

BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL

PRINCIPAL BENCH, NEW DELHI

O.A. No. 515 OF 2023

IN THE MATTER OF:-

GANGA POLLUTION

.....APPLICANT

VERSUS

STATE OF U.P &amp; ORS.

... RESPONDENTS

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**FILED THROUGH: -**



**DATE: 13.09.2024**  
**PLACE: NEW DELHI**

BHANWAR PAL SINGH JADON  
STANDING COUNSEL, STATE OF UP  
NATIONAL GREEN TRIBUNAL, NEW DELHI  
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BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL  
PRINCIPAL BENCH, NEW DELHI

O.A. No. 515 OF 2023

IN THE MATTER OF:-

GANGA POLLUTION

....APPLICANT

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...RESPONDENTS

ACTION TAKEN REPORT/STATUS REPORT ON  
BEHALF OF PRINCIPAL SECRETARY, IRRIGATION  
DEPARTMENT, STATE OF UTTAR PRADESH IN  
COMPLIANCE WITH THE ORDER DATED 27.05.2024  
and 11.07.2024

1. At the outset, with the utmost respect it is submitted that all the officers and authorities of the State of Uttar Pradesh have the highest respect and regard to the orders passed by the Hon'ble Tribunal and duty bound to fulfil the obligation which are assigned under the law and directions passed by this Hon'ble Tribunal in true letter and spirit.

(2)

2. That in the present Original Application 515/2023 Ganga Pollution vs. State of U.P. the core issue involved revolves around defining the flood plain zone of river Ganga and its tributaries in the State of U.P. and actions taken by the concerned authorities to protect the flood plain zone.
3. It is respectfully submitted that a report dated 24.02.2020, pertaining to the demarcation of Phase-I, has already been submitted before this Hon'ble Tribunal. Additionally, a report dated 24.05.2024, concerning compliance with the order dated 15.03.2024, has also been submitted before this Hon'ble Tribunal.

That the matter was listed on 27.05.2024 and 11.07.2024 and the Hon'ble Tribunal was pleased to pass the following order.

**Order dated 27.05.2024:-**

- I. **Para 9** "We also take note of the fact that in respect of the stretch of Yamuna River at Gautam Budh Nagar and Greater Noida in OA No. 275/2023, exercise for demarcation of floodplain zone has been undertaken on the basis of the map obtained from Survey of India with 01m contour interval. Therefore, State authorities may consider as to why the same approach cannot be adopted for demarcating the floodplain zone of river Ganga in the stretch under consideration".
- II. **Para 10** "Learned Counsel appearing for State of UP has submitted that NIH will be able to submit the interim report by October 2024 and completion of work defined in the Agreement dated 22.12.2023 will be completed by December 2024."

(3)

**Order dated 11.07.2024:-**

III. **Para 3** "Principal Secretary, Irrigation Department, State of UP has also submitted that authorities will approach Survey of India to obtain map of the relevant stretch with 01 m contour interval and explore the possibility of demarcation of flood plain on that basis."

IV. **Para 4** "In respect of dividing the flood plain in three zones i.e. (i) prohibited zone: recurrence interval of 05 years; (ii) regulatory zone: 25 year return period flood; (iii) warning zone: 100 year return period flood as stated in the report dated 24.05.2024, a reliance has been placed upon the order of the Tribunal dated 13.07.2017 in OA No. 200/2014 and connected matters in the case of M. C. Mehta v. Union of India & Ors. Ganga Rejuvenation Order, 2016 was not brought to the notice of the Tribunal when the order dated 13.07.2017 was passed. If statutory order exists then the same is required to be complied with"

4. It is hereby submitted that vide letter 327/CE/ISO/2024- 25 dated 22.07.2024, the Chief Engineer/ UPSW Information System Organisation Irrigation & Water Resource Department IWRD Luknow, U.P has addressed a letter to the Director, Uttar Pradesh Geo-Spatial Directorate, Survey Of India, Manচিতra Bhawan Lucknow. It is submitted that under the Guidance and support of Central Water Commission (CWC), Irrigation and Water Resource Department, U.P has initiated working on with NIH, to delineate and demarcate the Flood Plain Zone (FPZ) from Unnao to Ballia. The Chief Engineer, Information System Organisation,

(4)

Irrigation and Water Resource Department, Uttar Pradesh, Parikalp Bhawan, Telibagh, Lucknow, requested to provide the 01m Contour Interval for Uttar Pradesh so that the demarcation and delineation of the Flood Plain Zone can be done. True Copy of the letter no. 327/CE/ISO/2024-25 dated 22.07.2024 is annexed herein as **ANNEXURE R1**.

5. It is most humbly submitted that vide letter No. 4189/39- EI dated 07.08.2024, the Director/Survey of India Map Bhawan/Manchitra Bhawan Uttar Pradesh Geospatial Directorate (Northern Zone) Uttar Pradesh G.D (Northern Zone) Luknow, has written a letter to the Chief Engineer, Irrigation and Water Resources Department Luknow. In the described letter the soft copy of 01m Contour interval of the Flood Plain Zone of river Ganga has been sent to the Assistant Engineer in Invoice No. RK/3773/UPGDC/LUCKNOW. True Copy of the letter no. 4189/39-EI dated 07.08.2024 is annexed herein as **ANNEXURE R2**.

6. It is pertinent to note that, as per letter No. 366/M.A. (S.P.S)/2024-25 dated 08.08.2024, the Chief Engineer, Information System Organisation, Irrigation and Water Resource Department, Uttar Pradesh, Parikalp Bhawan, Telibagh, Lucknow, has corresponded with the Scientist, Head, Surface Water and Hydrology Division, National Institute of Hydrology (NIH), Rorkee, Uttarakhand. It is submitted that the 01-meter contour interval map received from the Survey of India is intended for the purposes of demarcation and determination of the Flood Plain Zone (FPZ): True Copy of the letter no. 366/M.A.

