 257.1 | 257.9 |
| 10 | Akbarpur | 252.82 | 253.11 | 253.33 |
| 11 | After confluence With Ratmau | 248.522 | 248.88 | 249.17 |
| 12 | Mohammadpur | 237.4 | 238.24 | 238.60 |

## 9. Results Analysis & Physical Validation

For validation, the floodplain modeling is correlated recent year flood mark. Modeled flood extent is matching with the observed flood extent between at various bridge locations. Mostly crop land and open land will be submerged.

## 10. Sensitivity Waterway

The analysis incorporates the estimated discharge at a 25-year return period for each location of flow change to determine the necessary channel width or Lacey's Waterway. The provision of waterway width varies based on the riverbed conditions, ranging from 0.25 to 0.9 times Lacey's Waterway, contingent upon the site's topography. In this study, areas where the natural waterway measures less than 0.65 times Lacey's Waterway are classified as sensitive zones. (Reference: Theory and Design of Irrigation Structures by Dr. Varshney)

**Table 40: Lacey's Waterway (in m) at 25-year Return flood considered at flow change location.**

| Identification Name | Catchment Area of Drain($km^2$) | Cumulative Catchment Area ($km^2$) | Q25 (cumec) | Lacey's Waterway(m) | Required Min. Watereway (m) |
|---|---|---|---|---|---|
| Kheri | 232 | 232 | 600 | 72.35 | 47.03 |
| Hasanpur | 35 | 267 | 691 | 77.62 | 50.45 |
| Shahpur | 144 | 411 | 1065 | 96.30 | 62.59 |
| Roorkee | 107 | 518 | 1342 | 108.11 | 70.27 |
| Solani Ratmau Conf. | 366 | 884 | 2290 | 141.23 | 91.80 |
| Outlet | 117 | 1001 | 2446 | 150.28 | 97.68 |

## 11. Results & Finding: -

The flood inundation area map was created utilizing flood propagation modeling, employing optimized roughness parameters acquired through automated calibration with HEC-RAS within a GIS environment. To address uncertainties in hydrological input, an uncertainty analysis was conducted using a Monte Carlo framework. Notably, the novelty of this approach lies in its consideration of the

return time of flooding rather than solely focusing on the hydrograph. While a deterministic approach typically advocates for the consideration of fixed hydrodynamic variables based on a flood hydrograph with predetermined return periods, our study delved into discharges at specific return periods. Additionally, boundary conditions for each cross-section were established using the average bed slope.

## REFERENCES: -

1. Jain, V., Preston, N., Fryirs, K. and Brierley, G. (2006) Comparative assessment of threeapproaches for deriving stream power plots along long profiles in the upper Hunter River catchment, New South Wales, Australia.Geomorphology74, 297-317.

2.Chow, V.T. (1959) Open-Channel Hydraulics. Blackburn Press: Caldwell, NJ, USA.

3. Syme, W.J. (2008) Flooding In Urban Areas-2D Modelling Approaches for Buildings and Fences. In Proceedings of the Engineers Australia, 9th National Conference on Hydraulics in Water Engineering, Darwin, NT, Australia, 23–26 September.

4. Flood Estimation Report for Western Himalayan Zone-7.

5. PMP Atlas for Ganga River Basin Including Yamuna Final Report,2015.

6. “Regional Flood Frequency Estimation in India.” by Rakesh Kumar.2009.

# Annexures

# ANNEXURE-1

## Probability paper based on (Cs, T)

Here mentioning the logarithmic probability paper used for flood frequency & D-index calculations.

| Coefficient of skew, $C_s$ | Recurrence interval $T$ in years | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 | 10 | 25 | 50 | 100 | 200 | 1000 |
| 3.0 | –0.396 | 1.180 | 2.278 | 3.152 | 4.051 | 4.970 | 7.250 |
| 2.5 | –0.360 | 1.250 | 2.262 | 3.048 | 3.845 | 4.652 | 6.600 |
| 2.2 | –0.330 | 1.284 | 2.240 | 2.970 | 3.705 | 4.444 | 6.200 |
| 2.0 | –0.307 | 1.302 | 2.219 | 2.912 | 3.605 | 4.298 | 5.910 |
| 1.8 | –0.282 | 1.318 | 2.193 | 2.848 | 3.499 | 4.147 | 5.660 |
| 1.6 | –0.254 | 1.329 | 2.163 | 2.780 | 3.388 | 3.990 | 5.390 |
| 1.4 | –0.225 | 1.337 | 2.128 | 2.706 | 3.271 | 3.828 | 5.110 |
| 1.2 | –0.195 | 1.340 | 2.087 | 2.626 | 3.149 | 3.661 | 4.820 |
| 1.0 | –0.164 | 1.340 | 2.043 | 2.542 | 3.022 | 3.489 | 4.540 |
| 0.9 | –0.148 | 1.339 | 2.018 | 2.498 | 2.957 | 3.401 | 4.395 |
| 0.8 | –0.132 | 1.336 | 1.998 | 2.453 | 2.891 | 3.312 | 4.250 |
| 0.7 | –0.116 | 1.333 | 1.967 | 2.407 | 2.824 | 3.223 | 4.105 |
| 0.6 | –0.099 | 1.328 | 1.939 | 2.359 | 2.755 | 3.132 | 3.960 |
| 0.5 | –0.083 | 1.323 | 1.910 | 2.311 | 2.686 | 3.041 | 3.815 |
| 0.4 | –0.066 | 1.317 | 1.880 | 2.261 | 2.615 | 2.949 | 3.670 |
| 0.3 | –0.050 | 1.309 | 1.849 | 2.211 | 2.544 | 2.856 | 3.525 |
| 0.2 | –0.033 | 1.301 | 1.818 | 2.159 | 2.472 | 2.763 | 3.380 |
| 0.1 | –0.017 | 1.292 | 1.785 | 2.107 | 2.400 | 2.670 | 3.235 |
| **0.0** | **0.000** | **1.282** | **1.751** | **2.054** | **2.326** | **2.576** | **3.090** |
| –0.1 | 0.017 | 1.270 | 1.716 | 2.000 | 2.252 | 2.482 | 2.950 |
| –0.2 | 0.033 | 1.258 | 1.680 | 1.945 | 2.178 | 2.388 | 2.810 |
| –0.3 | 0.050 | 1.245 | 1.643 | 1.890 | 2.104 | 2.294 | 2.675 |
| –0.4 | 0.066 | 1.231 | 1.606 | 1.834 | 2.029 | 2.201 | 2.540 |
| –0.5 | 0.083 | 1.216 | 1.567 | 1.777 | 1.955 | 2.108 | 2.400 |
| –0.6 | 0.099 | 1.200 | 1.528 | 1.720 | 1.880 | 2.016 | 2.275 |
| –0.7 | 0.116 | 1.183 | 1.488 | 1.663 | 1.806 | 1.926 | 2.150 |
| –0.8 | 0.132 | 1.166 | 1.448 | 1.606 | 1.733 | 1.837 | 2.035 |
| –0.9 | 0.148 | 1.147 | 1.407 | 1.549 | 1.660 | 1.749 | 1.910 |
| –1.0 | 0.164 | 1.128 | 1.366 | 1.492 | 1.588 | 1.664 | 1.880 |
| –1.4 | 0.225 | 1.041 | 1.198 | 1.270 | 1.318 | 1.351 | 1.465 |
| –1.8 | 0.282 | 0.945 | 1.035 | 1.069 | 1.087 | 1.097 | 1.130 |
| –2.2 | 0.330 | 0.844 | 0.888 | 0.900 | 0.905 | 0.907 | 0.910 |
| –3.0 | 0.396 | 0.660 | 0.666 | 0.666 | 0.667 | 0.667 | 0.668 |

[**Note:** $C_s$ = 0 corresponds to log-normal distribution]

# ANNEXURE-2

## Distribution Table

**Annexure 2.1** (The Table is taken from CWC flood estimation report for western Himalayan Zone-7)

ZONE - 7

| CATCHMENT AREA (Km²) | DESIGN STORM DURATION (HOURS) | | | | | | | | | | | | | | | | | | | | | | | | CATCHMENT AREA (Km²) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | |
| 0000 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 0000 |
| 50 | 94.00 | 95.20 | 96.40 | 96.83 | 97.27 | 97.70 | 97.79 | 97.88 | 97.97 | 98.07 | 98.16 | 98.25 | 98.31 | 98.38 | 98.44 | 98.50 | 98.56 | 98.62 | 98.69 | 98.75 | 98.81 | 98.88 | 98.94 | 99.00 | 50 |
| 100 | 89.00 | 90.95 | 92.90 | 93.73 | 94.57 | 95.40 | 95.58 | 95.77 | 95.95 | 96.13 | 96.32 | 96.50 | 96.62 | 96.75 | 96.88 | 97.00 | 97.12 | 97.25 | 97.38 | 97.50 | 97.62 | 97.75 | 97.87 | 98.00 | 100 |
| 150 | 84.50 | 87.00 | 89.50 | 90.70 | 91.90 | 93.10 | 93.42 | 93.73 | 94.05 | 94.37 | 94.68 | 95.00 | 95.17 | 95.33 | 95.50 | 95.67 | 95.83 | 96.00 | 96.17 | 96.33 | 96.50 | 96.67 | 96.83 | 97.00 | 150 |
| 200 | 80.75 | 83.47 | 86.20 | 87.40 | 88.60 | 89.80 | 90.42 | 91.03 | 91.65 | 92.27 | 92.88 | 93.50 | 93.71 | 93.92 | 94.12 | 94.33 | 94.54 | 94.75 | 94.96 | 95.17 | 95.37 | 95.58 | 95.79 | 96.00 | 200 |
| 250 | 77.25 | 80.12 | 83.00 | 84.03 | 86.67 | 88.50 | 89.08 | 89.67 | 90.25 | 90.83 | 91.42 | 92.00 | 92.27 | 92.53 | 92.80 | 93.07 | 93.33 | 93.60 | 93.87 | 94.13 | 94.40 | 94.67 | 94.93 | 95.20 | 250 |
| 300 | 74.25 | 77.12 | 80.00 | 82.07 | 84.13 | 86.20 | 86.92 | 87.63 | 88.35 | 89.07 | 89.78 | 90.50 | 90.82 | 91.15 | 91.47 | 91.80 | 92.12 | 92.45 | 92.77 | 93.10 | 93.42 | 93.75 | 94.07 | 94.40 | 300 |
| 350 | | | 77.20 | 79.43 | 81.67 | 83.90 | 84.77 | 85.63 | 86.50 | 87.37 | 88.23 | 89.10 | 89.48 | 89.87 | 90.25 | 90.63 | 91.02 | 91.40 | 91.78 | 92.17 | 92.55 | 92.93 | 93.32 | 93.70 | 350 |
| 400 | | | 74.50 | 76.87 | 79.23 | 81.60 | 82.62 | 83.65 | 84.67 | 85.70 | 86.72 | 87.75 | 88.19 | 88.62 | 89.06 | 89.50 | 89.94 | 90.37 | 90.81 | 91.25 | 91.69 | 92.12 | 92.56 | 93.00 | 400 |
| 450 | | | 72.00 | 74.50 | 77.00 | 79.50 | 80.67 | 81.83 | 83.00 | 84.17 | 85.33 | 86.50 | 86.98 | 87.47 | 87.95 | 88.43 | 88.92 | 89.40 | 89.88 | 90.37 | 90.85 | 91.33 | 91.82 | 92.30 | 450 |
| 500 | | | 70.00 | 72.40 | 74.80 | 77.20 | 78.56 | 79.88 | 81.22 | 82.57 | 83.91 | 85.25 | 85.78 | 86.31 | 86.84 | 87.37 | 87.90 | 88.42 | 88.95 | 89.48 | 90.01 | 90.54 | 91.07 | 91.60 | 500 |
| 600 | | | | | | | | | | | | 83.00 | 83.60 | 84.21 | 84.81 | 85.42 | 86.02 | 86.62 | 87.23 | 87.83 | 88.44 | 89.04 | 89.65 | 90.25 | 600 |
| 700 | | | | | | | | | | | | 81.00 | 81.67 | 82.33 | 83.00 | 83.67 | 84.33 | 85.00 | 85.67 | 86.33 | 87.00 | 87.67 | 88.33 | 89.00 | 700 |
| 800 | | | | | | | | | | | | 79.60 | 80.30 | 81.00 | 81.70 | 82.40 | 83.10 | 83.80 | 84.50 | 85.20 | 85.90 | 86.60 | 87.30 | 88.00 | 800 |
| 900 | | | | | | | | | | | | 78.40 | 79.12 | 79.83 | 80.55 | 81.27 | 81.98 | 82.70 | 83.42 | 84.13 | 84.85 | 85.57 | 86.28 | 87.00 | 900 |
| 1000 | | | | | | | | | | | | 77.20 | 77.95 | 78.71 | 79.46 | 80.22 | 80.97 | 81.72 | 82.48 | 83.23 | 83.99 | 84.74 | 85.50 | 86.25 | 1000 |
| 1100 | | | | | | | | | | | | 76.20 | 76.97 | 77.75 | 78.52 | 79.30 | 80.07 | 80.85 | 81.62 | 82.40 | 83.17 | 83.95 | 84.72 | 85.50 | 1100 |
| 1200 | | | | | | | | | | | | 75.50 | 76.29 | 77.08 | 77.87 | 78.67 | 79.46 | 80.25 | 81.04 | 81.83 | 82.62 | 83.42 | 84.21 | 85.00 | 1200 |
| 1300 | | | | | | | | | | | | | | | | | | | | | | | | 84.50 | 1300 |
| 1400 | | | | | | | | | | | | | | | | | | | | | | | | 84.00 | 1400 |
| 1500 | | | | | | | | | | | | | | | | | | | | | | | | 83.50 | 1500 |
| 2000 | | | | | | | | | | | | | | | | | | | | | | | | 82.70 | 2000 |

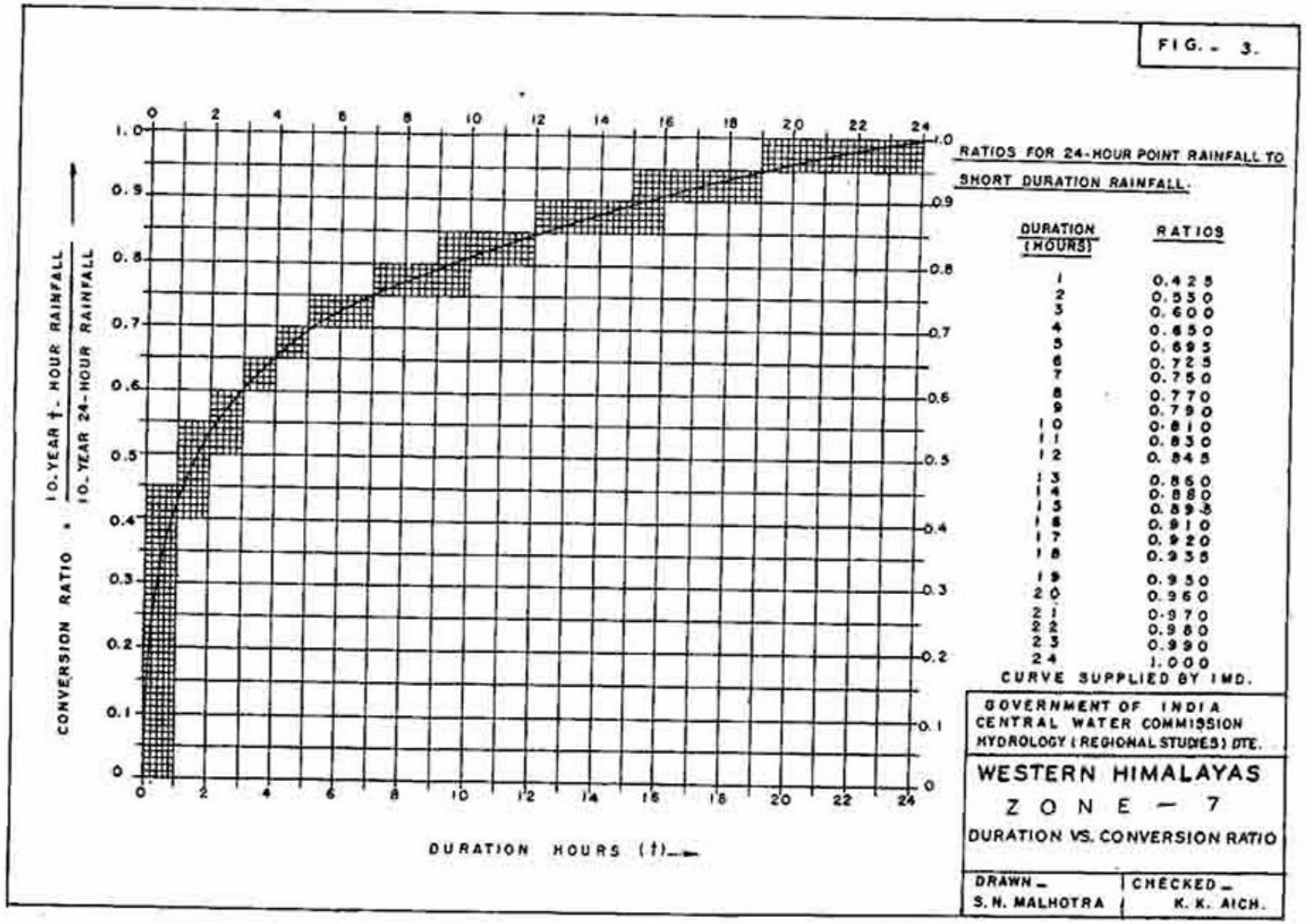
**Annexure 2.2** (The Table is taken from CWC flood estimation report for western Himalayan Zone-7)

| INTER-MEDIATE HOURS | DESIGN STORM DURATION (HOURS) | | | | | | | | | | | | | | | | | | | | | | | | INTER-MEDIATE HOURS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | |
| 1 | 1.00 | 0.85 | 0.73 | 0.62 | 0.56 | 0.52 | 0.46 | 0.43 | 0.41 | 0.38 | 0.37 | 0.34 | 0.32 | 0.30 | 0.28 | 0.26 | 0.25 | 0.23 | 0.21 | 0.20 | 0.19 | 0.18 | 0.17 | 0.17 | 1 |
| 2 | | 1.00 | 0.92 | 0.82 | 0.75 | 0.69 | 0.63 | 0.60 | 0.57 | 0.54 | 0.52 | 0.49 | 0.44 | 0.43 | 0.41 | 0.40 | 0.39 | 0.37 | 0.33 | 0.32 | 0.31 | 0.30 | 0.28 | 0.27 | 2 |
| 3 | | | 1.00 | 0.94 | 0.87 | 0.82 | 0.75 | 0.71 | 0.68 | 0.65 | 0.62 | 0.60 | 0.55 | 0.53 | 0.51 | 0.50 | 0.48 | 0.46 | 0.43 | 0.41 | 0.39 | 0.38 | 0.37 | 0.36 | 3 |
| 4 | | | | 1.00 | 0.96 | 0.91 | 0.85 | 0.81 | 0.76 | 0.73 | 0.71 | 0.67 | 0.63 | 0.61 | 0.59 | 0.57 | 0.56 | 0.54 | 0.50 | 0.48 | 0.46 | 0.45 | 0.44 | 0.43 | 4 |
| 5 | | | | | 1.00 | 0.97 | 0.92 | 0.88 | 0.84 | 0.81 | 0.77 | 0.74 | 0.70 | 0.68 | 0.66 | 0.64 | 0.62 | 0.60 | 0.56 | 0.54 | 0.52 | 0.51 | 0.50 | 0.48 | 5 |
| 6 | | | | | | 1.00 | 0.97 | 0.94 | 0.90 | 0.87 | 0.83 | 0.81 | 0.77 | 0.74 | 0.72 | 0.69 | 0.68 | 0.66 | 0.61 | 0.59 | 0.57 | 0.56 | 0.55 | 0.53 | 6 |
| 7 | | | | | | | 1.00 | 0.97 | 0.95 | 0.92 | 0.88 | 0.86 | 0.82 | 0.79 | 0.77 | 0.74 | 0.73 | 0.71 | 0.66 | 0.64 | 0.62 | 0.61 | 0.60 | 0.58 | 7 |
| 8 | | | | | | | | 1.00 | 0.98 | 0.95 | 0.93 | 0.90 | 0.86 | 0.84 | 0.81 | 0.79 | 0.77 | 0.75 | 0.71 | 0.69 | 0.67 | 0.66 | 0.65 | 0.63 | 8 |
| 9 | | | | | | | | | 1.00 | 0.98 | 0.96 | 0.94 | 0.90 | 0.87 | 0.85 | 0.83 | 0.81 | 0.79 | 0.75 | 0.73 | 0.71 | 0.70 | 0.69 | 0.67 | 9 |
| 10 | | | | | | | | | | 1.00 | 0.98 | 0.96 | 0.93 | 0.90 | 0.88 | 0.87 | 0.85 | 0.83 | 0.79 | 0.77 | 0.74 | 0.73 | 0.72 | 0.70 | 10 |
| 11 | | | | | | | | | | | 1.00 | 0.98 | 0.96 | 0.93 | 0.91 | 0.90 | 0.88 | 0.86 | 0.82 | 0.80 | 0.77 | 0.76 | 0.75 | 0.73 | 11 |
| 12 | | | | | | | | | | | | 1.00 | 0.98 | 0.96 | 0.94 | 0.92 | 0.90 | 0.88 | 0.85 | 0.83 | 0.80 | 0.79 | 0.78 | 0.76 | 12 |
| 13 | | | | | | | | | | | | | 1.00 | 0.98 | 0.96 | 0.94 | 0.92 | 0.90 | 0.88 | 0.86 | 0.83 | 0.82 | 0.81 | 0.79 | 13 |
| 14 | | | | | | | | | | | | | | 1.00 | 0.98 | 0.96 | 0.94 | 0.92 | 0.90 | 0.89 | 0.86 | 0.85 | 0.83 | 0.82 | 14 |
| 15 | | | | | | | | | | | | | | | 1.00 | 0.98 | 0.96 | 0.94 | 0.92 | 0.91 | 0.89 | 0.87 | 0.85 | 0.84 | 15 |
| 16 | | | | | | | | | | | | | | | | 1.00 | 0.98 | 0.96 | 0.94 | 0.93 | 0.91 | 0.89 | 0.87 | 0.86 | 16 |
| 17 | | | | | | | | | | | | | | | | | 1.00 | 0.98 | 0.96 | 0.95 | 0.93 | 0.91 | 0.89 | 0.88 | 17 |
| 18 | | | | | | | | | | | | | | | | | | 1.00 | 0.98 | 0.97 | 0.95 | 0.93 | 0.91 | 0.90 | 18 |
| 19 | | | | | | | | | | | | | | | | | | | 1.00 | 0.99 | 0.97 | 0.95 | 0.93 | 0.92 | 19 |
| 20 | | | | | | | | | | | | | | | | | | | | 1.00 | 0.99 | 0.97 | 0.95 | 0.94 | 20 |
| 21 | | | | | | | | | | | | | | | | | | | | | 1.00 | 0.99 | 0.97 | 0.96 | 21 |
| 22 | | | | | | | | | | | | | | | | | | | | | | 1.00 | 0.99 | 0.98 | 22 |
| 23 | | | | | | | | | | | | | | | | | | | | | | | 1.00 | 0.99 | 23 |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | 1.00 | 24 |

41

(Time distribution coefficient table for cumulative hourly rainfall)

**Annexure 2.3** (The Table is taken from CWC flood estimation report for western Himalayan Zone-7)



# ANNEXURE-3

## Chow's table for Manning's N

| Type of Channel and Description | Minimum | Normal | Maximum |
|---|---|---|---|
| **1. Main Channels** | | | |
| a. clean, straight, full stage, no rifts or deep pools | 0.025 | 0.03 | 0.033 |
| b. same as above, but more stones and weeds | 0.03 | 0.035 | 0.04 |
| c. clean, winding, some pools and shoals | 0.033 | 0.04 | 0.045 |
| d. same as above, but some weeds and stones | 0.035 | 0.045 | 0.05 |
| e. same as above, lower stages, more ineffective slopes and sections | 0.04 | 0.048 | 0.055 |
| f. same as "d" with more stones | 0.045 | 0.05 | 0.06 |
| g. sluggish reaches, weedy, deep pools | 0.05 | 0.07 | 0.08 |
| h. very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush | 0.075 | 0.1 | 0.15 |
| **2. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages** | | | |
| a. bottom: gravels, cobbles, and few boulders | 0.03 | 0.04 | 0.05 |
| b. bottom: cobbles with large boulders | 0.04 | 0.05 | 0.07 |
| **3. Floodplains** | | | |
| a. Pasture, no brush | | | |
| 1.short grass | 0.025 | 0.03 | 0.035 |
| 2. high grass | 0.03 | 0.035 | 0.05 |
| b. Cultivated areas | | | |
| 1. no crop | 0.02 | 0.03 | 0.04 |
| 2. mature row crops | 0.025 | 0.035 | 0.045 |
| 3. mature field crops | 0.03 | 0.04 | 0.05 |
| c. Brush | | | |
| 1. scattered brush, heavy weeds | 0.035 | 0.05 | 0.07 |
| 2. light brush and trees, in winter | 0.035 | 0.05 | 0.06 |
| 3. light brush and trees, in summer | 0.04 | 0.06 | 0.08 |
| 4. medium to dense brush, in winter | 0.045 | 0.07 | 0.11 |
| 5. medium to dense brush, in summer | 0.07 | 0.1 | 0.16 |
| d. Trees | | | |
| 1. dense willows, summer, straight | 0.11 | 0.15 | 0.2 |
| 2. cleared land with tree stumps, no sprouts | 0.03 | 0.04 | 0.05 |
| 3. same as above, but with heavy growth of sprouts | 0.05 | 0.06 | 0.08 |
| 4. heavy stand of timber, a few down trees, little undergrowth, flood stage below branches | 0.08 | 0.1 | 0.12 |

| | | | |
|---|---|---|---|
| 5. same as 4. with flood stage reaching branches | 0.1 | 0.12 | 0.16 |
| **4. Excavated or Dredged Channels** | | | |
| a. Earth, straight, and uniform | | | |
| 1. clean, recently completed | 0.016 | 0.018 | 0.02 |
| 2. clean, after weathering | 0.018 | 0.022 | 0.025 |
| 3. gravel, uniform section, clean | 0.022 | 0.025 | 0.03 |
| 4. with short grass, few weeds | 0.022 | 0.027 | 0.033 |
| b. Earth winding and sluggish | | | |
| 1. no vegetation | 0.023 | 0.025 | 0.03 |
| 2. grass, some weeds | 0.025 | 0.03 | 0.033 |
| 3. dense weeds or aquatic plants in deep channels | 0.03 | 0.035 | 0.04 |
| 4. earth bottom and rubble sides | 0.028 | 0.03 | 0.035 |
| 5. stony bottom and weedy banks | 0.025 | 0.035 | 0.04 |
| 6. cobble bottom and clean sides | 0.03 | 0.04 | 0.05 |
| c. Dragline-excavated or dredged | | | |
| 1. no vegetation | 0.025 | 0.028 | 0.033 |
| 2. light brush on banks | 0.035 | 0.05 | 0.06 |
| d. Rock cuts | | | |
| 1. smooth and uniform | 0.025 | 0.035 | 0.04 |
| 2. jagged and irregular | 0.035 | 0.04 | 0.05 |
| e. Channels not maintained, weeds and brush uncut | | | |
| 1. dense weeds, high as flow depth | 0.05 | 0.08 | 0.12 |
| 2. clean bottom, brush on sides | 0.04 | 0.05 | 0.08 |
| 3. same as above, highest stage of flow | 0.045 | 0.07 | 0.11 |
| 4. dense brush, high stage | 0.08 | 0.1 | 0.14 |
| **5. Lined or Constructed Channels** | | | |
| a. Cement | | | |
| 1. neat surface | 0.01 | 0.011 | 0.013 |
| 2. mortar | 0.011 | 0.013 | 0.015 |
| b. Wood | | | |
| 1. planed, untreated | 0.01 | 0.012 | 0.014 |
| 2. planed, creosoted | 0.011 | 0.012 | 0.015 |
| 3. unplaned | 0.011 | 0.013 | 0.015 |
| 4. plank with battens | 0.012 | 0.015 | 0.018 |
| 5. lined with roofing paper | 0.01 | 0.014 | 0.017 |
| c. Concrete | | | |

| | | | |
|---|---|---|---|
| 1. trowel finish | 0.011 | 0.013 | 0.015 |
| 2. float finish | 0.013 | 0.015 | 0.016 |
| 3. finished, with gravel on bottom | 0.015 | 0.017 | 0.02 |
| 4. unfinished | 0.014 | 0.017 | 0.02 |
| 5. gunite, good section | 0.016 | 0.019 | 0.023 |
| 6. gunite, wavy section | 0.018 | 0.022 | 0.025 |
| 7. on good excavated rock | 0.017 | 0.02 | |
| 8. on irregular excavated rock | 0.022 | 0.027 | |
| d. Concrete bottom float finish with sides of: | | | |
| 1. dressed stone in mortar | 0.015 | 0.017 | 0.02 |
| 2. random stone in mortar | 0.017 | 0.02 | 0.024 |
| 3. cement rubble masonry, plastered | 0.016 | 0.02 | 0.024 |
| 4. cement rubble masonry | 0.02 | 0.025 | 0.03 |
| 5. dry rubble or riprap | 0.02 | 0.03 | 0.035 |
| e. Gravel bottom with sides of: | | | |
| 1. formed concrete | 0.017 | 0.02 | 0.025 |
| 2. random stone mortar | 0.02 | 0.023 | 0.026 |
| 3. dry rubble or riprap | 0.023 | 0.033 | 0.036 |
| f. Brick | | | |
| 1. glazed | 0.011 | 0.013 | 0.015 |
| 2. in cement mortar | 0.012 | 0.015 | 0.018 |
| g. Masonry | | | |
| 1. cemented rubble | 0.017 | 0.025 | 0.03 |
| 2. dry rubble | 0.023 | 0.032 | 0.035 |
| h. Dressed ashlar/stone paving | 0.013 | 0.015 | 0.017 |
| i. Asphalt | | | |
| 1. smooth | 0.013 | 0.013 | |
| 2. rough | 0.016 | 0.016 | |
| j. Vegetal lining | 0.03 | | 0.5 |

| 5 Year HFL Points | | | |
|---|---|---|---|
| S. No. | Right Bank | | |
| | Easting (X) | Northing (Y) | Elevation (m) |
| 1 | 770693.76 | 3332771.19 | 301.28 |
| 2 | 770719.85 | 3332728.56 | 301.17 |
| 3 | 770742.32 | 3332683.89 | 301.00 |
| 4 | 770747.63 | 3332634.24 | 300.88 |
| 5 | 770763.93 | 3332587.73 | 300.78 |
| 6 | 770793.88 | 3332547.97 | 300.81 |
| 7 | 770828.36 | 3332511.78 | 301.12 |
| 8 | 770863.82 | 3332476.53 | 301.36 |
| 9 | 770901.11 | 3332443.26 | 301.51 |
| 10 | 770939.16 | 3332410.83 | 301.48 |
| 11 | 770977.21 | 3332378.39 | 300.66 |
| 12 | 771015.27 | 3332345.96 | 300.84 |
| 13 | 771053.71 | 3332314.03 | 301.22 |
| 14 | 771094.89 | 3332285.68 | 301.57 |
| 15 | 771136.08 | 3332257.33 | 301.42 |
| 16 | 771177.48 | 3332229.29 | 301.08 |
| 17 | 771218.87 | 3332201.24 | 300.80 |
| 18 | 771259.16 | 3332171.63 | 300.54 |
| 19 | 771298.43 | 3332140.70 | 300.37 |
| 20 | 771338.24 | 3332110.57 | 300.13 |
| 21 | 771381.48 | 3332085.70 | 300.14 |
| 22 | 771425.77 | 3332062.64 | 299.44 |
| 23 | 771466.44 | 3332033.74 | 299.58 |
| 24 | 771502.76 | 3331999.56 | 299.53 |
| 25 | 771529.79 | 3331957.85 | 299.42 |
| 26 | 771558.93 | 3331917.35 | 299.37 |
| 27 | 771582.42 | 3331873.46 | 299.44 |
| 28 | 771603.13 | 3331827.95 | 299.90 |
| 29 | 771625.84 | 3331783.41 | 301.15 |
| 30 | 771647.62 | 3331738.42 | 300.33 |
| 31 | 771669.68 | 3331693.55 | 301.69 |
| 32 | 771694.54 | 3331650.21 | 301.90 |
| 33 | 771720.15 | 3331607.35 | 302.12 |
| 34 | 771745.87 | 3331564.50 | 302.41 |
| 35 | 771762.72 | 3331517.87 | 302.20 |
| 36 | 771754.10 | 3331469.61 | 301.84 |
| 37 | 771741.70 | 3331421.20 | 300.74 |
| 38 | 771736.48 | 3331371.47 | 300.86 |
| 39 | 771725.20 | 3331323.26 | 301.10 |
| 40 | 771705.81 | 3331277.21 | 302.17 |
| 41 | 771681.56 | 3331233.48 | 302.16 |
| 42 | 771651.75 | 3331193.60 | 301.22 |
| 43 | 771619.17 | 3331155.70 | 299.10 |
| 44 | 771581.81 | 3331122.47 | 298.63 |

| | | | |
|---|---|---|---|
| 45 | 771544.17 | 3331089.60 | 298.28 |
| 46 | 771503.03 | 3331061.18 | 297.94 |
| 47 | 771459.26 | 3331037.79 | 297.50 |
| 48 | 771412.47 | 3331020.18 | 297.23 |
| 49 | 771367.33 | 3330998.68 | 297.15 |
| 50 | 771322.21 | 3330977.12 | 297.03 |
| 51 | 771277.10 | 3330955.57 | 296.97 |
| 52 | 771230.55 | 3330937.32 | 296.90 |
| 53 | 771184.83 | 3330917.22 | 296.81 |
| 54 | 771140.09 | 3330894.88 | 296.72 |
| 55 | 771095.36 | 3330872.55 | 296.60 |
| 56 | 771050.53 | 3330850.40 | 296.50 |
| 57 | 771005.68 | 3330828.30 | 296.43 |
| 58 | 770960.83 | 3330806.21 | 296.36 |
| 59 | 770914.69 | 3330786.99 | 296.43 |
| 60 | 770868.55 | 3330767.87 | 296.43 |
| 61 | 770825.63 | 3330742.21 | 296.29 |
| 62 | 770782.72 | 3330716.55 | 296.09 |
| 63 | 770739.81 | 3330690.89 | 295.97 |
| 64 | 770699.16 | 3330661.77 | 295.80 |
| 65 | 770658.85 | 3330632.28 | 295.70 |
| 66 | 770626.46 | 3330594.19 | 295.68 |
| 67 | 770594.07 | 3330556.10 | 295.69 |
| 68 | 770560.98 | 3330518.63 | 296.31 |
| 69 | 770527.00 | 3330481.95 | 296.60 |
| 70 | 770493.42 | 3330444.92 | 297.06 |
| 71 | 770461.58 | 3330406.37 | 296.91 |
| 72 | 770429.73 | 3330367.82 | 297.17 |
| 73 | 770398.19 | 3330329.03 | 297.68 |
| 74 | 770366.71 | 3330290.18 | 298.19 |
| 75 | 770344.33 | 3330245.55 | 298.22 |
| 76 | 770343.67 | 3330195.82 | 297.66 |
| 77 | 770345.04 | 3330145.84 | 297.07 |
| 78 | 770352.33 | 3330096.38 | 296.81 |
| 79 | 770361.96 | 3330047.47 | 296.71 |
| 80 | 770376.99 | 3329999.87 | 296.66 |
| 81 | 770379.14 | 3329949.92 | 296.62 |
| 82 | 770383.50 | 3329900.19 | 296.57 |
| 83 | 770393.40 | 3329851.18 | 296.53 |
| 84 | 770429.84 | 3329824.56 | 296.20 |
| 85 | 770476.82 | 3329836.37 | 295.90 |
| 86 | 770525.08 | 3329848.19 | 295.72 |
| 87 | 770574.32 | 3329856.88 | 295.27 |
| 88 | 770623.56 | 3329865.56 | 295.12 |
| 89 | 770672.95 | 3329873.30 | 294.90 |
| 90 | 770722.49 | 3329878.47 | 294.92 |
| 91 | 770772.43 | 3329880.86 | 294.85 |