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(S.P.S)/2024-25 dated 08.08 is annexed herein as **ANNEXURE R3.**

7. It is respectfully submitted that, by virtue of letter No. 07/Superintending Engineer/FMISC/2023-24 dated 16.01.2024, the Superintending Engineer, Flood Management Information System Centre, Irrigation and Water Resource Department, Uttar Pradesh, Lucknow, has formally communicated with the Chief Engineer, Lower Ganga Basin Organization (LGBO), Central Water Commission (CWC), Amarnath Road, Adaltganj, Patna 800001, for providing data and cross section data of maximum number of years of Gauge and Discharge stations established under LGBO on Ganga river and its tributaries located in Uttar Pradesh. It is further submitted that Gauge & Discharge and cross section data are very important for Flood Plain Zone determination and demarcation due to Uttar Pradesh being a flat land. A table of water level and Discharge of several Gauge stations of CWC has been obtained through WIMS portal, in which 55 years of maximum data has been obtained of Varanasi Gauge Station. True Copy of the letter no. 07/Adhikshan Abhiyanta/FMISC/2023-24 dated 16.01.2024 is annexed herein as **ANNEXURE R4.**

8. It is pertinent to note that in response to the vide letter No. Mu.A/N.G.B.S./D.B Hydro-Data/ 2024/ 160 dated 18.01.2024, the Chief Engineer, Water Resource, River Development, and Ganga Conservation Department, Lower Ganga Basin Organisation, Patna, has addressed a communication to the Superintending Engineer, Flood Management Information

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(2)

System Centre, Irrigation and Water Resources Department, Uttar Pradesh, Lucknow. This correspondence includes an enclosed list detailing all. Gauge and Discharge stations established by the LGBO on the Ganga Basin River and its tributaries within Uttar Pradesh. True Copy of the letter no. Mu.A/N.G.B.S./D.B. Hydro-Data/2024/160 dated 18.01.2024 is annexed herein as **ANNEXURE R5.**

9. It is respectfully submitted for the esteemed consideration of this Hon'ble Tribunal that the report from the NIH July-2024 and the progress report till August has been annexed herein as **ANNEXURE R6.**

10. It is important to submit that the demarcation of the floodplain zone has been conducted with consideration of a 100-year spread, using the Hybrid Methodology. This approach utilizes a 100-year return period flood, which is estimated through flood frequency analysis of the annual maximum flood discharge data from available G&D (Gauge and Discharge) sites over the relevant periods. The estimation is conducted using hydraulic modeling-HEC-RAS, the flood frequency analysis is calculated using the L-Moment Ratio method and 37 years of data obtained through satellite imagery using Landsat data. The Hybrid Methodology was chosen because both satellite analysis and modeling have inherent limitations. Specifically, satellite data may not capture the full extent of flood events, and model results are subject to the quality of the Digital Elevation Model (DEM). True copy of the methodologies is annexed herein as **ANNEXURE R7.**

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11. It is submitted that the study analysed the maximum yearly river discharge data from six sites using frequency distribution method i.e. Extreme Value (EVI), General Extreme Value (GEV), Logistic (LOS), Generalized Logistic (GLO), Normal (NOR), generalized pareto (GPA), generalized normal (GNO), Uniform (UNF), Exponential (EXP), Pearson Type-III (PT3), Kappa (KAP) and Wakeby (WAK), using flood frequency analysis with the L- moments approach. Twelve different statistical distributions were tested to find the best fit for predicting flood levels. The most suitable distributions were identified using specific criteria i.e., L-moment and Zisd statistics, and the estimated flood levels for different and 100 year return periods at each site were summarized in a table. True copy of the 6 G&D Site wise observed annual maximum data graphs and the table of estimated floods of various return periods are annexed herein as **ANNEXURE R8.**

12. It is respectfully submitted that this action taken report/status report, combining flood frequency analysis, satellite data, and hydraulic modelling, will ensure accurate delineation and demarcation of the Flood Plain Zones for Unnao to Ballia of the River Ganga, in compliance with the Hon'ble Tribunal's directives. It is submitted that the entire process for the earmarking of the flood plain zone would be completed by the December 2024.

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(8)

13. That the Irrigation Department of the State of Uttar Pradesh is fully committed to adhering to the directives of the Hon'ble Tribunal and ensuring compliance with the statutory orders outlined in the Ganga Rejuvenation Order, 2016.

(Anil Garg)

Principal Secretary

From: -

Suprabhat Singh  
Chief Engineer / Nodal Officer UPSW  
Information System Organisation  
Irrigation & Water Resources Department, IWRD  
Lucknow, U.P.

To:

The Director,  
Uttar Pradesh Geo-spatial Directorate,  
Survey of India, Manchitra Bhawan,  
5 - Vibhuti Khand, Gomti Nagar,  
LUCKNOW PIN - 226 010

Letter No.: 327 /CE/ISO/2024-25

Date: 22/07/2024

Subject: - Regarding providing the map with 01 m contour interval of Uttar Pradesh

Dear Sir,

Honorable, National Green Tribunal (NGT) has ordered to delineate and demarcate the Flood Plain Zone (FPZ) with 100 Year's Return period of river Ganga and its tributaries.

Under the guidance and support of the Central Water Commission (CWC), Irrigation & Water Resources Department, Uttar Pradesh (I&WRD, UP) has initiated working on it with the assistance of National Institute of Hydrology (NIH), Roorkee to delineate and demarcate the Flood Plain Zone (FPZ) from Unnao (near Kanpur) to Ballia

Honourable, National Green Tribunal in its order dated 11.07.2024 has directed Irrigation and Water Resources Department, Uttar Pradesh to obtain the map of relevant stretch with 01 m contour interval from Survey of India and explore the possibility of demarcation of flood plain zone on that basis.

In view of the above, undersigned request you to kindly provide the map with 01 m contour interval for Uttar Pradesh so that the demarcation and delineation of flood plain zone can be done.

NGT order dated 11.07.2024 has been enclosed for your kind perusal.  
Your support and cooperation in this regard will be of utmost importance

Enclosure: As above

Yours faithfully,

(Suprabhat Singh)

Chief Engineer / Nodal Officer UPSW  
ISO, IWRD, UP  
Lucknow

Letter No: 327 /CE/ISO/2024-25 Dated:- 22/07/2024

Copy to: -

1. Special Secretary, Section-4, Uttar Pradesh Secretariat, Irrigation & Water Resources Department Lucknow.
2. Engineer-in-Chief & Head of Dept., Irrigation & Water Resources Department, Lucknow.
3. Engineer-in-Chief (D. & P.), Irrigation & Water Resources Department, Lucknow.
4. Chief Engineer, Sharda Sahayak, Irrigation & Water Resources Department, Lucknow.
5. Chief Engineer, Sone, Irrigation & Water Resources Department, Lucknow.
6. Chief Engineer, Water Resources, Irrigation & Water Resources Department, Lucknow.
7. Superintending Engineer FMISC, Irrigation & Water Resources Department, Lucknow.

(Suprabhat Singh)

Chief Engineer / Nodal Officer UPSW  
ISO, IWRD, UP  
Lucknow

Received  
22/07/24

10

## ANNEXURE - R2

भारत सरकार  
GOVT. OF INDIA



टेली-फैक्स/Tele-fax – 0522-2720634  
दूरभाष/Telephone-0522-2720638  
ई-मेल/E-mail: up.gdc.soi@gov.in (Tech)  
upgdc-lko@up.nic.in (Admn)

निदेशक का कार्यालय/Office of Director  
भारतीय सर्वेक्षण विभाग/Survey of India  
मानचित्र भवन/Manchitra Bhawan  
उत्तर प्रदेश भू-स्थानिक निदेशालय (उत्तरीक्षेत्र)  
Uttar Pradesh G.D (Northern Zone)  
5, विभूतिखण्ड, गोमतीनगर, लखनऊ -226010(उप्र)  
5. Vibhuti Khand, Gomti Nagar, Lucknow-226010 (UP)

पत्र सं० त- /39-ED(कोर्ट केस)  
4189

दिनांक: 07/08/2024

सेवा में,

श्री सुप्रभात सिंह  
मुख्य अभियन्ता,  
सूचना प्रणाली संगठन  
सिंचाई एवं जल संसाधन विभाग उ० प्र०,  
परिकल्प भवन, तेलीवाग,  
लखनऊ।

विषय:- उत्तर प्रदेश राज्य का 1 मीटर कंटूर इन्टरवल (Contour Interval) मानचित्र उपलब्ध कराने के संबंध में ।

संदर्भ:- आपके कार्यालय का पत्र क्रमांक सं. 327/मु.अधि./सू.प्र.सं./2024-25 दिनांक 22/07/2024

महोदय,

उपरोक्त संदर्भित विषय में आपको अवगत कराना है कि आपके द्वारा की गयी वांछित गंगा नदी के फ्लड जोन (उन्नाय से बलिया) के 1 मीटर Contour Interval का साफ्ट कौपी डाटा (Lidar Data) आपके कार्यालय से आये अधिकारी श्री हेमंत कुमार, सहायक अभियन्ता को दिनांक 07/08/2024 को इस कार्यालय के Invoice No. RK/3773/UPGDC/LUCKNOW दिनांक 07/08/2024 के द्वारा उपलब्ध करा दिया गया है।

उक्त डेटा इस आशय के साथ आपको सुपूर्द किया जा रहा है कि उपरोक्त डेटा का उपयोग केवल विषयक कार्य हेतु किया जायेगा तथा इसके अलावा डेटा को आपके द्वारा किसी व्यक्ति व संस्था के साथ साक्षा नहीं किया जायेगा तथा डेटा की पूर्ण सुरक्षा की जायेगी।

संलग्न:- 1. Invoice No. RK/3773/UPGDC/LUCKNOW दिनांक 07/08/2024

2. आपके कार्यालय का पत्र क्रमांक सं.327/मु.अधि./सू.प्र.सं./2024-25 दिनांक 22/07/2024

R 7/8/24

(रविन्द्र मीना)

अधीक्षण सर्वेक्षक

कृते निदेशक

प्रतिलिपि:-

1. भारत के महासर्वेक्षक, देहरादून को सूचनार्थ प्रेषित।
2. अपर महासर्वेक्षक, उत्तरी क्षेत्र, चण्डीगढ़ को सूचनार्थ प्रेषित।
3. लीगल सेल, भारत के महासर्वेक्षक कार्यालय, देहरादून को सूचनार्थ प्रेषित।

(11)

भारतीय सर्वेक्षण विभाग  
Survey of India

INVOICE NO. R.K/3773/UPGDC, LUCKNOW  
Dt.07-08-2024.

प्रेषक From

निदेशक

उत्तर प्रदेश भू-स्थानिक निदेशालय (उ०क्षेत्र)

भारतीय सर्वेक्षण विभाग

विभूति खण्ड

गोमती नगर, लखनऊ-226010

सेवा में, To,

अधिसासी अभियंता

सिचाई विभाग

लखनऊ

संदर्भ: आपका पत्र सं०..... आपको निम्नलिखित रजिस्टर्ड/पार्सल/मालगाड़ी, सवारी गाड़ी द्वारा भेजी गई है कृपया हस्ताक्षर करके इस वीजक की एक प्रति वापस कीजिए

Reference your Letter No. 324/327/UP/आ.वि.०/स.प.३६/२०२४-२५ दि. २२-७-२४

The under mentioned ..... have been dispatched to you by hand/Registered/Parcel Post/Train. Please sign and return one copy of this invoice

हस्ताक्षर Signature.....

पद Designation.....

नाम साफ अक्षरों में Name in Block Letter.....

(मोहन लाल/MOHAN LAI  
मुख्य कार्यनिर्वाहक/Chief Officer  
स.प. ३६, निदेशालय/U.P.G.D.  
भारतीय सर्वेक्षण विभाग, लखनऊ  
Survey of India, Lucknow

क्रम सं० Sl. No	विवरण Description	SPACE			REMARK
		FILES	FOLDERS		
1	NGD_TO_UPGD_NHP_NGT (UNNAO To BALIA)	646 GB	69241	83	
2	NDDC TO UPGD _NMCG-NGT_ (UNNAO To BALIA)	151 GB	11932	24	

संख्या No.  
तारीख Date

उपयुक्त प्राप्त किया Received the above  
हस्ताक्षर Signature  
पद Designation  
नाम साफ अक्षर Name in block letter

प्रेषक,

मुख्य अभियन्ता,  
सूचना प्रणाली संगठन,  
सिंचाई एवं जल संसाधन विभाग, उ०प्र०,  
परिकल्प भवन, तेलीबाग, लखनऊ।

प्रेष्य,

डा० ए०के० लोहानी,  
वैज्ञानिक जी, प्रमुख, सतही जल एवं जल विज्ञान प्रभाग,  
राष्ट्रीय जल विज्ञान संस्थान (NIH), रुड़की, उत्तराखण्ड।

पत्रांक:— 366/मु०अभि०(सू०प्र०सं०)/2024-25

लखनऊ, दिनांक: 08 अगस्त, 2024

विषय:—गंगा नदी के Segment B, Phase-II (उन्नाव से बलिया) का Flood Plain Zone (FPZ) के निर्धारण एवं सीमांकन (Delincation & Demarcation) हेतु Survey of India से प्राप्त 01 मी० कंटूर इन्टरवल (Contour Interval) मानचित्र/डेटा हस्तगत कराने के संबंध में।

महोदय,

मा० राष्ट्रीय हरित अधिकरण द्वारा दिनांक 11.07.2024 को दिये गये निर्देशों का अनुपालन करते हुए सर्वे ऑफ इंडिया, लखनऊ कार्यालय से गंगा नदी के Segment B, Phase-II (उन्नाव से बलिया) का Flood Plain Zone (FPZ) के निर्धारण एवं सीमांकन (Delincation & Demarcation) हेतु 01 मी० कंटूर इन्टरवल (Contour Interval) मानचित्र की वांछना की गई थी, जिसके क्रम में सर्वे ऑफ इंडिया द्वारा दिनांक 07.08.2024 को 01 मी० कंटूर इन्टरवल (Contour Interval) डेटा (LiDAR data) साफ्ट कॉपी में उपलब्ध करा दिया गया है।