| | | | |
|---|---|---|---|
| 92 | 770822.37 | 3329883.24 | 294.44 |
| 93 | 770872.29 | 3329884.78 | 293.59 |
| 94 | 770922.21 | 3329887.70 | 293.23 |
| 95 | 770971.91 | 3329886.28 | 293.00 |
| 96 | 771021.31 | 3329878.55 | 292.88 |
| 97 | 771063.30 | 3329851.97 | 292.73 |
| 98 | 771098.73 | 3329817.99 | 292.60 |
| 99 | 771117.62 | 3329771.70 | 292.48 |
| 100 | 771134.81 | 3329725.04 | 292.31 |
| 101 | 771130.47 | 3329675.23 | 292.13 |
| 102 | 771126.94 | 3329625.51 | 291.95 |
| 103 | 771122.86 | 3329576.06 | 291.76 |
| 104 | 771116.95 | 3329526.41 | 291.60 |
| 105 | 771111.03 | 3329476.76 | 291.47 |
| 106 | 771104.75 | 3329427.17 | 291.36 |
| 107 | 771077.36 | 3329386.05 | 291.27 |
| 108 | 771047.16 | 3329346.20 | 291.20 |
| 109 | 771016.96 | 3329306.35 | 291.13 |
| 110 | 770984.54 | 3329268.29 | 291.05 |
| 111 | 770951.94 | 3329230.39 | 291.02 |
| 112 | 770915.45 | 3329196.53 | 290.93 |
| 113 | 770876.16 | 3329165.62 | 290.89 |
| 114 | 770836.53 | 3329135.13 | 290.85 |
| 115 | 770796.59 | 3329105.04 | 290.77 |
| 116 | 770756.63 | 3329075.20 | 290.64 |
| 117 | 770714.17 | 3329048.80 | 290.51 |
| 118 | 770671.84 | 3329022.19 | 290.35 |
| 119 | 770637.39 | 3328986.30 | 290.22 |
| 120 | 770601.17 | 3328951.83 | 290.10 |
| 121 | 770582.95 | 3328905.54 | 290.00 |
| 122 | 770564.83 | 3328858.94 | 289.90 |
| 123 | 770546.72 | 3328812.34 | 289.80 |
| 124 | 770520.80 | 3328769.92 | 289.79 |
| 125 | 770491.96 | 3328729.08 | 289.69 |
| 126 | 770464.08 | 3328687.66 | 289.63 |
| 127 | 770441.48 | 3328643.05 | 289.58 |
| 128 | 770418.88 | 3328598.45 | 289.50 |
| 129 | 770396.28 | 3328553.85 | 289.42 |
| 130 | 770373.68 | 3328509.25 | 289.36 |
| 131 | 770351.08 | 3328464.65 | 289.35 |
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| 892 | 784826.68 | 3304753.98 | 247.87 |
| 893 | 784876.67 | 3304752.94 | 248.01 |
| 894 | 784926.60 | 3304750.57 | 248.01 |
| 895 | 784976.52 | 3304748.24 | 247.78 |
| 896 | 785026.48 | 3304746.17 | 247.40 |
| 897 | 785076.30 | 3304743.89 | 247.21 |
| 898 | 785126.30 | 3304744.12 | 247.03 |
| 899 | 785176.29 | 3304744.48 | 246.83 |
| 900 | 785226.12 | 3304747.49 | 246.61 |
| 901 | 785274.68 | 3304758.81 | 246.29 |
| 902 | 785314.75 | 3304787.10 | 245.59 |
| 903 | 785343.16 | 3304827.76 | 245.14 |
| 904 | 785364.96 | 3304872.65 | 244.98 |
| 905 | 785383.96 | 3304918.86 | 244.88 |
| 906 | 785399.10 | 3304966.52 | 245.78 |
| 907 | 785407.92 | 3305015.26 | 245.91 |
| 908 | 785409.64 | 3305065.23 | 245.62 |
| 909 | 785415.38 | 3305114.90 | 245.45 |
| 910 | 785428.00 | 3305162.91 | 244.53 |
| 911 | 785445.53 | 3305209.74 | 244.44 |
| 912 | 785473.37 | 3305250.23 | 244.95 |
| 913 | 785509.33 | 3305284.28 | 244.93 |
| 914 | 785553.30 | 3305307.70 | 244.89 |
| 915 | 785603.12 | 3305311.94 | 245.04 |
| 916 | 785651.88 | 3305303.60 | 244.87 |
| 917 | 785700.19 | 3305290.71 | 246.00 |
| 918 | 785744.31 | 3305268.14 | 246.02 |
| 919 | 785785.36 | 3305239.77 | 246.24 |
| 920 | 785824.27 | 3305208.36 | 246.42 |
| 921 | 785859.52 | 3305173.11 | 246.63 |
| 922 | 785893.62 | 3305136.61 | 246.91 |
| 923 | 785920.71 | 3305094.59 | 247.20 |
| 924 | 785947.40 | 3305052.50 | 247.31 |
| 925 | 785968.25 | 3305007.05 | 247.29 |
| 926 | 785986.83 | 3304961.02 | 247.20 |
| 927 | 785990.62 | 3304911.17 | 247.17 |
| 928 | 785994.41 | 3304861.31 | 247.08 |
| 929 | 785996.88 | 3304811.41 | 247.05 |
| 930 | 785996.24 | 3304761.42 | 247.08 |
| 931 | 785997.99 | 3304711.48 | 247.14 |
| 932 | 786001.15 | 3304661.58 | 247.26 |
| 933 | 786004.31 | 3304611.68 | 247.34 |
| 934 | 786001.54 | 3304561.77 | 247.33 |
| 935 | 786010.95 | 3304513.46 | 247.31 |
| 936 | 786029.77 | 3304467.40 | 247.11 |
| 937 | 786056.15 | 3304425.03 | 246.88 |

| 938 | 786087.38 | 3304385.99 | 246.67 |
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| 939 | 786123.21 | 3304351.44 | 246.52 |
| 940 | 786161.59 | 3304319.39 | 246.40 |
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| 943 | 786250.60 | 3304199.62 | 246.50 |
| 944 | 786277.30 | 3304157.34 | 246.27 |
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| 946 | 786326.91 | 3304070.91 | 246.00 |
| 947 | 786344.28 | 3304024.03 | 245.74 |
| 948 | 786361.66 | 3303977.15 | 245.58 |
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| 954 | 786397.24 | 3303685.23 | 245.91 |
| 955 | 786378.35 | 3303639.38 | 245.93 |
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| 960 | 786213.45 | 3303479.21 | 245.66 |
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| 962 | 786140.28 | 3303415.01 | 245.79 |
| 963 | 786116.13 | 3303371.23 | 246.05 |
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| 982 | 785703.00 | 3302539.66 | 245.99 |
| 983 | 785704.72 | 3302489.92 | 245.95 |
| 984 | 785713.90 | 3302440.77 | 245.87 |

| 985 | 785729.41 | 3302393.29 | 245.68 |
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| 986 | 785745.52 | 3302345.96 | 245.45 |
| 987 | 785761.63 | 3302298.62 | 245.33 |
| 988 | 785779.86 | 3302252.12 | 245.23 |
| 989 | 785800.29 | 3302206.48 | 245.09 |
| 990 | 785820.50 | 3302160.77 | 244.91 |
| 991 | 785842.25 | 3302115.75 | 244.73 |
| 992 | 785864.01 | 3302070.73 | 244.46 |
| 993 | 785885.76 | 3302025.71 | 244.41 |
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| 995 | 785946.57 | 3301946.36 | 244.28 |
| 996 | 785980.44 | 3301909.65 | 244.12 |
| 997 | 786018.63 | 3301877.94 | 243.91 |
| 998 | 786062.51 | 3301855.83 | 243.77 |
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| 1002 | 786260.61 | 3301875.38 | 242.87 |
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| 1004 | 786325.34 | 3301943.74 | 243.22 |
| 1005 | 786337.05 | 3301992.36 | 243.35 |
| 1006 | 786331.74 | 3302041.69 | 243.29 |
| 1007 | 786323.60 | 3302091.01 | 242.93 |
| 1008 | 786314.62 | 3302140.19 | 242.29 |
| 1009 | 786305.79 | 3302189.40 | 244.23 |
| 1010 | 786297.07 | 3302238.63 | 244.34 |
| 1011 | 786288.65 | 3302287.92 | 244.46 |
| 1012 | 786280.23 | 3302337.21 | 244.62 |
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| 1015 | 786285.35 | 3302485.83 | 244.91 |
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| 1017 | 786338.39 | 3302569.72 | 244.75 |
| 1018 | 786375.80 | 3302602.87 | 244.59 |
| 1019 | 786418.28 | 3302627.94 | 244.01 |
| 1020 | 786464.94 | 3302645.90 | 243.90 |
| 1021 | 786514.05 | 3302647.16 | 243.80 |
| 1022 | 786563.51 | 3302645.33 | 243.74 |
| 1023 | 786613.28 | 3302640.71 | 243.62 |
| 1024 | 786663.02 | 3302635.56 | 243.46 |
| 1025 | 786712.32 | 3302627.98 | 243.21 |
| 1026 | 786760.78 | 3302615.68 | 243.05 |
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| 1033 | 787068.30 | 3302464.55 | 242.98 |
| 1034 | 787103.04 | 3302428.81 | 242.86 |
| 1035 | 787134.43 | 3302389.89 | 241.64 |
| 1036 | 787155.35 | 3302344.85 | 241.66 |
| 1037 | 787170.78 | 3302297.59 | 241.70 |
| 1038 | 787176.75 | 3302247.95 | 242.47 |
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| 1040 | 787182.28 | 3302148.39 | 242.45 |
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| 1042 | 787145.61 | 3302057.49 | 242.67 |
| 1043 | 787119.89 | 3302015.02 | 242.97 |
| 1044 | 787094.24 | 3301972.10 | 243.18 |
| 1045 | 787070.63 | 3301928.60 | 243.29 |
| 1046 | 787042.67 | 3301887.14 | 243.37 |
| 1047 | 787015.65 | 3301845.29 | 243.34 |
| 1048 | 786992.03 | 3301801.56 | 243.33 |
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| 1050 | 786959.07 | 3301708.30 | 244.23 |
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| 1052 | 786970.95 | 3301610.24 | 243.48 |
| 1053 | 787002.19 | 3301572.04 | 243.40 |
| 1054 | 787036.73 | 3301535.89 | 243.53 |
| 1055 | 787081.37 | 3301514.82 | 243.57 |
| 1056 | 787127.47 | 3301495.67 | 243.46 |
| 1057 | 787172.12 | 3301473.19 | 243.25 |
| 1058 | 787218.34 | 3301455.30 | 243.05 |
| 1059 | 787267.48 | 3301446.08 | 243.07 |
| 1060 | 787315.35 | 3301432.21 | 243.00 |
| 1061 | 787358.98 | 3301409.51 | 242.88 |
| 1062 | 787401.41 | 3301383.07 | 242.74 |
| 1063 | 787443.85 | 3301356.63 | 242.74 |
| 1064 | 787486.24 | 3301330.12 | 242.79 |
| 1065 | 787528.53 | 3301303.44 | 242.73 |
| 1066 | 787571.40 | 3301277.73 | 242.72 |
| 1067 | 787614.99 | 3301253.24 | 242.59 |
| 1068 | 787642.85 | 3301214.44 | 242.65 |
| 1069 | 787659.86 | 3301167.74 | 242.67 |
| 1070 | 787668.52 | 3301118.50 | 242.76 |
| 1071 | 787666.48 | 3301068.92 | 242.79 |
| 1072 | 787652.59 | 3301021.87 | 242.72 |
| 1073 | 787628.51 | 3300978.05 | 242.48 |
| 1074 | 787599.81 | 3300937.57 | 241.89 |
| 1075 | 787565.75 | 3300900.96 | 241.69 |
| 1076 | 787531.69 | 3300864.36 | 241.07 |
| 1077 | 787498.08 | 3300827.35 | 240.80 |
| 1078 | 787465.18 | 3300789.70 | 241.07 |

| 1079 | 787435.19 | 3300749.76 | 241.58 |
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| 1080 | 787414.03 | 3300705.83 | 241.55 |
| 1081 | 787406.82 | 3300656.35 | 243.02 |
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| 1085 | 787555.51 | 3300537.01 | 242.75 |
| 1086 | 787595.28 | 3300507.63 | 242.73 |
| 1087 | 787623.94 | 3300466.66 | 242.68 |
| 1088 | 787652.61 | 3300425.69 | 242.70 |
| 1089 | 787681.27 | 3300384.72 | 242.77 |
| 1090 | 787709.93 | 3300343.75 | 242.79 |
| 1091 | 787738.59 | 3300302.78 | 242.80 |
| 1092 | 787757.96 | 3300256.74 | 242.91 |
| 1093 | 787776.85 | 3300210.45 | 242.94 |
| 1094 | 787789.97 | 3300162.98 | 242.97 |
| 1095 | 787789.29 | 3300112.98 | 242.94 |
| 1096 | 787789.33 | 3300063.27 | 242.90 |
| 1097 | 787790.38 | 3300013.78 | 242.91 |
| 1098 | 787799.51 | 3299964.62 | 242.73 |
| 1099 | 787808.79 | 3299915.49 | 242.47 |
| 1100 | 787818.07 | 3299866.36 | 242.14 |
| 1101 | 787827.71 | 3299817.35 | 242.03 |
| 1102 | 787849.32 | 3299772.26 | 239.39 |
| 1103 | 787870.93 | 3299727.17 | 239.51 |
| 1104 | 787885.97 | 3299679.70 | 240.58 |
| 1105 | 787898.56 | 3299631.32 | 241.68 |
| 1106 | 787908.43 | 3299582.31 | 241.54 |
| 1107 | 787904.29 | 3299532.90 | 241.47 |
| 1108 | 787896.47 | 3299483.59 | 241.26 |
| 1109 | 787879.01 | 3299436.74 | 241.04 |
| 1110 | 787861.02 | 3299390.09 | 240.15 |
| 1111 | 787843.02 | 3299343.43 | 239.57 |
| 1112 | 787818.67 | 3299300.59 | 239.21 |
| 1113 | 787786.07 | 3299262.67 | 239.70 |
| 1114 | 787751.49 | 3299226.83 | 239.11 |
| 1115 | 787712.36 | 3299195.69 | 241.63 |
| 1116 | 787673.24 | 3299164.56 | 241.81 |
| 1117 | 787634.50 | 3299132.98 | 241.89 |
| 1118 | 787597.53 | 3299099.31 | 242.06 |
| 1119 | 787560.57 | 3299065.63 | 242.15 |
| 1120 | 787522.96 | 3299032.69 | 242.24 |
| 1121 | 787485.64 | 3298999.43 | 242.33 |
| 1122 | 787447.32 | 3298967.48 | 242.37 |
| 1123 | 787409.09 | 3298935.25 | 242.35 |
| 1124 | 787369.96 | 3298904.20 | 242.20 |
| 1125 | 787328.91 | 3298875.66 | 242.08 |

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| 1126 | 787287.85 | 3298847.12 | 241.93 |
| 1127 | 787247.27 | 3298817.92 | 241.91 |
| 1128 | 787206.83 | 3298788.51 | 241.65 |
| 1129 | 787166.00 | 3298759.65 | 241.19 |
| 1130 | 787125.03 | 3298731.00 | 240.60 |
| 1131 | 787084.05 | 3298702.34 | 239.49 |
| 1132 | 787044.39 | 3298671.90 | 239.47 |
| 1133 | 787004.85 | 3298641.30 | 240.36 |
| 1134 | 786965.32 | 3298610.69 | 240.94 |
| 1135 | 786926.16 | 3298579.61 | 239.71 |
| 1136 | 786887.91 | 3298547.41 | 238.33 |
| 1137 | 786849.66 | 3298515.21 | 239.21 |
| 1138 | 786811.46 | 3298483.25 | 241.27 |
| 1139 | 786774.46 | 3298449.63 | 240.49 |
| 1140 | 786737.45 | 3298416.00 | 241.37 |
| 1141 | 786700.45 | 3298382.38 | 241.39 |
| 1142 | 786663.44 | 3298348.75 | 241.45 |
| 1143 | 786627.90 | 3298313.67 | 241.41 |
| 1144 | 786594.49 | 3298276.47 | 241.46 |
| 1145 | 786561.08 | 3298239.27 | 241.45 |
| 1146 | 786526.70 | 3298202.98 | 241.44 |
| 1147 | 786491.94 | 3298167.04 | 241.45 |
| 1148 | 786453.08 | 3298136.02 | 241.40 |
| 1149 | 786412.93 | 3298106.23 | 241.41 |
| 1150 | 786380.93 | 3298069.30 | 241.35 |
| 1151 | 786351.54 | 3298028.85 | 241.21 |
| 1152 | 786327.03 | 3297985.75 | 241.13 |
| 1153 | 786306.45 | 3297940.18 | 241.09 |
| 1154 | 786284.74 | 3297895.87 | 241.10 |
| 1155 | 786259.35 | 3297852.80 | 241.08 |
| 1156 | 786244.73 | 3297806.68 | 241.03 |
| 1157 | 786238.29 | 3297757.09 | 241.00 |
| 1158 | 786231.84 | 3297707.51 | 241.02 |
| 1159 | 786228.03 | 3297657.79 | 241.08 |
| 1160 | 786229.84 | 3297607.82 | 241.14 |
| 1161 | 786231.64 | 3297557.86 | 241.17 |
| 1162 | 786235.06 | 3297508.22 | 241.14 |
| 1163 | 786249.67 | 3297460.47 | 241.08 |
| 1164 | 786262.75 | 3297412.21 | 241.02 |
| 1165 | 786280.82 | 3297365.84 | 240.86 |
| 1166 | 786299.63 | 3297319.51 | 240.71 |
| 1167 | 786318.44 | 3297273.18 | 240.52 |
| 1168 | 786334.03 | 3297225.83 | 240.44 |
| 1169 | 786345.36 | 3297177.13 | 240.51 |
| 1170 | 786355.10 | 3297128.22 | 240.61 |
| 1171 | 786356.87 | 3297078.26 | 240.70 |
| 1172 | 786353.56 | 3297028.63 | 240.71 |

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| 1173 | 786345.10 | 3296979.35 | 240.64 |
| 1174 | 786334.03 | 3296930.59 | 240.52 |
| 1175 | 786327.06 | 3296881.27 | 240.39 |
| 1176 | 786324.60 | 3296831.33 | 240.34 |
| 1177 | 786322.12 | 3296781.40 | 240.12 |
| 1178 | 786319.63 | 3296731.46 | 240.35 |
| 1179 | 786326.26 | 3296682.78 | 240.51 |
| 1180 | 786348.00 | 3296639.78 | 240.56 |
| 1181 | 786392.08 | 3296617.32 | 240.67 |
| 1182 | 786441.46 | 3296625.16 | 240.49 |
| 1183 | 786489.89 | 3296637.00 | 240.42 |
| 1184 | 786538.93 | 3296646.36 | 240.45 |
| 1185 | 786588.72 | 3296650.45 | 240.52 |
| 1186 | 786638.30 | 3296655.57 | 240.58 |
| 1187 | 786688.27 | 3296655.87 | 240.63 |
| 1188 | 786735.62 | 3296670.07 | 240.60 |
| 1189 | 786782.18 | 3296688.31 | 240.56 |
| 1190 | 786828.73 | 3296706.55 | 240.43 |
| 1191 | 786877.76 | 3296708.80 | 240.21 |
| 1192 | 786927.65 | 3296705.49 | 240.10 |
| 1193 | 786977.54 | 3296702.18 | 240.07 |
| 1194 | 787023.83 | 3296689.84 | 240.02 |
| 1195 | 787062.30 | 3296657.90 | 239.98 |
| 1196 | 787100.77 | 3296625.96 | 240.02 |
| 1197 | 787139.24 | 3296594.02 | 238.68 |
| 1198 | 787160.99 | 3296549.58 | 237.87 |
| 1199 | 787180.75 | 3296503.65 | 239.80 |
| 1200 | 787200.29 | 3296457.65 | 239.95 |
| 1201 | 787212.73 | 3296409.22 | 239.94 |
| 1202 | 787225.17 | 3296360.79 | 239.93 |
| 1203 | 787237.62 | 3296312.36 | 240.01 |
| 1204 | 787272.62 | 3296280.24 | 237.79 |
| 1205 | 787314.70 | 3296253.25 | 240.35 |

| 5 Year HFL Points | | | |
|---|---|---|---|
| S. No. | Left Bank | | |
| | Easting (X) | Northing (Y) | Elevation (m) |
| 1 | 770521.23 | 3332679.19 | 301.28 |
| 2 | 770542.97 | 3332634.17 | 301.17 |
| 3 | 770564.71 | 3332589.14 | 301.00 |
| 4 | 770589.09 | 3332545.61 | 300.88 |
| 5 | 770616.70 | 3332503.93 | 300.78 |
| 6 | 770656.78 | 3332478.13 | 300.81 |
| 7 | 770703.84 | 3332461.25 | 301.12 |
| 8 | 770751.83 | 3332447.20 | 301.36 |
| 9 | 770794.86 | 3332422.47 | 301.51 |
| 10 | 770835.15 | 3332393.01 | 301.48 |
| 11 | 770873.36 | 3332360.76 | 300.66 |
| 12 | 770911.57 | 3332328.51 | 300.84 |
| 13 | 770949.35 | 3332295.76 | 301.22 |
| 14 | 770986.82 | 3332262.66 | 301.57 |
| 15 | 771025.05 | 3332230.48 | 301.42 |
| 16 | 771064.91 | 3332200.29 | 301.08 |
| 17 | 771105.33 | 3332170.92 | 300.80 |
| 18 | 771147.91 | 3332144.72 | 300.54 |
| 19 | 771188.90 | 3332116.18 | 300.37 |
| 20 | 771228.91 | 3332086.19 | 300.13 |
| 21 | 771268.92 | 3332056.20 | 300.14 |
| 22 | 771309.70 | 3332027.27 | 299.44 |
| 23 | 771350.50 | 3331998.37 | 299.58 |
| 24 | 771389.45 | 3331967.01 | 299.53 |
| 25 | 771427.83 | 3331935.11 | 299.42 |
| 26 | 771458.10 | 3331895.31 | 299.37 |
| 27 | 771483.98 | 3331853.10 | 299.44 |
| 28 | 771503.94 | 3331807.26 | 299.90 |
| 29 | 771520.89 | 3331760.22 | 301.15 |
| 30 | 771537.77 | 3331713.16 | 300.33 |
| 31 | 771554.64 | 3331666.09 | 301.69 |
| 32 | 771574.62 | 3331620.29 | 301.90 |
| 33 | 771595.62 | 3331574.92 | 302.12 |
| 34 | 771616.86 | 3331529.65 | 302.41 |
| 35 | 771638.15 | 3331484.42 | 302.20 |
| 36 | 771646.55 | 3331435.52 | 301.84 |
| 37 | 771649.87 | 3331385.77 | 300.74 |
| 38 | 771647.02 | 3331335.85 | 300.86 |
| 39 | 771631.10 | 3331290.17 | 301.10 |
| 40 | 771604.10 | 3331248.08 | 302.17 |
| 41 | 771572.00 | 3331211.16 | 302.16 |
| 42 | 771529.64 | 3331184.60 | 301.22 |
| 43 | 771487.27 | 3331158.04 | 299.10 |
| 44 | 771445.77 | 3331130.19 | 298.63 |

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|---|---|---|---|
| 45 | 771404.78 | 3331101.56 | 298.28 |
| 46 | 771359.16 | 3331081.16 | 297.94 |
| 47 | 771313.39 | 3331061.02 | 297.50 |
| 48 | 771267.63 | 3331040.89 | 297.23 |
| 49 | 771222.03 | 3331020.37 | 297.15 |
| 50 | 771176.47 | 3330999.77 | 297.03 |
| 51 | 771130.45 | 3330980.24 | 296.97 |
| 52 | 771084.28 | 3330961.04 | 296.90 |
| 53 | 771038.34 | 3330941.35 | 296.81 |
| 54 | 770993.93 | 3330918.39 | 296.72 |
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| 1187 | 786801.46 | 3294898.75 | 240.63 |
| 1188 | 786756.28 | 3294920.18 | 240.60 |
| 1189 | 786710.05 | 3294938.95 | 240.56 |
| 1190 | 786662.48 | 3294954.33 | 240.43 |
| 1191 | 786614.90 | 3294969.72 | 240.21 |
| 1192 | 786567.22 | 3294984.68 | 240.10 |
| 1193 | 786518.40 | 3294995.51 | 240.07 |
| 1194 | 786469.40 | 3295005.38 | 240.02 |
| 1195 | 786420.11 | 3295013.80 | 239.98 |
| 1196 | 786370.63 | 3295019.77 | 240.02 |
| 1197 | 786320.64 | 3295019.24 | 238.68 |
| 1198 | 786270.64 | 3295018.71 | 237.87 |
| 1199 | 786222.51 | 3295005.26 | 239.80 |
| 1200 | 786174.43 | 3294991.53 | 239.95 |
| 1201 | 786127.03 | 3294975.64 | 239.94 |
| 1202 | 786079.91 | 3294959.05 | 239.93 |
| 1203 | 786035.16 | 3294936.74 | 240.01 |
| 1204 | 785995.86 | 3294909.30 | 237.79 |
| 1205 | 785976.27 | 3294863.30 | 240.35 |

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RASTERVA X Y

| 25 Year HFL Points | | | |
|---|---|---|---|
| S. No. | Right Bank | | |
| | Easting (X) | Northing (Y) | Elevation (m) |
| 1 | 770600.74 | 3332762.78 | 301.61 |
| 2 | 770588.85 | 3332756.20 | 301.98 |
| 3 | 770544.91 | 3332732.49 | 303.96 |
| 4 | 770502.93 | 3332705.33 | 303.85 |
| 5 | 770495.06 | 3332668.64 | 303.89 |
| 6 | 770511.01 | 3332622.14 | 304.66 |
| 7 | 770534.87 | 3332578.77 | 303.66 |
| 8 | 770558.45 | 3332534.74 | 303.33 |
| 9 | 770582.66 | 3332491.85 | 304.12 |
| 10 | 770618.15 | 3332457.83 | 301.02 |
| 11 | 770657.52 | 3332427.76 | 302.26 |
| 12 | 770705.27 | 3332427.55 | 303.13 |
| 13 | 770754.20 | 3332423.22 | 302.05 |
| 14 | 770796.70 | 3332397.12 | 301.88 |
| 15 | 770836.54 | 3332367.17 | 301.81 |
| 16 | 770876.52 | 3332337.16 | 302.19 |
| 17 | 770905.11 | 3332296.14 | 301.62 |
| 18 | 770934.72 | 3332256.17 | 301.33 |
| 19 | 770976.38 | 3332228.51 | 301.34 |
| 20 | 771018.03 | 3332200.86 | 300.90 |
| 21 | 771059.37 | 3332172.73 | 300.74 |
| 22 | 771100.65 | 3332144.51 | 300.97 |
| 23 | 771140.83 | 3332114.77 | 301.24 |
| 24 | 771180.78 | 3332084.70 | 301.54 |
| 25 | 771220.64 | 3332054.53 | 301.82 |
| 26 | 771260.49 | 3332024.33 | 301.80 |
| 27 | 771300.20 | 3331993.94 | 301.96 |
| 28 | 771338.90 | 3331962.28 | 302.08 |
| 29 | 771377.60 | 3331930.63 | 301.88 |
| 30 | 771416.31 | 3331898.97 | 301.66 |
| 31 | 771452.52 | 3331865.09 | 301.50 |
| 32 | 771470.35 | 3331820.02 | 301.09 |
| 33 | 771483.95 | 3331773.95 | 300.56 |
| 34 | 771504.53 | 3331728.66 | 300.06 |
| 35 | 771519.36 | 3331681.18 | 300.03 |
| 36 | 771542.34 | 3331637.45 | 299.63 |
| 37 | 771568.04 | 3331596.94 | 301.87 |
| 38 | 771585.22 | 3331549.98 | 301.76 |
| 39 | 771605.78 | 3331507.84 | 300.80 |
| 40 | 771621.60 | 3331460.94 | 301.18 |
| 41 | 771621.91 | 3331411.06 | 300.41 |
| 42 | 771620.97 | 3331361.07 | 300.04 |
| 43 | 771616.52 | 3331311.58 | 300.35 |
| 44 | 771600.89 | 3331264.56 | 301.08 |

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| 45 | 771571.06 | 3331224.43 | 300.90 |
| 46 | 771526.78 | 3331202.07 | 300.56 |
| 47 | 771479.89 | 3331184.96 | 300.51 |
| 48 | 771432.76 | 3331168.51 | 300.98 |
| 49 | 771388.09 | 3331146.05 | 300.84 |
| 50 | 771343.43 | 3331123.58 | 300.31 |
| 51 | 771298.76 | 3331101.11 | 299.46 |
| 52 | 771254.09 | 3331078.64 | 298.38 |
| 53 | 771209.42 | 3331056.17 | 298.07 |
| 54 | 771164.58 | 3331034.09 | 297.64 |
| 55 | 771118.94 | 3331013.65 | 297.46 |
| 56 | 771072.71 | 3330994.66 | 297.45 |
| 57 | 771026.09 | 3330976.59 | 297.30 |
| 58 | 770979.83 | 3330957.92 | 297.19 |
| 59 | 770936.60 | 3330932.80 | 297.16 |
| 60 | 770893.36 | 3330907.69 | 297.18 |
| 61 | 770850.13 | 3330882.57 | 296.85 |
| 62 | 770808.47 | 3330854.94 | 296.69 |
| 63 | 770767.04 | 3330826.96 | 296.55 |
| 64 | 770725.60 | 3330798.97 | 296.43 |
| 65 | 770684.17 | 3330770.99 | 296.29 |
| 66 | 770644.55 | 3330740.64 | 296.17 |
| 67 | 770606.97 | 3330707.66 | 296.05 |
| 68 | 770571.08 | 3330672.97 | 295.89 |
| 69 | 770537.62 | 3330635.81 | 295.80 |
| 70 | 770504.17 | 3330598.66 | 295.70 |
| 71 | 770471.24 | 3330561.04 | 295.62 |
| 72 | 770438.66 | 3330523.11 | 295.55 |
| 73 | 770406.20 | 3330485.08 | 295.51 |
| 74 | 770373.91 | 3330446.90 | 295.49 |
| 75 | 770341.70 | 3330408.66 | 295.48 |
| 76 | 770310.17 | 3330369.85 | 295.52 |
| 77 | 770278.97 | 3330330.81 | 295.70 |
| 78 | 770252.06 | 3330288.67 | 296.43 |
| 79 | 770236.65 | 3330241.71 | 297.30 |
| 80 | 770227.60 | 3330192.68 | 296.34 |
| 81 | 770225.82 | 3330142.72 | 296.48 |
| 82 | 770225.43 | 3330092.79 | 296.34 |
| 83 | 770230.22 | 3330043.02 | 296.80 |
| 84 | 770235.12 | 3329993.26 | 297.41 |
| 85 | 770240.57 | 3329943.56 | 297.36 |
| 86 | 770249.22 | 3329894.45 | 297.38 |
| 87 | 770262.02 | 3329846.12 | 296.08 |
| 88 | 770279.08 | 3329799.29 | 294.64 |
| 89 | 770299.31 | 3329753.57 | 294.40 |
| 90 | 770318.32 | 3329707.33 | 294.41 |
| 91 | 770347.01 | 3329666.67 | 294.43 |

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| 92 | 770367.29 | 3329621.17 | 294.47 |
| 93 | 770385.13 | 3329574.48 | 294.49 |
| 94 | 770401.93 | 3329527.42 | 294.47 |
| 95 | 770416.58 | 3329479.63 | 294.42 |
| 96 | 770433.58 | 3329432.61 | 294.44 |
| 97 | 770450.75 | 3329385.75 | 294.50 |
| 98 | 770447.69 | 3329336.25 | 294.64 |
| 99 | 770424.03 | 3329293.81 | 294.69 |
| 100 | 770392.69 | 3329254.86 | 294.71 |
| 101 | 770359.74 | 3329217.28 | 294.68 |
| 102 | 770325.77 | 3329180.60 | 294.64 |
| 103 | 770291.80 | 3329143.90 | 294.68 |
| 104 | 770257.89 | 3329107.17 | 294.69 |
| 105 | 770223.97 | 3329070.43 | 294.83 |
| 106 | 770192.51 | 3329031.61 | 294.80 |
| 107 | 770161.82 | 3328992.14 | 294.45 |
| 108 | 770132.46 | 3328951.74 | 294.41 |
| 109 | 770104.14 | 3328910.53 | 294.19 |
| 110 | 770076.02 | 3328869.19 | 294.07 |
| 111 | 770048.81 | 3328827.24 | 294.05 |
| 112 | 770023.11 | 3328784.43 | 294.17 |
| 113 | 770000.43 | 3328739.86 | 294.37 |
| 114 | 769979.17 | 3328694.64 | 294.46 |
| 115 | 769959.47 | 3328648.68 | 294.52 |
| 116 | 769939.77 | 3328602.73 | 294.51 |
| 117 | 769920.60 | 3328556.55 | 294.37 |
| 118 | 769902.18 | 3328510.07 | 294.24 |
| 119 | 769882.13 | 3328464.35 | 294.11 |
| 120 | 769858.15 | 3328420.48 | 293.97 |
| 121 | 769834.17 | 3328376.60 | 293.79 |
| 122 | 769816.70 | 3328329.79 | 293.60 |
| 123 | 769799.66 | 3328282.78 | 293.49 |
| 124 | 769782.61 | 3328235.78 | 293.44 |
| 125 | 769765.57 | 3328188.77 | 293.34 |
| 126 | 769748.52 | 3328141.77 | 293.18 |
| 127 | 769729.87 | 3328095.38 | 293.02 |
| 128 | 769711.07 | 3328049.05 | 292.85 |
| 129 | 769699.80 | 3328000.43 | 292.74 |
| 130 | 769689.66 | 3327951.47 | 292.63 |
| 131 | 769679.52 | 3327902.51 | 292.51 |
| 132 | 769669.22 | 3327853.59 | 292.38 |
| 133 | 769657.64 | 3327804.94 | 292.20 |
| 134 | 769646.07 | 3327756.30 | 292.02 |
| 135 | 769634.49 | 3327707.66 | 291.89 |
| 136 | 769616.01 | 3327661.28 | 291.69 |
| 137 | 769596.59 | 3327615.20 | 291.48 |
| 138 | 769576.33 | 3327569.50 | 291.37 |

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| 139 | 769555.27 | 3327524.15 | 291.27 |
| 140 | 769534.21 | 3327478.80 | 291.18 |
| 141 | 769510.36 | 3327434.88 | 291.09 |
| 142 | 769485.91 | 3327391.27 | 290.99 |
| 143 | 769461.45 | 3327347.66 | 290.86 |
| 144 | 769432.60 | 3327306.97 | 290.77 |
| 145 | 769401.91 | 3327267.49 | 290.68 |
| 146 | 769371.23 | 3327228.01 | 290.57 |
| 147 | 769340.74 | 3327188.39 | 290.50 |
| 148 | 769310.53 | 3327148.55 | 290.38 |
| 149 | 769280.67 | 3327108.44 | 290.23 |
| 150 | 769250.98 | 3327068.21 | 290.09 |
| 151 | 769220.47 | 3327028.66 | 289.89 |
| 152 | 769186.47 | 3326991.99 | 289.76 |
| 153 | 769154.58 | 3326953.52 | 289.63 |
| 154 | 769123.86 | 3326914.10 | 289.60 |
| 155 | 769095.94 | 3326872.61 | 289.58 |
| 156 | 769067.23 | 3326831.70 | 289.43 |
| 157 | 769037.08 | 3326791.81 | 289.26 |
| 158 | 768990.63 | 3326780.71 | 289.10 |
| 159 | 768944.48 | 3326763.81 | 288.93 |
| 160 | 768907.45 | 3326732.59 | 288.79 |
| 161 | 768879.93 | 3326690.85 | 288.68 |
| 162 | 768854.49 | 3326647.80 | 288.60 |
| 163 | 768837.51 | 3326601.06 | 288.54 |
| 164 | 768824.76 | 3326552.85 | 288.51 |
| 165 | 768819.84 | 3326503.09 | 288.48 |
| 166 | 768789.06 | 3326465.42 | 288.42 |
| 167 | 768744.73 | 3326444.22 | 288.34 |
| 168 | 768698.69 | 3326424.93 | 288.25 |
| 169 | 768653.97 | 3326402.57 | 288.18 |
| 170 | 768614.09 | 3326372.58 | 288.09 |
| 171 | 768576.33 | 3326340.61 | 287.97 |
| 172 | 768561.83 | 3326292.76 | 287.85 |
| 173 | 768548.25 | 3326244.64 | 287.77 |
| 174 | 768534.66 | 3326196.52 | 287.72 |
| 175 | 768520.14 | 3326148.68 | 287.66 |
| 176 | 768504.67 | 3326101.17 | 287.62 |
| 177 | 768486.05 | 3326054.76 | 287.63 |
| 178 | 768467.00 | 3326008.54 | 287.67 |
| 179 | 768446.77 | 3325962.81 | 287.68 |
| 180 | 768421.85 | 3325919.86 | 287.67 |
| 181 | 768391.58 | 3325880.06 | 287.62 |
| 182 | 768362.07 | 3325839.71 | 287.53 |
| 183 | 768333.12 | 3325798.94 | 287.43 |
| 184 | 768304.67 | 3325757.83 | 287.32 |
| 185 | 768274.72 | 3325717.83 | 287.18 |

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| 186 | 768246.96 | 3325676.48 | 287.09 |
| 187 | 768226.56 | 3325631.10 | 287.01 |
| 188 | 768213.72 | 3325582.97 | 286.93 |
| 189 | 768213.37 | 3325532.97 | 286.84 |
| 190 | 768213.02 | 3325482.97 | 286.74 |
| 191 | 768212.68 | 3325432.98 | 286.56 |
| 192 | 768212.33 | 3325382.98 | 286.32 |
| 193 | 768211.98 | 3325332.98 | 286.17 |
| 194 | 768211.64 | 3325282.98 | 286.09 |
| 195 | 768211.29 | 3325232.98 | 286.02 |
| 196 | 768210.90 | 3325182.98 | 285.95 |
| 197 | 768209.46 | 3325133.01 | 285.88 |
| 198 | 768210.18 | 3325083.04 | 285.82 |
| 199 | 768208.79 | 3325033.06 | 285.75 |
| 200 | 768208.31 | 3324983.06 | 285.65 |
| 201 | 768208.75 | 3324933.09 | 285.56 |
| 202 | 768208.42 | 3324883.10 | 285.45 |
| 203 | 768207.37 | 3324833.15 | 285.34 |
| 204 | 768182.64 | 3324791.69 | 285.24 |
| 205 | 768177.28 | 3324741.99 | 285.14 |
| 206 | 768174.12 | 3324692.10 | 285.04 |
| 207 | 768172.70 | 3324642.12 | 284.96 |
| 208 | 768184.08 | 3324594.46 | 284.91 |
| 209 | 768200.14 | 3324547.26 | 284.84 |
| 210 | 768212.77 | 3324498.89 | 284.79 |
| 211 | 768228.00 | 3324451.33 | 284.69 |
| 212 | 768249.50 | 3324406.19 | 284.60 |
| 213 | 768273.28 | 3324362.25 | 284.49 |
| 214 | 768298.34 | 3324318.98 | 284.38 |
| 215 | 768318.71 | 3324273.40 | 284.29 |
| 216 | 768337.83 | 3324227.20 | 284.22 |
| 217 | 768357.27 | 3324181.13 | 284.10 |
| 218 | 768374.92 | 3324134.38 | 284.00 |
| 219 | 768391.20 | 3324087.10 | 283.93 |
| 220 | 768405.60 | 3324039.27 | 283.84 |
| 221 | 768411.07 | 3323989.57 | 283.74 |
| 222 | 768414.87 | 3323939.93 | 283.63 |
| 223 | 768405.99 | 3323890.72 | 283.55 |
| 224 | 768400.07 | 3323841.10 | 283.48 |
| 225 | 768393.48 | 3323791.57 | 283.46 |
| 226 | 768384.57 | 3323742.37 | 283.46 |
| 227 | 768369.75 | 3323695.06 | 283.45 |
| 228 | 768348.43 | 3323649.84 | 283.39 |
| 229 | 768328.63 | 3323603.94 | 283.27 |
| 230 | 768309.60 | 3323557.70 | 283.15 |
| 231 | 768292.60 | 3323510.78 | 283.04 |
| 232 | 768279.67 | 3323462.48 | 283.06 |

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| 233 | 768274.65 | 3323413.81 | 283.25 |
| 234 | 768283.04 | 3323364.52 | 283.50 |
| 235 | 768286.67 | 3323314.73 | 283.62 |
| 236 | 768284.82 | 3323265.04 | 283.63 |
| 237 | 768275.91 | 3323215.84 | 283.55 |
| 238 | 768268.14 | 3323166.46 | 283.52 |
| 239 | 768261.47 | 3323116.91 | 283.48 |
| 240 | 768254.89 | 3323067.34 | 283.36 |
| 241 | 768248.35 | 3323017.77 | 283.15 |
| 242 | 768245.99 | 3322967.84 | 282.93 |
| 243 | 768243.62 | 3322917.91 | 282.75 |
| 244 | 768239.97 | 3322868.04 | 282.52 |
| 245 | 768257.45 | 3322822.18 | 282.42 |
| 246 | 768279.12 | 3322777.13 | 282.28 |
| 247 | 768305.16 | 3322736.25 | 282.11 |
| 248 | 768312.59 | 3322690.60 | 281.93 |
| 249 | 768307.76 | 3322640.83 | 281.86 |
| 250 | 768301.81 | 3322591.26 | 281.80 |
| 251 | 768289.88 | 3322542.70 | 281.78 |
| 252 | 768277.03 | 3322494.43 | 281.85 |
| 253 | 768259.67 | 3322447.54 | 281.86 |
| 254 | 768242.32 | 3322400.65 | 281.86 |
| 255 | 768224.97 | 3322353.76 | 281.83 |
| 256 | 768203.65 | 3322308.78 | 281.65 |
| 257 | 768177.84 | 3322265.95 | 281.52 |
| 258 | 768152.15 | 3322223.09 | 281.44 |
| 259 | 768122.03 | 3322183.19 | 281.38 |
| 260 | 768106.55 | 3322138.46 | 281.33 |
| 261 | 768107.11 | 3322088.47 | 281.29 |
| 262 | 768095.45 | 3322040.14 | 281.52 |
| 263 | 768081.47 | 3321992.14 | 281.52 |
| 264 | 768054.73 | 3321951.08 | 281.77 |
| 265 | 768018.99 | 3321916.78 | 281.80 |
| 266 | 767980.93 | 3321886.24 | 281.81 |
| 267 | 767964.51 | 3321840.73 | 281.77 |
| 268 | 767971.86 | 3321791.27 | 281.91 |
| 269 | 767980.76 | 3321742.12 | 281.86 |
| 270 | 767993.01 | 3321693.65 | 281.66 |
| 271 | 768005.26 | 3321645.17 | 281.50 |
| 272 | 768007.61 | 3321595.34 | 281.40 |
| 273 | 767989.90 | 3321550.11 | 281.42 |
| 274 | 767964.11 | 3321507.36 | 281.27 |
| 275 | 767933.83 | 3321467.57 | 281.13 |
| 276 | 767902.70 | 3321428.49 | 281.06 |
| 277 | 767868.88 | 3321391.67 | 280.95 |
| 278 | 767833.76 | 3321356.21 | 280.79 |
| 279 | 767795.16 | 3321324.44 | 280.59 |

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| 280 | 767756.55 | 3321292.66 | 280.41 |
| 281 | 767746.89 | 3321244.62 | 280.24 |
| 282 | 767763.35 | 3321197.66 | 280.10 |
| 283 | 767793.95 | 3321158.34 | 279.99 |
| 284 | 767835.21 | 3321130.11 | 279.91 |
| 285 | 767879.72 | 3321107.47 | 279.82 |
| 286 | 767925.83 | 3321088.23 | 279.77 |
| 287 | 767973.24 | 3321072.88 | 279.73 |
| 288 | 768022.52 | 3321066.49 | 279.67 |
| 289 | 768072.36 | 3321070.46 | 279.62 |
| 290 | 768122.19 | 3321074.56 | 279.60 |
| 291 | 768170.98 | 3321085.46 | 279.52 |
| 292 | 768219.37 | 3321097.92 | 279.41 |
| 293 | 768267.49 | 3321111.39 | 279.29 |
| 294 | 768316.13 | 3321122.81 | 279.16 |
| 295 | 768362.54 | 3321140.37 | 279.01 |
| 296 | 768412.29 | 3321145.33 | 278.85 |
| 297 | 768461.84 | 3321151.99 | 278.72 |
| 298 | 768511.66 | 3321155.52 | 278.66 |
| 299 | 768561.63 | 3321157.31 | 278.63 |
| 300 | 768611.60 | 3321155.73 | 278.66 |
| 301 | 768661.58 | 3321154.14 | 278.66 |
| 302 | 768711.55 | 3321152.54 | 278.61 |
| 303 | 768761.53 | 3321150.94 | 278.49 |
| 304 | 768811.50 | 3321149.35 | 278.41 |
| 305 | 768861.47 | 3321147.70 | 278.30 |
| 306 | 768910.91 | 3321140.20 | 278.20 |
| 307 | 768960.34 | 3321132.70 | 278.13 |
| 308 | 769009.77 | 3321125.20 | 278.06 |
| 309 | 769058.92 | 3321116.61 | 277.98 |
| 310 | 769105.59 | 3321098.66 | 277.96 |
| 311 | 769152.25 | 3321080.71 | 277.88 |
| 312 | 769198.92 | 3321062.76 | 277.83 |
| 313 | 769245.58 | 3321044.80 | 277.76 |
| 314 | 769292.25 | 3321026.85 | 277.67 |
| 315 | 769338.92 | 3321008.90 | 277.58 |
| 316 | 769386.13 | 3320992.61 | 277.48 |
| 317 | 769434.33 | 3320979.31 | 277.43 |
| 318 | 769482.53 | 3320966.01 | 277.41 |
| 319 | 769530.72 | 3320952.71 | 277.41 |
| 320 | 769578.92 | 3320939.40 | 277.40 |
| 321 | 769627.12 | 3320926.10 | 277.39 |
| 322 | 769675.32 | 3320912.80 | 277.32 |
| 323 | 769718.89 | 3320888.59 | 277.26 |
| 324 | 769761.94 | 3320863.16 | 277.22 |
| 325 | 769804.98 | 3320837.73 | 277.17 |
| 326 | 769843.37 | 3320805.94 | 277.14 |

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| 327 | 769880.55 | 3320772.51 | 277.17 |
| 328 | 769912.20 | 3320735.05 | 277.22 |
| 329 | 769931.89 | 3320689.29 | 277.44 |
| 330 | 769930.91 | 3320639.34 | 277.50 |
| 331 | 769930.72 | 3320589.34 | 277.44 |
| 332 | 769930.52 | 3320539.34 | 277.32 |
| 333 | 769929.68 | 3320489.36 | 277.23 |
| 334 | 769927.97 | 3320439.39 | 277.17 |
| 335 | 769926.25 | 3320389.42 | 277.20 |
| 336 | 769924.54 | 3320339.44 | 277.36 |
| 337 | 769922.10 | 3320289.52 | 277.62 |
| 338 | 769918.13 | 3320239.67 | 278.19 |
| 339 | 769914.17 | 3320189.83 | 278.62 |
| 340 | 769910.20 | 3320139.99 | 281.20 |
| 341 | 769906.14 | 3320090.15 | 280.96 |
| 342 | 769902.08 | 3320040.32 | 278.72 |
| 343 | 769903.22 | 3319990.37 | 279.34 |
| 344 | 769905.02 | 3319940.40 | 278.47 |
| 345 | 769903.99 | 3319890.46 | 278.37 |
| 346 | 769901.83 | 3319840.50 | 278.25 |
| 347 | 769898.14 | 3319790.64 | 278.20 |
| 348 | 769894.44 | 3319740.78 | 278.48 |
| 349 | 769890.12 | 3319690.97 | 278.36 |
| 350 | 769884.64 | 3319641.27 | 278.17 |
| 351 | 769879.16 | 3319591.57 | 278.23 |
| 352 | 769878.41 | 3319541.84 | 278.36 |
| 353 | 769874.27 | 3319492.30 | 277.95 |
| 354 | 769878.40 | 3319442.52 | 276.66 |
| 355 | 769895.33 | 3319395.81 | 276.32 |
| 356 | 769912.35 | 3319349.20 | 276.23 |
| 357 | 769914.10 | 3319299.59 | 276.25 |
| 358 | 769924.55 | 3319251.13 | 276.25 |
| 359 | 769950.94 | 3319208.66 | 276.20 |
| 360 | 769978.25 | 3319167.90 | 276.11 |
| 361 | 770003.08 | 3319124.51 | 275.95 |
| 362 | 770031.17 | 3319083.16 | 275.67 |
| 363 | 770064.02 | 3319045.47 | 275.30 |
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| 1108 | 786638.08 | 3294993.13 | 244.33 |
| 1109 | 786589.32 | 3295004.18 | 244.14 |
| 1110 | 786540.56 | 3295015.24 | 243.85 |
| 1111 | 786491.80 | 3295026.30 | 243.40 |
| 1112 | 786442.09 | 3295031.66 | 243.21 |
| 1113 | 786392.37 | 3295037.00 | 243.14 |
| 1114 | 786342.66 | 3295042.33 | 243.30 |
| 1115 | 786293.06 | 3295039.51 | 244.17 |
| 1116 | 786243.53 | 3295032.69 | 244.03 |
| 1117 | 786194.83 | 3295021.54 | 243.99 |
| 1118 | 786146.27 | 3295009.60 | 244.08 |
| 1119 | 786097.91 | 3294997.09 | 244.12 |
| 1120 | 786051.94 | 3294977.42 | 244.19 |
| 1121 | 786007.83 | 3294953.94 | 244.27 |
| 1122 | 785972.31 | 3294919.02 | 244.42 |
| 1123 | 785948.60 | 3294876.41 | 244.55 |
| 1124 | 785951.35 | 3294826.64 | 244.52 |
| 1125 | 785962.50 | 3294777.90 | 244.64 |

| 1126 | 785973.69 | 3294729.17 | 244.76 |
|---|---|---|---|
| 1127 | 785985.34 | 3294680.54 | 244.40 |
| 1128 | 785997.68 | 3294632.10 | 243.86 |
| 1129 | 786011.38 | 3294584.01 | 243.54 |
| 1130 | 786005.14 | 3294535.15 | 243.49 |
| 1131 | 785991.44 | 3294487.42 | 243.53 |
| 1132 | 785969.51 | 3294442.49 | 243.50 |
| 1133 | 785947.57 | 3294397.56 | 243.60 |
| 1134 | 785914.79 | 3294360.21 | 243.61 |
| 1135 | 785880.15 | 3294324.15 | 244.13 |
| 1136 | 785836.73 | 3294300.20 | 243.25 |
| 1137 | 785789.02 | 3294288.91 | 242.89 |
| 1138 | 785739.60 | 3294282.97 | 242.81 |
| 1139 | 785691.29 | 3294270.11 | 242.72 |
| 1140 | 785644.78 | 3294251.99 | 242.75 |
| 1141 | 785598.82 | 3294232.30 | 242.79 |
| 1142 | 785561.52 | 3294200.46 | 242.81 |
| 1143 | 785527.90 | 3294163.45 | 242.81 |
| 1144 | 785494.28 | 3294126.44 | 242.84 |
| 1145 | 785465.48 | 3294085.85 | 242.76 |
| 1146 | 785439.64 | 3294043.04 | 242.68 |
| 1147 | 785413.80 | 3294000.23 | 242.62 |
| 1148 | 785387.96 | 3293957.43 | 242.60 |
| 1149 | 785366.07 | 3293912.62 | 242.62 |
| 1150 | 785346.86 | 3293866.46 | 242.70 |
| 1151 | 785327.65 | 3293820.30 | 242.66 |
| 1152 | 785308.81 | 3293774.02 | 242.63 |
| 1153 | 785296.93 | 3293725.45 | 242.49 |
| 1154 | 785285.05 | 3293676.88 | 242.32 |
| 1155 | 785265.23 | 3293631.45 | 242.13 |
| 1156 | 785240.65 | 3293587.92 | 241.97 |
| 1157 | 785222.76 | 3293541.78 | 241.73 |
| 1158 | 785211.56 | 3293493.05 | 241.58 |
| 1159 | 785200.37 | 3293444.32 | 241.46 |
| 1160 | 785189.17 | 3293395.59 | 241.36 |
| 1161 | 785177.05 | 3293347.08 | 241.32 |
| 1162 | 785164.72 | 3293298.63 | 241.31 |
| 1163 | 785152.38 | 3293250.17 | 241.31 |
| 1164 | 785140.80 | 3293201.53 | 241.33 |
| 1165 | 785129.31 | 3293152.87 | 241.32 |
| 1166 | 785116.62 | 3293104.51 | 241.34 |
| 1167 | 785103.77 | 3293056.19 | 241.39 |
| 1168 | 785090.86 | 3293007.89 | 241.43 |
| 1169 | 785077.73 | 3292959.64 | 241.53 |
| 1170 | 785064.60 | 3292911.40 | 241.57 |
| 1171 | 785051.47 | 3292863.15 | 241.66 |
| 1172 | 785037.65 | 3292815.12 | 241.68 |

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|---|---|---|---|
| 1173 | 785020.78 | 3292768.05 | 241.60 |
| 1174 | 785003.92 | 3292720.98 | 241.53 |
| 1175 | 784987.05 | 3292673.91 | 241.44 |
| 1176 | 784970.19 | 3292626.84 | 241.38 |
| 1177 | 784953.32 | 3292579.77 | 241.34 |
| 1178 | 784936.46 | 3292532.70 | 241.31 |
| 1179 | 784921.13 | 3292485.13 | 241.23 |
| 1180 | 784906.83 | 3292437.22 | 241.23 |
| 1181 | 784892.53 | 3292389.31 | 241.22 |
| 1182 | 784878.23 | 3292341.40 | 241.19 |
| 1183 | 784863.93 | 3292293.48 | 241.17 |
| 1184 | 784849.63 | 3292245.57 | 241.14 |
| 1185 | 784834.84 | 3292197.81 | 241.11 |
| 1186 | 784819.99 | 3292150.07 | 241.11 |
| 1187 | 784805.14 | 3292102.32 | 241.14 |
| 1188 | 784790.28 | 3292054.58 | 241.13 |
| 1189 | 784775.43 | 3292006.84 | 241.05 |
| 1190 | 784760.58 | 3291959.09 | 241.01 |
| 1191 | 784744.08 | 3291911.94 | 241.05 |
| 1192 | 784725.56 | 3291865.49 | 241.09 |
| 1193 | 784707.04 | 3291819.05 | 241.15 |
| 1194 | 784688.52 | 3291772.60 | 241.14 |
| 1195 | 784670.01 | 3291726.16 | 241.21 |
| 1196 | 784646.66 | 3291682.44 | 241.05 |
| 1197 | 784616.37 | 3291642.67 | 240.92 |
| 1198 | 784586.07 | 3291602.89 | 240.70 |
| 1199 | 784555.77 | 3291563.12 | 240.50 |
| 1200 | 784519.68 | 3291528.58 | 240.53 |
| 1201 | 784483.17 | 3291494.41 | 240.82 |
| 1202 | 784447.54 | 3291459.53 | 240.94 |
| 1203 | 784421.19 | 3291417.04 | 240.82 |
| 1204 | 784394.83 | 3291374.55 | 240.84 |
| 1205 | 784372.47 | 3291330.03 | 240.83 |

| 25 Year HFL Points | | | |
|---|---|---|---|
| S. No. | Left Bank | | |
| | Easting (X) | Northing (Y) | Elevation (m) |
| 1 | 770600.74 | 3332762.78 | 302.19 |
| 2 | 770644.48 | 3332787.01 | 302.57 |
| 3 | 770688.21 | 3332811.24 | 304.54 |
| 4 | 770715.72 | 3332779.88 | 304.43 |
| 5 | 770744.36 | 3332738.90 | 304.48 |
| 6 | 770771.78 | 3332697.10 | 305.25 |
| 7 | 770799.43 | 3332655.44 | 304.25 |
| 8 | 770827.74 | 3332614.23 | 303.91 |
| 9 | 770855.28 | 3332572.54 | 304.71 |
| 10 | 770872.41 | 3332526.10 | 301.60 |
| 11 | 770900.83 | 3332488.70 | 302.84 |
| 12 | 770941.03 | 3332459.16 | 303.72 |
| 13 | 770980.73 | 3332428.77 | 302.64 |
| 14 | 771020.44 | 3332398.38 | 302.46 |
| 15 | 771060.14 | 3332367.99 | 302.39 |
| 16 | 771098.19 | 3332335.57 | 302.78 |
| 17 | 771135.95 | 3332302.79 | 302.20 |
| 18 | 771175.03 | 3332271.65 | 301.91 |
| 19 | 771214.86 | 3332241.42 | 301.93 |
| 20 | 771254.69 | 3332211.19 | 301.48 |
| 21 | 771294.77 | 3332181.33 | 301.32 |
| 22 | 771336.87 | 3332154.36 | 301.55 |
| 23 | 771378.98 | 3332127.40 | 301.83 |
| 24 | 771421.92 | 3332101.78 | 302.12 |
| 25 | 771465.03 | 3332076.47 | 302.40 |
| 26 | 771508.19 | 3332053.23 | 302.38 |
| 27 | 771537.43 | 3332013.46 | 302.55 |
| 28 | 771565.04 | 3331972.70 | 302.66 |
| 29 | 771591.10 | 3331932.44 | 302.47 |
| 30 | 771611.65 | 3331889.17 | 302.25 |
| 31 | 771634.84 | 3331847.12 | 302.08 |
| 32 | 771656.02 | 3331802.86 | 301.67 |
| 33 | 771671.13 | 3331756.84 | 301.15 |
| 34 | 771689.39 | 3331710.29 | 300.65 |
| 35 | 771713.92 | 3331669.36 | 300.61 |
| 36 | 771743.47 | 3331630.94 | 300.22 |
| 37 | 771766.42 | 3331586.52 | 302.45 |
| 38 | 771783.34 | 3331539.79 | 302.35 |
| 39 | 771787.96 | 3331490.06 | 301.38 |
| 40 | 771779.95 | 3331440.82 | 301.76 |
| 41 | 771761.37 | 3331394.54 | 300.99 |
| 42 | 771747.80 | 3331346.86 | 300.63 |
| 43 | 771732.59 | 3331299.45 | 300.94 |
| 44 | 771715.10 | 3331252.71 | 301.66 |

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|---|---|---|---|
| 45 | 771688.13 | 3331211.35 | 301.48 |
| 46 | 771656.72 | 3331173.91 | 301.14 |
| 47 | 771628.36 | 3331132.75 | 301.09 |
| 48 | 771591.81 | 3331099.03 | 301.56 |
| 49 | 771552.16 | 3331068.57 | 301.42 |
| 50 | 771510.32 | 3331042.43 | 300.90 |
| 51 | 771463.18 | 3331025.75 | 300.04 |
| 52 | 771416.05 | 3331009.08 | 298.97 |
| 53 | 771370.49 | 3330988.60 | 298.65 |
| 54 | 771325.46 | 3330966.87 | 298.23 |
| 55 | 771279.74 | 3330946.67 | 298.04 |
| 56 | 771233.63 | 3330927.34 | 298.03 |
| 57 | 771188.10 | 3330906.68 | 297.88 |
| 58 | 771142.58 | 3330886.00 | 297.77 |
| 59 | 771097.25 | 3330864.90 | 297.75 |
| 60 | 771051.92 | 3330843.79 | 297.77 |
| 61 | 771008.14 | 3330819.66 | 297.43 |
| 62 | 770964.55 | 3330795.17 | 297.27 |
| 63 | 770920.75 | 3330771.06 | 297.14 |
| 64 | 770876.92 | 3330747.01 | 297.01 |
| 65 | 770833.24 | 3330722.68 | 296.88 |
| 66 | 770789.92 | 3330697.70 | 296.76 |
| 67 | 770746.61 | 3330672.72 | 296.64 |
| 68 | 770706.16 | 3330643.53 | 296.47 |
| 69 | 770667.03 | 3330612.41 | 296.38 |
| 70 | 770631.44 | 3330577.64 | 296.28 |
| 71 | 770599.18 | 3330539.44 | 296.20 |
| 72 | 770566.99 | 3330501.18 | 296.14 |
| 73 | 770534.84 | 3330462.88 | 296.10 |
| 74 | 770502.55 | 3330424.71 | 296.08 |
| 75 | 770469.54 | 3330387.16 | 296.06 |
| 76 | 770436.53 | 3330349.60 | 296.10 |
| 77 | 770403.52 | 3330312.05 | 296.29 |
| 78 | 770370.81 | 3330274.44 | 297.02 |
| 79 | 770353.12 | 3330227.79 | 297.89 |
| 80 | 770359.05 | 3330178.15 | 296.92 |
| 81 | 770364.99 | 3330128.50 | 297.07 |
| 82 | 770371.18 | 3330078.90 | 296.92 |
| 83 | 770383.60 | 3330030.47 | 297.39 |
| 84 | 770396.03 | 3329982.04 | 297.99 |
| 85 | 770404.15 | 3329932.93 | 297.95 |
| 86 | 770431.72 | 3329892.58 | 297.97 |
| 87 | 770479.37 | 3329880.81 | 296.66 |
| 88 | 770528.67 | 3329887.71 | 295.23 |
| 89 | 770576.48 | 3329902.36 | 294.99 |
| 90 | 770621.73 | 3329923.54 | 294.99 |
| 91 | 770668.21 | 3329941.90 | 295.01 |

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|---|---|---|---|
| 92 | 770715.45 | 3329957.82 | 295.05 |
| 93 | 770764.79 | 3329965.92 | 295.08 |
| 94 | 770814.63 | 3329967.27 | 295.05 |
| 95 | 770864.63 | 3329966.93 | 295.00 |
| 96 | 770914.61 | 3329965.78 | 295.02 |
| 97 | 770964.58 | 3329964.35 | 295.08 |
| 98 | 771014.51 | 3329961.70 | 295.23 |
| 99 | 771059.02 | 3329940.07 | 295.28 |
| 100 | 771098.49 | 3329910.76 | 295.29 |
| 101 | 771133.53 | 3329875.32 | 295.27 |
| 102 | 771160.25 | 3329833.65 | 295.23 |
| 103 | 771184.41 | 3329790.07 | 295.26 |
| 104 | 771189.76 | 3329742.31 | 295.28 |
| 105 | 771202.87 | 3329695.98 | 295.41 |
| 106 | 771207.25 | 3329647.66 | 295.38 |
| 107 | 771192.85 | 3329599.99 | 295.03 |
| 108 | 771192.16 | 3329550.00 | 295.00 |
| 109 | 771179.04 | 3329502.22 | 294.77 |
| 110 | 771163.32 | 3329454.99 | 294.66 |
| 111 | 771138.15 | 3329411.79 | 294.64 |
| 112 | 771124.23 | 3329364.29 | 294.76 |
| 113 | 771110.06 | 3329316.34 | 294.95 |
| 114 | 771095.89 | 3329268.38 | 295.05 |
| 115 | 771081.72 | 3329220.43 | 295.11 |
| 116 | 771065.75 | 3329173.07 | 295.09 |
| 117 | 771048.95 | 3329125.98 | 294.95 |
| 118 | 771032.16 | 3329078.88 | 294.82 |
| 119 | 771010.43 | 3329034.08 | 294.69 |
| 120 | 770985.25 | 3328990.88 | 294.55 |
| 121 | 770960.07 | 3328947.69 | 294.38 |
| 122 | 770934.89 | 3328904.49 | 294.19 |
| 123 | 770907.93 | 3328862.40 | 294.07 |
| 124 | 770880.39 | 3328820.67 | 294.02 |
| 125 | 770852.85 | 3328778.94 | 293.93 |
| 126 | 770825.31 | 3328737.20 | 293.76 |
| 127 | 770795.55 | 3328697.10 | 293.60 |
| 128 | 770763.97 | 3328658.34 | 293.43 |
| 129 | 770732.38 | 3328619.58 | 293.32 |
| 130 | 770700.53 | 3328581.05 | 293.21 |
| 131 | 770667.08 | 3328543.88 | 293.09 |
| 132 | 770633.64 | 3328506.71 | 292.97 |
| 133 | 770600.20 | 3328469.54 | 292.78 |
| 134 | 770559.20 | 3328441.62 | 292.60 |
| 135 | 770516.09 | 3328416.30 | 292.47 |
| 136 | 770472.97 | 3328390.98 | 292.28 |
| 137 | 770431.62 | 3328362.94 | 292.07 |
| 138 | 770390.87 | 3328333.97 | 291.95 |

| 139 | 770358.84 | 3328297.45 | 291.85 |
|---|---|---|---|
| 140 | 770336.04 | 3328252.96 | 291.77 |
| 141 | 770314.42 | 3328207.95 | 291.67 |
| 142 | 770297.43 | 3328160.92 | 291.57 |
| 143 | 770280.17 | 3328114.00 | 291.44 |
| 144 | 770262.08 | 3328067.38 | 291.36 |
| 145 | 770238.55 | 3328023.85 | 291.26 |
| 146 | 770207.91 | 3327984.33 | 291.15 |
| 147 | 770177.27 | 3327944.82 | 291.08 |
| 148 | 770144.11 | 3327907.42 | 290.97 |
| 149 | 770110.60 | 3327870.32 | 290.82 |
| 150 | 770078.56 | 3327831.95 | 290.67 |
| 151 | 770047.14 | 3327793.05 | 290.48 |
| 152 | 770018.22 | 3327752.80 | 290.35 |
| 153 | 770002.58 | 3327705.31 | 290.21 |
| 154 | 770008.58 | 3327656.23 | 290.18 |
| 155 | 770012.01 | 3327610.97 | 290.17 |
| 156 | 769988.00 | 3327567.31 | 290.01 |
| 157 | 769960.26 | 3327525.84 | 289.84 |
| 158 | 769935.80 | 3327482.24 | 289.69 |
| 159 | 769905.54 | 3327442.48 | 289.52 |
| 160 | 769876.56 | 3327401.81 | 289.37 |
| 161 | 769850.08 | 3327359.40 | 289.26 |
| 162 | 769811.80 | 3327330.51 | 289.19 |
| 163 | 769774.63 | 3327297.58 | 289.13 |
| 164 | 769738.73 | 3327262.78 | 289.10 |
| 165 | 769703.84 | 3327227.10 | 289.06 |
| 166 | 769674.65 | 3327186.51 | 289.01 |
| 167 | 769645.45 | 3327145.92 | 288.92 |
| 168 | 769616.25 | 3327105.33 | 288.84 |
| 169 | 769585.26 | 3327066.14 | 288.76 |
| 170 | 769552.98 | 3327027.95 | 288.67 |
| 171 | 769520.70 | 3326989.77 | 288.55 |
| 172 | 769496.44 | 3326946.33 | 288.44 |
| 173 | 769474.30 | 3326901.50 | 288.36 |
| 174 | 769448.67 | 3326858.82 | 288.30 |
| 175 | 769418.60 | 3326818.87 | 288.25 |
| 176 | 769388.52 | 3326778.92 | 288.20 |
| 177 | 769371.24 | 3326733.36 | 288.21 |
| 178 | 769362.14 | 3326684.19 | 288.25 |
| 179 | 769353.03 | 3326635.03 | 288.27 |
| 180 | 769338.56 | 3326587.24 | 288.25 |
| 181 | 769322.91 | 3326539.75 | 288.20 |
| 182 | 769298.83 | 3326497.19 | 288.12 |
| 183 | 769265.12 | 3326460.27 | 288.01 |
| 184 | 769230.86 | 3326423.94 | 287.90 |
| 185 | 769191.28 | 3326393.38 | 287.76 |

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| 186 | 769149.19 | 3326368.34 | 287.67 |
| 187 | 769100.14 | 3326358.64 | 287.60 |
| 188 | 769051.09 | 3326348.94 | 287.52 |
| 189 | 769004.96 | 3326330.39 | 287.42 |
| 190 | 768959.76 | 3326309.03 | 287.32 |
| 191 | 768913.22 | 3326291.22 | 287.15 |
| 192 | 768864.58 | 3326280.28 | 286.90 |
| 193 | 768816.82 | 3326271.14 | 286.76 |
| 194 | 768784.60 | 3326232.91 | 286.67 |
| 195 | 768754.38 | 3326193.22 | 286.60 |
| 196 | 768728.13 | 3326150.67 | 286.53 |
| 197 | 768704.65 | 3326106.54 | 286.47 |
| 198 | 768681.25 | 3326062.37 | 286.40 |
| 199 | 768652.55 | 3326021.43 | 286.33 |
| 200 | 768623.84 | 3325980.49 | 286.23 |
| 201 | 768598.69 | 3325937.32 | 286.14 |
| 202 | 768574.37 | 3325893.64 | 286.03 |
| 203 | 768550.05 | 3325849.95 | 285.92 |
| 204 | 768528.88 | 3325804.70 | 285.82 |
| 205 | 768508.25 | 3325759.17 | 285.72 |
| 206 | 768485.38 | 3325714.71 | 285.62 |
| 207 | 768471.95 | 3325666.70 | 285.54 |
| 208 | 768459.91 | 3325618.17 | 285.49 |
| 209 | 768452.86 | 3325568.69 | 285.42 |
| 210 | 768446.90 | 3325519.06 | 285.37 |
| 211 | 768442.53 | 3325469.25 | 285.27 |
| 212 | 768438.16 | 3325419.44 | 285.18 |
| 213 | 768433.79 | 3325369.63 | 285.08 |
| 214 | 768429.43 | 3325319.82 | 284.96 |
| 215 | 768425.06 | 3325270.01 | 284.88 |
| 216 | 768420.69 | 3325220.20 | 284.80 |
| 217 | 768420.83 | 3325170.22 | 284.69 |
| 218 | 768421.17 | 3325120.22 | 284.59 |
| 219 | 768421.29 | 3325070.22 | 284.51 |
| 220 | 768421.68 | 3325020.22 | 284.43 |
| 221 | 768422.12 | 3324970.23 | 284.32 |
| 222 | 768422.75 | 3324920.23 | 284.22 |
| 223 | 768422.86 | 3324870.23 | 284.13 |
| 224 | 768422.63 | 3324820.23 | 284.06 |
| 225 | 768408.37 | 3324775.43 | 284.05 |
| 226 | 768400.24 | 3324726.10 | 284.04 |
| 227 | 768392.11 | 3324676.76 | 284.04 |
| 228 | 768392.93 | 3324627.12 | 283.97 |
| 229 | 768397.70 | 3324577.35 | 283.85 |
| 230 | 768402.86 | 3324527.62 | 283.74 |
| 231 | 768411.10 | 3324478.51 | 283.63 |
| 232 | 768425.84 | 3324430.74 | 283.64 |

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| 233 | 768447.91 | 3324385.88 | 283.83 |
| 234 | 768470.81 | 3324341.46 | 284.09 |
| 235 | 768496.92 | 3324298.82 | 284.21 |
| 236 | 768520.66 | 3324254.82 | 284.22 |
| 237 | 768534.37 | 3324207.17 | 284.13 |
| 238 | 768545.62 | 3324158.45 | 284.11 |
| 239 | 768557.01 | 3324109.77 | 284.07 |
| 240 | 768564.75 | 3324060.40 | 283.94 |
| 241 | 768568.98 | 3324010.73 | 283.73 |
| 242 | 768567.89 | 3323960.74 | 283.51 |
| 243 | 768551.16 | 3323914.39 | 283.33 |
| 244 | 768540.91 | 3323865.63 | 283.11 |
| 245 | 768538.17 | 3323815.71 | 283.00 |
| 246 | 768545.67 | 3323766.84 | 282.86 |
| 247 | 768536.20 | 3323718.64 | 282.70 |
| 248 | 768522.95 | 3323670.42 | 282.52 |
| 249 | 768510.36 | 3323622.04 | 282.45 |
| 250 | 768498.04 | 3323573.59 | 282.39 |
| 251 | 768489.92 | 3323524.25 | 282.37 |
| 252 | 768481.80 | 3323474.92 | 282.43 |
| 253 | 768474.59 | 3323425.46 | 282.45 |
| 254 | 768469.15 | 3323375.75 | 282.44 |
| 255 | 768466.02 | 3323326.13 | 282.42 |
| 256 | 768475.12 | 3323276.97 | 282.24 |
| 257 | 768486.11 | 3323228.28 | 282.10 |
| 258 | 768501.52 | 3323180.72 | 282.02 |
| 259 | 768516.93 | 3323133.15 | 281.97 |
| 260 | 768517.13 | 3323083.85 | 281.92 |
| 261 | 768512.80 | 3323034.04 | 281.87 |
| 262 | 768508.48 | 3322984.23 | 282.10 |
| 263 | 768504.16 | 3322934.41 | 282.11 |
| 264 | 768499.83 | 3322884.60 | 282.35 |
| 265 | 768495.51 | 3322834.79 | 282.39 |
| 266 | 768491.19 | 3322784.97 | 282.40 |
| 267 | 768480.97 | 3322736.76 | 282.35 |
| 268 | 768460.90 | 3322690.97 | 282.49 |
| 269 | 768443.59 | 3322644.15 | 282.44 |
| 270 | 768428.94 | 3322596.34 | 282.24 |
| 271 | 768414.64 | 3322548.44 | 282.09 |
| 272 | 768401.10 | 3322500.30 | 281.98 |
| 273 | 768387.49 | 3322452.19 | 282.00 |
| 274 | 768372.79 | 3322404.40 | 281.86 |
| 275 | 768358.03 | 3322356.63 | 281.72 |
| 276 | 768343.05 | 3322308.93 | 281.64 |
| 277 | 768327.24 | 3322261.49 | 281.54 |
| 278 | 768315.66 | 3322212.94 | 281.37 |
| 279 | 768305.99 | 3322163.89 | 281.18 |