उक्त डेटा का कुल Volume- 798 GB है, जिसको कार्य की महत्ता के दृष्टिगत रखते हुए आपसे अनुरोध है कि तत्काल किसी जिम्मेदार अधिकारी को नामित कर डेटा प्राप्त करने हेतु 1TB की hard disk के साथ भेजने का कष्ट करें, जिससे कि उक्त प्राप्त डेटा तत्काल आपको अग्रिम कार्यवाही हेतु अग्रसारित की जा सके।

उपरोक्त डेटा इस आशय के साथ आपको हस्तगत किया जा रहा है कि इसका उपयोग केवल विषयक कार्य हेतु किया जायेगा तथा इसके अलावा इस डेटा का प्रयोग किसी भी परिस्थिति में न तो किसी अन्य कार्य के लिए किया जायेगा और न ही किसी अन्य व्यक्ति व संस्था के साथ साझा किया जायेगा तथा डेटा की पूर्ण सुरक्षा की जायेगी।

(सुप्रभात सिंह)

मुख्य अभियन्ता (सू०प्र०सं०)

08/08/2024

पत्रांक:— /मु०अभि०(सू०प्र०सं०)/2024-25 / तदिनांक:

प्रतिलिपि निम्नलिखित को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित है।

1. मुख्य अभियन्ता (शारदा सहायक), सिंचाई एवं जल संसाधन विभाग, उ०प्र०, लखनऊ।
2. मुख्य अभियन्ता (सोन), सिंचाई एवं जल संसाधन विभाग, उ०प्र०, वाराणसी।
3. मुख्य अभियन्ता (जल संसाधन), सिंचाई एवं जल संसाधन विभाग, उ०प्र०, लखनऊ।
4. अधीक्षण अभियन्ता, एफ०एम०आई०एससी, सिंचाई एवं जल संसाधन विभाग, उ०प्र०, लखनऊ।

(सुप्रभात सिंह)

मुख्य अभियन्ता (सू०प्र०सं०)

प्रेषक,

अधीक्षण अभियन्ता,  
बाढ़ प्रबन्धन सूचना प्रणाली केन्द्र,  
सिंचाई एवं जल संसाधन विभाग,  
उ०प्र०, लखनऊ।

प्रेष्य,

मुख्य अभियन्ता,  
लोवर गंगा बेसिन संगठन (LGBO),  
केन्द्रीय जल आयोग, अमरनाथ रोड,  
अदालतगंज, पटना-800001

पत्रांक:- 07 /अधी०अभि०/एफएमआईएससी/2023-24

दिनांक: 16 जनवरी, 2024

विषय:- उ०प्र० में स्थित गंगा नदी एवं उसकी सहायक नदियों पर LGBO के अन्तर्गत स्थापित Gauge & Discharge stations का अधिक से अधिक वर्षों का डेटा एवं Cross-section data उपलब्ध कराने के सम्बन्ध में।

महोदय,

माननीय राष्ट्रीय हरित अधिकरण, नई दिल्ली के निर्देशों के अनुपालन में गंगा नदी के Segment-B, Phase-II (उन्नाव से बलिया) की Flood Plain Zone (FPZ) के निर्धारण एवं सीमांकन (Delineation & Demarcation) का कार्य सिंचाई एवं जल संसाधन विभाग, उ०प्र० द्वारा किया जा रहा है।

Flood Plain Zone निर्धारण एवं सीमांकन हेतु Gauge & Discharge एवं Cross-section data उ०प्र० का समतल भूभाग होने के कारण अत्यधिक महत्वपूर्ण है, जिसमें हमें WIMS Portal के माध्यम से निम्नलिखित गेज स्टेशनों के Water Level एवं Discharge data प्राप्त हुआ है -

S. no	District	Gauge Station Name	Water Level	Discharge	Data availability	Remarks
1	Fategarh	Fategarh	14-11-1971 to 31-05-2023	14-11-1971 to 31-05-2023	53 yrs	
2	Kanpur Nagar	Ankinghat	01-01-1974 to 20-03-2023	01-01-1974 to 20-03-2023	30 Yrs	
3	Kanpur Nagar	Kanpur	01-01-1974 to 28-02-2023	01-01-1974 to 28-02-2023	30 yrs	
4	Dalmou	Raibareli	N/A	N/A		
5	Phaphamau	Prayagraj	N/A	N/A		
6	Chhatnag	Prayagraj	03-07-1970 to 20-07-2023	03-07-1970 to 20-07-2023	53 Yrs	
7	Mirzapur	Mirzapur	01-06-1976 to 30-06-2023	01-06-1976 to 30-06-2023	48 yrs	
8	Varanasi	Varanasi	01-01-1968 to 30-06-2023	01-01-1968 to 30-06-2023	55 Yrs	
9	Ghazipur	Ghazipur	01-06-2014 to 16-08-2023	N/A	10 yrs	Discharge Not available
10	Ballia	Turtipar	01-01-1974 to 14-08-2023	01-01-1974 to 14-08-2023	50 yrs.	
11	Fatehpur	Bhitaure	01-01-1974 to 31-07-2023	01-01-1974 to 31-07-2023	49 yrs.	
12	-	Chunar	15-10-2018 to 16-05-2023	15-10-2018 to 16-05-2023	06 yrs	
13	-	Narayanpur	15-10-2018 to 31-07-2023	15-10-2018 to 31-07-2023	06 yrs.	



S. no	District	Gauge Station Name	Water Level	Discharge	Data availability	Remarks
14	-	Saidpur	15-10-2018 to 31-07-2023	15-10-2018 to 31-07-2023	06 yrs	
15	-	Buxar	01-01-1974 to 15-08-2023	01-01-1974 to 15-08-2023	49 yrs.	

अतः आपसे अनुरोध है कि आपके संगठन में उपरोक्त स्टेशनों के अतिरिक्त उ०प्र० में स्थित गंगा नदी एवं उसकी सहायक नदियों का Gauge & Discharge data एवं Cross-section data उपलब्ध कराने कष्ट करें, जिससे कि कार्य को अविलम्ब पूर्ण किया जा सके।

(देवेश शुक्ला)

अधीक्षण अभियन्ता

**पत्रांक:— /अधी०अभि० / एफएमआईएससी / 2023-24 / दिनांक:**

प्रतिलिपि—निम्नलिखित को सूचनार्थ एवं आवश्यक कार्यवाही हेतु प्रेषित—

1. मुख्य अभियन्ता, सूचना प्रणाली संगठन, सिंचाई एवं जल संसाधन विभाग, उ०प्र०, लखनऊ।
2. मुख्य अभियन्ता (शारदा सहायक), सिंचाई एवं जल संसाधन विभाग, उ०प्र०, लखनऊ।
3. अधिशासी अभियन्ता, बाढ़ प्रबन्धन सूचना प्रणाली केन्द्र, सिंचाई एवं जल संसाधन विभाग, उ०प्र०, लखनऊ।

(देवेश शुक्ला)