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| 280 | 768296.17 | 3322114.86 | 280.99 |
| 281 | 768285.88 | 3322065.93 | 280.82 |
| 282 | 768274.47 | 3322017.35 | 280.69 |
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| 1037 | 787208.27 | 3302289.96 | 248.07 |
| 1038 | 787211.36 | 3302240.06 | 247.98 |
| 1039 | 787214.34 | 3302190.15 | 247.52 |
| 1040 | 787210.14 | 3302141.22 | 246.98 |
| 1041 | 787195.03 | 3302093.61 | 246.61 |
| 1042 | 787183.79 | 3302044.89 | 246.40 |
| 1043 | 787167.17 | 3301997.96 | 246.09 |
| 1044 | 787148.50 | 3301951.66 | 245.67 |
| 1045 | 787134.62 | 3301903.63 | 245.58 |
| 1046 | 787130.08 | 3301854.24 | 245.37 |
| 1047 | 787130.19 | 3301804.24 | 245.50 |
| 1048 | 787131.35 | 3301754.26 | 245.42 |
| 1049 | 787137.11 | 3301705.21 | 245.25 |
| 1050 | 787155.57 | 3301658.74 | 244.88 |
| 1051 | 787174.02 | 3301612.27 | 244.00 |
| 1052 | 787204.37 | 3301573.57 | 244.81 |
| 1053 | 787242.73 | 3301542.55 | 244.90 |
| 1054 | 787288.00 | 3301521.32 | 245.57 |
| 1055 | 787334.67 | 3301503.52 | 246.17 |
| 1056 | 787381.82 | 3301486.86 | 246.37 |
| 1057 | 787428.72 | 3301469.59 | 246.68 |
| 1058 | 787474.83 | 3301450.24 | 246.84 |
| 1059 | 787517.21 | 3301424.38 | 246.87 |
| 1060 | 787557.31 | 3301394.51 | 246.84 |
| 1061 | 787597.41 | 3301364.65 | 246.82 |
| 1062 | 787635.91 | 3301333.27 | 246.83 |
| 1063 | 787663.27 | 3301291.42 | 246.82 |
| 1064 | 787690.63 | 3301249.57 | 246.72 |
| 1065 | 787717.99 | 3301207.72 | 246.50 |
| 1066 | 787734.62 | 3301161.03 | 246.27 |
| 1067 | 787747.87 | 3301112.82 | 245.94 |
| 1068 | 787761.12 | 3301064.61 | 245.82 |
| 1069 | 787774.38 | 3301016.40 | 245.68 |
| 1070 | 787787.63 | 3300968.19 | 245.67 |
| 1071 | 787798.32 | 3300919.39 | 245.49 |
| 1072 | 787807.52 | 3300870.24 | 245.32 |
| 1073 | 787816.72 | 3300821.09 | 245.23 |
| 1074 | 787825.92 | 3300771.95 | 244.99 |
| 1075 | 787836.69 | 3300723.12 | 244.76 |
| 1076 | 787847.83 | 3300674.38 | 244.53 |
| 1077 | 787858.97 | 3300625.64 | 244.55 |
| 1078 | 787870.12 | 3300576.90 | 244.81 |

| 1079 | 787885.00 | 3300529.18 | 244.44 |
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| 1080 | 787900.23 | 3300481.55 | 244.46 |
| 1081 | 787915.46 | 3300433.93 | 244.75 |
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| 1087 | 788016.06 | 3300151.36 | 244.90 |
| 1088 | 788033.34 | 3300104.44 | 245.13 |
| 1089 | 788050.36 | 3300057.43 | 245.47 |
| 1090 | 788066.35 | 3300010.05 | 245.62 |
| 1091 | 788082.33 | 3299962.68 | 245.53 |
| 1092 | 788098.32 | 3299915.30 | 245.58 |
| 1093 | 788114.30 | 3299867.92 | 245.53 |
| 1094 | 788130.29 | 3299820.55 | 245.38 |
| 1095 | 788146.27 | 3299773.17 | 245.30 |
| 1096 | 788155.66 | 3299724.09 | 243.82 |
| 1097 | 788166.22 | 3299675.25 | 243.56 |
| 1098 | 788173.04 | 3299626.31 | 244.77 |
| 1099 | 788170.35 | 3299576.39 | 245.00 |
| 1100 | 788161.86 | 3299527.33 | 245.26 |
| 1101 | 788147.52 | 3299479.67 | 245.29 |
| 1102 | 788124.32 | 3299435.37 | 245.16 |
| 1103 | 788096.83 | 3299393.81 | 245.09 |
| 1104 | 788066.61 | 3299353.97 | 245.04 |
| 1105 | 788036.39 | 3299314.13 | 245.11 |
| 1106 | 788007.94 | 3299273.04 | 245.03 |
| 1107 | 787979.97 | 3299231.59 | 244.97 |
| 1108 | 787952.01 | 3299190.14 | 244.91 |
| 1109 | 787922.36 | 3299150.02 | 244.72 |
| 1110 | 787888.54 | 3299113.19 | 244.43 |
| 1111 | 787854.72 | 3299076.37 | 243.99 |
| 1112 | 787820.90 | 3299039.54 | 243.80 |
| 1113 | 787787.18 | 3299002.62 | 243.73 |
| 1114 | 787753.59 | 3298965.58 | 243.89 |
| 1115 | 787720.00 | 3298928.55 | 244.76 |
| 1116 | 787686.41 | 3298891.51 | 244.62 |
| 1117 | 787653.02 | 3298854.29 | 244.58 |
| 1118 | 787619.74 | 3298816.98 | 244.66 |
| 1119 | 787586.46 | 3298779.67 | 244.71 |
| 1120 | 787554.64 | 3298741.24 | 244.77 |
| 1121 | 787527.54 | 3298699.22 | 244.86 |
| 1122 | 787500.44 | 3298657.20 | 245.01 |
| 1123 | 787470.91 | 3298616.86 | 245.13 |
| 1124 | 787441.27 | 3298576.60 | 245.11 |
| 1125 | 787412.59 | 3298535.64 | 245.22 |

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|---|---|---|---|
| 1126 | 787383.97 | 3298494.65 | 245.34 |
| 1127 | 787357.92 | 3298451.97 | 244.99 |
| 1128 | 787331.87 | 3298409.30 | 244.44 |
| 1129 | 787308.75 | 3298365.48 | 244.12 |
| 1130 | 787299.17 | 3298316.41 | 244.08 |
| 1131 | 787297.51 | 3298266.95 | 244.11 |
| 1132 | 787302.38 | 3298217.19 | 244.09 |
| 1133 | 787307.67 | 3298167.47 | 244.18 |
| 1134 | 787316.69 | 3298118.41 | 244.20 |
| 1135 | 787328.61 | 3298069.85 | 244.71 |
| 1136 | 787341.83 | 3298021.75 | 243.83 |
| 1137 | 787363.19 | 3297976.54 | 243.47 |
| 1138 | 787384.56 | 3297931.34 | 243.39 |
| 1139 | 787400.58 | 3297884.04 | 243.31 |
| 1140 | 787415.65 | 3297836.36 | 243.33 |
| 1141 | 787430.71 | 3297788.68 | 243.38 |
| 1142 | 787445.77 | 3297741.01 | 243.40 |
| 1143 | 787461.60 | 3297693.63 | 243.40 |
| 1144 | 787483.06 | 3297648.47 | 243.42 |
| 1145 | 787504.53 | 3297603.31 | 243.34 |
| 1146 | 787525.99 | 3297558.15 | 243.26 |
| 1147 | 787545.72 | 3297512.25 | 243.20 |
| 1148 | 787563.95 | 3297465.69 | 243.18 |
| 1149 | 787582.19 | 3297419.13 | 243.20 |
| 1150 | 787599.27 | 3297372.15 | 243.29 |
| 1151 | 787615.46 | 3297324.85 | 243.25 |
| 1152 | 787631.65 | 3297277.54 | 243.21 |
| 1153 | 787647.83 | 3297230.23 | 243.08 |
| 1154 | 787665.59 | 3297183.52 | 242.90 |
| 1155 | 787684.86 | 3297137.38 | 242.71 |
| 1156 | 787704.14 | 3297091.25 | 242.56 |
| 1157 | 787723.42 | 3297045.12 | 242.31 |
| 1158 | 787740.78 | 3296998.34 | 242.17 |
| 1159 | 787753.16 | 3296949.90 | 242.04 |
| 1160 | 787765.54 | 3296901.45 | 241.94 |
| 1161 | 787777.91 | 3296853.01 | 241.90 |
| 1162 | 787790.29 | 3296804.56 | 241.89 |
| 1163 | 787797.69 | 3296755.14 | 241.90 |
| 1164 | 787804.55 | 3296705.62 | 241.92 |
| 1165 | 787811.40 | 3296656.09 | 241.90 |
| 1166 | 787818.25 | 3296606.56 | 241.92 |
| 1167 | 787825.10 | 3296557.03 | 241.98 |
| 1168 | 787810.33 | 3296510.86 | 242.01 |
| 1169 | 787788.77 | 3296465.75 | 242.11 |
| 1170 | 787770.05 | 3296419.45 | 242.16 |
| 1171 | 787753.04 | 3296372.43 | 242.24 |
| 1172 | 787736.04 | 3296325.41 | 242.27 |

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|---|---|---|---|
| 1173 | 787719.03 | 3296278.39 | 242.19 |
| 1174 | 787700.45 | 3296232.15 | 242.11 |
| 1175 | 787673.46 | 3296190.06 | 242.03 |
| 1176 | 787646.48 | 3296147.96 | 241.97 |
| 1177 | 787623.74 | 3296103.58 | 241.92 |
| 1178 | 787603.45 | 3296057.89 | 241.89 |
| 1179 | 787591.56 | 3296009.46 | 241.81 |
| 1180 | 787581.13 | 3295960.56 | 241.81 |
| 1181 | 787591.13 | 3295911.57 | 241.81 |
| 1182 | 787605.34 | 3295863.96 | 241.78 |
| 1183 | 787626.19 | 3295818.51 | 241.75 |
| 1184 | 787653.10 | 3295777.46 | 241.73 |
| 1185 | 787689.79 | 3295743.48 | 241.70 |
| 1186 | 787726.56 | 3295709.61 | 241.70 |
| 1187 | 787765.77 | 3295678.58 | 241.73 |
| 1188 | 787804.98 | 3295647.56 | 241.72 |
| 1189 | 787844.59 | 3295617.21 | 241.63 |
| 1190 | 787890.53 | 3295597.48 | 241.59 |
| 1191 | 787936.47 | 3295577.74 | 241.63 |
| 1192 | 787974.57 | 3295548.46 | 241.67 |
| 1193 | 788002.88 | 3295507.24 | 241.74 |
| 1194 | 788020.90 | 3295462.03 | 241.72 |
| 1195 | 788027.85 | 3295412.52 | 241.80 |
| 1196 | 788034.81 | 3295363.00 | 241.63 |
| 1197 | 788041.32 | 3295313.43 | 241.50 |
| 1198 | 788047.36 | 3295263.80 | 241.29 |
| 1199 | 788053.41 | 3295214.16 | 241.08 |
| 1200 | 788059.45 | 3295164.53 | 241.11 |
| 1201 | 788065.50 | 3295114.90 | 241.40 |
| 1202 | 788069.26 | 3295065.09 | 241.52 |
| 1203 | 788065.24 | 3295015.56 | 241.40 |
| 1204 | 788033.67 | 3294977.93 | 241.42 |
| 1205 | 787993.36 | 3294948.43 | 241.42 |
| 1206 | 787951.85 | 3294920.55 | 241.34 |
| 1207 | 787910.15 | 3294892.98 | 241.35 |
| 1208 | 787867.67 | 3294866.61 | 241.27 |
| 1209 | 787825.31 | 3294840.05 | 241.24 |
| 1210 | 787783.39 | 3294812.79 | 240.95 |
| 1211 | 787741.47 | 3294785.54 | 240.74 |
| 1212 | 787699.16 | 3294758.90 | 240.95 |
| 1213 | 787657.36 | 3294731.52 | 240.23 |
| 1214 | 787616.90 | 3294702.16 | 241.23 |
| 1215 | 787578.67 | 3294670.41 | 241.30 |
| 1216 | 787554.11 | 3294627.42 | 241.34 |
| 1217 | 787537.41 | 3294580.41 | 241.37 |
| 1218 | 787523.63 | 3294532.35 | 241.34 |
| 1219 | 787509.24 | 3294484.46 | 241.18 |

| 1220 | 787493.59 | 3294437.81 | 240.98 |
|---|---|---|---|
| 1221 | 787453.85 | 3294408.22 | 241.12 |
| 1222 | 787416.44 | 3294375.06 | 241.06 |
| 1223 | 787379.02 | 3294341.89 | 241.04 |
| 1224 | 787341.60 | 3294308.73 | 241.06 |
| 1225 | 787304.18 | 3294275.56 | 241.04 |
| 1226 | 787270.58 | 3294239.11 | 241.01 |
| 1227 | 787243.33 | 3294197.19 | 240.91 |
| 1228 | 787216.08 | 3294155.27 | 240.85 |
| 1229 | 787188.83 | 3294113.35 | 240.73 |
| 1230 | 787159.03 | 3294073.27 | 240.62 |
| 1231 | 787127.57 | 3294034.41 | 240.47 |
| 1232 | 787096.11 | 3293995.55 | 240.36 |
| 1233 | 787064.65 | 3293956.69 | 240.28 |
| 1234 | 787033.19 | 3293917.83 | 240.27 |
| 1235 | 787001.73 | 3293878.97 | 240.26 |
| 1236 | 786970.27 | 3293840.10 | 240.29 |
| 1237 | 786938.81 | 3293801.24 | 240.30 |
| 1238 | 786907.35 | 3293762.38 | 240.37 |
| 1239 | 786875.89 | 3293723.52 | 240.39 |
| 1240 | 786840.41 | 3293688.38 | 240.41 |
| 1241 | 786804.09 | 3293654.01 | 240.39 |
| 1242 | 786767.77 | 3293619.64 | 240.34 |
| 1243 | 786731.46 | 3293585.28 | 240.26 |
| 1244 | 786695.14 | 3293550.91 | 240.13 |
| 1245 | 786658.78 | 3293516.61 | 239.99 |
| 1246 | 786610.70 | 3293502.90 | 239.94 |
| 1247 | 786562.62 | 3293489.19 | 240.00 |
| 1248 | 786515.35 | 3293472.99 | 240.04 |
| 1249 | 786468.51 | 3293455.50 | 240.00 |
| 1250 | 786421.67 | 3293438.00 | 240.01 |
| 1251 | 786374.83 | 3293420.51 | 239.99 |
| 1252 | 786327.99 | 3293403.02 | 239.91 |
| 1253 | 786281.15 | 3293385.52 | 239.86 |
| 1254 | 786234.31 | 3293368.03 | 239.90 |
| 1255 | 786187.47 | 3293350.54 | 240.03 |
| 1256 | 786140.63 | 3293333.04 | 240.07 |
| 1257 | 786092.58 | 3293319.42 | 240.08 |
| 1258 | 786044.12 | 3293307.09 | 240.05 |
| 1259 | 785995.67 | 3293294.77 | 240.02 |
| 1260 | 785947.21 | 3293282.44 | 239.90 |
| 1261 | 785899.22 | 3293268.42 | 239.77 |
| 1262 | 785851.28 | 3293254.20 | 239.70 |
| 1263 | 785803.35 | 3293239.97 | 239.66 |
| 1264 | 785755.42 | 3293225.75 | 239.63 |
| 1265 | 785707.48 | 3293211.52 | 239.56 |
| 1266 | 785662.11 | 3293190.72 | 239.63 |

| 1267 | 785617.17 | 3293168.81 | 239.99 |
|---|---|---|---|
| 1268 | 785572.23 | 3293146.89 | 240.48 |
| 1269 | 785527.29 | 3293124.97 | 240.28 |
| 1270 | 785482.35 | 3293103.06 | 239.74 |
| 1271 | 785437.40 | 3293081.14 | 239.58 |
| 1272 | 785400.16 | 3293049.96 | 239.56 |
| 1273 | 785370.39 | 3293009.79 | 239.67 |
| 1274 | 785349.18 | 3292965.51 | 239.59 |
| 1275 | 785336.42 | 3292917.16 | 239.50 |
| 1276 | 785324.91 | 3292868.59 | 239.50 |
| 1277 | 785319.94 | 3292818.84 | 239.45 |
| 1278 | 785313.57 | 3292769.26 | 239.40 |
| 1279 | 785305.81 | 3292719.87 | 239.38 |
| 1280 | 785298.06 | 3292670.47 | 239.29 |
| 1281 | 785290.31 | 3292621.08 | 239.29 |
| 1282 | 785281.82 | 3292571.81 | 239.24 |
| 1283 | 785272.52 | 3292522.68 | 239.31 |
| 1284 | 785263.22 | 3292473.56 | 239.29 |
| 1285 | 785253.92 | 3292424.43 | 239.32 |
| 1286 | 785244.81 | 3292375.27 | 239.37 |
| 1287 | 785237.68 | 3292325.78 | 239.45 |
| 1288 | 785230.54 | 3292276.29 | 239.44 |
| 1289 | 785223.41 | 3292226.80 | 239.39 |
| 1290 | 785216.27 | 3292177.32 | 239.37 |
| 1291 | 785209.14 | 3292127.83 | 239.30 |
| 1292 | 785196.38 | 3292079.50 | 239.19 |
| 1293 | 785183.34 | 3292031.23 | 239.02 |
| 1294 | 785170.29 | 3291982.96 | 238.88 |
| 1295 | 785157.25 | 3291934.69 | 238.71 |
| 1296 | 785144.21 | 3291886.42 | 238.59 |
| 1297 | 785133.29 | 3291838.72 | 238.52 |
| 1298 | 785115.85 | 3291791.86 | 238.47 |
| 1299 | 785098.42 | 3291745.00 | 238.44 |
| 1300 | 785080.99 | 3291698.13 | 238.41 |
| 1301 | 785068.56 | 3291649.86 | 238.39 |
| 1302 | 785058.85 | 3291600.81 | 238.32 |
| 1303 | 785049.25 | 3291551.74 | 238.27 |
| 1304 | 785044.25 | 3291501.99 | 238.23 |
| 1305 | 785036.71 | 3291452.79 | 238.17 |
| 1306 | 785020.77 | 3291405.40 | 238.13 |
| 1307 | 785004.31 | 3291358.20 | 238.07 |
| 1308 | 784986.84 | 3291311.34 | 238.02 |
| 1309 | 784969.38 | 3291264.49 | 237.98 |
| 1310 | 784950.79 | 3291218.09 | 237.93 |
| 1311 | 784930.95 | 3291172.20 | 237.88 |
| 1312 | 784911.11 | 3291126.31 | 237.83 |
| 1313 | 784891.26 | 3291080.41 | 237.79 |

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| 1314 | 784871.42 | 3291034.52 | 237.76 |
| 1315 | 784851.57 | 3290988.63 | 237.66 |
| 1316 | 784823.68 | 3290947.34 | 237.56 |
| 1317 | 784794.18 | 3290906.96 | 237.48 |
| 1318 | 784764.69 | 3290866.59 | 237.44 |
| 1319 | 784736.00 | 3290825.67 | 237.46 |
| 1320 | 784709.85 | 3290783.06 | 237.55 |
| 1321 | 784683.69 | 3290740.45 | 237.65 |
| 1322 | 784657.53 | 3290697.83 | 237.74 |
| 1323 | 784630.18 | 3290656.07 | 237.80 |
| 1324 | 784598.85 | 3290617.10 | 237.79 |
| 1325 | 784567.52 | 3290578.13 | 237.74 |
| 1326 | 784536.07 | 3290539.27 | 237.61 |
| 1327 | 784501.80 | 3290502.86 | 237.61 |
| 1328 | 784474.42 | 3290515.58 | 237.55 |
| 1329 | 784449.76 | 3290558.96 | 237.54 |
| 1330 | 784421.12 | 3290599.95 | 235.59 |
| 1331 | 784395.30 | 3290636.88 | 234.53 |

| 50 Year HFL Points | | | |
|---|---|---|---|
| S. No. | Right Bank | | |
| | Easting (X) | Northing (Y) | Elevation (m) |
| 1 | 770483.92 | 3332677.99 | 301.83 |
| 2 | 770499.94 | 3332630.62 | 301.74 |
| 3 | 770518.25 | 3332584.28 | 301.59 |
| 4 | 770542.95 | 3332540.81 | 301.49 |
| 5 | 770569.43 | 3332498.41 | 301.45 |
| 6 | 770602.41 | 3332461.57 | 301.42 |
| 7 | 770641.28 | 3332430.15 | 301.90 |
| 8 | 770686.43 | 3332412.21 | 301.55 |
| 9 | 770736.28 | 3332410.90 | 302.20 |
| 10 | 770781.78 | 3332390.62 | 302.28 |
| 11 | 770821.37 | 3332360.58 | 302.20 |
| 12 | 770856.88 | 3332325.51 | 302.18 |
| 13 | 770890.05 | 3332288.09 | 302.24 |
| 14 | 770926.73 | 3332254.33 | 302.13 |
| 15 | 770965.40 | 3332222.64 | 302.25 |
| 16 | 771005.38 | 3332192.61 | 302.05 |
| 17 | 771045.77 | 3332163.15 | 301.73 |
| 18 | 771086.59 | 3332134.28 | 301.74 |
| 19 | 771127.29 | 3332105.24 | 301.45 |
| 20 | 771167.84 | 3332075.97 | 301.45 |
| 21 | 771207.11 | 3332045.03 | 300.66 |
| 22 | 771246.99 | 3332014.95 | 299.92 |
| 23 | 771288.08 | 3331986.60 | 299.86 |
| 24 | 771326.68 | 3331954.81 | 300.23 |
| 25 | 771366.63 | 3331924.75 | 300.43 |
| 26 | 771404.30 | 3331891.94 | 301.12 |
| 27 | 771434.11 | 3331852.13 | 302.41 |
| 28 | 771454.35 | 3331806.64 | 302.15 |
| 29 | 771478.25 | 3331763.77 | 302.29 |
| 30 | 771498.45 | 3331719.04 | 302.24 |
| 31 | 771517.48 | 3331672.85 | 301.75 |
| 32 | 771535.90 | 3331626.45 | 302.45 |
| 33 | 771558.74 | 3331581.99 | 302.56 |
| 34 | 771579.36 | 3331536.44 | 302.61 |
| 35 | 771598.46 | 3331490.23 | 302.90 |
| 36 | 771605.70 | 3331440.79 | 302.85 |
| 37 | 771605.62 | 3331390.90 | 301.66 |
| 38 | 771603.80 | 3331340.94 | 301.42 |
| 39 | 771597.55 | 3331291.40 | 302.33 |
| 40 | 771568.70 | 3331250.56 | 302.11 |
| 41 | 771532.20 | 3331219.38 | 301.72 |
| 42 | 771486.02 | 3331200.22 | 299.68 |
| 43 | 771440.00 | 3331180.67 | 299.16 |
| 44 | 771393.98 | 3331161.11 | 298.98 |

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|---|---|---|---|
| 45 | 771348.43 | 3331140.53 | 298.67 |
| 46 | 771303.49 | 3331118.62 | 298.53 |
| 47 | 771258.63 | 3331096.53 | 298.36 |
| 48 | 771214.54 | 3331072.97 | 298.61 |
| 49 | 771170.44 | 3331049.40 | 298.26 |
| 50 | 771126.34 | 3331025.84 | 297.78 |
| 51 | 771080.34 | 3331006.29 | 297.65 |
| 52 | 771034.15 | 3330987.15 | 297.53 |
| 53 | 770987.95 | 3330968.02 | 297.41 |
| 54 | 770942.75 | 3330946.84 | 297.24 |
| 55 | 770899.09 | 3330922.48 | 297.14 |
| 56 | 770856.01 | 3330897.09 | 297.08 |
| 57 | 770813.12 | 3330871.42 | 297.09 |
| 58 | 770772.45 | 3330842.33 | 297.30 |
| 59 | 770731.78 | 3330813.24 | 297.21 |
| 60 | 770691.28 | 3330783.92 | 297.08 |
| 61 | 770650.78 | 3330754.60 | 296.96 |
| 62 | 770612.24 | 3330722.76 | 296.63 |
| 63 | 770576.85 | 3330687.52 | 296.49 |
| 64 | 770542.89 | 3330650.85 | 296.33 |
| 65 | 770510.53 | 3330612.73 | 296.21 |
| 66 | 770476.41 | 3330576.18 | 296.25 |
| 67 | 770442.44 | 3330539.49 | 296.69 |
| 68 | 770409.61 | 3330501.82 | 297.37 |
| 69 | 770378.49 | 3330462.69 | 297.62 |
| 70 | 770347.37 | 3330423.56 | 297.51 |
| 71 | 770315.84 | 3330384.75 | 297.50 |
| 72 | 770283.75 | 3330346.41 | 298.03 |
| 73 | 770256.82 | 3330304.28 | 298.49 |
| 74 | 770234.80 | 3330260.17 | 298.44 |
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| 1166 | 784918.47 | 3292539.66 | 239.18 |
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| 50 Year HFL Points | | | |
|---|---|---|---|
| S. No. | Left Bank | | |
| | Easting (X) | Northing (Y) | Elevation (m) |
| 1 | 770709.21 | 3332807.99 | 301.83 |
| 2 | 770736.97 | 3332766.40 | 301.74 |
| 3 | 770764.84 | 3332724.89 | 301.59 |
| 4 | 770792.93 | 3332683.52 | 301.49 |
| 5 | 770820.68 | 3332641.94 | 301.45 |
| 6 | 770847.60 | 3332599.80 | 301.42 |
| 7 | 770875.84 | 3332558.57 | 301.90 |
| 8 | 770908.75 | 3332521.23 | 301.55 |
| 9 | 770945.46 | 3332487.27 | 302.20 |
| 10 | 770983.95 | 3332455.40 | 302.28 |
| 11 | 771022.71 | 3332423.81 | 302.20 |
| 12 | 771061.46 | 3332392.21 | 302.18 |
| 13 | 771100.21 | 3332360.62 | 302.24 |
| 14 | 771138.99 | 3332329.06 | 302.13 |
| 15 | 771178.76 | 3332298.75 | 302.25 |
| 16 | 771218.52 | 3332268.44 | 302.05 |
| 17 | 771258.29 | 3332238.13 | 301.73 |
| 18 | 771298.05 | 3332207.82 | 301.74 |
| 19 | 771338.46 | 3332178.39 | 301.45 |
| 20 | 771379.73 | 3332150.16 | 301.45 |
| 21 | 771420.96 | 3332121.88 | 300.66 |
| 22 | 771462.19 | 3332093.61 | 299.92 |
| 23 | 771503.54 | 3332065.58 | 299.86 |
| 24 | 771538.32 | 3332030.33 | 300.23 |
| 25 | 771568.37 | 3331990.37 | 300.43 |
| 26 | 771596.58 | 3331949.09 | 301.12 |
| 27 | 771620.02 | 3331904.96 | 302.41 |
| 28 | 771643.10 | 3331860.60 | 302.15 |
| 29 | 771662.08 | 3331814.37 | 302.29 |
| 30 | 771684.71 | 3331770.37 | 302.24 |
| 31 | 771709.66 | 3331727.11 | 301.75 |
| 32 | 771732.20 | 3331682.94 | 302.45 |
| 33 | 771758.29 | 3331640.71 | 302.56 |
| 34 | 771780.96 | 3331596.46 | 302.61 |
| 35 | 771793.24 | 3331548.50 | 302.90 |
| 36 | 771805.25 | 3331500.59 | 302.85 |
| 37 | 771804.74 | 3331450.70 | 301.66 |
| 38 | 771790.80 | 3331402.84 | 301.42 |
| 39 | 771779.83 | 3331354.44 | 302.33 |
| 40 | 771762.02 | 3331308.07 | 302.11 |
| 41 | 771742.29 | 3331262.36 | 301.72 |
| 42 | 771717.60 | 3331219.80 | 299.68 |
| 43 | 771692.24 | 3331176.71 | 299.16 |
| 44 | 771663.48 | 3331136.24 | 298.98 |

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| 45 | 771631.64 | 3331098.25 | 298.67 |
| 46 | 771593.41 | 3331067.18 | 298.53 |
| 47 | 771549.84 | 3331043.37 | 298.36 |
| 48 | 771505.47 | 3331021.49 | 298.61 |
| 49 | 771465.89 | 3330991.67 | 298.26 |
| 50 | 771421.31 | 3330969.85 | 297.78 |
| 51 | 771375.02 | 3330952.06 | 297.65 |
| 52 | 771327.31 | 3330938.19 | 297.53 |
| 53 | 771281.96 | 3330917.89 | 297.41 |
| 54 | 771239.80 | 3330891.17 | 297.24 |
| 55 | 771193.22 | 3330873.40 | 297.14 |
| 56 | 771146.98 | 3330855.22 | 297.08 |
| 57 | 771102.85 | 3330831.98 | 297.09 |
| 58 | 771057.56 | 3330811.31 | 297.30 |
| 59 | 771012.53 | 3330790.08 | 297.21 |
| 60 | 770967.15 | 3330769.80 | 297.08 |
| 61 | 770922.78 | 3330746.75 | 296.96 |
| 62 | 770878.41 | 3330723.70 | 296.63 |
| 63 | 770834.25 | 3330700.25 | 296.49 |
| 64 | 770790.84 | 3330675.52 | 296.33 |
| 65 | 770748.66 | 3330648.67 | 296.21 |
| 66 | 770707.32 | 3330620.55 | 296.25 |
| 67 | 770667.07 | 3330591.16 | 296.69 |
| 68 | 770634.62 | 3330553.17 | 297.37 |
| 69 | 770602.66 | 3330514.72 | 297.62 |
| 70 | 770570.70 | 3330476.27 | 297.51 |
| 71 | 770538.73 | 3330437.82 | 297.50 |
| 72 | 770506.02 | 3330400.02 | 298.03 |
| 73 | 770472.85 | 3330362.61 | 298.49 |
| 74 | 770439.68 | 3330325.20 | 298.44 |
| 75 | 770415.25 | 3330282.69 | 298.43 |
| 76 | 770399.57 | 3330235.28 | 297.62 |
| 77 | 770397.33 | 3330185.33 | 297.35 |
| 78 | 770400.37 | 3330135.86 | 297.16 |
| 79 | 770411.39 | 3330087.09 | 297.10 |
| 80 | 770422.41 | 3330038.32 | 297.05 |
| 81 | 770436.39 | 3329990.32 | 296.99 |
| 82 | 770448.69 | 3329941.92 | 296.96 |
| 83 | 770479.67 | 3329909.41 | 296.95 |
| 84 | 770527.97 | 3329916.64 | 296.70 |
| 85 | 770574.61 | 3329934.07 | 296.53 |
| 86 | 770620.74 | 3329952.79 | 296.51 |
| 87 | 770666.79 | 3329970.21 | 295.91 |
| 88 | 770714.82 | 3329982.45 | 296.01 |
| 89 | 770764.64 | 3329986.61 | 295.69 |
| 90 | 770814.59 | 3329986.81 | 295.87 |
| 91 | 770864.58 | 3329985.78 | 295.87 |

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| 92 | 770914.46 | 3329983.56 | 295.17 |
| 93 | 770964.39 | 3329980.98 | 294.21 |
| 94 | 771013.91 | 3329974.82 | 293.78 |
| 95 | 771063.09 | 3329965.81 | 293.54 |
| 96 | 771102.67 | 3329937.73 | 293.38 |
| 97 | 771136.96 | 3329901.60 | 293.21 |
| 98 | 771166.54 | 3329861.29 | 293.08 |
| 99 | 771189.33 | 3329817.35 | 292.89 |
| 100 | 771206.32 | 3329770.33 | 292.70 |
| 101 | 771223.30 | 3329723.30 | 292.52 |
| 102 | 771236.12 | 3329675.54 | 292.30 |
| 103 | 771236.26 | 3329625.54 | 292.11 |
| 104 | 771234.34 | 3329575.78 | 291.96 |
| 105 | 771220.45 | 3329527.74 | 291.80 |
| 106 | 771206.57 | 3329479.71 | 291.65 |
| 107 | 771191.71 | 3329431.97 | 291.56 |
| 108 | 771176.79 | 3329384.25 | 291.47 |
| 109 | 771161.93 | 3329336.53 | 291.38 |
| 110 | 771144.33 | 3329289.73 | 291.30 |
| 111 | 771126.72 | 3329242.93 | 291.24 |
| 112 | 771109.12 | 3329196.14 | 291.18 |
| 113 | 771089.30 | 3329150.24 | 291.12 |
| 114 | 771069.08 | 3329104.51 | 291.06 |
| 115 | 771048.87 | 3329058.78 | 290.97 |
| 116 | 771028.60 | 3329013.07 | 290.85 |
| 117 | 771007.30 | 3328967.84 | 290.74 |
| 118 | 770986.00 | 3328922.60 | 290.62 |
| 119 | 770962.10 | 3328878.76 | 290.51 |
| 120 | 770936.11 | 3328836.05 | 290.43 |
| 121 | 770910.12 | 3328793.34 | 290.36 |
| 122 | 770884.12 | 3328750.62 | 290.30 |
| 123 | 770858.13 | 3328707.91 | 290.31 |
| 124 | 770832.14 | 3328665.20 | 290.27 |
| 125 | 770803.77 | 3328624.14 | 290.24 |
| 126 | 770772.76 | 3328584.92 | 290.16 |
| 127 | 770741.75 | 3328545.70 | 290.12 |
| 128 | 770708.20 | 3328508.94 | 290.13 |
| 129 | 770669.95 | 3328476.74 | 290.14 |
| 130 | 770631.62 | 3328444.62 | 290.03 |
| 131 | 770593.22 | 3328412.60 | 289.96 |
| 132 | 770554.82 | 3328380.58 | 289.89 |
| 133 | 770516.42 | 3328348.56 | 289.70 |
| 134 | 770476.09 | 3328319.04 | 289.57 |
| 135 | 770435.46 | 3328289.89 | 289.44 |
| 136 | 770405.58 | 3328250.23 | 289.36 |
| 137 | 770377.12 | 3328209.12 | 289.32 |
| 138 | 770353.05 | 3328165.30 | 289.22 |

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| 139 | 770331.37 | 3328120.61 | 289.34 |
| 140 | 770304.51 | 3328078.44 | 289.84 |
| 141 | 770277.66 | 3328036.26 | 290.14 |
| 142 | 770250.80 | 3327994.08 | 290.36 |
| 143 | 770221.38 | 3327953.75 | 290.56 |
| 144 | 770187.10 | 3327917.53 | 290.34 |
| 145 | 770151.34 | 3327883.19 | 290.05 |
| 146 | 770114.52 | 3327849.37 | 289.84 |
| 147 | 770082.63 | 3327810.92 | 290.05 |
| 148 | 770060.11 | 3327766.70 | 290.13 |
| 149 | 770045.26 | 3327719.64 | 290.28 |
| 150 | 770042.58 | 3327670.17 | 289.75 |
| 151 | 770046.91 | 3327620.46 | 290.69 |
| 152 | 770024.85 | 3327575.59 | 290.30 |
| 153 | 770002.14 | 3327531.08 | 289.93 |
| 154 | 769975.40 | 3327488.83 | 288.99 |
| 155 | 769948.66 | 3327446.59 | 288.22 |
| 156 | 769920.75 | 3327405.12 | 287.75 |
| 157 | 769892.05 | 3327364.17 | 287.46 |
| 158 | 769863.35 | 3327323.23 | 287.31 |
| 159 | 769834.65 | 3327282.29 | 287.00 |
| 160 | 769805.95 | 3327241.34 | 286.73 |
| 161 | 769776.50 | 3327200.95 | 286.67 |
| 162 | 769745.94 | 3327161.38 | 286.69 |
| 163 | 769715.38 | 3327121.81 | 286.83 |
| 164 | 769684.81 | 3327082.23 | 287.14 |
| 165 | 769654.25 | 3327042.66 | 287.40 |
| 166 | 769623.69 | 3327003.09 | 287.99 |
| 167 | 769593.45 | 3326963.28 | 288.56 |
| 168 | 769564.51 | 3326922.51 | 288.03 |
| 169 | 769535.56 | 3326881.74 | 288.13 |
| 170 | 769506.62 | 3326840.97 | 287.74 |
| 171 | 769477.67 | 3326800.20 | 287.78 |
| 172 | 769454.49 | 3326756.23 | 287.30 |
| 173 | 769435.03 | 3326710.18 | 287.07 |
| 174 | 769414.68 | 3326664.50 | 287.27 |
| 175 | 769393.04 | 3326619.62 | 287.07 |
| 176 | 769361.86 | 3326580.53 | 287.69 |
| 177 | 769342.33 | 3326534.76 | 287.66 |
| 178 | 769327.71 | 3326487.38 | 287.32 |
| 179 | 769313.61 | 3326439.41 | 286.76 |
| 180 | 769303.03 | 3326390.73 | 286.33 |
| 181 | 769296.53 | 3326341.15 | 286.88 |
| 182 | 769290.03 | 3326291.58 | 286.55 |
| 183 | 769283.53 | 3326242.00 | 286.77 |
| 184 | 769274.03 | 3326192.96 | 286.42 |
| 185 | 769263.24 | 3326144.13 | 286.47 |