अधीक्षण अभियन्ता

जल शक्ति मंत्रालय, भारत सरकार  
जल संसाधन, नदी विकास एवं गंगा संरक्षण विभाग  
मुख्य अभियंता कार्यालय  
निचली गंगा बेसिन संगठन  
केंद्रीय जल आयोग, पटना



Ministry of Jal Shakti, Government of India  
Deptt. of Water Resources, RD & GR  
Office of the Chief Engineer  
Lower Ganga Basin Organisation  
Central Water Commission, Patna

सं. मु.अ/नि.गं.बे.सं/डी.बी. हाइड्रो-डाटा/2024/160

दिनांक-18.01.2024

सेवा मे,

अधीक्षण अभियंता,  
बढ़ प्रबंधन सूचना प्रणाली केंद्र,  
सिंचाई एवं जल संसाधन विभाग,  
उ० प्र०, लखनऊ ।

विषय: उ० प्र० मे स्थित गंगा नदी एवं उसकी सहायक नदियों पर LGBO के अंतर्गत स्थापित गेज & Discharge stations का अधिक से अधिक वर्षों का डाटा एवं cross-section data उपलब्ध करने के संबंध में ।

संदर्भ: आपका पत्रांक 07 / अधी०अभि०/एफएमआईसी/2023-24 दिनांक: 16.01.2024।

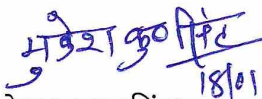
महोदय,

संदर्भित पत्र के द्वारा आपने यह सूचित किया है कि सिंचाई एवं जल संसाधन विभाग द्वारा गंगा नदी के Segment-BI Phase-II (उन्नाव से बलिया) की Flood Plain Zone (FPZ) के निर्धारण एवं सीमांकन (Delineation & Demarcation) का कार्य हेतु, CWC के गेज stations के Water Level एवं Discharge, WIMS पोर्टल से प्राप्त हो गए हैं । साथ ही उत्तर प्रदेश मे स्थित गंगा नदी एवं उसकी सहायक नदियों का Gauge & Discharge एवं cross-section data उपलब्ध कराने का अनुरोध किया गया है ।

इस संबंध मे यह बताना है कि उत्तर प्रदेश मे स्थित गंगा नदी एवं उसकी सहायक नदियों पर LGBO के अंतर्गत स्थापित सभी Gauge & Discharge stations की सूची संलग्न कर प्रेषित की जा रही है । इन सभी sites से संबंधित आंकड़े WIMS Portal पर उपलब्ध जिसे आवश्यक कारवाई हेतु download किया जा सकता है ।

यह मुख्य अभियंता की अनुमति से जारी किया जाता है ।

भवदीय

  
(मुकेश कुमार सिंह)  
अधीक्षण अभियंता (सम०)

अदालतगंज, पटना,

दूरभाष : 0612-2541087/2541065

फैक्स : 0612-2541865/2541087

e-mail: celgbo-cwc@nic.in



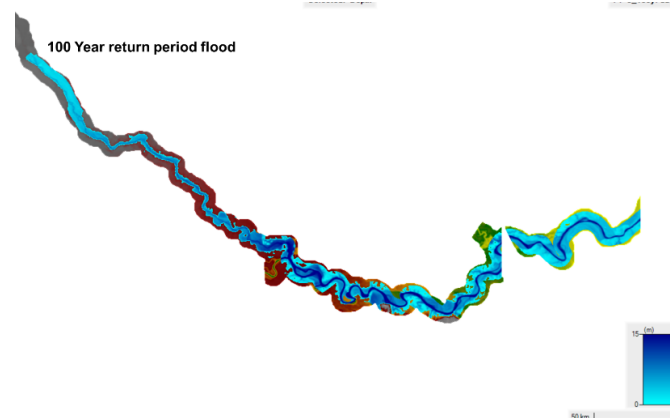
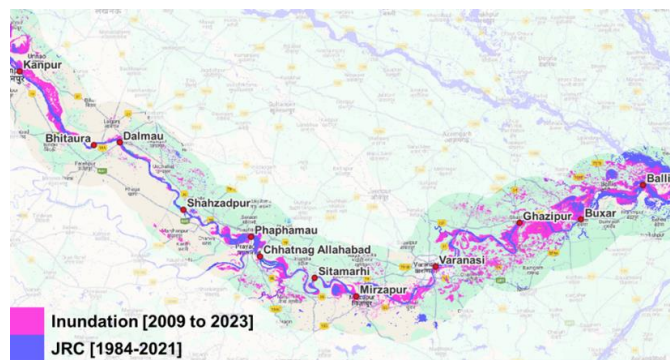
Adalatganj, Patna – 800001  
Telephone: 0612-2541087/2541065  
FAX: 0612-2541865/2541087  
e-mail: celgbo-cwc@nic.in

**Sites under LGBO in Uttar Pradesh**

S. No	Site Name	RIVER NETWORK	Sub - Basin	DISTRICT	STATE
1	Chhitaunighat	Ganga/Gandak	Gandak	Kushi Nagar	Uttar Pradesh
2	Ahrora	Ganga/Jirgo	Jargo	Mirzapur	Uttar Pradesh
3	Akbarpur	Ganga/Chhoti Sarju	Chhoti Sarju	Ambedkar Nagar	Uttar Pradesh
4	Ashatpur	Ganga/Chhoti Sarju/Maghai	Chhoti Sarju	Ghazipur	Uttar Pradesh
5	Azamgarh	Ganga/Chhoti Sarju	Chhoti Sarju	Azamgarh	Uttar Pradesh
6	Mau	Ganga/Chhoti Saryu	Chhoti Sarju	Mau	Uttar Pradesh
7	Chakghat	Ganga/Tons	Tons	Allahabad	Uttar Pradesh
8	Chopan	Ganga/Sone	Sone	Sonbhadra	Uttar Pradesh
9	Chunar	Ganga	Ganga	Mirzapur	Uttar Pradesh
10	Devkali	Ganga/Gaangi	Gaangi	Ghazipur	Uttar Pradesh
11	Duddhi	Ganga/Sone/Kanhar	Sone	Sonbhadra	Uttar Pradesh
12	Jalalpur	Ganga/Gomti/Sai	Gomti	Jaunpur	Uttar Pradesh
13	Kasmabad	Ganga/Chhoti Saryu	Chhoti Sarju	Ghazipur	Uttar Pradesh
14	Kohdarghat (Tones Aquaduct)	Ganga/Tons	Tons	Allahabad	Uttar Pradesh
15	Lalganj	Ganga/Tons/Belan	Tons	Mirzapur	Uttar Pradesh
16	Maighat	Ganga/Gomti	Gomti	Jaunpur	Uttar Pradesh
17	Mejaroad	Ganga/Tons	Tons	Allahabad	Uttar Pradesh
18	Narahan	Ganga/Durgawati/Karamnasa	Durgawati	Chandauli	Uttar Pradesh
19	Narayanpur	Ganga	Ganga	Mirzapur	Uttar Pradesh
20	Negai	Ganga/Sone	Sone	Sonebhadra	Uttar Pradesh
21	Niwari	Ganga/Sone	Sone	Sonebhadra	Uttar Pradesh
22	Pratapgarh	Ganga/Gomti/Sai	Gomti	Pratapgarh	Uttar Pradesh
23	Saidpur	Ganga	Ganga	Saidpur	Uttar Pradesh
24	Shahzadpur	Ganga	Ganga	Kaushambi	Uttar Pradesh
25	Sitamarhi	Ganga	Ganga	Sant Ravidas Nagar	Uttar Pradesh
26	Sultanpur	Ganga/Gomti	Gomti	Sultanpur	Uttar Pradesh
27	Tendui	Ganga/Varun	Varun	Varanasi	Uttar Pradesh
28	Khadda	Ganga/Gandak	Gandak	Kushi Nagar	Uttar Pradesh
29	Rihand Dam	Ganga/Sone/Rihand	Sone	Sonbhadra	Uttar Pradesh
30	Allahabad	Ganga	Ganga	Allahabad	Uttar Pradesh
31	Ballia	Ganga	Ganga	Ballia	Uttar Pradesh
32	Gazipur	Ganga	Ganga	Gazipur	Uttar Pradesh
33	Jaunpur	Ganga/Gomti	Gomti	Jaunpur	Uttar Pradesh
34	Mirzapur	Ganga	Ganga	Mirzapur	Uttar Pradesh
35	Phaphamau	Ganga	Ganga	Allahabad	Uttar Pradesh
36	Varanasi	Ganga	Ganga	Varanasi	Uttar Pradesh

**ANNEXURE - R6**  
**Progress Report**

**FLOOD PLAIN ZONE DELINEATION**  
**FROM UNNAO TO BALIA**



**National Institute of Hydrology**

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

**July, 2024**

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## 1 INTRODUCTION

Floods constitute one of the major national calamities faced by India 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 not only impossible but also not economically viable. The emphasis has therefore been rightly shifted to non-structural measures like Flood Plain Zoning and Regulation, Flood Forecasting, etc., to effectively supplement the structural measures for providing sustainable protection to flood affected areas. The broad concept in flood plain zoning is to regulate the land use in order to mitigate the damage potential. The role of flood plains and need for flood plain zoning was recognized by the Central Water Commission (CWC) as early as 1975. CWC had prepared a Model Floodplain Zoning Bill for adaptation by states but it did not receive due attention of states.

In pursuance to the directions contained in the judgment passed by Hon'ble NGT a Report on identification and demarcation of the flood plains of river Ganga in segment B of Phase- I (Haridwar to Unnao) was prepared by CWC in 2019. Subsequently, the Irrigation and Water Resources Department, Govt. of UP has approached NIH Roorkee to carry out the study "Flood plain zone delineation from Unnao to Balia" as per direction given by Hon'ble NGT. This study was originally envisaged with similar methodologies as used by CWC in the earlier study for the Ganga River in the stretch of Haridwar to Unnao. However, as per direction given by Hon'ble NGT it was decided to first demarcate the flood plain corresponding to once in hundred years return period (REGD. NO. D. L.-33004/99; 2016).

## 2 OBJECTIVES AND SCOPE OF WORK

The following tasks are to be carried out by NIH, Roorkee for this study.

- a) Estimation of floods of various return periods viz. 2 year, 3 year, 10 year, 25 year, 50 year and 100 year at different gauging sites based on flood frequency

- analysis
- Flood Plain Demarcation based on Satellite Data/Images.
  - Flood Plain Demarcation based on hydraulic modelling.
  - Demarcation of flood plain by combining results of Satellite Data/Images and hydraulic modelling.

### 3 STUDY AREA AND DATA

The study reach of Ganga river from Unnao to Balia is shown in Figure 1. The length of river stretch is about 700 km and 30 km buffer zone is also demarcated for analysis.

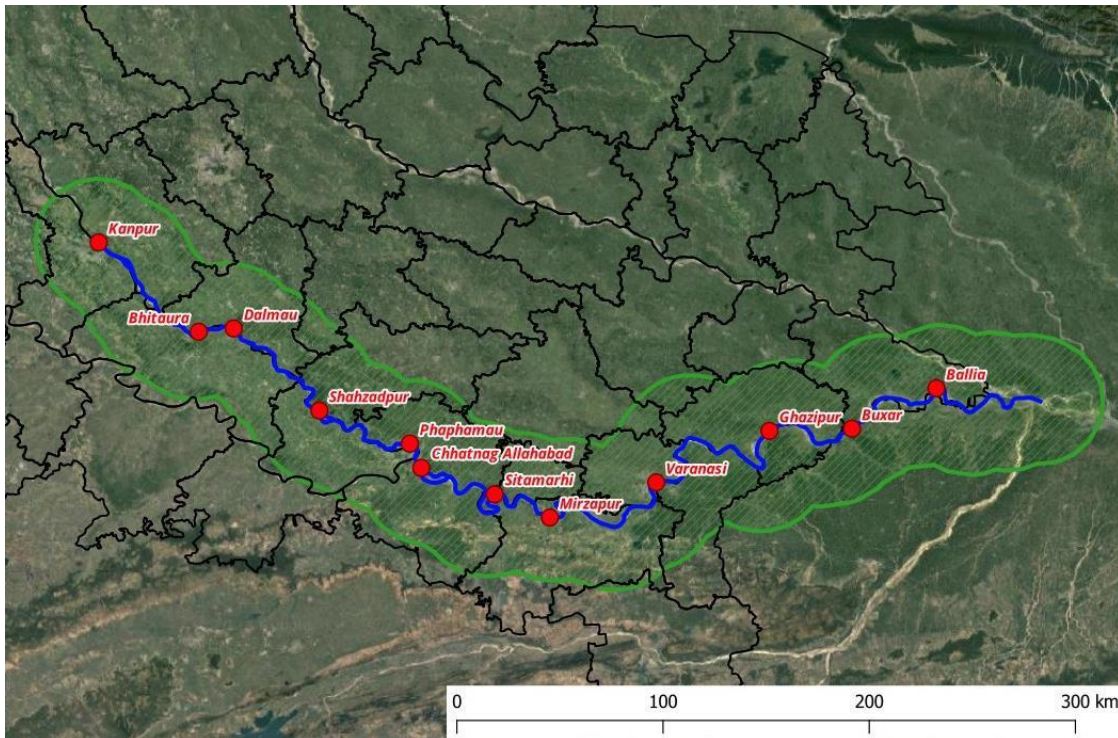


Figure 1: Index Map of the Study Area

#### 3.1 Data

The locations of G&D sites (CWC) and contributing catchment area is shown in Figure 2. The long term annual maximum data and water level are available at six G&D sites. Details are given in Table 1.