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| 186 | 769253.93 | 3326095.20 | 286.53 |
| 187 | 769240.05 | 3326047.33 | 286.43 |
| 188 | 769224.76 | 3325999.72 | 286.38 |
| 189 | 769208.52 | 3325952.44 | 286.40 |
| 190 | 769192.25 | 3325905.16 | 286.77 |
| 191 | 769175.98 | 3325857.88 | 285.97 |
| 192 | 769159.71 | 3325810.60 | 285.60 |
| 193 | 769143.43 | 3325763.32 | 285.45 |
| 194 | 769127.16 | 3325716.05 | 285.35 |
| 195 | 769110.89 | 3325668.77 | 285.34 |
| 196 | 769094.62 | 3325621.49 | 285.21 |
| 197 | 769078.34 | 3325574.21 | 285.13 |
| 198 | 769063.20 | 3325526.56 | 285.23 |
| 199 | 769048.12 | 3325478.89 | 285.26 |
| 200 | 769033.04 | 3325431.22 | 285.06 |
| 201 | 769020.89 | 3325382.98 | 284.77 |
| 202 | 769009.75 | 3325334.24 | 284.48 |
| 203 | 768998.62 | 3325285.49 | 284.18 |
| 204 | 768987.48 | 3325236.75 | 283.97 |
| 205 | 768976.34 | 3325188.00 | 283.83 |
| 206 | 768965.21 | 3325139.26 | 283.57 |
| 207 | 768954.07 | 3325090.52 | 283.36 |
| 208 | 768942.93 | 3325041.77 | 283.20 |
| 209 | 768931.79 | 3324993.03 | 283.12 |
| 210 | 768920.66 | 3324944.28 | 283.01 |
| 211 | 768902.94 | 3324897.83 | 282.93 |
| 212 | 768881.45 | 3324852.68 | 282.87 |
| 213 | 768858.29 | 3324808.58 | 282.78 |
| 214 | 768826.86 | 3324769.70 | 282.74 |
| 215 | 768795.42 | 3324730.82 | 282.67 |
| 216 | 768756.51 | 3324699.70 | 282.61 |
| 217 | 768716.58 | 3324669.61 | 282.55 |
| 218 | 768676.65 | 3324639.52 | 282.65 |
| 219 | 768639.48 | 3324607.33 | 282.50 |
| 220 | 768621.30 | 3324560.76 | 282.97 |
| 221 | 768603.36 | 3324514.33 | 283.63 |
| 222 | 768581.70 | 3324469.27 | 283.93 |
| 223 | 768565.29 | 3324422.74 | 284.02 |
| 224 | 768563.18 | 3324372.78 | 283.95 |
| 225 | 768561.07 | 3324322.83 | 283.77 |
| 226 | 768563.86 | 3324272.98 | 283.60 |
| 227 | 768568.15 | 3324223.16 | 283.19 |
| 228 | 768572.96 | 3324173.42 | 283.12 |
| 229 | 768578.27 | 3324123.70 | 283.14 |
| 230 | 768583.45 | 3324073.97 | 283.21 |
| 231 | 768588.27 | 3324024.20 | 282.87 |
| 232 | 768589.27 | 3323974.37 | 282.51 |

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| 233 | 768585.99 | 3323924.48 | 282.15 |
| 234 | 768582.70 | 3323874.59 | 281.98 |
| 235 | 768579.42 | 3323824.70 | 281.87 |
| 236 | 768580.68 | 3323774.73 | 281.81 |
| 237 | 768582.26 | 3323724.75 | 281.76 |
| 238 | 768579.74 | 3323674.92 | 281.65 |
| 239 | 768574.63 | 3323625.19 | 281.49 |
| 240 | 768569.53 | 3323575.45 | 281.33 |
| 241 | 768570.80 | 3323525.91 | 281.17 |
| 242 | 768572.52 | 3323475.94 | 281.03 |
| 243 | 768574.24 | 3323425.97 | 280.87 |
| 244 | 768576.52 | 3323376.16 | 280.71 |
| 245 | 768571.53 | 3323326.43 | 280.61 |
| 246 | 768566.67 | 3323276.66 | 280.57 |
| 247 | 768561.81 | 3323226.90 | 280.54 |
| 248 | 768556.96 | 3323177.14 | 280.46 |
| 249 | 768556.38 | 3323127.21 | 280.38 |
| 250 | 768557.54 | 3323077.23 | 280.33 |
| 251 | 768558.27 | 3323027.27 | 280.29 |
| 252 | 768550.91 | 3322977.81 | 280.24 |
| 253 | 768543.54 | 3322928.36 | 280.17 |
| 254 | 768534.06 | 3322879.28 | 280.11 |
| 255 | 768523.96 | 3322830.31 | 280.04 |
| 256 | 768513.87 | 3322781.34 | 279.97 |
| 257 | 768503.77 | 3322732.37 | 279.91 |
| 258 | 768493.23 | 3322683.49 | 279.87 |
| 259 | 768482.62 | 3322634.63 | 279.82 |
| 260 | 768466.93 | 3322587.24 | 279.75 |
| 261 | 768449.80 | 3322540.26 | 279.69 |
| 262 | 768432.68 | 3322493.29 | 279.66 |
| 263 | 768415.56 | 3322446.31 | 279.61 |
| 264 | 768401.88 | 3322398.30 | 279.58 |
| 265 | 768390.28 | 3322349.66 | 279.51 |
| 266 | 768378.68 | 3322301.03 | 279.44 |
| 267 | 768366.18 | 3322252.62 | 279.38 |
| 268 | 768353.25 | 3322204.32 | 279.32 |
| 269 | 768340.32 | 3322156.02 | 279.32 |
| 270 | 768327.39 | 3322107.72 | 279.32 |
| 271 | 768316.93 | 3322058.89 | 279.37 |
| 272 | 768308.92 | 3322009.54 | 279.33 |
| 273 | 768300.90 | 3321960.18 | 279.26 |
| 274 | 768292.89 | 3321910.83 | 279.10 |
| 275 | 768284.88 | 3321861.48 | 279.01 |
| 276 | 768277.86 | 3321811.97 | 279.23 |
| 277 | 768270.92 | 3321762.46 | 282.62 |
| 278 | 768262.04 | 3321713.27 | 283.90 |
| 279 | 768252.08 | 3321664.28 | 284.37 |

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| 280 | 768242.12 | 3321615.28 | 284.30 |
| 281 | 768242.07 | 3321566.33 | 285.20 |
| 282 | 768252.53 | 3321517.44 | 288.34 |
| 283 | 768262.98 | 3321468.54 | 290.11 |
| 284 | 768269.95 | 3321419.04 | 286.86 |
| 285 | 768299.04 | 3321380.12 | 285.18 |
| 286 | 768344.17 | 3321362.83 | 284.05 |
| 287 | 768392.98 | 3321351.98 | 281.56 |
| 288 | 768442.64 | 3321346.62 | 281.10 |
| 289 | 768492.43 | 3321342.07 | 280.20 |
| 290 | 768542.36 | 3321339.40 | 279.49 |
| 291 | 768592.29 | 3321336.78 | 279.30 |
| 292 | 768642.06 | 3321341.10 | 278.95 |
| 293 | 768691.82 | 3321346.00 | 278.69 |
| 294 | 768741.61 | 3321350.65 | 278.67 |
| 295 | 768791.39 | 3321355.30 | 278.59 |
| 296 | 768841.17 | 3321359.95 | 278.51 |
| 297 | 768890.96 | 3321364.60 | 278.38 |
| 298 | 768940.72 | 3321369.50 | 278.21 |
| 299 | 768990.51 | 3321373.51 | 278.10 |
| 300 | 769040.48 | 3321372.03 | 278.02 |
| 301 | 769090.46 | 3321370.55 | 277.94 |
| 302 | 769140.44 | 3321369.07 | 277.87 |
| 303 | 769190.42 | 3321367.59 | 277.77 |
| 304 | 769240.40 | 3321366.11 | 277.71 |
| 305 | 769290.14 | 3321362.27 | 277.66 |
| 306 | 769339.42 | 3321353.81 | 277.62 |
| 307 | 769388.69 | 3321345.34 | 277.57 |
| 308 | 769437.97 | 3321336.87 | 277.49 |
| 309 | 769487.25 | 3321328.41 | 277.46 |
| 310 | 769536.45 | 3321319.60 | 277.36 |
| 311 | 769584.37 | 3321305.35 | 277.21 |
| 312 | 769632.30 | 3321291.10 | 277.02 |
| 313 | 769680.23 | 3321276.85 | 276.83 |
| 314 | 769729.38 | 3321268.11 | 276.78 |
| 315 | 769778.83 | 3321260.75 | 276.85 |
| 316 | 769828.29 | 3321253.39 | 276.95 |
| 317 | 769877.84 | 3321252.93 | 277.00 |
| 318 | 769927.48 | 3321258.89 | 276.96 |
| 319 | 769977.13 | 3321264.85 | 276.83 |
| 320 | 770024.48 | 3321279.71 | 276.70 |
| 321 | 770070.84 | 3321298.45 | 276.62 |
| 322 | 770117.59 | 3321316.07 | 276.54 |
| 323 | 770165.81 | 3321327.65 | 276.49 |
| 324 | 770215.68 | 3321331.29 | 276.38 |
| 325 | 770264.09 | 3321320.97 | 276.24 |
| 326 | 770311.02 | 3321304.18 | 276.03 |

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| 327 | 770356.15 | 3321282.67 | 275.79 |
| 328 | 770395.44 | 3321255.02 | 275.64 |
| 329 | 770419.04 | 3321210.94 | 275.53 |
| 330 | 770442.64 | 3321166.86 | 275.46 |
| 331 | 770448.26 | 3321117.32 | 275.47 |
| 332 | 770453.17 | 3321067.56 | 275.61 |
| 333 | 770458.08 | 3321017.80 | 275.73 |
| 334 | 770454.08 | 3320968.38 | 279.01 |
| 335 | 770449.82 | 3320918.57 | 285.63 |
| 336 | 770445.55 | 3320868.75 | 287.11 |
| 337 | 770441.53 | 3320818.92 | 287.24 |
| 338 | 770433.32 | 3320769.86 | 286.78 |
| 339 | 770421.64 | 3320721.24 | 282.12 |
| 340 | 770409.95 | 3320672.63 | 281.96 |
| 341 | 770398.27 | 3320624.01 | 280.31 |
| 342 | 770384.21 | 3320576.18 | 280.58 |
| 343 | 770364.26 | 3320530.33 | 280.10 |
| 344 | 770344.30 | 3320484.49 | 280.83 |
| 345 | 770324.35 | 3320438.64 | 280.21 |
| 346 | 770292.14 | 3320401.58 | 282.97 |
| 347 | 770255.16 | 3320367.92 | 279.64 |
| 348 | 770223.03 | 3320330.13 | 278.70 |
| 349 | 770195.64 | 3320288.30 | 280.49 |
| 350 | 770168.25 | 3320246.47 | 280.72 |
| 351 | 770154.81 | 3320198.71 | 278.69 |
| 352 | 770143.72 | 3320149.96 | 280.02 |
| 353 | 770132.64 | 3320101.20 | 279.74 |
| 354 | 770121.56 | 3320052.45 | 275.32 |
| 355 | 770118.30 | 3320002.75 | 274.58 |
| 356 | 770117.50 | 3319952.75 | 274.63 |
| 357 | 770116.70 | 3319902.76 | 274.61 |
| 358 | 770115.90 | 3319852.77 | 274.57 |
| 359 | 770115.07 | 3319803.11 | 274.60 |
| 360 | 770115.30 | 3319753.11 | 274.48 |
| 361 | 770114.19 | 3319703.14 | 274.27 |
| 362 | 770111.94 | 3319653.19 | 274.15 |
| 363 | 770109.69 | 3319603.24 | 274.13 |
| 364 | 770107.44 | 3319553.29 | 275.89 |
| 365 | 770113.68 | 3319504.16 | 276.91 |
| 366 | 770125.55 | 3319455.59 | 277.13 |
| 367 | 770137.42 | 3319407.02 | 275.79 |
| 368 | 770149.38 | 3319358.47 | 274.89 |
| 369 | 770161.36 | 3319309.93 | 274.50 |
| 370 | 770187.72 | 3319268.25 | 274.15 |
| 371 | 770219.39 | 3319229.96 | 273.52 |
| 372 | 770260.97 | 3319202.19 | 273.65 |
| 373 | 770305.70 | 3319181.30 | 273.56 |

| 374 | 770352.54 | 3319163.81 | 273.50 |
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| 375 | 770399.97 | 3319152.68 | 273.34 |
| 376 | 770449.23 | 3319161.24 | 273.01 |
| 377 | 770498.13 | 3319171.10 | 272.86 |
| 378 | 770544.74 | 3319189.19 | 272.79 |
| 379 | 770592.69 | 3319202.28 | 272.70 |
| 380 | 770641.53 | 3319204.50 | 272.56 |
| 381 | 770688.07 | 3319186.25 | 272.43 |
| 382 | 770734.62 | 3319167.99 | 272.35 |
| 383 | 770780.05 | 3319147.17 | 272.30 |
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| 1133 | 787808.26 | 3296909.85 | 239.66 |
| 1134 | 787820.13 | 3296861.28 | 239.60 |
| 1135 | 787832.00 | 3296812.70 | 239.61 |
| 1136 | 787843.87 | 3296764.13 | 239.58 |
| 1137 | 787855.74 | 3296715.56 | 239.66 |
| 1138 | 787864.29 | 3296666.32 | 239.59 |
| 1139 | 787872.29 | 3296616.96 | 239.57 |
| 1140 | 787880.30 | 3296567.61 | 239.54 |
| 1141 | 787883.25 | 3296519.04 | 239.48 |
| 1142 | 787860.67 | 3296474.42 | 239.41 |
| 1143 | 787838.10 | 3296429.81 | 239.35 |
| 1144 | 787816.00 | 3296384.97 | 239.33 |
| 1145 | 787795.20 | 3296339.50 | 239.38 |
| 1146 | 787774.40 | 3296294.03 | 239.52 |
| 1147 | 787753.60 | 3296248.56 | 239.75 |
| 1148 | 787732.80 | 3296203.10 | 239.90 |
| 1149 | 787708.13 | 3296159.73 | 239.91 |
| 1150 | 787681.04 | 3296117.70 | 239.83 |
| 1151 | 787653.95 | 3296075.68 | 239.72 |
| 1152 | 787634.22 | 3296029.90 | 239.54 |
| 1153 | 787616.14 | 3295983.29 | 239.50 |
| 1154 | 787615.70 | 3295934.07 | 239.44 |
| 1155 | 787619.58 | 3295884.23 | 239.53 |
| 1156 | 787634.90 | 3295836.84 | 239.50 |
| 1157 | 787657.93 | 3295794.03 | 239.58 |
| 1158 | 787696.21 | 3295761.86 | 239.54 |
| 1159 | 787734.48 | 3295729.69 | 239.55 |
| 1160 | 787773.51 | 3295698.47 | 239.47 |
| 1161 | 787814.93 | 3295670.49 | 239.38 |
| 1162 | 787856.84 | 3295643.23 | 239.08 |
| 1163 | 787900.38 | 3295618.64 | 238.97 |
| 1164 | 787943.91 | 3295594.05 | 239.10 |
| 1165 | 787984.14 | 3295565.18 | 239.12 |
| 1166 | 788018.93 | 3295529.27 | 239.18 |
| 1167 | 788030.64 | 3295481.55 | 239.22 |
| 1168 | 788039.40 | 3295432.32 | 239.23 |
| 1169 | 788046.91 | 3295382.92 | 238.99 |
| 1170 | 788052.32 | 3295333.21 | 238.82 |
| 1171 | 788057.14 | 3295283.45 | 238.61 |
| 1172 | 788060.44 | 3295233.56 | 238.44 |

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|---|---|---|---|
| 1173 | 788064.72 | 3295183.76 | 238.22 |
| 1174 | 788069.90 | 3295134.02 | 238.13 |
| 1175 | 788074.96 | 3295084.28 | 238.05 |
| 1176 | 788074.70 | 3295034.43 | 238.03 |
| 1177 | 788054.80 | 3294989.81 | 237.99 |
| 1178 | 788017.58 | 3294956.78 | 237.93 |
| 1179 | 787976.44 | 3294928.45 | 237.95 |
| 1180 | 787934.07 | 3294901.90 | 237.84 |
| 1181 | 787891.81 | 3294875.19 | 237.83 |
| 1182 | 787849.89 | 3294847.93 | 237.78 |
| 1183 | 787807.94 | 3294820.73 | 237.73 |
| 1184 | 787765.80 | 3294793.81 | 237.71 |
| 1185 | 787723.42 | 3294767.29 | 237.67 |
| 1186 | 787681.44 | 3294740.16 | 237.63 |
| 1187 | 787639.86 | 3294712.38 | 237.51 |
| 1188 | 787599.68 | 3294682.73 | 237.43 |
| 1189 | 787566.48 | 3294646.20 | 237.44 |
| 1190 | 787548.20 | 3294599.80 | 237.44 |
| 1191 | 787533.06 | 3294552.15 | 237.47 |
| 1192 | 787519.18 | 3294504.12 | 237.47 |
| 1193 | 787504.92 | 3294456.20 | 237.52 |
| 1194 | 787475.20 | 3294420.99 | 237.56 |
| 1195 | 787446.38 | 3294380.24 | 237.61 |
| 1196 | 787417.78 | 3294339.23 | 237.65 |
| 1197 | 787388.98 | 3294298.36 | 237.71 |
| 1198 | 787358.83 | 3294258.47 | 237.71 |
| 1199 | 787328.69 | 3294218.57 | 237.71 |
| 1200 | 787298.55 | 3294178.68 | 237.71 |
| 1201 | 787269.16 | 3294138.25 | 237.71 |
| 1202 | 787240.90 | 3294097.00 | 237.72 |
| 1203 | 787212.63 | 3294055.76 | 237.70 |
| 1204 | 787183.74 | 3294014.97 | 237.69 |
| 1205 | 787153.10 | 3293975.46 | 237.70 |

| 100 Year HFL Points | | | |
|---|---|---|---|
| S. No. | Right Bank | | |
| | Easting (X) | Northing (Y) | Elevation (m) |
| 1 | 770596.97 | 3332771.82 | 302.24 |
| 2 | 770573.79 | 3332761.28 | 302.18 |
| 3 | 770528.51 | 3332740.15 | 302.16 |
| 4 | 770486.04 | 3332713.77 | 302.25 |
| 5 | 770472.95 | 3332670.56 | 302.25 |
| 6 | 770491.60 | 3332624.17 | 302.14 |
| 7 | 770512.34 | 3332578.67 | 302.00 |
| 8 | 770535.97 | 3332534.75 | 301.91 |
| 9 | 770562.89 | 3332492.61 | 301.87 |
| 10 | 770591.69 | 3332452.27 | 301.97 |
| 11 | 770632.51 | 3332423.39 | 302.24 |
| 12 | 770676.10 | 3332400.35 | 301.95 |
| 13 | 770724.91 | 3332397.10 | 302.39 |
| 14 | 770769.71 | 3332374.91 | 302.54 |
| 15 | 770811.52 | 3332348.14 | 302.57 |
| 16 | 770844.24 | 3332310.62 | 302.51 |
| 17 | 770874.37 | 3332270.72 | 302.58 |
| 18 | 770911.04 | 3332237.77 | 302.56 |
| 19 | 770952.71 | 3332210.14 | 302.57 |
| 20 | 770990.02 | 3332176.86 | 302.43 |
| 21 | 771030.14 | 3332147.28 | 302.16 |
| 22 | 771072.20 | 3332120.24 | 302.08 |
| 23 | 771111.67 | 3332089.60 | 301.83 |
| 24 | 771150.80 | 3332058.46 | 302.24 |
| 25 | 771188.69 | 3332026.11 | 301.40 |
| 26 | 771220.22 | 3331987.58 | 300.51 |
| 27 | 771262.27 | 3331960.53 | 300.34 |
| 28 | 771302.86 | 3331931.52 | 300.33 |
| 29 | 771340.93 | 3331899.10 | 300.80 |
| 30 | 771376.99 | 3331864.60 | 302.16 |
| 31 | 771411.07 | 3331828.02 | 302.74 |
| 32 | 771440.73 | 3331788.23 | 302.59 |
| 33 | 771464.83 | 3331744.43 | 302.68 |
| 34 | 771485.93 | 3331699.10 | 302.69 |
| 35 | 771506.88 | 3331653.70 | 302.81 |
| 36 | 771526.74 | 3331607.86 | 302.85 |
| 37 | 771543.49 | 3331560.75 | 302.81 |
| 38 | 771560.25 | 3331513.64 | 302.64 |
| 39 | 771574.72 | 3331466.02 | 302.71 |
| 40 | 771579.48 | 3331416.25 | 302.13 |
| 41 | 771584.25 | 3331366.48 | 301.52 |
| 42 | 771574.10 | 3331319.09 | 301.30 |
| 43 | 771553.82 | 3331273.44 | 301.96 |
| 44 | 771519.53 | 3331237.05 | 301.43 |

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|---|---|---|---|
| 45 | 771475.74 | 3331214.77 | 300.05 |
| 46 | 771428.66 | 3331198.25 | 299.61 |
| 47 | 771384.34 | 3331175.15 | 299.45 |
| 48 | 771340.60 | 3331150.91 | 299.10 |
| 49 | 771296.87 | 3331126.68 | 298.95 |
| 50 | 771252.58 | 3331103.49 | 298.87 |
| 51 | 771208.15 | 3331080.54 | 299.20 |
| 52 | 771163.73 | 3331057.59 | 298.84 |
| 53 | 771118.27 | 3331036.99 | 298.32 |
| 54 | 771071.46 | 3331019.42 | 298.18 |
| 55 | 771024.64 | 3331001.86 | 298.01 |
| 56 | 770979.11 | 3330981.20 | 297.85 |
| 57 | 770933.59 | 3330960.51 | 297.69 |
| 58 | 770889.29 | 3330937.73 | 297.61 |
| 59 | 770848.84 | 3330908.34 | 297.54 |
| 60 | 770808.40 | 3330878.94 | 297.56 |
| 61 | 770767.95 | 3330849.55 | 297.83 |
| 62 | 770727.72 | 3330819.86 | 297.67 |
| 63 | 770687.70 | 3330789.88 | 297.59 |
| 64 | 770647.88 | 3330759.66 | 297.49 |
| 65 | 770609.22 | 3330727.95 | 297.08 |
| 66 | 770571.40 | 3330695.40 | 297.00 |
| 67 | 770539.38 | 3330656.99 | 296.82 |
| 68 | 770507.14 | 3330618.79 | 296.66 |
| 69 | 770472.94 | 3330582.31 | 296.72 |
| 70 | 770438.75 | 3330545.83 | 297.30 |
| 71 | 770406.85 | 3330507.40 | 297.96 |
| 72 | 770376.44 | 3330467.71 | 298.07 |
| 73 | 770345.26 | 3330428.65 | 297.96 |
| 74 | 770312.49 | 3330390.89 | 297.90 |
| 75 | 770280.21 | 3330352.77 | 298.43 |
| 76 | 770254.09 | 3330310.13 | 298.86 |
| 77 | 770229.15 | 3330267.06 | 298.76 |
| 78 | 770221.34 | 3330217.67 | 298.71 |
| 79 | 770213.52 | 3330168.29 | 297.91 |
| 80 | 770214.03 | 3330118.55 | 297.75 |
| 81 | 770217.59 | 3330068.67 | 297.55 |
| 82 | 770221.67 | 3330018.85 | 297.48 |
| 83 | 770226.96 | 3329969.13 | 297.43 |
| 84 | 770232.26 | 3329919.41 | 297.38 |
| 85 | 770245.87 | 3329871.56 | 297.34 |
| 86 | 770262.39 | 3329824.37 | 297.33 |
| 87 | 770278.49 | 3329777.03 | 297.17 |
| 88 | 770294.55 | 3329729.68 | 297.01 |
| 89 | 770311.96 | 3329682.85 | 297.12 |
| 90 | 770331.28 | 3329636.73 | 296.77 |
| 91 | 770344.79 | 3329588.70 | 296.84 |

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| 92 | 770362.46 | 3329542.03 | 296.60 |
| 93 | 770382.35 | 3329496.16 | 296.48 |
| 94 | 770402.82 | 3329450.58 | 296.27 |
| 95 | 770417.21 | 3329402.69 | 295.94 |
| 96 | 770425.07 | 3329353.64 | 294.78 |
| 97 | 770395.46 | 3329314.38 | 294.26 |
| 98 | 770363.60 | 3329275.84 | 293.98 |
| 99 | 770331.74 | 3329237.31 | 293.84 |
| 100 | 770298.73 | 3329199.76 | 293.68 |
| 101 | 770265.22 | 3329162.65 | 293.50 |
| 102 | 770231.71 | 3329125.54 | 293.28 |
| 103 | 770199.06 | 3329087.71 | 293.10 |
| 104 | 770168.14 | 3329048.42 | 292.90 |
| 105 | 770137.22 | 3329009.12 | 292.68 |
| 106 | 770106.31 | 3328969.83 | 292.49 |
| 107 | 770075.39 | 3328930.53 | 292.32 |
| 108 | 770049.44 | 3328887.85 | 292.16 |
| 109 | 770024.09 | 3328844.75 | 292.02 |
| 110 | 769998.75 | 3328801.64 | 291.91 |
| 111 | 769973.40 | 3328758.54 | 291.82 |
| 112 | 769951.67 | 3328713.59 | 291.72 |
| 113 | 769932.29 | 3328667.51 | 291.63 |
| 114 | 769912.38 | 3328621.69 | 291.56 |
| 115 | 769889.36 | 3328577.31 | 291.51 |
| 116 | 769866.34 | 3328532.92 | 291.46 |
| 117 | 769843.32 | 3328488.54 | 291.40 |
| 118 | 769820.30 | 3328444.15 | 291.31 |
| 119 | 769803.28 | 3328397.35 | 291.20 |
| 120 | 769789.21 | 3328349.38 | 291.09 |
| 121 | 769775.13 | 3328301.40 | 290.98 |
| 122 | 769761.06 | 3328253.42 | 290.88 |
| 123 | 769742.25 | 3328207.22 | 290.80 |
| 124 | 769721.21 | 3328161.87 | 290.74 |
| 125 | 769700.16 | 3328116.51 | 290.71 |
| 126 | 769684.82 | 3328069.26 | 290.75 |
| 127 | 769674.60 | 3328020.32 | 290.69 |
| 128 | 769664.37 | 3327971.38 | 290.69 |
| 129 | 769654.15 | 3327922.43 | 290.63 |
| 130 | 769643.92 | 3327873.49 | 290.60 |
| 131 | 769632.65 | 3327824.79 | 290.60 |
| 132 | 769620.30 | 3327776.34 | 290.63 |
| 133 | 769607.95 | 3327727.89 | 290.50 |
| 134 | 769595.61 | 3327679.44 | 290.41 |
| 135 | 769580.92 | 3327631.83 | 290.31 |
| 136 | 769559.38 | 3327586.71 | 290.13 |
| 137 | 769536.69 | 3327542.17 | 289.98 |
| 138 | 769512.92 | 3327498.18 | 289.87 |

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| 139 | 769489.15 | 3327454.20 | 289.78 |
| 140 | 769460.80 | 3327413.42 | 289.77 |
| 141 | 769427.53 | 3327376.10 | 289.89 |
| 142 | 769394.25 | 3327338.78 | 290.54 |
| 143 | 769360.98 | 3327301.46 | 291.00 |
| 144 | 769327.70 | 3327264.14 | 291.05 |
| 145 | 769294.43 | 3327226.82 | 291.23 |
| 146 | 769261.15 | 3327189.50 | 291.20 |
| 147 | 769227.88 | 3327152.18 | 291.25 |
| 148 | 769194.60 | 3327114.86 | 290.90 |
| 149 | 769162.05 | 3327076.91 | 290.69 |
| 150 | 769129.59 | 3327038.88 | 290.87 |
| 151 | 769097.13 | 3327000.84 | 291.19 |
| 152 | 769064.68 | 3326962.81 | 291.07 |
| 153 | 769032.22 | 3326924.78 | 290.82 |
| 154 | 768998.93 | 3326887.48 | 290.67 |
| 155 | 768965.14 | 3326850.62 | 290.48 |
| 156 | 768931.36 | 3326813.76 | 289.67 |
| 157 | 768896.61 | 3326777.87 | 288.95 |
| 158 | 768859.81 | 3326744.01 | 288.54 |
| 159 | 768823.02 | 3326710.16 | 288.28 |
| 160 | 768786.22 | 3326676.31 | 288.15 |
| 161 | 768746.27 | 3326646.31 | 288.16 |
| 162 | 768705.83 | 3326616.90 | 288.33 |
| 163 | 768665.39 | 3326587.49 | 288.62 |
| 164 | 768624.96 | 3326558.08 | 288.56 |
| 165 | 768584.52 | 3326528.68 | 288.62 |
| 166 | 768550.09 | 3326494.13 | 288.78 |
| 167 | 768527.31 | 3326449.62 | 288.66 |
| 168 | 768504.54 | 3326405.11 | 288.74 |
| 169 | 768481.77 | 3326360.60 | 288.87 |
| 170 | 768458.99 | 3326316.08 | 288.70 |
| 171 | 768442.06 | 3326269.57 | 288.67 |
| 172 | 768432.78 | 3326220.44 | 288.66 |
| 173 | 768423.50 | 3326171.31 | 288.78 |
| 174 | 768402.21 | 3326127.31 | 288.58 |
| 175 | 768373.15 | 3326086.62 | 288.45 |
| 176 | 768346.31 | 3326044.54 | 288.25 |
| 177 | 768322.52 | 3326000.57 | 288.27 |
| 178 | 768298.73 | 3325956.59 | 288.32 |
| 179 | 768270.70 | 3325915.52 | 288.30 |
| 180 | 768238.20 | 3325877.53 | 288.34 |
| 181 | 768206.43 | 3325839.08 | 288.57 |
| 182 | 768186.98 | 3325793.02 | 288.26 |
| 183 | 768167.53 | 3325746.96 | 287.85 |
| 184 | 768148.08 | 3325700.89 | 287.51 |
| 185 | 768128.63 | 3325654.83 | 287.43 |

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| 186 | 768109.18 | 3325608.77 | 287.40 |
| 187 | 768110.66 | 3325559.37 | 287.48 |
| 188 | 768114.81 | 3325509.54 | 287.31 |
| 189 | 768118.96 | 3325459.71 | 287.37 |
| 190 | 768123.12 | 3325409.89 | 287.26 |
| 191 | 768127.27 | 3325360.06 | 287.17 |
| 192 | 768131.17 | 3325310.21 | 286.96 |
| 193 | 768135.00 | 3325260.36 | 286.91 |
| 194 | 768138.84 | 3325210.51 | 286.72 |
| 195 | 768142.67 | 3325160.65 | 286.59 |
| 196 | 768141.08 | 3325110.84 | 286.73 |
| 197 | 768136.55 | 3325061.04 | 286.29 |
| 198 | 768132.03 | 3325011.25 | 286.26 |
| 199 | 768127.50 | 3324961.45 | 286.04 |
| 200 | 768122.97 | 3324911.66 | 286.03 |
| 201 | 768117.10 | 3324862.01 | 285.94 |
| 202 | 768111.19 | 3324812.36 | 285.79 |
| 203 | 768105.28 | 3324762.71 | 285.69 |
| 204 | 768099.37 | 3324713.06 | 285.49 |
| 205 | 768098.46 | 3324663.32 | 285.36 |
| 206 | 768102.62 | 3324613.49 | 285.09 |
| 207 | 768106.78 | 3324563.67 | 284.76 |
| 208 | 768110.94 | 3324513.84 | 284.59 |
| 209 | 768115.10 | 3324464.01 | 284.68 |
| 210 | 768131.74 | 3324417.27 | 284.68 |
| 211 | 768151.27 | 3324371.24 | 284.67 |
| 212 | 768170.80 | 3324325.22 | 284.65 |
| 213 | 768190.33 | 3324279.19 | 284.44 |
| 214 | 768209.86 | 3324233.16 | 284.30 |
| 215 | 768225.97 | 3324186.13 | 284.28 |
| 216 | 768234.37 | 3324136.84 | 284.30 |
| 217 | 768242.77 | 3324087.55 | 284.62 |
| 218 | 768251.16 | 3324038.26 | 284.42 |
| 219 | 768259.56 | 3323988.97 | 285.54 |
| 220 | 768267.96 | 3323939.68 | 285.76 |
| 221 | 768270.03 | 3323889.91 | 285.79 |
| 222 | 768269.17 | 3323839.92 | 285.53 |
| 223 | 768268.31 | 3323789.93 | 285.01 |
| 224 | 768261.56 | 3323740.92 | 284.77 |
| 225 | 768246.08 | 3323693.38 | 284.56 |
| 226 | 768231.74 | 3323645.53 | 284.44 |
| 227 | 768221.48 | 3323596.59 | 284.40 |
| 228 | 768211.22 | 3323547.66 | 284.28 |
| 229 | 768200.96 | 3323498.72 | 283.71 |
| 230 | 768190.70 | 3323449.78 | 283.44 |
| 231 | 768180.44 | 3323400.85 | 283.22 |
| 232 | 768170.18 | 3323351.91 | 283.16 |

| 233 | 768164.38 | 3323302.44 | 283.09 |
|---|---|---|---|
| 234 | 768162.82 | 3323252.47 | 282.97 |
| 235 | 768161.26 | 3323202.49 | 282.84 |
| 236 | 768159.70 | 3323152.52 | 282.62 |
| 237 | 768156.56 | 3323102.62 | 282.39 |
| 238 | 768153.29 | 3323052.72 | 282.29 |
| 239 | 768150.02 | 3323002.83 | 282.21 |
| 240 | 768159.99 | 3322954.53 | 282.14 |
| 241 | 768174.99 | 3322906.83 | 282.00 |
| 242 | 768189.99 | 3322859.14 | 281.88 |
| 243 | 768204.99 | 3322811.44 | 281.73 |
| 244 | 768214.96 | 3322763.01 | 281.61 |
| 245 | 768214.10 | 3322713.02 | 281.52 |
| 246 | 768213.24 | 3322663.03 | 281.49 |
| 247 | 768211.90 | 3322613.10 | 281.26 |
| 248 | 768198.85 | 3322564.84 | 281.04 |
| 249 | 768185.81 | 3322516.57 | 281.02 |
| 250 | 768172.76 | 3322468.30 | 280.97 |
| 251 | 768161.89 | 3322419.51 | 280.86 |
| 252 | 768151.58 | 3322370.58 | 280.74 |
| 253 | 768141.26 | 3322321.66 | 280.67 |
| 254 | 768127.86 | 3322273.76 | 280.61 |
| 255 | 768106.91 | 3322228.36 | 280.57 |
| 256 | 768085.95 | 3322182.96 | 280.51 |
| 257 | 768065.00 | 3322137.57 | 280.44 |
| 258 | 768044.04 | 3322092.17 | 280.36 |
| 259 | 768023.09 | 3322046.77 | 280.30 |
| 260 | 767991.39 | 3322008.88 | 280.23 |
| 261 | 767955.98 | 3321973.58 | 280.21 |
| 262 | 767920.56 | 3321938.29 | 280.20 |
| 263 | 767890.55 | 3321899.70 | 280.19 |
| 264 | 767875.41 | 3321852.05 | 280.10 |
| 265 | 767860.28 | 3321804.39 | 280.09 |
| 266 | 767845.15 | 3321756.74 | 280.06 |
| 267 | 767825.68 | 3321710.80 | 280.21 |
| 268 | 767804.09 | 3321665.70 | 280.18 |
| 269 | 767781.46 | 3321621.13 | 280.25 |
| 270 | 767757.84 | 3321577.06 | 280.33 |
| 271 | 767734.23 | 3321532.99 | 280.33 |
| 272 | 767716.18 | 3321486.85 | 280.43 |
| 273 | 767705.42 | 3321438.03 | 280.35 |
| 274 | 767694.65 | 3321389.20 | 280.14 |
| 275 | 767683.89 | 3321340.37 | 279.97 |
| 276 | 767691.51 | 3321291.71 | 279.78 |
| 277 | 767703.16 | 3321243.09 | 279.70 |
| 278 | 767726.41 | 3321200.65 | 279.69 |
| 279 | 767760.30 | 3321163.88 | 279.89 |

| 280 | 767799.97 | 3321134.24 | 279.87 |
|---|---|---|---|
| 281 | 767842.91 | 3321108.63 | 279.84 |
| 282 | 767887.32 | 3321085.83 | 279.81 |
| 283 | 767932.92 | 3321065.32 | 279.79 |
| 284 | 767980.08 | 3321051.90 | 279.76 |
| 285 | 768030.08 | 3321051.31 | 279.73 |
| 286 | 768080.03 | 3321051.33 | 279.71 |
| 287 | 768129.30 | 3321059.82 | 279.68 |
| 288 | 768178.58 | 3321068.31 | 279.65 |
| 289 | 768226.54 | 3321082.36 | 279.63 |
| 290 | 768274.42 | 3321096.77 | 279.60 |
| 291 | 768322.41 | 3321110.79 | 281.80 |
| 292 | 768372.01 | 3321111.15 | 281.49 |
| 293 | 768421.95 | 3321108.61 | 280.98 |
| 294 | 768471.88 | 3321106.08 | 280.30 |
| 295 | 768521.82 | 3321103.54 | 279.68 |
| 296 | 768571.75 | 3321101.00 | 279.29 |
| 297 | 768621.69 | 3321098.47 | 279.23 |
| 298 | 768671.62 | 3321095.93 | 279.16 |
| 299 | 768721.56 | 3321093.39 | 278.99 |
| 300 | 768771.49 | 3321090.86 | 278.89 |
| 301 | 768821.43 | 3321088.32 | 278.67 |
| 302 | 768870.34 | 3321079.69 | 278.58 |
| 303 | 768918.38 | 3321065.80 | 278.45 |
| 304 | 768966.41 | 3321051.92 | 278.34 |
| 305 | 769014.44 | 3321038.03 | 278.24 |
| 306 | 769060.35 | 3321018.82 | 278.11 |
| 307 | 769104.76 | 3320995.85 | 278.01 |
| 308 | 769149.18 | 3320972.88 | 277.94 |
| 309 | 769193.59 | 3320949.91 | 277.88 |
| 310 | 769237.63 | 3320926.46 | 277.83 |
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| 1060 | 786157.12 | 3296259.55 | 242.42 |
| 1061 | 786187.20 | 3296219.61 | 242.37 |
| 1062 | 786217.29 | 3296179.68 | 242.34 |
| 1063 | 786256.61 | 3296150.63 | 242.29 |
| 1064 | 786300.93 | 3296127.49 | 242.28 |
| 1065 | 786345.25 | 3296104.36 | 242.30 |
| 1066 | 786389.58 | 3296081.22 | 242.26 |
| 1067 | 786433.98 | 3296058.24 | 242.24 |
| 1068 | 786478.59 | 3296035.64 | 242.27 |
| 1069 | 786523.19 | 3296013.05 | 242.34 |
| 1070 | 786566.65 | 3295989.25 | 242.40 |
| 1071 | 786591.68 | 3295945.96 | 242.37 |
| 1072 | 786616.70 | 3295902.67 | 242.31 |
| 1073 | 786641.72 | 3295859.38 | 242.23 |
| 1074 | 786666.74 | 3295816.10 | 242.19 |
| 1075 | 786691.76 | 3295772.81 | 242.20 |
| 1076 | 786716.78 | 3295729.52 | 242.16 |
| 1077 | 786741.80 | 3295686.23 | 242.11 |
| 1078 | 786768.90 | 3295644.29 | 241.98 |