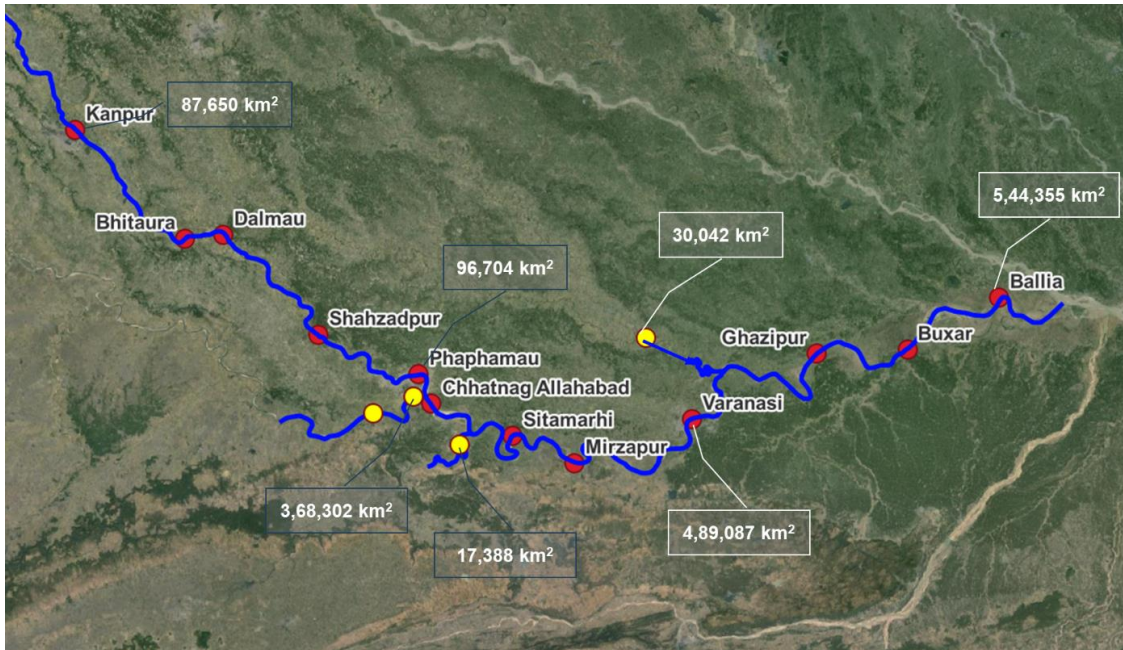


Figure 2: Location of G&D sites and their catchment area

Table 1: Summary of data availability at various G&D sites.

SN	HO Site	Data available
1	Kanpur	01/01/1974 to 28/02/2023
2	Bhitaura	01/01/1974 to 31/07/2023
3	Chhatang Allahabad	03/07/1970 to 20/07/2023
4	Mirzapur	01/06/1976 to 04/07/2023
5	Varanasi	01/01/1968 to 30/06/2023
6	Buxar	01/01/1974 to 15/08/2023

River cross-sections at these CWC's HO locations are provided to NIH. Further, river cross-sections at 25 locations surveyed by AECOM are also made available. In additions cross-section survey at 19 locations are carried out for this study. The LiDAR DEM (Digital Elevation Model) prepared by the survey of India under the National Hydrology Project (NHP) for improved flood hazard mapping and other planning purposes was also made available. As per survey of India the DEM is of 0.5 m vertical accuracy and having 1m X 1m grid size. Extent of DEM and location of

surveyed Cross-sections are shown in Figure 3. Moreover, as per recent direction of Hon'ble NGT attempts are being made to obtain 1 m contour data of the area from SOI. These DEM doesn't capture topography under water as shown in Figure 4 and ANNEXURE-I. Hence these surveyed river cross-sections are also important for hydraulic modelling for proper representation of conveyance (discharge capacity of river).