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| 1079 | 786798.40 | 3295603.92 | 241.75 |
| 1080 | 786827.90 | 3295563.55 | 241.63 |
| 1081 | 786857.39 | 3295523.18 | 241.59 |
| 1082 | 786886.89 | 3295482.81 | 241.58 |
| 1083 | 786906.76 | 3295436.96 | 241.55 |
| 1084 | 786926.36 | 3295390.96 | 241.42 |
| 1085 | 786945.97 | 3295344.96 | 241.34 |
| 1086 | 786965.57 | 3295298.97 | 241.30 |
| 1087 | 786978.82 | 3295250.89 | 241.32 |
| 1088 | 786985.42 | 3295202.49 | 241.33 |
| 1089 | 786968.36 | 3295155.49 | 241.32 |
| 1090 | 786950.33 | 3295109.34 | 241.26 |
| 1091 | 786906.16 | 3295085.90 | 241.21 |
| 1092 | 786862.00 | 3295062.46 | 241.21 |
| 1093 | 786816.10 | 3295043.75 | 241.23 |
| 1094 | 786767.23 | 3295033.16 | 241.28 |
| 1095 | 786718.37 | 3295022.58 | 241.21 |
| 1096 | 786669.36 | 3295027.07 | 241.10 |
| 1097 | 786620.31 | 3295036.77 | 240.88 |
| 1098 | 786571.26 | 3295046.47 | 240.77 |
| 1099 | 786522.13 | 3295055.55 | 240.81 |
| 1100 | 786472.26 | 3295059.14 | 240.81 |
| 1101 | 786422.39 | 3295062.74 | 240.85 |
| 1102 | 786372.52 | 3295066.34 | 240.95 |
| 1103 | 786322.64 | 3295066.80 | 241.02 |
| 1104 | 786272.75 | 3295063.52 | 239.60 |
| 1105 | 786222.85 | 3295060.24 | 238.21 |
| 1106 | 786173.32 | 3295053.57 | 240.80 |
| 1107 | 786123.83 | 3295046.41 | 240.81 |
| 1108 | 786076.43 | 3295031.95 | 240.80 |
| 1109 | 786030.64 | 3295011.88 | 240.78 |
| 1110 | 785988.39 | 3294985.39 | 240.80 |
| 1111 | 785950.36 | 3294954.55 | 240.74 |
| 1112 | 785930.29 | 3294908.75 | 239.06 |
| 1113 | 785922.67 | 3294860.60 | 241.33 |
| 1114 | 785924.63 | 3294810.64 | 241.41 |
| 1115 | 785926.60 | 3294760.68 | 241.33 |
| 1116 | 785928.56 | 3294710.72 | 241.23 |
| 1117 | 785930.53 | 3294660.76 | 241.19 |
| 1118 | 785930.73 | 3294610.81 | 241.18 |
| 1119 | 785927.66 | 3294560.91 | 241.17 |
| 1120 | 785904.59 | 3294516.72 | 241.16 |
| 1121 | 785880.49 | 3294472.92 | 241.08 |
| 1122 | 785855.95 | 3294429.36 | 241.04 |
| 1123 | 785824.87 | 3294391.33 | 240.80 |
| 1124 | 785784.10 | 3294363.40 | 240.66 |
| 1125 | 785736.34 | 3294348.61 | 240.56 |

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| 1126 | 785686.71 | 3294349.95 | 240.45 |
| 1127 | 785636.84 | 3294353.47 | 240.26 |
| 1128 | 785587.60 | 3294345.77 | 240.17 |
| 1129 | 785541.92 | 3294330.13 | 240.09 |
| 1130 | 785507.09 | 3294294.26 | 240.10 |
| 1131 | 785477.00 | 3294254.89 | 240.12 |
| 1132 | 785453.05 | 3294211.01 | 240.14 |
| 1133 | 785429.09 | 3294167.12 | 240.14 |
| 1134 | 785404.17 | 3294123.79 | 240.06 |
| 1135 | 785377.94 | 3294081.22 | 240.02 |
| 1136 | 785351.71 | 3294038.65 | 240.06 |
| 1137 | 785325.49 | 3293996.08 | 239.99 |
| 1138 | 785302.77 | 3293951.56 | 240.07 |
| 1139 | 785280.27 | 3293906.90 | 239.92 |
| 1140 | 785257.77 | 3293862.25 | 239.90 |
| 1141 | 785241.56 | 3293815.42 | 239.95 |
| 1142 | 785231.54 | 3293766.43 | 239.91 |
| 1143 | 785213.80 | 3293720.44 | 239.77 |
| 1144 | 785188.17 | 3293677.51 | 239.74 |
| 1145 | 785162.55 | 3293634.57 | 239.72 |
| 1146 | 785147.24 | 3293587.06 | 239.73 |
| 1147 | 785132.89 | 3293539.17 | 239.87 |
| 1148 | 785119.89 | 3293490.89 | 240.08 |
| 1149 | 785106.88 | 3293442.61 | 240.28 |
| 1150 | 785094.56 | 3293394.21 | 240.38 |
| 1151 | 785090.05 | 3293344.42 | 240.34 |
| 1152 | 785086.03 | 3293294.58 | 240.24 |
| 1153 | 785082.70 | 3293244.69 | 240.12 |
| 1154 | 785070.25 | 3293196.37 | 239.97 |
| 1155 | 785056.74 | 3293148.23 | 239.92 |
| 1156 | 785048.86 | 3293098.95 | 239.91 |
| 1157 | 785042.61 | 3293049.34 | 239.95 |
| 1158 | 785032.22 | 3293000.51 | 239.96 |
| 1159 | 785020.09 | 3292952.00 | 239.95 |
| 1160 | 785007.96 | 3292903.50 | 239.95 |
| 1161 | 784995.84 | 3292854.99 | 239.90 |
| 1162 | 784983.71 | 3292806.48 | 239.85 |
| 1163 | 784971.58 | 3292757.98 | 239.70 |
| 1164 | 784957.75 | 3292710.01 | 239.46 |
| 1165 | 784939.69 | 3292663.39 | 239.44 |
| 1166 | 784921.62 | 3292616.76 | 239.60 |
| 1167 | 784903.56 | 3292570.14 | 239.65 |
| 1168 | 784885.49 | 3292523.52 | 239.65 |
| 1169 | 784867.76 | 3292476.79 | 239.66 |
| 1170 | 784856.66 | 3292428.04 | 239.61 |
| 1171 | 784845.56 | 3292379.29 | 239.42 |
| 1172 | 784829.72 | 3292331.99 | 239.20 |

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|---|---|---|---|
| 1173 | 784811.54 | 3292285.42 | 239.02 |
| 1174 | 784793.35 | 3292238.84 | 238.86 |
| 1175 | 784775.16 | 3292192.27 | 238.66 |
| 1176 | 784768.17 | 3292142.81 | 238.54 |
| 1177 | 784756.14 | 3292094.49 | 238.51 |
| 1178 | 784740.63 | 3292046.95 | 238.50 |
| 1179 | 784725.12 | 3291999.42 | 238.42 |
| 1180 | 784709.60 | 3291951.89 | 238.39 |
| 1181 | 784694.09 | 3291904.35 | 238.36 |
| 1182 | 784678.58 | 3291856.82 | 238.33 |
| 1183 | 784663.07 | 3291809.29 | 238.30 |
| 1184 | 784647.56 | 3291761.75 | 238.22 |
| 1185 | 784622.08 | 3291719.90 | 238.19 |
| 1186 | 784589.10 | 3291682.32 | 238.16 |
| 1187 | 784556.11 | 3291644.74 | 238.09 |
| 1188 | 784523.13 | 3291607.16 | 237.98 |
| 1189 | 784485.17 | 3291574.72 | 237.88 |
| 1190 | 784446.59 | 3291542.92 | 237.87 |
| 1191 | 784408.01 | 3291511.11 | 237.88 |
| 1192 | 784370.78 | 3291478.24 | 237.92 |
| 1193 | 784348.58 | 3291433.44 | 237.93 |
| 1194 | 784326.38 | 3291388.63 | 237.96 |
| 1195 | 784304.19 | 3291343.83 | 238.00 |
| 1196 | 784281.99 | 3291299.03 | 238.04 |
| 1197 | 784259.61 | 3291254.32 | 238.08 |
| 1198 | 784237.09 | 3291209.67 | 238.11 |
| 1199 | 784220.55 | 3291162.58 | 238.12 |
| 1200 | 784205.40 | 3291114.94 | 238.13 |
| 1201 | 784193.84 | 3291066.29 | 238.14 |
| 1202 | 784182.81 | 3291017.54 | 238.15 |
| 1203 | 784173.82 | 3290968.35 | 238.14 |
| 1204 | 784166.07 | 3290918.97 | 238.13 |
| 1205 | 784159.51 | 3290869.40 | 238.11 |

| 100 Year HFL Points | | | |
|---|---|---|---|
| S. No. | Left Bank | | |
| | Easting (X) | Northing (Y) | Elevation (m) |
| 1 | 770597.0 | 3332771.8 | 302.24 |
| 2 | 770640.0 | 3332797.3 | 302.18 |
| 3 | 770683.8 | 3332821.2 | 302.16 |
| 4 | 770720.2 | 3332811.3 | 302.25 |
| 5 | 770747.8 | 3332769.6 | 302.25 |
| 6 | 770775.5 | 3332728.0 | 302.14 |
| 7 | 770803.2 | 3332686.3 | 302.00 |
| 8 | 770830.8 | 3332644.7 | 301.91 |
| 9 | 770858.3 | 3332602.9 | 301.87 |
| 10 | 770886.3 | 3332561.5 | 301.97 |
| 11 | 770920.6 | 3332525.1 | 302.24 |
| 12 | 770957.4 | 3332491.5 | 301.95 |
| 13 | 770997.2 | 3332461.3 | 302.39 |
| 14 | 771036.9 | 3332430.9 | 302.54 |
| 15 | 771076.4 | 3332400.3 | 302.57 |
| 16 | 771116.1 | 3332369.8 | 302.51 |
| 17 | 771155.8 | 3332339.5 | 302.58 |
| 18 | 771192.4 | 3332305.5 | 302.56 |
| 19 | 771228.6 | 3332270.9 | 302.57 |
| 20 | 771270.7 | 3332244.1 | 302.43 |
| 21 | 771313.2 | 3332217.7 | 302.16 |
| 22 | 771356.5 | 3332192.7 | 302.08 |
| 23 | 771394.8 | 3332161.5 | 301.83 |
| 24 | 771433.1 | 3332129.7 | 302.24 |
| 25 | 771473.8 | 3332100.7 | 301.40 |
| 26 | 771514.5 | 3332071.6 | 300.51 |
| 27 | 771550.4 | 3332038.1 | 300.34 |
| 28 | 771576.5 | 3331995.5 | 300.33 |
| 29 | 771606.2 | 3331955.3 | 300.80 |
| 30 | 771632.9 | 3331913.2 | 302.16 |
| 31 | 771657.5 | 3331869.6 | 302.74 |
| 32 | 771682.1 | 3331826.1 | 302.59 |
| 33 | 771706.7 | 3331782.6 | 302.68 |
| 34 | 771729.6 | 3331738.1 | 302.69 |
| 35 | 771752.4 | 3331693.6 | 302.81 |
| 36 | 771774.5 | 3331648.8 | 302.85 |
| 37 | 771793.9 | 3331602.7 | 302.81 |
| 38 | 771808.5 | 3331555.0 | 302.64 |
| 39 | 771819.1 | 3331506.2 | 302.71 |
| 40 | 771823.5 | 3331456.4 | 302.13 |
| 41 | 771814.6 | 3331407.3 | 301.52 |
| 42 | 771805.2 | 3331358.2 | 301.30 |
| 43 | 771789.3 | 3331310.9 | 301.96 |
| 44 | 771772.1 | 3331264.0 | 301.43 |

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| 45 | 771754.8 | 3331217.0 | 300.05 |
| 46 | 771726.4 | 3331176.2 | 299.61 |
| 47 | 771696.5 | 3331136.1 | 299.45 |
| 48 | 771666.7 | 3331096.0 | 299.10 |
| 49 | 771628.0 | 3331064.9 | 298.95 |
| 50 | 771587.0 | 3331036.4 | 298.87 |
| 51 | 771546.3 | 3331007.3 | 299.20 |
| 52 | 771506.1 | 3330977.6 | 298.84 |
| 53 | 771462.2 | 3330953.6 | 298.32 |
| 54 | 771418.2 | 3330929.9 | 298.18 |
| 55 | 771374.0 | 3330906.6 | 298.01 |
| 56 | 771327.4 | 3330888.6 | 297.85 |
| 57 | 771280.8 | 3330870.4 | 297.69 |
| 58 | 771234.6 | 3330851.3 | 297.61 |
| 59 | 771188.8 | 3330831.2 | 297.54 |
| 60 | 771144.3 | 3330808.6 | 297.56 |
| 61 | 771099.7 | 3330785.9 | 297.83 |
| 62 | 771055.1 | 3330763.3 | 297.67 |
| 63 | 771011.3 | 3330740.0 | 297.59 |
| 64 | 770966.1 | 3330719.5 | 297.49 |
| 65 | 770919.3 | 3330701.9 | 297.08 |
| 66 | 770872.4 | 3330684.4 | 297.00 |
| 67 | 770830.7 | 3330657.5 | 296.82 |
| 68 | 770790.7 | 3330627.6 | 296.66 |
| 69 | 770749.8 | 3330598.8 | 296.72 |
| 70 | 770706.3 | 3330574.2 | 297.30 |
| 71 | 770669.3 | 3330541.1 | 297.96 |
| 72 | 770634.4 | 3330505.4 | 298.07 |
| 73 | 770600.6 | 3330468.5 | 297.96 |
| 74 | 770568.7 | 3330430.1 | 297.90 |
| 75 | 770536.7 | 3330391.6 | 298.43 |
| 76 | 770504.8 | 3330353.1 | 298.86 |
| 77 | 770471.9 | 3330315.6 | 298.76 |
| 78 | 770434.6 | 3330283.5 | 298.71 |
| 79 | 770431.2 | 3330234.3 | 297.91 |
| 80 | 770429.2 | 3330184.3 | 297.75 |
| 81 | 770427.7 | 3330134.4 | 297.55 |
| 82 | 770439.0 | 3330085.7 | 297.48 |
| 83 | 770450.2 | 3330037.0 | 297.43 |
| 84 | 770467.0 | 3329990.2 | 297.38 |
| 85 | 770501.6 | 3329956.4 | 297.34 |
| 86 | 770550.5 | 3329950.6 | 297.33 |
| 87 | 770599.1 | 3329962.5 | 297.17 |
| 88 | 770643.1 | 3329985.4 | 297.01 |
| 89 | 770685.7 | 3330011.4 | 297.12 |
| 90 | 770735.4 | 3330013.9 | 296.77 |
| 91 | 770785.4 | 3330015.4 | 296.84 |

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| 92 | 770835.4 | 3330016.8 | 296.60 |
| 93 | 770885.3 | 3330018.2 | 296.48 |
| 94 | 770935.1 | 3330015.8 | 296.27 |
| 95 | 770984.7 | 3330009.6 | 295.94 |
| 96 | 771034.4 | 3330003.4 | 294.78 |
| 97 | 771084.0 | 3329997.2 | 294.26 |
| 98 | 771119.2 | 3329962.8 | 293.98 |
| 99 | 771153.2 | 3329926.2 | 293.84 |
| 100 | 771187.3 | 3329889.6 | 293.68 |
| 101 | 771217.8 | 3329850.9 | 293.50 |
| 102 | 771233.8 | 3329803.5 | 293.28 |
| 103 | 771249.9 | 3329756.2 | 293.10 |
| 104 | 771265.9 | 3329708.8 | 292.90 |
| 105 | 771281.9 | 3329661.4 | 292.68 |
| 106 | 771281.4 | 3329613.0 | 292.49 |
| 107 | 771271.6 | 3329564.0 | 292.32 |
| 108 | 771261.8 | 3329514.9 | 292.16 |
| 109 | 771251.3 | 3329466.1 | 292.02 |
| 110 | 771231.7 | 3329420.1 | 291.91 |
| 111 | 771212.2 | 3329374.1 | 291.82 |
| 112 | 771192.3 | 3329328.2 | 291.72 |
| 113 | 771171.6 | 3329282.7 | 291.63 |
| 114 | 771150.9 | 3329237.2 | 291.56 |
| 115 | 771130.2 | 3329191.7 | 291.51 |
| 116 | 771109.5 | 3329146.2 | 291.46 |
| 117 | 771090.7 | 3329099.9 | 291.40 |
| 118 | 771072.7 | 3329053.2 | 291.31 |
| 119 | 771054.7 | 3329006.6 | 291.20 |
| 120 | 771036.7 | 3328959.9 | 291.09 |
| 121 | 771018.8 | 3328913.3 | 290.98 |
| 122 | 770999.2 | 3328867.2 | 290.88 |
| 123 | 770979.7 | 3328821.2 | 290.80 |
| 124 | 770960.1 | 3328775.2 | 290.74 |
| 125 | 770940.5 | 3328729.2 | 290.71 |
| 126 | 770917.2 | 3328685.0 | 290.75 |
| 127 | 770893.5 | 3328640.9 | 290.69 |
| 128 | 770868.9 | 3328597.4 | 290.69 |
| 129 | 770844.3 | 3328553.9 | 290.63 |
| 130 | 770815.0 | 3328513.4 | 290.60 |
| 131 | 770785.5 | 3328473.0 | 290.60 |
| 132 | 770749.7 | 3328438.7 | 290.63 |
| 133 | 770709.7 | 3328408.8 | 290.50 |
| 134 | 770666.6 | 3328383.6 | 290.41 |
| 135 | 770621.7 | 3328361.9 | 290.31 |
| 136 | 770575.1 | 3328343.6 | 290.13 |
| 137 | 770534.9 | 3328316.7 | 289.98 |
| 138 | 770503.2 | 3328278.0 | 289.87 |

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| 139 | 770471.6 | 3328239.3 | 289.78 |
| 140 | 770441.2 | 3328199.6 | 289.77 |
| 141 | 770411.8 | 3328159.2 | 289.89 |
| 142 | 770382.4 | 3328118.8 | 290.54 |
| 143 | 770352.9 | 3328078.3 | 291.00 |
| 144 | 770323.5 | 3328037.9 | 291.05 |
| 145 | 770292.9 | 3327998.5 | 291.23 |
| 146 | 770258.0 | 3327962.7 | 291.20 |
| 147 | 770223.1 | 3327926.9 | 291.25 |
| 148 | 770188.1 | 3327891.2 | 290.90 |
| 149 | 770151.6 | 3327857.0 | 290.69 |
| 150 | 770121.4 | 3327817.8 | 290.87 |
| 151 | 770096.8 | 3327774.3 | 291.19 |
| 152 | 770080.1 | 3327727.2 | 291.07 |
| 153 | 770079.8 | 3327678.1 | 290.82 |
| 154 | 770074.3 | 3327629.2 | 290.67 |
| 155 | 770058.0 | 3327582.2 | 290.48 |
| 156 | 770034.1 | 3327538.3 | 289.67 |
| 157 | 770010.1 | 3327494.4 | 288.95 |
| 158 | 769985.8 | 3327450.7 | 288.54 |
| 159 | 769961.1 | 3327407.3 | 288.28 |
| 160 | 769936.4 | 3327363.8 | 288.15 |
| 161 | 769911.6 | 3327320.4 | 288.16 |
| 162 | 769886.9 | 3327276.9 | 288.33 |
| 163 | 769856.9 | 3327237.0 | 288.62 |
| 164 | 769826.2 | 3327197.5 | 288.56 |
| 165 | 769795.4 | 3327158.1 | 288.62 |
| 166 | 769764.6 | 3327118.7 | 288.78 |
| 167 | 769733.9 | 3327079.3 | 288.66 |
| 168 | 769704.8 | 3327038.7 | 288.74 |
| 169 | 769676.8 | 3326997.2 | 288.87 |
| 170 | 769648.8 | 3326955.8 | 288.70 |
| 171 | 769620.9 | 3326914.3 | 288.67 |
| 172 | 769592.9 | 3326872.9 | 288.66 |
| 173 | 769566.4 | 3326830.6 | 288.78 |
| 174 | 769542.8 | 3326786.5 | 288.58 |
| 175 | 769519.2 | 3326742.4 | 288.45 |
| 176 | 769495.6 | 3326698.3 | 288.25 |
| 177 | 769472.0 | 3326654.2 | 288.27 |
| 178 | 769443.6 | 3326613.9 | 288.32 |
| 179 | 769406.6 | 3326580.2 | 288.30 |
| 180 | 769369.6 | 3326546.6 | 288.34 |
| 181 | 769365.6 | 3326498.6 | 288.57 |
| 182 | 769366.3 | 3326448.6 | 288.26 |
| 183 | 769366.9 | 3326398.6 | 287.85 |
| 184 | 769367.6 | 3326348.6 | 287.51 |
| 185 | 769368.4 | 3326298.6 | 287.43 |

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| 186 | 769371.7 | 3326248.8 | 287.40 |
| 187 | 769375.0 | 3326198.9 | 287.48 |
| 188 | 769378.3 | 3326149.0 | 287.31 |
| 189 | 769394.4 | 3326103.3 | 287.37 |
| 190 | 769421.4 | 3326061.2 | 287.26 |
| 191 | 769423.9 | 3326015.5 | 287.17 |
| 192 | 769410.5 | 3325967.3 | 286.96 |
| 193 | 769397.0 | 3325919.2 | 286.91 |
| 194 | 769383.6 | 3325871.0 | 286.72 |
| 195 | 769370.1 | 3325822.9 | 286.59 |
| 196 | 769357.9 | 3325774.4 | 286.73 |
| 197 | 769346.0 | 3325725.8 | 286.29 |
| 198 | 769334.2 | 3325677.2 | 286.26 |
| 199 | 769322.4 | 3325628.6 | 286.04 |
| 200 | 769311.7 | 3325579.8 | 286.03 |
| 201 | 769301.3 | 3325530.9 | 285.94 |
| 202 | 769295.1 | 3325481.5 | 285.79 |
| 203 | 769293.4 | 3325431.5 | 285.69 |
| 204 | 769292.5 | 3325381.6 | 285.49 |
| 205 | 769296.1 | 3325331.7 | 285.36 |
| 206 | 769298.2 | 3325281.7 | 285.09 |
| 207 | 769285.2 | 3325235.5 | 284.76 |
| 208 | 769259.0 | 3325193.0 | 284.59 |
| 209 | 769233.1 | 3325150.2 | 284.68 |
| 210 | 769207.9 | 3325107.1 | 284.68 |
| 211 | 769182.8 | 3325063.8 | 284.67 |
| 212 | 769158.6 | 3325020.0 | 284.65 |
| 213 | 769134.5 | 3324976.3 | 284.44 |
| 214 | 769110.5 | 3324932.4 | 284.30 |
| 215 | 769086.9 | 3324888.3 | 284.28 |
| 216 | 769063.3 | 3324844.2 | 284.30 |
| 217 | 769036.2 | 3324802.2 | 284.62 |
| 218 | 769008.5 | 3324760.6 | 284.42 |
| 219 | 768980.7 | 3324719.0 | 285.54 |
| 220 | 768944.1 | 3324685.0 | 285.76 |
| 221 | 768907.4 | 3324651.0 | 285.79 |
| 222 | 768870.7 | 3324617.1 | 285.53 |
| 223 | 768834.0 | 3324583.1 | 285.01 |
| 224 | 768797.3 | 3324549.2 | 284.77 |
| 225 | 768760.6 | 3324515.2 | 284.56 |
| 226 | 768726.2 | 3324479.0 | 284.44 |
| 227 | 768692.9 | 3324441.7 | 284.40 |
| 228 | 768659.7 | 3324404.4 | 284.28 |
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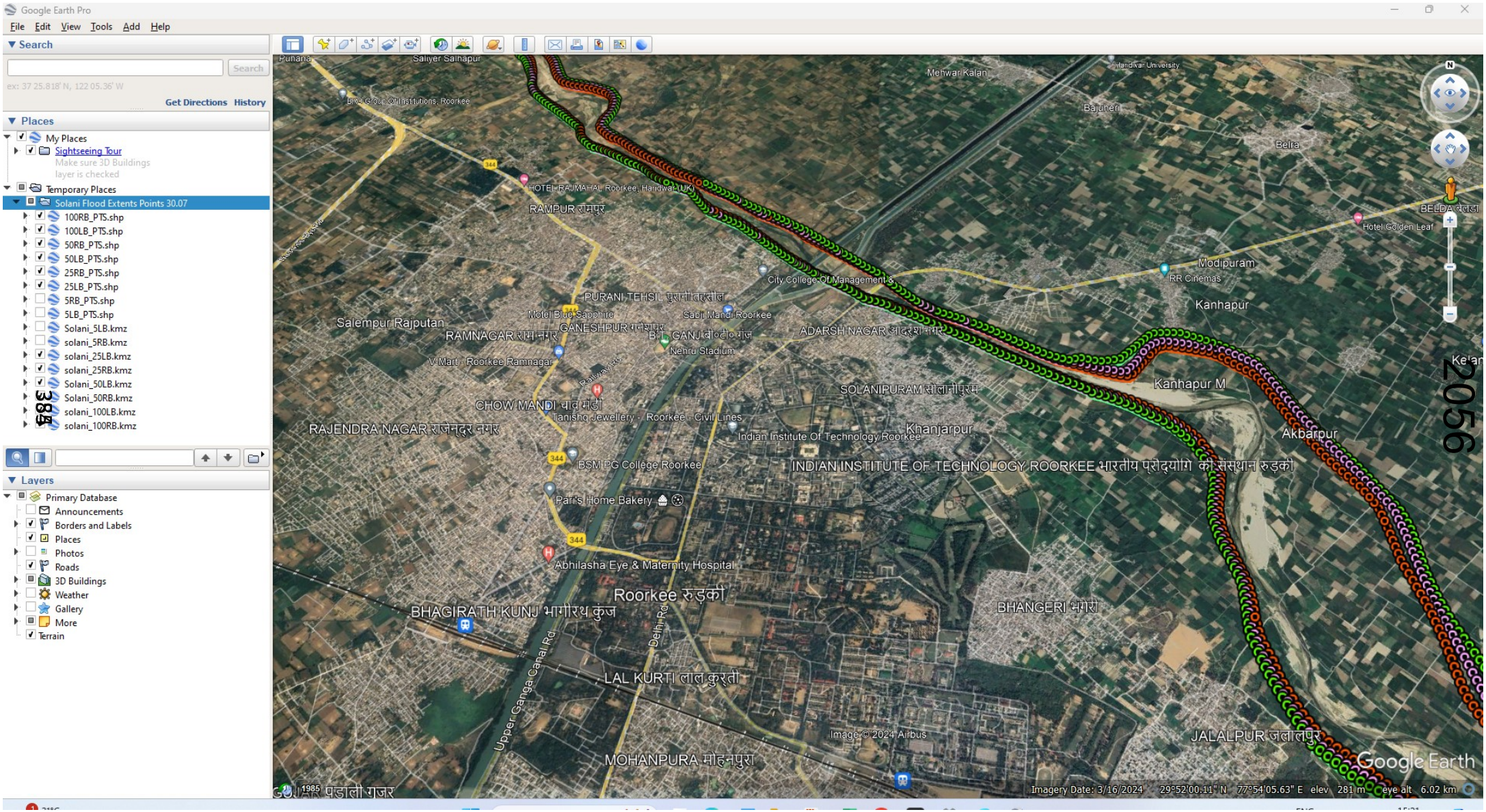
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RAMPUR रामपुर
Hotel Golden Leaf
Modipuram
RR Cinemas
City College Of Management &
PURANI TEHSIL पुरानी तहसील
Motel Blue Sapphire
Sabri Mand, Roorkee
Salempur Rajputan
RAMNAGAR राम नगर
GANESHPUR गणेशपुर
GANJ गंज
ADARSH NAGAR आदर्श नगर
Nehru Stadium
V Mart - Roorkee Ramnagar
Kanhapur
Kanhapur M
SOLANIPURAM सोलानीपुरम
CHOW MANDI चौक मंडी
Tanishq Jewellery - Roorkee - Civil Lines
RAJENDRA NAGAR राजेन्द्र नगर
Indian Institute Of Technology Roorkee
Khanjarpur
Akbarpur
BSM PG College Roorkee
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE भारतीय प्रोद्योगिकी संस्थान रुड़की
Paris Home Bakery
Abhilasha Eye & Maternity Hospital
Roorkee रुड़की
BHAGIRATH KUNJ भागीरथ कुंज
BHANGERI भंगेरी
Delhi Rd
Upper Ganga Canal Rd
LAL KURTI लाल कुर्ती
Image © 2024 Airbus
JALALPUR जलालपुर
MOHANPURA मोहनपुरा
GUJAR पडाली गुजर
Google Earth
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Annexure No. 3

Annexure-2

कार्यालय अधिशासी अभियन्ता
उत्तरी खण्ड गंगा नहर, रुड़की

पत्रांकः— 1932 /उखगनरू/एस0टी0पी0, दिनांकः रुड़की: 21/08/ 2024

विषयः— मा0 नेशनल ग्रीन ट्रिब्यूनल (ए0जी0टी0) मे योजित मूल आवेदन संख्या— 632/2022 वी0के0 त्यागी बनाम उत्तराखण्ड राज्य व अन्य में पारित आदेश दिनांक 30.04.2024 के द्वारा उपजिलाधिकारी, रुड़की द्वारा दिनांक 12.06.2024 को एक आहूत बैठक में बिन्दुवार आख्या के सम्बन्ध में।

## क्षेत्रीय प्रदूषण नियन्त्रण अधिकारी, रुड़की।

उक्त आहूत बैठक के कम में प्रश्नगत प्रकरण के अन्तर्गत इस खण्ड से सम्बन्धित बिन्दुओ पर आख्या निम्नवत् हैः—

1. सोलानी नदी का फ्लड प्लेन क्षेत्र का निर्धारण कार्य जल विज्ञान खण्ड, बहादराबाद द्वारा किया जा रहा है फ्लड प्लेन जोन निर्धारण के उपरान्त एस0पी0एस0 हेतु अनापत्ति की कार्यवाही की जायेगी।
2. सिंचाई विभाग, उ0प्र0 का नियन्त्रण सोलानी नदी में सोलानी एक्वाडक्ट से 1000 मी0 अपस्ट्रीम एवं 500 मी0 डाउनस्ट्रीम पर है शेष सोलानी नदी का भाग जनपद हरिद्वार, उत्तराखण्ड में पडता है, उदगम स्थल से उत्तराखण्ड राज्य में पडने वाली सोलानी नदी के भाग का बाढ परिक्षेत्रण निर्धारण का कार्य जल विज्ञान खण्ड, बहादराबाद द्वारा किया जा रहा है।
3. उत्तरी खण्ड गंगा नहर के नियन्त्रणाधीन सोलानी नदी के क्षेत्र में किसी प्रकार का कोई स्थाई अतिक्रमण नही है कृषि कार्य हेतु पट्टे आवन्टित किये गये थे जिनको निरस्त करने के उपरान्त मौके से अतिक्रमण हटा दिया गया था वर्तमान में किसी प्रकार का कोई अतिक्रमण नही है।
4. सोलनी नदी में मिलने वाले 07 ड्रेन जोकि घरेलू अशुद्धिकृत उतप्रवाह को carry करते है यह सभी ड्रेन नगर निगम क्षेत्र रूडकी के अन्तर्गत पडने के कारण सभी नालों का रख—रखाव नगर निगम, रूडकी द्वारा किया जाता है जिस पर नाला टैपिंग आदि कार्यो की अनापत्ति हेतु यथाप्रस्ताव कार्यवाही कर दी जाये।

कृपया उक्तानुसार कार्यवाही करने का कष्ट करें।

अधिशासी अभियन्ता
उत्तरी खण्ड गंगा नहर
रुड़की

पत्रांकः— /उखगनरू/एस0टी0पी0, तदिनांकः

प्रतिलिपि निम्नलिखित को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित हैः—

1. अधीक्षण अभियन्ता, गंगा नहर संचालन मण्डल, मेरठ।
2. ज्वाइंट मजिस्ट्रेट, रुड़की।
3. सहायक अभियन्ता—तृतीय/उपराजस्व अधिकारी, उत्तरी खण्ड गंगा नहर, रुड़की।
4. कोर्ट अनुभाग, उत्तरी खण्ड गंगा नहर, रुड़की।

अधिशासी अभियन्ता
उत्तरी खण्ड गंगा नहर
रुड़की

2058

Annexure No. 4

# उत्तर प्रदेश सरकार
## सिंचाई एवं जल संसाधन विभाग


कार्यालय अधिशासी अभियन्ता
Office of The Executive Engineer
उत्तरी खण्ड गंगा नहर, रूडकी
Northern Division Ganga Canal, Roorkee

गंगोत्री भवन कैम्पस, मलकपुर चुँगी, रूडकी
Gangotri Bhavan Campus, Malakpur
Chungi, Roorkee-247667
E.mail:- eendgcrke@gmail.com


पत्रांक 1859 /उखगनरू/अनापत्ति, दिनांक 27/07/2024

**विषयः— माननीय राष्ट्रीय हरित प्रधिकरण में योजित मूल आवेदन संख्या— 632/2022 वी0के0 त्यागी बनाम उत्तराखण्ड राज्य व अन्य में पारित आदेश दिनांक 30.04.2024 के अनुपालन के सम्बन्ध में।**

**सन्दर्भः— आपका पत्रांक 1759/कार्य—25/21, दिनांक 15.06.2024**

**परियोजना प्रबन्धक, निर्माण एवं अनुरक्षण इकाई (गंगा), उत्तराखण्ड पेयजल निगम, जगजीतपुर, पोस्ट—कनखल, हरिद्वार—249408**

उपरोक्त विषयक सन्दर्भित पत्र का अवलोकन करें। माननीय राष्ट्रीय हरित प्राधिकरण में योजित मूल आवेदन संख्या 632/2022 वी0के0 त्यागी बनाम उत्तराखण्ड राज्य व अन्य में पारित आदेश दिनांक 30.04.2024 के अनुपालन एवं ज्वाइन्ट मजिस्ट्रेट महोदय, हरिद्वार के पत्रांक 328/पी0ए0, दिनांक 13.06.2024 के कार्यवृत्त के बिन्दु संख्या 04 के अनुपालन में नगर निगम, रूडकी, सिंचाई खण्ड रूडकी (उत्तराखण्ड), उत्तराखण्ड पेयजल निगम, राजस्व विभाग, रूडकी एवं इस खण्ड के अधिकारियों/कर्मचारियों द्वारा रूडकी स्थिल सोलानी नदी में गिरने वाले नालों के टैपिंग, एस0पी0एस0, सीवर लाईन एवं राईजिंग मेन बिछाने हेतु संयुक्त निरीक्षण उपरान्त चिन्हित की गई भूमि का विवरण उपलब्ध कराते हुये विषयगत कार्यों हेतु भूमि को निःशुल्क उपलब्ध कराने हेतु इस कार्यालय को पत्र प्रेषित किया गया है।

इस सम्बन्ध में अवगत कराना है कि एन0जी0टी0 के मूल आवेदन संख्या—632/2022 के अन्तर्गत दिये गये निर्देशों के अनुपालन में सिंचाई विभाग, उत्तर प्रदेश एवं उत्तराखण्ड द्वारा सोलानी नदी के फ्लड प्लेन जोन का निर्धारण उपरान्त निर्देशित मानकों के आलोक में विषयगत भूमि पर अनापत्ति/अनुमति सम्बन्धित कार्यवाही किया जाना सम्भव हो सकेगा।

अधिशासी अभियन्ता
उत्तरी खण्ड गंगा नहर
रूड़की

पत्रांक /उखगनरू/तदिनांक 2024

प्रतिलिपि निम्नलिखित को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित हैः—

1. जिलाधिकारी महोदय, हरिद्वार।
2. ज्वाइन्ट मजिस्ट्रेट महोदय, रूडकी।
3. अधीक्षण अभियन्ता, मध्य गंगा नहर निर्माण मण्डल, रूडकी।

कार्यालय परियोजना प्रबन्धक, निर्माण एवं अनुरक्षण
इकाई (गंगा), उत्तराखण्ड पेयजल निगम, हरिद्वार
पत्रांक 2210/4/14-25/29 दिनांक 2/8/24
प्रतिलिपि: 1 Ex. P.S. Bisht PE dorse

अधिशासी अभियन्ता
उत्तरी खण्ड गंगा नहर
रूड़की

02/08/24

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Annexure No. 5

## UTTARAKHAND POLLUTION CONTROL BOARD, REGIONAL OFFICE, ROORKEE

### Surface Water Quality of D/s River Solani near U/s of Village Kuankhera, Haridwar for year 2023 and 2024

| Month | Colour | Odour | Temperature (°C) | pH | TDS (mg/l) | EC (µS/cm) | DO (mg/l) | Chloride (mg/l) | Hardness (mg/l) | Calcium Hardness (mg/l) | Magnesium Hardness (mg/l) | Alkalinity (mg/l) | BOD (mg/l) 27°C for 3 days | COD (mg/l) | TC (MPN/100 ml) | FC (MPN/100 ml) | FS (MPN/100 ml) | Nitrate-N (mg/l) | Nitrite-N(mg/l) | Sulphate (mg/l) | Phosphate (mg/l) | Fluoride (mg/l) | Sodium (mg/l) | Potassium (mg/l) | SAR | Class of Water as per CPCB Designated Best Use |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **02-Jan-23** | Colourless | Odourless | 13.4 | 7.71 | 561 | 878 | 7.2 | 35 | 237 | 199 | 38 | 218 | 2.2 | 12 | 84 | 25 | 14 | 0.53 | 0.01 | 29.22 | 0.26 | 0.97 | 30.3 | 7.9 | 0.86 | Class-B |
| **07-Feb-23** | Colourless | Odourless | 19.2 | 8.10 | 472 | 737 | 6.2 | 30 | 140 | 88 | 52 | 204 | 2.0 | 15 | 94 | 58 | 21 | 0.55 | 0.02 | 25.8 | 0.30 | 0.55 | 28.6 | 6.6 | 1.04 | Class-B |
| **03-Mar-23** | Colourless | Odourless | 22.7 | 7.95 | 324 | 506 | 6.2 | 24 | 266 | 152 | 114 | 252 | 1.8 | 10 | 110 | 63 | 33 | 1.01 | 0.64 | 22.48 | 0.12 | 0.68 | 35.4 | 10 | 0.94 | Class-B |
| **13-Apr-23** | Colourless | Odourless | 22.0 | 8.00 | 315 | 492 | 7.8 | 22.0 | 271 | 150 | 121 | 244 | 2.0 | 8.3 | 84 | 49 | 17 | 0.52 | 0.03 | 22.6 | 0.34 | 0.54 | 30.8 | 9.6 | 0.81 | Class-B |
| **12-May-23** | Colourless | Odourless | 25.4 | 7.68 | 308 | 481 | 7.4 | 18.0 | 186 | 56 | 130 | 110 | 2.4 | 7 | 79 | 26 | 17 | 0.49 | 0.31 | 35.98 | 0.59 | 0.55 | 9.1 | 2.6 | 0.29 | Class-B |
| **21-Jun-23** | Turbid | Odourless | 22.1 | 8.10 | 277 | 432 | 7.6 | 20 | 280 | 145 | 135 | 120 | 2.1 | 8.4 | 110 | 32 | 14 | 0.76 | 0.31 | 27.27 | 0.13 | 0.70 | 31.2 | 9.4 | 0.81 | Class-B |
| **04-Jul-23** | Turbid | Odourless | 32.3 | 7.79 | 513 | 802 | 5.8 | 18 | 92 | 52 | 40 | 142 | 2.8 | 16 | 170 | 79 | 63 | 0.34 | 0.18 | 36.45 | 0.36 | 0.29 | 33.2 | 13.3 | 1.50 | Class-B |
| **19-Aug-23** | Turbid | Odourless | 24 | 7.52 | 198 | 312 | 6.5 | 16 | 115 | 62 | 53 | 138 | 2.6 | 10 | 150 | 41 | 27 | 0.64 | 0.28 | 32.45 | 0.47 | 0.49 | 28.6 | 11.3 | 1.16 | Class-B |
| **05-Sep-23** | Turbid | Odourless | 28.0 | 7.67 | 512 | 800 | 7.6 | 10 | 196 | 114 | 82 | 130 | 2.0 | 9 | 130 | 43 | 22 | 0.32 | 0.12 | 35.9 | 0.27 | 0.25 | 27.9 | 6.0 | 0.86 | Class-B |
| **05-Oct-23** | Turbid | Odourless | 27.3 | 7.90 | 210 | 328 | 6.0 | 16 | 322 | 215 | 107 | 340 | 2.8 | 12 | 110 | 46 | 17 | 1.75 | 0.32 | 30.21 | 0.15 | 0.72 | 20.1 | 9.6 | 0.49 | Class-B |
| **01-Nov-23** | Turbid | Odourless | 24.7 | 7.21 | 201 | 315 | 6.8 | 14 | 197 | 124 | 73 | 219 | 2.2 | 10 | 94 | 70 | 9.3 | 0.59 | 0.32 | 35.66 | 0.51 | 0.62 | 25.0 | 16.0 | 0.77 | Class-B |
| **04-Dec-23** | Colourless | Odourless | 20.6 | 8.04 | 200 | 313 | 7.8 | 12 | 225 | 110 | 115 | 185 | 1.8 | 16 | 120 | 70 | 9.2 | 0.99 | 0.33 | 29.41 | 0.16 | 0.68 | 21.0 | 10.1 | 0.61 | Class-B |
| **02-Jan-24** | Colourless | Odourless | 20.4 | 7.10 | 455 | 712 | 7.9 | 13 | 189 | 93 | 96 | 167 | 1.2 | 16 | 120 | 94 | 14 | 0.59 | 0.22 | 32.89 | 0.29 | 0.43 | 17.8 | 4.5 | 0.56 | Class-B |
| **06-Feb-24** | Colourless | Odourless | 16.5 | 7.60 | 320 | 500 | 7.8 | 14 | 200 | 102 | 98 | 175 | 2.2 | 20 | 110 | 79 | 17 | 0.99 | 0.33 | 33.54 | 0.18 | 0.48 | 18.6 | 11.2 | 0.57 | Class-B |
| **04-Mar-24** | Turbid | Odourless | 20.6 | 8.10 | 307 | 480 | 7.6 | 11 | 206 | 98 | 108 | 209 | 2.0 | 9 | 150 | 94 | 14 | 0.69 | 0.37 | 38.54 | 0.58 | 0.58 | 18.1 | 9.3 | 0.55 | Class-B |
| **04-Apr-24** | Colourless | Odourless | 20.0 | 7.20 | 310 | 484 | 7.8 | 16 | 160 | 75 | 85 | 173 | 2.0 | 14 | 120 | 84 | 7.8 | 0.59 | 0.35 | 34.57 | 0.22 | 0.48 | 30.8 | 8.7 | 1.05 | Class-B |
| **06-May-24** | Colourless | Odourless | 22.0 | 7.30 | 250 | 390 | 7.6 | 13 | 160 | 78 | 82 | 188 | 2.4 | 16 | 170 | 79 | 9.3 | 0.58 | 0.38 | 35.57 | 0.62 | 0.58 | 25.8 | 12.7 | 0.88 | Class-B |
| **13-Jun-24** | Turbid | Odourless | 21.5 | 7.15 | 350 | 547 | 7.6 | 14 | 190 | 100 | 90 | 170 | 2.6 | 18 | 220 | 140 | 9.3 | 0.74 | 0.33 | 33.54 | 0.61 | 0.5 | 18.4 | 10.8 | 0.58 | Class-B |
| **Acceptable limits (AL)/ Permissible limits (PL)** | | | | **(6.5-8.5)/ No relaxation** | 500/ 2000 (mg/l) | | **5 mg/l or more** | **250/1000 (mg/l)** | **200/600 (mg/l)** | | | **200/600 (mg/l)** | **3 mg/l or less** | | **500 or less** | | | **(45 mg/l)/no relaxation** | | **200/400 (mg/l)** | | **1.0/1.5 (mg/l)** | | | | |

Annexure No. 6

**UTTARAKHAND POLLUTION CONTROL BOARD, REGIONAL OFFICE, ROORKEE**

**Performance monitoring of data of 33 MLD capacity STP located at Saliyar (Roorkee) from January, 2023 to June, 2024**

| 33 MLD, Saliyar, Roorkee | INLET | | | OUTLET | | | |
|---|---|---|---|---|---|---|---|
| | pH | BOD (mg/L) | TSS (mg/L) | pH | BOD (mg/L) | TSS (mg/L) | Fecal Coliform (MPN/100 ml) |
| **Jan-23** | 7.70 | 225 | 206 | 7.60 | 86 | 96 | >1600 |
| **Feb-23** | 7.56 | 175 | 265 | 7.76 | 24 | 52 | 110 |
| **Mar-23** | 7.31 | 255 | 280 | 7.62 | 10 | 50 | 220 |
| **Apr-23** | 7.49 | 255 | 295 | 7.67 | 22 | 78 | 170 |
| **May-23** | 7.90 | 235 | 210 | 7.98 | 12 | 20 | 110 |
| **Jun-23** | 7.53 | 275 | 250 | 7.81 | 40 | 62 | 920 |
| **Jul-23** | 7.64 | 220 | 240 | 7.82 | 24 | 30 | 920 |
| **Aug-23** | 7.23 | 170 | 320 | 7.56 | 26 | 20 | 280 |
| **Sep-23** | 7.32 | 210 | 220 | 7.88 | 14 | 26 | 84 |
| **Sep-23** | 7.12 | 120 | 360 | 7.58 | 16 | 20 | 220 |
| | **Joint monitoring with Uttarakhand Jal Sansthan** | | | | | | |
| **Oct-23** | 7.23 | 255 | 260 | 7.68 | 28 | 30 | 1600 |
| **Nov-23** | 7.39 | 180 | 210 | 7.68 | 12 | 16 | 280 |
| **Dec-23** | 6.59 | 170 | 210 | 7.28 | 18.0 | 28.0 | 220 |
| **Jan-24** | 7.19 | 160 | 190 | 7.66 | 12.0 | 20.0 | 170 |
| **Feb-24** | 7.15 | 160 | 120 | 7.66 | 10.0 | 10.0 | 220 |
| **Mar-24** | 7.20 | 160 | 180 | 7.60 | 8.0 | 9.0 | 280 |
| **Apr-24** | 6.70 | 180 | 140 | 7.70 | 10.0 | 10.0 | 540 |
| **May-24** | 7.27 | 170 | 160 | 7.40 | 10.0 | 9.0 | 350 |
| **Jun-24** | 7.03 | 160 | 140 | 7.56 | 9.6 | 8.0 | 280 |
| **Prescribed Outlet Standards as per Hon'ble NGT** | | | | **5.5-9.0** | **<10** | **<20** | **<230** |
| **Prescribed Outlet Standards as per MoEF&CC under E(P) Rules, 1986** | | | | **6.5-9.0** | **<30** | **<100** | **<1000** |

Annexure No. 7

**Minutes of the Meeting held on 26.07.2024 in compliance of order dated 30.04.2024 passed by the Hon'ble National Green Tribunal in the matter of O.A. No. 632 of 2022 titled as "VK Tyagi Versus State of Uttarakhand & Ors."**

In compliance of order passed by the Hon'ble NGT in the matter of O.A. No 632 of 2022 titled as "VK Tyagi Versus State of Uttarakhand & Ors.", review meeting was held with the members of Joint Committee under the Chairmanship of Member Secretary, Uttarakhand Pollution Control Board, Dehradun on 26.07.2024. Following official and nominated members were participated the meeting virtually:

i) Dr. Y.R.S. Rao, Scientist 'G', National Institute of Hydrology, Roorkee.
ii) Dr. Pradeep Sachan, Scientist 'E', National Institute of Hydrology.
iii) Shri G.P. Srivastava, Chief Engineer - Ganga, UP Irrigation Department, Meerut.
iv) Shri Vipin Gupta, Scientist 'B', MoEFCC, Regional Office, Dehradun.
v) Shri Sanjeev Kumar Srivastava, Superintendent Engineer, Uttarakhand Irrigation Department, Dehradun.
vi) Shri P.L Nautiyal, Executive engineer, Irrigation department, Uttarakhand.
vii) Shri Vikas Tyagi, Executive Engineer, UP Irrigation Department, Roorkee.
viii) Shri Ankit Singh, Regional Officer, Uttar Pradesh Pollution Control Board, Regional Office, Muzaffarnagar.
ix) Shri Raman Kant, Grassroot Academy of Nature, Meerut (Non-Official Member).
x) Shri Vineet Kashyap, Development Researcher, New Delhi (Non-Official Member).
xi) Shri S.P. Singh, Regional Officer, Uttarakhand Pollution Control Board, Regional Office, Roorkee.
xii) Dr. Rajendra Singh, Scientific Officer, Uttarakhand Pollution Control Board, Dehradun.
xiii) Ms. Swati Kalra, JRF, Uttarakhand Pollution Control Board, Regional Office, Roorkee.

1. The Member Secretary, UKPCB welcomed all members of the Joint Committee and outlined the objectives of the meeting. With permission of Chair, Dr. Rajendra Singh, Scientific Officer, UKPCB briefed the background of application and latest order issued by the Hon'ble NGT. He informed that complaint was regarding encroachment in the river bed of Solani for cultivation which aversely affecting the flow of river. Discharge of polluted drains in to river Solani at Roorkee is also reported. These activities are having adverse impact on ecology of river Solani. Further, Hon'ble NGT constituted the Joint Committee for preparation of report for restoration of Ecology & aquatic life and in particular issues of:

O/C

i) Identification /demarcation of area of Sonali River and its translation on GIS Map;
ii) Rehabilitation and management of its catchment area;
iii) encroachments on the same and removal thereof;
iv) Tapping of all drains discharging in river Sonali by construction of STPs etc.;
v) Review of existing treatment facilities for treatment of industrial effluents and domestic sewage and improvements required to be made; and
vi) Reuse of treated water from STPs/CETPs for irrigation by connecting the same to irrigation canals/channels and industrial purposes by laying down pipelines connecting the concerned industries.

2. Member Secretary, UKPCB informed that the river Solani is non-perennial river and after receiving discharge of river Ratmao at downstream of Roorkee, flow is increase in river Solani. It was also informed that water quality monitoring of river Solani at Village Kuankheda is being carried out by Uttarakhand Pollution Control Board and analysis reports indicating Class "B" water quality as per CPCB's Water Quality Criteria. Further, Member Secretary invited the comments and progress made so far by the concerned departments in order to achieve the mandate of the Committee.

3. Shri P.L. Nautiyal, Executive Engineer, Uttarakhand Irrigation Department informed that for Flood Plain Zoning of river Solani, hydrological study with estimation of catchment area of river Solani has been completed and ground truthing is being done, which is expected to be completed by August, 2024. GIS map with demarcation of river Solani is now available and will be shared in KML format.

4. Shri Sanjeev Srivastava, Superintendent Engineer, Uttarakhand Irrigation Department stated that so far removal of encroachment on the bank of river Solani and rehabilitation is concerned, Irrigation Department has very limited role and same can be done by Administration /Nagar Nigam. Therefore, Members from District Administration and Nagar Nigam may be invited for meetings of the Joint Committee.

5. It was informed that there are 7 drains, having cumulative discharge of 5.43 MLD, have been identified and Uttarakhand Peyjal Nigam and prepared a proposal for Interception and Diversion (I&D) of these drains. It is proposed to divert these drains to STP of 33 MLD capacity located at Saliyar, Roorkee. Land required for I&Ds and SPS needs to be allotted by the Uttar Pradesh Irrigation department. Shri Vikas Tyagi, Executive Engineer, Uttar Pradesh Irrigation Department informed that proposal if any in this regard will be considered positively after establishing of status of HFL.

6. During the meeting it was informed that as such river Solani do not receive industrial effluent discharge from industries located in the catchment area. However, STP located at Saliyar discharge treated water in to river Solani.

O/C

Regional Officer, UPPCB, Muzaffarnagar also stated that no domestic and industrial waste water is discharge into river Solani in the State of UP.

7. Shri Raman Kant informed about his site visit along the river Solani and stated that considering the nature of river and its catchment characteristics, natural flow in the river may be generated through water recharging structures and large scale plantation etc. activities in the catchment area with active community participation. He also informed about report prepared by him and to be shared shortly with the Committee.

8. Dr. YRS Rao, Scientist, NIH Roorkee suggested that available information about the river Solani needs to be translated in to GIS map. During the course of discussion and considering the core competencies of NIH, Member Secretary, UKPCB requested Dr. Rao to lead the report writing part in the matter which was accepted by the Dr. Rao. All the required information will be made available to NIH by the concerned departments.

9. After due discussion and deliberations, following decision have been taken for compliance:

   i) Uttarakhand Irrigation Department will provide GIS map of demarcation of river Solani with available hydrological data and catchment details.

   **Action:** Executive Engineer, UK Irrigation Department.

   ii) The data related to the drains and its quality & quantity, Interception and Diversion plan etc. needs to be collected from Uttarakhand Peyjal Nigam and made available to NIH for further processing.

   **Action:** RO, UKPCB, Roorkee & NIH

   iii) Details of encroachments and their removal along the river Solani will be collected from Revenue department. Water quality assessment data of river Solani, performance assessment data of STP, connectivity to STPs etc. will be provided to NIH.

   **Action:** RO, UKPCB, Roorkee

   iv) The report prepared by Shri Raman Kant will also be shared with the Committee to record its field observations, recommendations and rejuvenation plan etc. to incorporate in the report of Joint Committee.

   **Action:** Shri Raman Kant, NIH & UKPCB

   v) In order to fulfillment of mandate of the Joint Committee and as a member of the Joint Committee, NIH will prepare the report on behalf of the Joint Committee. Administrative expenditure in this regard will be borne by UKPCB. NIH may share the inventory of additional information that would be required for preparation of report.

   **Action:** NIH & UKPCB

O/C

vi) Regional Officer, UKPCB, Roorkee will ensure co-ordination and collection of information from various departments and will made available them to NIH for further processing.

**Action:** RO, UKPCB, Roorkee

The meeting ended with vote of thanks to the Chair.

**Dr. Parag Madhukar Dhakate**
**MEMBER SECRETARY**

**HEAD OFFICE**
**Uttarakhand Pollution Control Board**
**"Gauradevi Paryavaran Bhawan"**
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**Ref. No.: UKPCB/HO/Gen-183-631/2024/ 692** **Date:02.08.2024**

**BY E-MAIL**

**Copy to:** Following for kind information and necessary action please.

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**MEMBER SECRETARY**

# PROJECT REPORT

## *3.1* INTRODUCTION

### *3.1.1 Authority for preparation of project*

Before the National Green Tribunal, Principal Bench, New Delhi, Original Application No. 632/2022 in the matter of V.K. Tyagi versus State of Uttarakhand, Hon'ble NGT directed to Uttarakhand Peyjal Nigam (UKPJN) to prepare a DPR for tapping and treatment of wastewater flow of drains directly discharging and contaminating the river Solani (tributary of River Ganga) at Roorkee **(Annexure-1).**

In compliance of above directions of Hon'ble NGT an estimate for "**Pollution Abatement Works (Interception & Diversion with STP) for Solani River at Roorkee, Uttarakhand"** under **"Namami Gange Programme"** has been prepared.

## 3.2 DESCRIPTION OF THE PROJECT AREA

### *3.2.1 Brief history of the town*

Roorkee is a Municipal Corporation in Haridwar district of Uttarakhand state in India. It is also a sub-divisional headquarter (Tehsil) of Haridwar district. It's just 31 km from Haridwar, the district headquarter. Roorkee derives its name from 'Ruri', the wife of a Bargujar Rajput Chieftain, and earlier it was even spelled as 'Ruri ki'. Vernacular belief amongs villagers around Roorkee is that it got its name from 'Roron ki' i.e. a dwelling of Rors.

Roorkee was the capital of a Moghul Mahal (similar to a present day Pargana) during the time of Akbar a is referred in 'Ain-e-Akbari', authored by Abul Fazal. During the 18th century, it came under the rule of Landhaura state, till the death of its Bargujar King, Raja Ramdaval Dev in 1813 and later became a part of the territories of the British East India Company.

The Ganga Canal flowing through Roorkee was the brainchild of Sir Proby Cautley. Its construction began in 1840, and the canal was opened by Governer-General Lord Dalhousie in April 1854. Before 1840s, when the work on the Ganga Canal began under the aegis of Proby Cautley, according to an officer in British Army, Roorkee was a mere mud built village on the banks of the hill torrent, named Solani. Digging work on the Upper Ganga Canal formally began in April 1842, and soon this village started developing into a city. The canal was formally opened in April 8, 1854, irrigating over 767,000 acres (3,100 Sq.Km) in 5000 villages.

The municipality of Roorkee was created in 1868, when it was already home to the Bengal Sappers and Miners since 1853, and two artillery units were stationed here. Today, the Roorkee Cantonment has a large army base with headquarters for Bengal Engineering Group and Centre (BEG&C), also known as Bengal Sappers, established in 1803.

Roorkee is home to first engineering collage Indian Institute of Technology, Roorkee, formally known as Thomson collage of civil engineering.

Later in 1901, when the city had a population of 17,197, it was made headquarters of the Roorkee Tehsil in Saharanpur district of the United Province of the British Raj; the tehsil included in it 426 villages (of the parganas of Jwalapur, Manglaur and Bhagwanpur) and six towns, most important among them being Haridwar and Manglaur. The Old Cemetery in the city is today a protected monument, by Archaeological Survey of India.

Roorkee is also famous for the shrine of 13th century, Sufi saint Alauddin Sabir Kaliyari - the dargah is also known as Sarkar Sabir Pak situated in Piryan Kaliyar village, where an annual 15-day spiritual fair (Urs) is held in his honour.

A freight train ran in between Roorkee and Piryan Kaliyar on 22 December 1851, this was 2 years before first passenger train were started between Bombay and Thane in 1853 and 14 years after first freight train ran in Chennai in 1837.
Before the creation of Uttarakhand on November 9, 2000, Roorkee was a part of the state of Uttar Pradesh.

### *3.2.2 Geographical Location*

Roorkee town is located at $29^0$52'4.80" North Latitude and $77^0$53'3.15"E East Longitude. It has an average elevation of 268 meters (879 feet). It is situated on National Highway (N.H.) 334, and is on Amritsar-Howrah main rail route. Roorkee is 175 km north of the Indian capital New Delhi and about 70 km from Dehradun the provisional capital of Uttarakhand and located between the rivers Ganga and Yamuna, close to the foot hills of Himalayas.




***Figure 1: Roorkee Aerial View***

Roorkee is well connected with roads to major destination of Uttarakhand state. Buses to Roorkee from Delhi are easily available. Roorkee is well connected with National Highway 334. It's also well connected by railways with major cities of India. Jolly Grant Airport is the nearest Airport to Roorkee situated at a distance of 69 km. Taxis and buses are available from Jolly Grant Airport to Roorkee.

### *3.2.3 Climate*

October and start in Decem the Himalayas
The climate of Roorkee is generally sub-tropical, although it varies from tropical; from hot in summers to severely cold in winter, depending upon the season and the altitude of the specific location. Summer starts in late March and continue till early July, with average temperatures around 28°C and maximum reaching 40°C. The monsoon season starts in July and goes on till October with torrential rainfall, due to blocking of the monsoon clouds by the Himalayas. The post monsoon season starts in October and goes on till November, with average temperature sliding from 21°C to 15°C. Winters start in December with lows close to freezing and frequent cold waves due to the cold winds blowing from the Himalayas. The total annual rainfall is about 2600 mm.

### *3.2.4 Topography*

The town has a gently sloping topography with slope from south to north towards river Solani, however the Ganga Canal slopes towards the southwest. The difference in the hightest and lowest ground level of the town is of the order of 18.5 meters. Depth of subsoil water in this area varies from 6.0 meters to 10.0 meters. The town lies in the Tarai belt and has tropical climate.

A. Topography

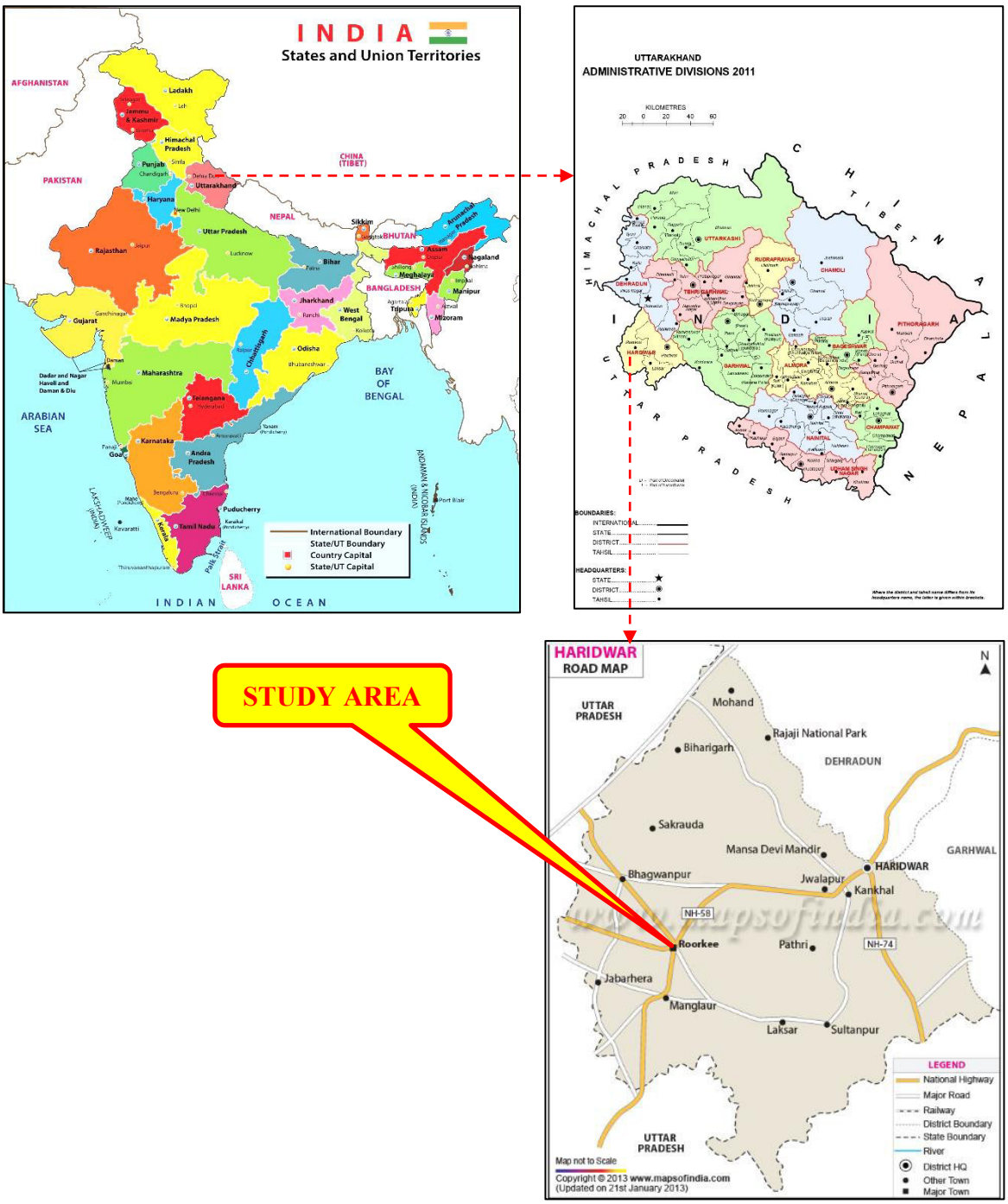



***Figure 2: Study Area***

B. Seismic Zone

The Roorkee town falls in seismic zone- IV as shown in Seismic Zone Map below:




***Figure 3: Seismic Zone Map of Uttarakhand***

This zone is called the High Damage Risk Zone of the Indian standard for establishing the criteria for earthquake resistant structures. The Code anticipates an intensity upto 8 in the seismic zone IV. In consideration, special measures are to be incorporated in designing of water / waste-water retaining structures. (Viz., Sewage Treatment Plant Sewage, Sewage Pumping Station or Wastewater Treatment Plants, as per provision of the Code).

### *3.2.5 River*

There is a Solani river, which is tributary of River Ganga. Solani river flows in the east direction of Roorkee town. Its origin passes through Rajaji National Park, Bhagwanpur and Roorkee of Haridwar district and finally meets the Ganga river via Shukratal (Uttar Pradesh). It is known for its ecological, cultural, and spiritual significance.

The Solani River originates in the Shivalik hills of Saharanpur district, formed by the confluence of two main streams, Khajnawar and Shahjahanpur, along with several smaller streams from these hills. Khajnawar and Shahjahanpur streams flow through the Shivalik forest about ten kilometers from the slopes of the Shivalik hills. After leaving the forest boundary, these streams converge approximately 10 kilometers downstream on the road from Dehradun to Sakumbhari near Saliyar Salahpur village. Before becoming the Solani River, it is joined by several other smaller streams. The Solani River flows gently, growing in size and importance.

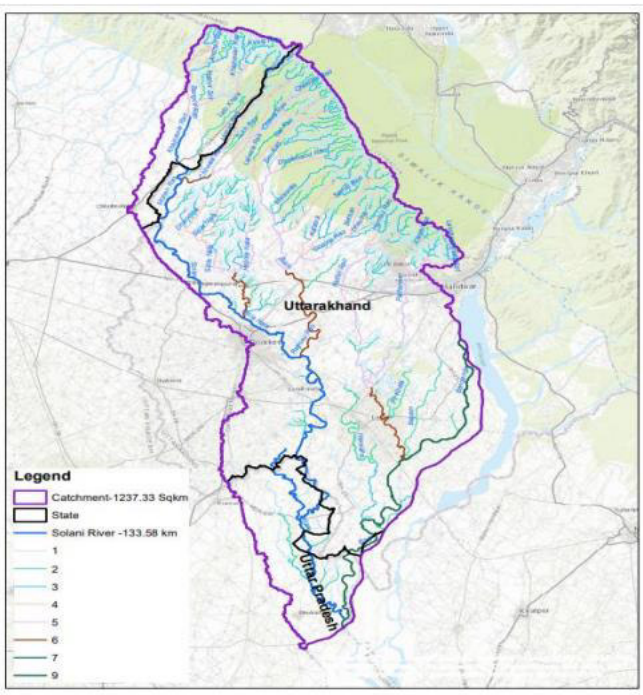



*figure 4: Solani River Catchment*

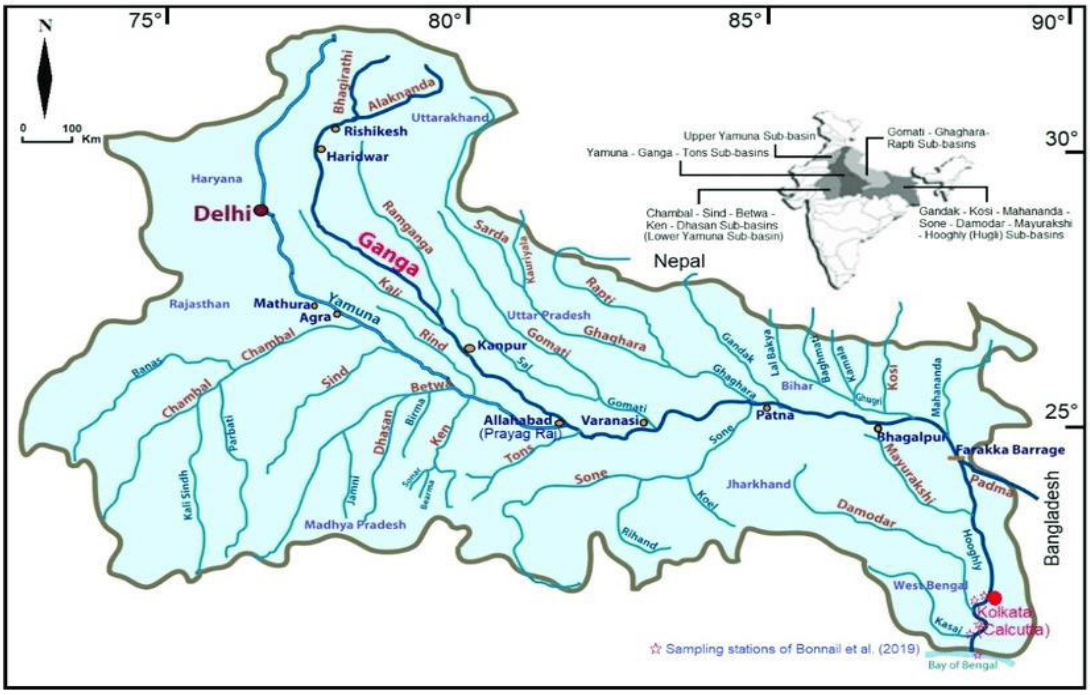



*figure 5: Ganga River Basin*

### *3.2.6 Commercial aspects*

The economy of the town is centred on the business, service sectors and institutional. Some portion of the town has rural base which makes the people engaged in agricultural activities. Roorkee is home to a number of division-level offices, thus having a large government-employee workforce.

### *3.2.7 Institutional / Educational activities*

Roorkee town have Graduate Colleges in the faculties of Engineering, Management, Science and Commerce and Polytechnics also.

### *3.2.8 Industrial Activities*

Roorkee is an industrial base of Haridwar district. It is partially industrialized. Its main industries are ship parts manufacture, surveying, drawing and mechanical instruments.

### *3.2.9 Other Activities*

The Bengal Engineering Group and Centre has its headquarter in Roorkee. Roorkee also has a cantonment area.

### *3.2.10 Socio-Economic Status*

The western party of Ganga canal area is thickly populated and generally comprises of service class, businessmen and other work force and the eastern party of Ganga canal generally comprises of intellectuals and service class peoples. Financial condition of most of the people of Roorkee is quite satisfactory and they can pay for utility charges.

### *3.2.11 Town Management*

In 2018, Roorkee Municipality (Nagar Palika Parishad) was upgraded to Roorkee Municipal Corporation (Nagar Nigam). Subsequently, the municipal area, population and number of wards have increased from 8.11 $km^2$, 97064 people (Census 2001) and 20 wards, to 28.91 $km^2$, 1,82,515 people (Census 2011 as per ULB 2018) and 40 wards.

The Roorkee Municipal Corporation has an elected body, and a 'Mayor' has been elected by the local people and all the representative of each wards are also elected members. One "Municipal Commissioner" post has been formulated by the Urban Development Department, Government of Uttarakhand to assist the Chairman for day-to-day activities.

At present the Municipal Corporation functions with five departments – a) Construction, b) Taxes, c) Electric, d) Sanitation & Solid waste Management and e) Administrative. Each department/section is represented by various manpower to handle the day-to-day work of the Municipal Corporation and to properly manage the town.

The Local Bodies play a critical role in the delivery of social, economic and infrastructure services like public-health, sanitation, primary education, solid waste management, and maintenance of road networks.

## 3.3 POPULATION WITHIN THE PROJECT AREA

### *3.3.1 Population of the Study Area*

In 2018, Roorkee Municipality (Nagar Palika Parishad) was upgraded to Roorkee Municipal Corporation (Nagar Nigam). Subsequently, the municipal area, population and number of wards have increased from 8.11 $km^2$, 97064 people (Census 2001) and 20 wards, to 28.91 $km^2$, 1,82,515 people (Census 2011 as per ULB 2018) and 40 wards **(Annexure-2).**

In order to obtain population data of different decades, Census Department as well as Nagar Nigam had been contacted and population for the past available decades was duly collected

for the town. The figures so obtained for previous eight (08) decades and provisional Census 2011 figure for Nagar Nigam Roorkee are shown below:

***Table 1: Census Population Growth***

| Year | Population | Decadal Increment | Decade Growth Rate | Average |
|---|---|---|---|---|
| 1931 | 13944 | - | - | |
| 1941 | 17334 | 3,390 | 24.31 | |
| 1951 | 23239 | 5,905 | 34.07 | |
| 1961 | 33657 | 10,418 | 44.83 | |
| 1971 | 47561 | 13,904 | 41.31 | |
| 1981 | 61851 | 14,290 | 30.05 | 30.88 |
| 1991 | 80262 | 18,411 | 29.77 | |
| 2001 | 97064 | 16,802 | 20.93 | |
| 2011 | 118200 (Nagar Palika Area) | 21,136 | 21.78 | |
| | | 1,04,256 | 247.04 | |
| | | 13,032.00 | | |

*Source : Census & Nagar Nigam, Roorkee*

### *3.3.2 Ward-wise Population*

The population distribution in 40 wards for the past three decades is given below:

***Table 2: Ward-wise population of Roorkee Town***

| Ward No. | Name of Ward | Population (Census 2011) Nagar Nigam Area |
|---|---|---|
| 1 | Sherpur | 5509 |
| 2 | Adarsh Nagar | 5677 |
| 3 | Solanipuram | 5148 |
| 4 | Khanjarpur | 5415 |
| 5 | C.B.R.I. | 5086 |
| 6 | I.I.T. | 4603 |
| 7 | Civil Lines | 3803 |
| 8 | Jadugar Road | 4357 |
| 9 | Mohanpura (North) | 3836 |
| 10 | Mohanpura (South) | 3838 |
| 11 | Defence Colony | 3137 |
| 12 | Asaf Nagar | 3052 |
| 13 | South Civil Line | 2880 |
| 14 | Preet Vihar | 3792 |
| 15 | Purva Vali | 5058 |
| 16 | Ganeshpur (South) | 4277 |
| 17 | Shekh Puri | 5066 |
| 18 | Ganeshpur (North) | 4994 |
| 19 | Shivpuram | 5025 |
| 20 | Chav Mandi | 5211 |
| 21 | Subhash Nagar | 5079 |
| 22 | Krishna Nagar | 5518 |
| 23 | Salempur Rajputana | 4942 |
| 24 | Salempur Industrial Area | 5294 |
| 25 | Ramnagar | 4396 |

| | | |
|---|---|---|
| 26 | Awas Vikas | 3966 |
| 27 | Maktulpuri | 4552 |
| 28 | East Deen Dayal | 4297 |
| 29 | Saket | 5566 |
| 30 | West Amber Talab | 4908 |
| 31 | East Amber Talab | 4475 |
| 32 | World Bank Colony | 3850 |
| 33 | Sot | 4339 |
| 34 | Satti | 3754 |
| 35 | Mahigram | 4874 |
| 36 | Bharat Nagar | 4728 |
| 37 | Old Tehsil | 4630 |
| 38 | Sunhera | 5131 |
| 39 | Kashipuri | 4439 |
| 40 | Matlabpur | 4013 |
| **TOTAL** | | **182515** |

*Source : Nagar Nigam, Roorkee*

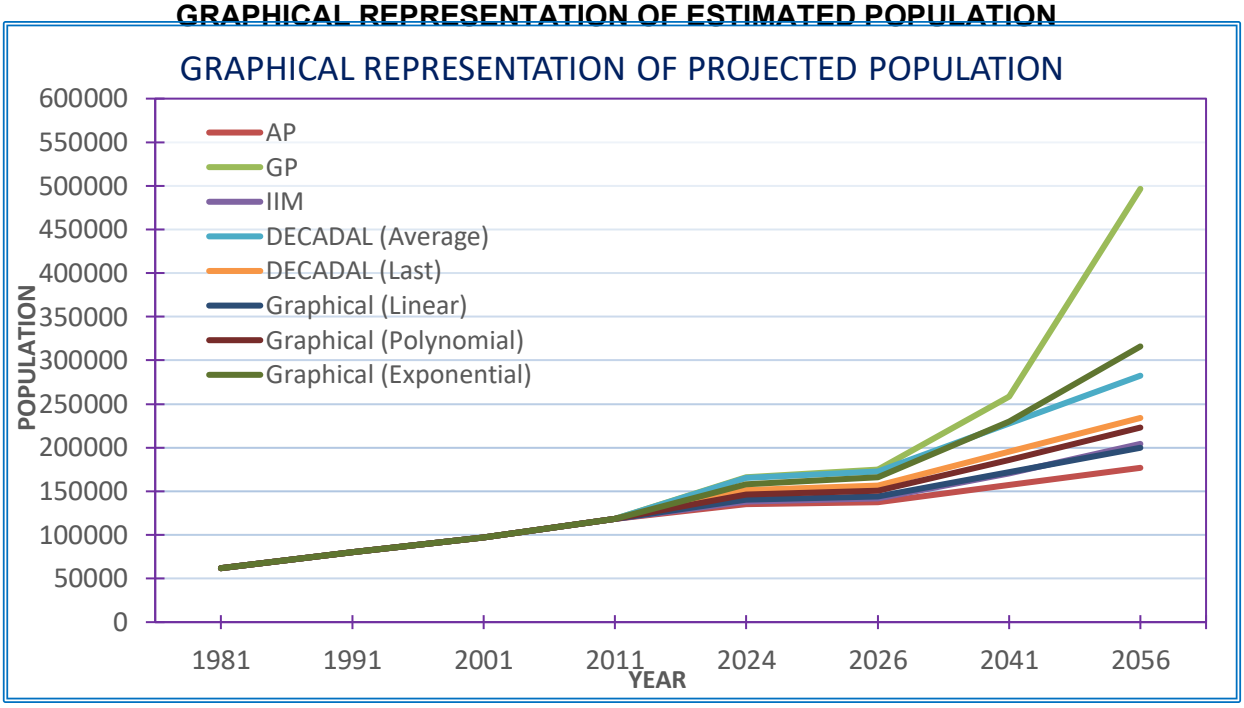
### *3.3.3 Estimation of Future Population by different Methods*

The future population can be estimated by several standard methods as the data for previous years are available. According to the census data given in the table 1, populations for the future years have been estimated by following different methods.

***Table 1: Summary of Population estimation by Different Methods***

| Year | AP | GP | IIM | DECADAL (Average) | DECADAL (Last) | Graphical (Linear) | Graphical (Polynomial) | Graphical (Exponential) |
|---|---|---|---|---|---|---|---|---|
| **1981** | 61851 | 61851 | 61851 | 61851 | 61851 | 61851 | 61851 | 61851 |
| **1991** | 80262 | 80262 | 80262 | 80262 | 80262 | 80262 | 80262 | 80262 |
| **2001** | 97064 | 97064 | 97064 | 97064 | 97064 | 97064 | 97064 | 97064 |
| **2011** | 118200 | 118200 | 118200 | 118200 | 118200 | 118200 | 118200 | 118200 |
| **2024** | 135142 | 165944 | 138458 | 165650 | 151660 | 140390 | 146000 | 158000 |
| **2026** | 137748 | 174836 | 141907 | 172950 | 156808 | 144106 | 151000 | 166000 |
| **2041** | 157296 | 258610 | 170606 | 227700 | 195415 | 171976 | 186000 | 230000 |
| **2056** | 176844 | 496594 | 204295 | 282451 | 234023 | 199846 | 223000 | 316000 |

**GRAPHICAL REPRESENTATION OF ESTIMATED POPULATION**




Polynomial Graphical Method is the most suitable method to demonstrate the growth pattern of the town. Project area is developing, hence adopted for population projections along with other calculations. In accordance with this method population projection and growth factors for design years have been considered.

### *3.3.4 Institutional / Floating Population*

Roorkee has two major institutional areas viz. IIT & CBRI, Roorkee also has a cantonment. Roorkee is also famous for the shrine of 13th century, Sufi saint Alauddin Sabir Kaliyari - the dargah is also known as Sarkar Sabir Pak situated in Piryan Kaliyar village, where an annual 15-day spiritual fair (Urs) is held in his honour.

Projected institutional and floating population taken from "Roorkee Sewerage Scheme DPR" **(Annexure-3)** and the summary is given below:-

***Table2: Institutional / Floating Population***

| Year | Projected Institutional / Floating Population |
|---|---|
| 2026 | 75,089 |
| 2041 | 92,140 |
| 2056 | 1,10,455 |

### *3.3.5 POPULATION PROJECTION*

The projected populations for the design period considering 2026 as base year (2024 to 2026, i.e. 2 years as Planning & construction period) have been estimated by different methods (with variation) and are tabulated below.

| Year | Permanent Population | Growth Factor | Remark |
|---|---|---|---|
| 2011 (Census) | 1,82,515 | | Population of Roorkee NN (2011) as per data received from Nagar Nigam |
| Present year (2024) | 1,46,000 | 1.2352 | |
| Base year (2026) | 1,51,000 | 1.2775 | |
| Intermediate year (2041) | 1,86,000 | 1.5736 | |
| Design year (2056) | 2,23,000 | 1.8866 | |

Polynomial Graphical Method is the most suitable method to demonstrate the growth pattern of the town. Project area is developing, hence adopted for population projections along with other calculations. In accordance with this method population projection and growth factors for design years have been considered.

***Table 5 : Future Resident Population***

| Year | Permanent Population |
|---|---|
| 2024 | 2,25,443 |
| 2026 | 2,33,163 |
| 2041 | 2,87,206 |
| 2056 | 3,44,333 |

Population for Roorkee Municipal Corporation in Base Year 2026, Mid Year (intermediate year) 2041 and Design year 2056 is projected as below:-

***Table 6: Summary of Population Projection***

| Year | Permanent Population | Floating + institutional population (As per Roorkee Sewerage DPR) | Design Population |
|---|---|---|---|
| **2011** | 1,82,515 | | |
| **2024** | 2,25,443 | | |
| **2026** | 2,33,163 | 75,089 | **3,08,252** |
| **2041** | 2,87,206 | 92,140 | **3,79,346** |
| **2056** | 3,44,333 | 1,10,455 | **4,54,788** |

## 3.4 STATUS OF EXISTING WATER SUPPLY

### *3.4.1 Present Status of Water supply*

At present the Uttarakhand Jal Sansthan run the water supply system in Roorkee Municipal Corporation area based on Tube well & gravity distribution system. Although it is supposed to be a municipal function, Roorkee Municipal Corporation is not involved in the planning, design,

construction, operation, maintenance and service delivery of this important Urban Infrastructure.

Water supply scheme for Roorkee is based on sub surface water. Raw water is abstracted through Tube wells, which is apparently filtered through sub-soil. Disinfection in the form of chlorination by Sodium Hypo Chloride is done at the storage points.
Uttarakhand Jal Sansthan" (UJS) is the Nodal Agency for Operation and Maintenance of Water Supply.

At present in Roorkee town, the water supply is being supplied to 135 lpcd.

## 3.5 SEWAGE GENERATION

### *3.5.1 Interception Factor*

As per CPHEEO Manual **80%** of the water supplied is taken as interception factor for design purposes.

### *3.5.2 Sewage Generation of town*

The design of sewerage system is based on @135 lpcd with interception factor of 80% as per CPHEEO Manual. Based on these considerations, the expected flow in design years are given below

***Table 7: Sewage Generation***

| Year | Design Population | Rate of Water supply (LPCD) | Inception factor (%) | Sewage Generation (MLD) |
|---|---|---|---|---|
| **2026** | 3,08,252 | 135 | 80% | **33.29** |
| **2041** | 3,79,346 | 135 | 80% | **40.97** |
| **2056** | 4,54,788 | 135 | 80% | **49.12** |

## 3.6 STATUS OF EXISTING WASTEWATER DISPOSAL WORKS

### *3.6.1 Existing Sanitation Scenario in Town*

The first sewerage scheme for Roorkee was introduced in 1963-64, excluding IIT Roorkee, CBRI and Cantonment area. The scheme comprised of laying of sewer line for a length of 22.0 Km and 02 nos sewage pumping stations along with rising main and sewage farm (150 acre) near Ibrahampur village.
The second sewerage scheme for Roorkee was executed in 1983-84 and thereafter the sewerage system was upgraded from time to time as and when required, but a comprehensive waste water management system has not been put in place for the complete town.

Sewerage Works in Phase-1 under ADB :- In Roorkee town, a sewerage system scheme sanctioned by UUSDIP, Govt. of Uk under ADB financial assistance programme, under this scheme out of 40 wards only 12 wards were fully covered and 8 wards were partially covered with sewerage network. Sewerage system comprising length of 78 km along with 02 nos sewage pumping stations and 33 MLD sewage treatment plant at Saliyar has been executed under this scheme. At present existing 33 MLD STP not running in its full capacity and receiving only 6 to 7 MLD sewage flow.

At present the open drains in the town act as the sewage carrier and in addition to this households and establishments on the bank of river Solani directly disposing their waste to the rivers.

The theoretical total sewage (DWF) generated in Roorkee is around 32.83 MLD for Year 2025. The increasing construction activities in the town has added to the degree of severity of the flow corridor and overflow of wastewater in open areas. The drains flow of the town ultimately reaches the river Ganga via the river Solani.

There are 13 (Thirteen) such major drainage channels which act as open sewer as well as to discharge the domestic wastewater and the surface runoff into the river Solani. No reliable updated database is currently available with Roorkee Nagar Nigam on the number of Domestic Units with toilets and corresponding informations on their connectivity to so called disposal system. As per the discussion with residents of the town, it is known that in the absence of complete structured sewerage system, septic tanks are the major form of treatment for the domestic sewage at source. Overflows from most of the septic tanks are connected to the open drains.

The 13 (Thirteen) Nalas flowing through the town carry the wastewater generated from residences as well as commercial establishments. The nalas ultimately flows through the channels constructed and discharge into the River Solani. This causes pollution in the river and enormous detrimental effect on overall aesthetic and hygiene condition of the town. This is further aggravated by indiscriminate disposal of solid wastes into the nalas. During the monsoons, roadside drains overflow and expose the populace to untreated sewage.

In absence of complete sewage collection and proper solid waste management system in town, the nalas are serving as the carrier of both sewage and solid waste generated from the town, which is finally carried to the River Solani.

The Sewage Pumping Station at Khanjarpur constructed in 1963-64 and rising main has already been completed their life. due to defunct condition of rising main, at present the flow pumped from Kanjarpur SPS directly discharging into Sot Mohalla Nala and contributing to pollution.



***33 MLD STP at Saliyar, Roorkee***




*Figure 6: Outfall of Pathanpura Nala.*




*Figure 7: Outfall of Machchhi Mohalla Nala*




*Figure 8: Outfall of Adarsh Nagar-1 Nala*

### *3.6.2 Status of Nalas (Drains) in Town*

#### i) Numbers and Details of Nala/Drain

The 13 (Thirteen) major polluted nalas in the town as mentioned earlier are majorly unlined. Further, being mostly open, choked, filled by solid waste and silted and thus, the drains are extremely inadequate to drain-out the storm water. The drains also pass through the thickly populated and congested localities and as such are encroached by permanent and semi-permanent structures/buildings, significantly affecting the carrying capacity of the limited drainage channels in the town.

The final outfall for all the major drains is River Solani. Details of the Nalas flowing through the city and dropping into the river Solani are provided in the table below:

***Table 8: Details of Nala and Outfall points***

| SL | Name | Coordinates of Outfall | | Outfall of Nala |
|---|---|---|---|---|
| | | Latitude | Longitude | |
| 1 | Pathanpura Nala | 29°52'47.24"N | 77°53'52.18"E | Solani River |
| 2 | Adarsh Nagar Nala-1 | 29°52'35.65"N | 77°54'13.87"E | |
| 3 | Adarsh Nagar Nala-2 | 29°52'35.24"N | 77°54'14.38"E | |
| 4 | Khanjarpur Nala | 29°52'4.07"N | 77°54'40.72"E | |
| 5 | Dhobi Gaat Nala | 29°52'54.93"N | 77°53'38.71"E | |
| 6 | Sot Mohalla Nala-1 | 29°52'58.21"N | 77°53'37.26"E | |
| 7 | Sot Mohalla Nala-2 | 29°52'58.21"N | 77°53'37.26"E | |
| 8 | Rampur Chungi Nala | 29°53'18.41"N | 77°52'55.62"E | |
| 9 | Macchi Mohalla Nala | 29°53'12.44"N | 77°53'16.25"E | |
| 10 | Bandha Road Nala-1 | 29°53'8.44"N | 77°53'23.01"E | |
| 11 | Bandha Road Nala-2 | 29°53'8.44"N | 77°53'23.01"E | |
| 12 | Imli Road Nala-1 | 29°53'7.45"N | 77°53'24.77"E | |
| 13 | Imli Road Nala-2 | 29°53'7.45"N | 77°53'24.77"E | |

#### ii) Details of measurements of flow in Nala/Drain

Flow of these Nalas/drains were measured **(Annexure-4)** which are shown below.



***Khanjarpur Nala***



***Sot Mohalla Nala***




***Bandha road Nala***

*Table 9: Details of flow in Nala/Drain*

| Sl. No. | Name of Nala | Average Discharge | |
|---|---|---|---|
| | | in MLD | in lps |
| 1 | Pathanpura Nala | 1.11 | 12.85 |
| 2 | Adarsh Nagar Nala-1 | 0.34 | 3.94 |
| 3 | Adarsh Nagar Nala-2 | 0.48 | 5.56 |
| 4 | Khanjarpur Nala | 8.80 | 101.85 |
| 5 | Dhobi Gaat Nala | 0.86 | 9.95 |
| 6 | Sot Mohalla Nala-1* | 1.62 | 18.75 |
| 7 | Sot Mohalla Nala-2 | 1.66 | 19.21 |
| 8 | Rampur Chungi Nala | 0.37 | 4.28 |
| 9 | Macchi Mohalla Nala | 9.92 | 114.83 |
| 10 | Bandha Road Nala-1 | 0.85 | 9.84 |
| 11 | Bandha Road Nala-2 | 0.34 | 3.94 |
| 12 | Imli Road Nala-1 | 0.36 | 4.17 |
| 13 | Imli Road Nala-2 | 0.39 | 4.51 |

* Discharge of Sot Mohalla Nala–1 :- 3.12 – 1.50 = 1.62 mld.

The Sewage Pumping Station at Khanjarpur constructed in 1963-64 and rising main has already been completed their life. Due to defunct condition of rising main, at present the flow approx. 1.50 MLD pumped from Kanjarpur SPS directly discharging into Sot Mohalla Nala and contributing to pollution. So, the discharge of pumping through existing rising main deducted from Sot Mohalla Nala-1 and considered 1.62 MLD discharge for Sot Mohalla Nala-1. The flow measurement tabulated as above are considered for design of STP/SPS.

**iii) Wastewater Characteristics of different Nalas/Drains**

Sampling was conducted along with the measurement of flow in drains. The analysis was done to know the quality of the wastewater **(Annexure-5).** The summary of the analytical results are given below:




*Adarsh Nagar Nala-2*




*Rampur Chungi Nala*




*Machchhi Mohalla Nala*

***Table 10: Quality Characteristic of Nala***

| Parameter | Unit | Concentration | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | O/F 1 | O/F 2 | O/F 3 | O/F 4 | O/F 5 | O/F 6 | O/F 7 | O/F 8 | O/F 9 | O/F 10 | O/F 11 | O/F 12 | O/F 13 |
| pH | -- | 7.15 | 7.2 | 6.86 | 7.26 | 7.12 | 7.33 | 7.21 | 7.65 | 7.24 | 7.08 | 7.05 | 7.06 | 7.05 |
| TSS | mg/L | 870 | 360 | 320 | 180 | 127 | 369 | 562 | 121 | 224 | 840 | 911 | 715 | 528 |
| BOD (3 Days) | mg/L | 193.3 | 150 | 173.3 | 24 | 42.3 | 136.4 | 166.7 | 28 | 79 | 266.7 | 300 | 280 | 88 |
| COD | mg/L | 761.9 | 567.7 | 593.6 | 79.4 | 179.3 | 488 | 571.4 | 169.3 | 298.8 | 946.2 | 1075 | 962.2 | 297.6 |
| Ammonical Nitrogen (NH3-N) | mg/L | 6.2 | 6.2 | 6.2 | 3.6 | 4.2 | 5.4 | 5.1 | 3.2 | 4.6 | 5.8 | 0.2 | 5.5 | 2.9 |
| Total Phosphorus (as PO4) | mg/L | 3.9 | 4 | 4.1 | 1.7 | 2.1 | 3.2 | 2.9 | 1.8 | 2.0 | 3.3 | 3.9 | 3.3 | 2.8 |
| Total Nitrogen (as N) | mg/L | 11.8 | 12.2 | 11.4 | 5.4 | 8.6 | 10.2 | 9.8 | 6.9 | 8.2 | 10.4 | 10.3 | 10.4 | 5.4 |
| Faecal Coliforms | MPN / 100 ml | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 | 1600 |

### *3.6.3 Status of Land*

As per the availability of land and requirement of project there are 01 SPS and 01 STP of 14.0 MLD are needed to be constructed. For construction of SPS and STP the land available at different location is as follows:

***Table 11: Land Details***

| SL | Location | Area (Ha) | Type of Land | Remark |
|---|---|---|---|---|
| 1. | Sewage Pumping Station | 0.075 | Govt. Land | No Objection Certificate (NOC) from concerned departments is not received yet. |
| 2. | Nala Tapping Arrangements | 0.100 | | |
| 3. | Sewage Treatment Plant | 0.250 | | |
| 4. | Carrier/Interceptor lines | 1.230 | | |
| 5. | Rising Main | 0.480 | | |
| | **TOTAL** | **2.135** | | |

On 12.06.2024, the inspection was done with officials of Municipal Corporation, Roorkee, Irrigation Section, Roorkee (Uttarakhand), Northern Section Ganga Canal, Irrigation Department (Uttar Pradesh), Local Administration (Revenue Department), Roorkee, Uttarakhand Pollution Control Board (UKPCB), Roorkee, and Uttarakhand Peyjal Nigam, Haridwar in the joint constituted committee for transfer of land to Uttarakhand Peyjal Nigam for pollution abatement works of Solani River (Interception & Diversion with STP works) viz. construction of Nala Tapping Arrangements, Sewage Pumping Station, Sewage Treatment Plant, rising main and laying of Carrier/Interceptor line etc., for which correspondence has already done with Municipal Corporation, Roorkee, Irrigation Section, Roorkee (Uttarakhand), Northern Section Ganga Canal, Irrigation Department (Uttar Pradesh) and Local Administration (Revenue Department), Roorkee.

***No objection certificate (NOC) has not yet been given by the concerned departments on the above mentioned land.***

## 3.7 JUSTIFICATION OF THE PROJECT

Roorkee is a fast growing urban body (Municipal Corporation), river side town and important institutional place in Uttarakhand State. The population of Roorkee has increased considerably in past few years. However, the town is deprived of complete planned sewage management system. Therefore, a substantial quantum of wastewater generated in town and nearby area is being discharged in open or nearby nalas, which ultimately falls into river Solani, which is a tributary to River Ganga. Since the wastewater remains untreated till final disposal in river, it is adversely impacting the river water quality.

Lack of complete sewerage collection system in town possess dual threat: one in form of river water pollution due to incoming contaminated water through nalas and second overall hygiene condition of the town due to absence of sewage collection system in the town. At present the effect of discharge of untreated wastewater on river water quality is very minimal (due to high dilution factor); however, these problems are only going to worsen with time as the population of the town increases and town become more and more dense and also due to increased floating population.

The Sewage Pumping Station at Khanjarpur constructed in 1963-64 and rising main has already been completed their life. due to defunct condition of rising main, at present the flow pumped from Kanjarpur SPS directly discharging into Sot Mohalla Nala and contributing to pollution.

Therefore, there is a need to replace the existing rising main and repair and renovation of Khanjarpur SPS for immediate relief till the complete sewerage network system is in place in the city. In view of the above, replacement of the existing rising main and repair and renovation works of Khanjarpur SPS have been included in this DPR.

**The above mentioned facts/shortcomings suggest the provision of new Scheme/Schemes with following components: -**

- ***Outfall drains tapping with carrier/interceptor line to carrying drains flow towards STP/SPS and construction of STP/SPS for immediate complete abatement of pollution due to discharge of wastewater in river Ganga via the river Solani.***

**<u>Following benefits are likely to be achieved:</u>**

- ✓ ***The expected project outcome is the reduction of pollution load from Roorkee town into river Ganga via river Solani along with the improvement in bio-diversity and eco-system of the river.***
- ✓ ***River water quality improvement will result in improvement of ground water quality.***
- ✓ ***Improvement in general hygiene and sanitation. It will also add to the overall aesthetics of the area.***
- ✓ ***Reduction in pollution load on river Solani.***

**The outcome indicated above being achieved after execution of this project.**

## 4.0 CONSIDERATION UNDER PROJECT

### 4.1 PROPOSED WORKS

#### 4.1.1 *Interception and Diversion with STP (for Immediate Mitigation Measure to curb river pollution caused at the nala outfalls)*

As described in preceding sections at present nalas in town are acting as the ultimate sewage carrier in town before disposal to River Solani. So, there is an immediate requirement to curb this pollution load from falling into the river, in order to maintain its pristine nature. This will take place with immediate effect and will cover the time period from now to the time until implementation of comprehensive sewage collection network in town. Under this project Nala Interception and diversion (I&D) infrastructure will be developed along with wastewater treatment capacity to cater to the pollution load coming from the nalas.

The I&D infrastructure thus proposed in this project will comprise of below given components with design horizon as mentioned:

**i) Nala tapping and interceptor/carrier line**

At present there are 13 nalas in town which carry wastewater along with surface run off directly to the river Solani. These nalas are the major concentrated point pollution loads coming to the river.

In order to effectively tap nalas and divert flow toward Collection Unit or Sewage Treatment Unit, it is proposed to strength existing nala section 10m before the tapping point, under this provision existing nala section will be constructed in RCC for the selected 10 m length at the outfall end of nala.

In order to effectively tap nalas and divert flow up to the inlet chamber of STP/SPS wet well, it is proposed to construct Nala Tapping arrangements and lay interceptor/carrier line (DI K-7 Pipe) of 250 - 800 mm dia connected to nalas and wastewater outfalls from households directly falling into the river.

**ii) Sewage Pumping Station**

01 no. of sewage pumping station at Shamshan Ghaat, Mahigran is proposed to collect wastewater diverted from 09 nos of Nalas viz. Rampur Chungi Nala, Machchhi Mohalla Nala, Bandha Road Nala-1, Bandha Road Nala-2, Imli Road Nala-1, Imli Road Nala-2, Sot Mohalla Nala-1, Sot Mohalla Nala-2 & Dhobi Ghaat Nala.
At present existing 33 MLD STP not running in its full capacity and receiving only 6 to 7 MLD sewage flow. Therefore, it is decided in joint meeting with Uttarakhand Jal Sansthan to divert flow from proposed SPS to existing 33 MLD STP.

**iii) Rising main**

Rising Mains of DI K-9, 600 mm dia is proposed to divert the wastewater from sewage pumping station to existing 33 MLD Sewage Treatment Plant.

### iv) Sewage Treatment Plant

Wastewater diverted from the nala will be collected in inlet collection chamber at Sewage Treatment Plant (STP) will be installed to treat the intercepted nala flow within the permissible limits set by NMCG (i.e. BOD:10 mg/l; Faecal Coliform: 100 mg/l; TSS: 10 mg/l)

01 No. of Sewage Treatment Plant near Shamshan Ghaat at Khanjarpur capacity of 14.0 MLD will be installed to treat 04 nos of nala's flow, in future when complete sewer network will be in place the same STP can be utilized to cater the treatment of domestic wastewater generated from nearby residential and commercial areas. The treatment capacity if needed may be enhanced to cater domestic sewage generated up to the year 2041.

***Table 12: Detail of STP & SPS***

| SL. No. | Collection Point | Description of source of Discharge | Avg. Flow for Base Year (2026) | Avg. Flow for STP Design Year (2041) | Capacity of STP (MLD) | Location of STP |
|---|---|---|---|---|---|---|
| **PART-A** | | | | | | |
| 1 | STP | Pathanpura Drain | 1.15 | 1.41 | **14.00** | Proposed Near Shamshan Ghat, Kanhapur, Khanjarpur |
| | | Adarsh Nagar Drain No -1 | 0.35 | 0.43 | | |
| | | Adarsh Nagar Drain No -2 | 0.50 | 0.61 | | |
| | | Khanjarpur Drain | 9.10 | 11.21 | | |
| | | **Sub Total** | **11.10** | **13.66** | | |
| **PART-B** | | | | | | |
| 2 | SPS near Shamshan Ghaat | Dhobi Ghat Nala | 0.89 | 1.10 | **SPS proposed & flow diverted from SPS to existing STP through Rising Main** | Existing 33.0 MLD STP, Saliyar |
| | | Sot Mohalla Nala-1 | 1.68 | 2.06 | | |
| | | Sot Mohalla Nala-2 | 1.72 | 2.11 | | |
| | | Emli Road Nala-1 | 0.38 | 0.47 | | |
| | | Emli Road Nala-2 | 10.26 | 12.64 | | |
| | | Bandha Road Nala-1 | 0.88 | 1.08 | | |
| | | Bandha Road Nala-2 | 0.35 | 0.43 | | |
| | | Machchhi Mohalla Nala | 0.37 | 0.46 | | |
| | | Rampur Chungi Nala | 0.40 | 0.50 | | |
| | | **Sub Total** | **16.93** | **20.85** | | |
| | | **Total (PART A + B)** | **28.03** | **34.51** | | |

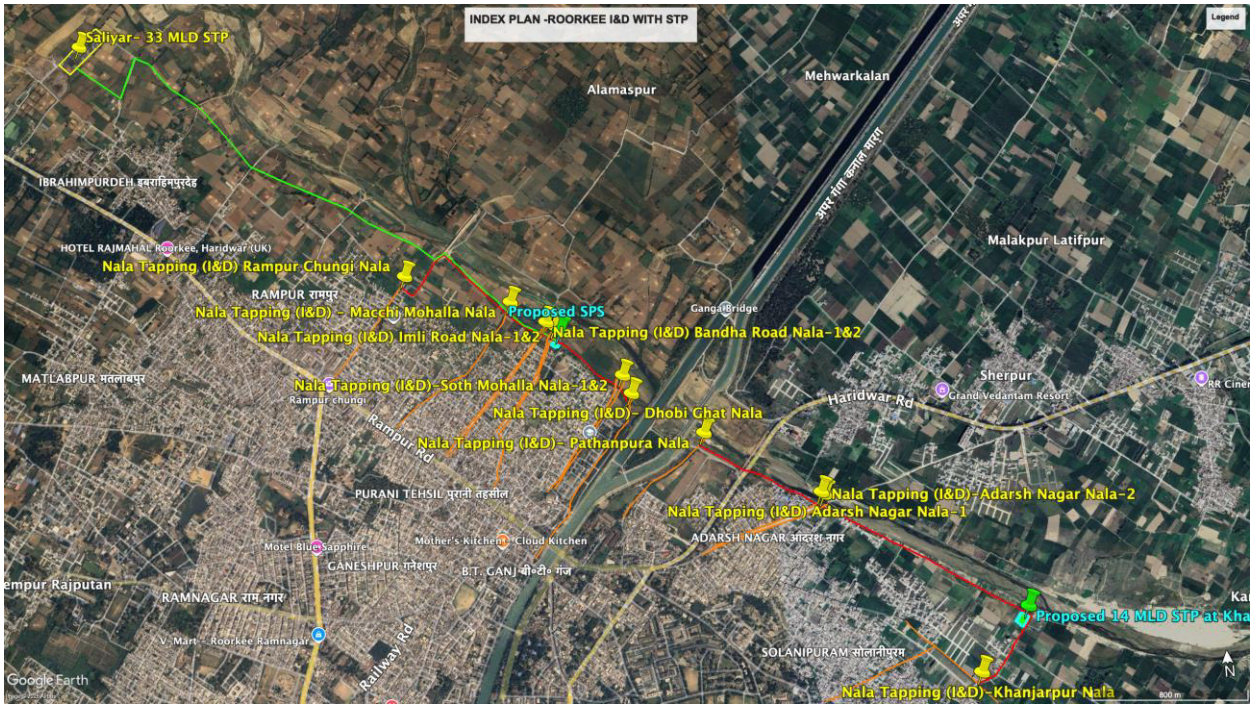
### v) Works for existing SPS & Rising Main at Khanjarpur

The Sewage Pumping Station at Khanjarpur constructed in 1963-64 and 350 mm dia rising main has already been completed their life. due to defunct condition of rising main, at present the flow pumped from Kanjarpur SPS directly discharging into Sot Mohalla Nala and contributing to pollution.

Therefore, there is a need to replace the existing 350 mm dia rising main and repair and renovation of Khanjarpur SPS for immediate relief till the complete sewerage network system is in place in the city. In view of the above, replacement of the existing rising main and repair and renovation works of Khanjarpur SPS have been included in this DPR.

***Table 13 : Summary of Proposed Works***

| SL | Description of works | Qty. |
|---|---|---|
| **A.** | **Interception and Diversion Works** | |
| 1. | Nala Tapping Arrangements | 10 Nos |
| 2. | Interception/Carrier Line | 4.02 Km. |
| 3. | Sewage Pumping Station | 01 No. |
| 4. | Rising Main | 3.20 Km |
| **B.** | **Sewage Treatment Plant** | |
| 1. | 14.0 MLD Capacity | 01 No |
| 2. | Upgradation of existing 33 MLD STP | 01 Job |
| **C.** | **Works for existing SPS & Rising Main at Khanjarpur** | 728 Nos |
| 1. | Repairs & Renovation of existing SPS | 01 Job |
| 2. | Replacement of existing rising main | 2.68 Km. |



## 4.2 IMPLEMENTATION PROGRAMME

The execution agency for the proposed scheme is Uttarakhand Peyjal Nigam (UKPJN). The Operation and Maintenances will be carried out by Uttarakhand Jal Sansthan (UJS).

### *4.2.1 Major Activities for implementation of the project*

#### *4.2.1.1 Preparation of Tender Document & Award of Work*

Tender documents shall be prepared for different components of proposed sewerage works.

***Table 14: Mode of Contract for proposed Works***

| SL | Description of Work | Mode of Contract |
|---|---|---|
| 1.0 | I&D with STP Work | Design Build Operate & Transfer (DBOT) |

#### *4.2.1.2 Public Awareness Activities*

A comprehensive programme will be framed and implemented with required assistance from local NGOs for taking up Information, Education & Communication (IEC) activities for the project. Active Public participation is of paramount importance for success of any projects. The programme will be executed by SPMG.

#### *4.2.1.3 Implementation Schedule*

The initial 06 months will be taken up by preliminary activities like permission of road cutting, utility diversions and for laying of interceptor/carrier lines under railway crossings, preparation of bid document, bidding process & award of Contract. Afterwards the project execution period is taken up as 21 months followed by 03 months for Trial Run and Commissioning period.

## 4.3 FINANCIAL AND ECONOMIC ANALYSIS

### *4.3.1 Schedule of Rates*

The rates have been adopted as prevailing schedules of rates 2023-24 in Uttarakhand Peyjal Nigam. In case where rates of some items are not available in the said schedules, rates of such items have been derived from CPWD, Delhi Schedule of Rates 2023 and Uttarakhand Public Work Department SOR 2024-25. In case where rates of some items are not available in the above said schedules, rates are analysed or taken from current market rates.

### *4.3.2 Other Provisions*

The provision of 4% cost of project preparation charges and the cost of supervision as 4% has been taken as per NGRBA guidelines in the estimate.

## 4.4 CONCLUSION

This **"Detailed Project Report for Pollution Abatement Works (Interception & Diversion with STP) of Solani River at Roorkee, Uttarakhand"** as reframed amounting to **Rs. 15,022.25 Lacs** is submitted for Administrative Approval, Financial Sanctions and allotment of funds under **"Namami Gange Program".**

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# POLLUTION ABATEMENT WORKS (INTERCEPTION & DIVERSION WITH STP) FOR SOLANI RIVER AT ROORKEE UNDER NAMAMI GANGE PROGRAMME.

## FORM - "J"

(Amount in Rs.)

| SL. NO. | DESCRIPTION | ESTIMATED COST | COST TO BE BORNE BY GOVT. OF INDIA (100%) |
|---|---|---|---|
| 1 | Total Cost of the project | 1,50,22,24,619.00 | 1,50,22,24,619.00 |
| | **Say Rs. in Lacs** | **15,022.25** | **15,022.25** |

Checked by

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