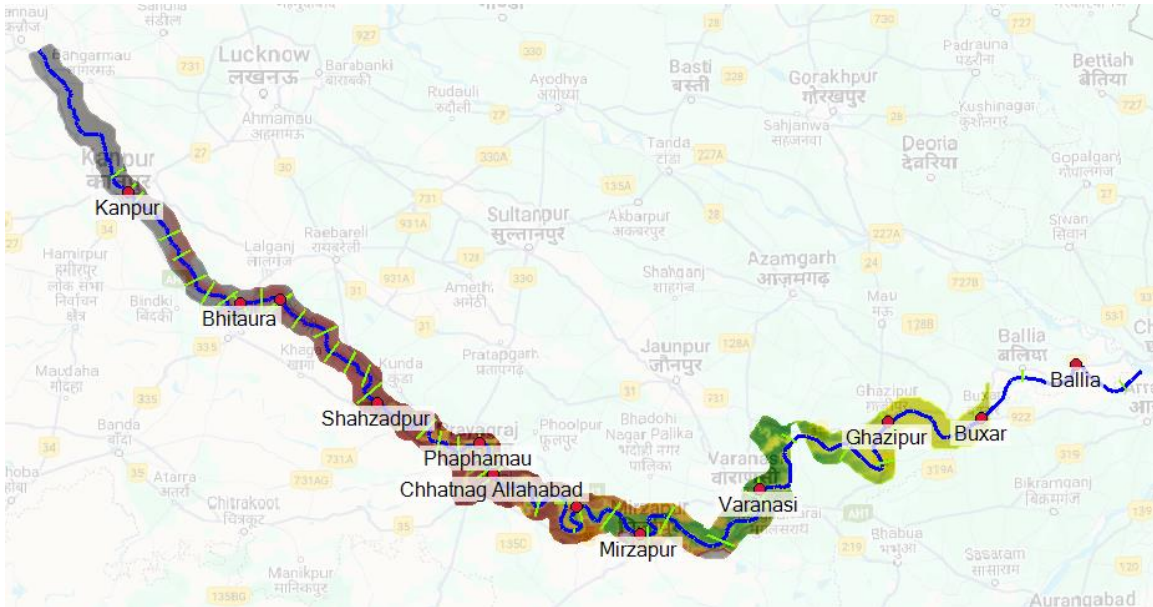


Figure 3: Extent of DEM and location of surveyed Cross-section

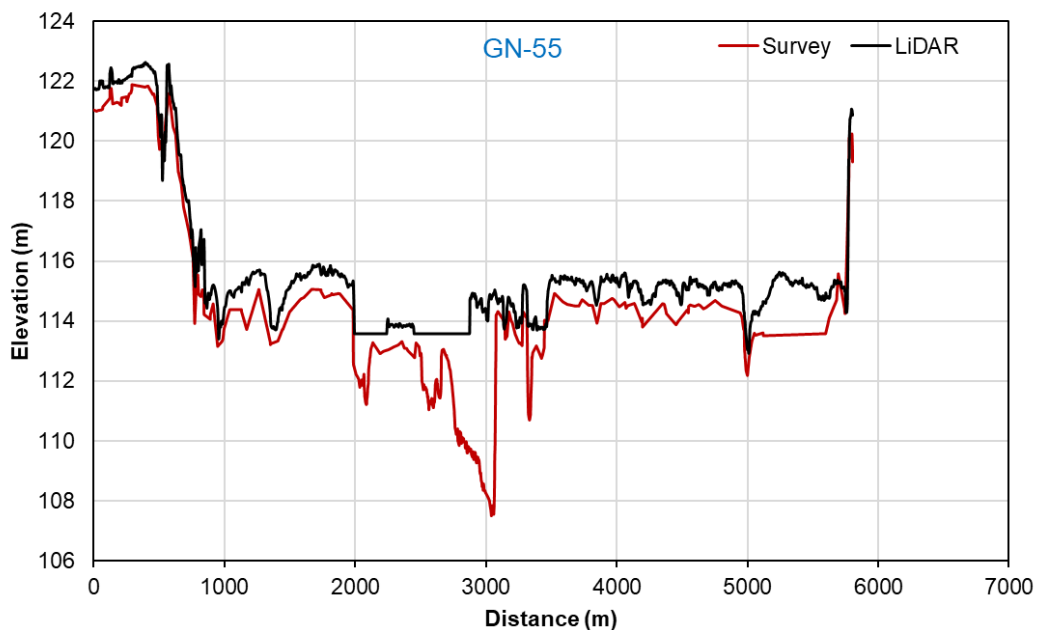


Figure 4: Comparison of river Surveyed River cross-section with DEM (SOI)

## 4 METHODOLOGY

The study will be carried out with the same methodology as used by Central Water Commission (CWC) in the study for river Ganga from Haridwar to Unnao (Phase-I). Three Types of Approaches will be used for flood plain zoning viz.

- a. Satellite
- b. Hydraulic Model - HEC RAS
- c. Hybrid

First, the flood frequency analysis will be carried out for various gauging sites in the study reach using various frequency distributions to estimate floods of various return periods up to 100-year return period.

### 4.1 Satellite base approach

The Joint Research Centre-European Commission has analyzed Landsat multispectral satellite images of the past 37 years (1984-2021) for deriving the frequency with which water returns from year to year i.e. recurrence interval. The same will be used in the study through the Google Earth engine platform. The flood inundation Extent of recent years as per availability (RSAC-UP/ NRSC) will be analyzed with reference to return period floods.

### 4.2 Hydraulic Model approach

HEC-RAS, a hydraulic model developed by the USACE, is extensively applied in calculating the hydraulic characteristics of rivers. HEC-RAS model needs details of river cross sections (for 1-D modelling) and DEM (for 2-D modelling and flood inundation mapping) apart from boundary conditions (discharge, water level etc.). The latest update on the program, HEC-RAS 6.5 includes capabilities to model the hydraulics both one and two dimensionally is used for this study. The HEC-RAS model is setup using:

- Upstream branch to provide constant flood magnitude equal to the given return period at upstream boundary (Unnao).
- Downstream boundary as normal depth at downstream of Balia.
- Flood plain bathymetry (DEM), River cross-section for routing the flows between Unnao and Balia.
- Different locations (G&D sites) flow is added to match the estimated flood of

corresponding return period at the intermediate gauging sites (Bhitora, Chhatnag\_Allahabad, Mirzapur, Varanasi, Buxar).

The HEC-RAS model will provide inundation extent for various return periods (corresponding to discharge)

### 4.3 Hybrid approach

The results of satellite analysis and modelling have their own limitation. Satellite may not cover the full flood event and model results are subjected to DEM quality. Therefore, hybrid approach will combine both the results by taking union of the areas obtained from both the results.

## 5 RESULTS AND DISCUSSIONS

### 5.1 Flood Frequency Analysis

The annual maximum discharge series of available six G&D sites are shown in Figure 5. The G&D site wise observed annual maximum discharge data are shown in Figure 6. Flood frequency analysis of annual maximum discharge series of available has been carried out using the L-moments approach as described elsewhere (Hosking and Wallis, 1997; Kumar and Chatterjee, 2005). Twelve frequency distributions viz. extreme value (EV1), general extreme value (GEV), logistic (LOS), generalized logistic (GLO), normal (NOR), generalized pareto (GPA), generalized normal (GNO), uniform (UNF), exponential (EXP), pearson Type-III (PT3), kappa (KAP) and wakeby (WAK) have been used to identify robust distribution based on the L-moment ratio diagrams and the  $Z_i^{dist}$ -statistic criteria. The Estimated floods of various return periods at six G&D sites are shown in Table 2.

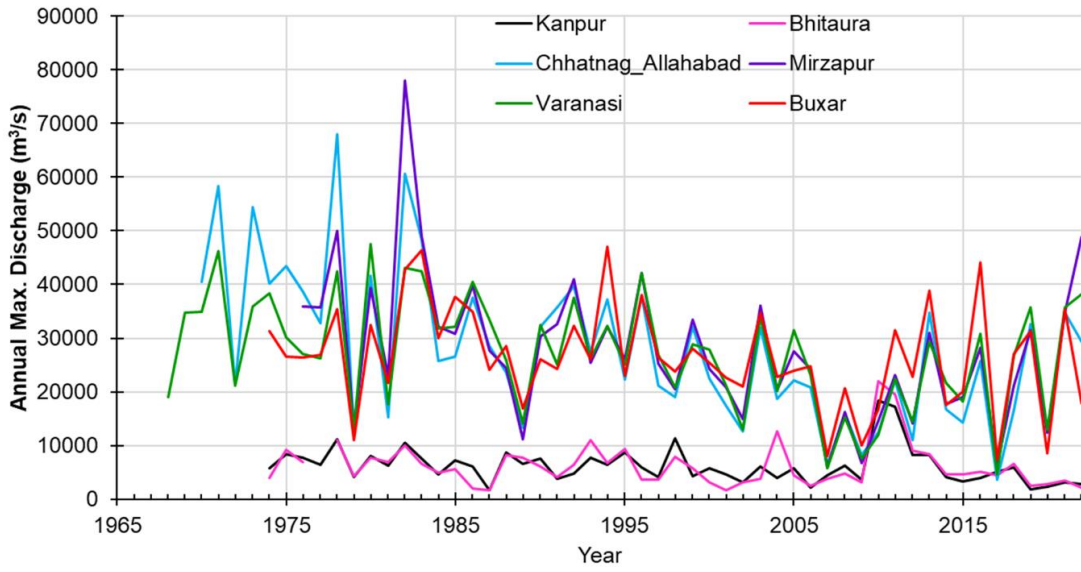
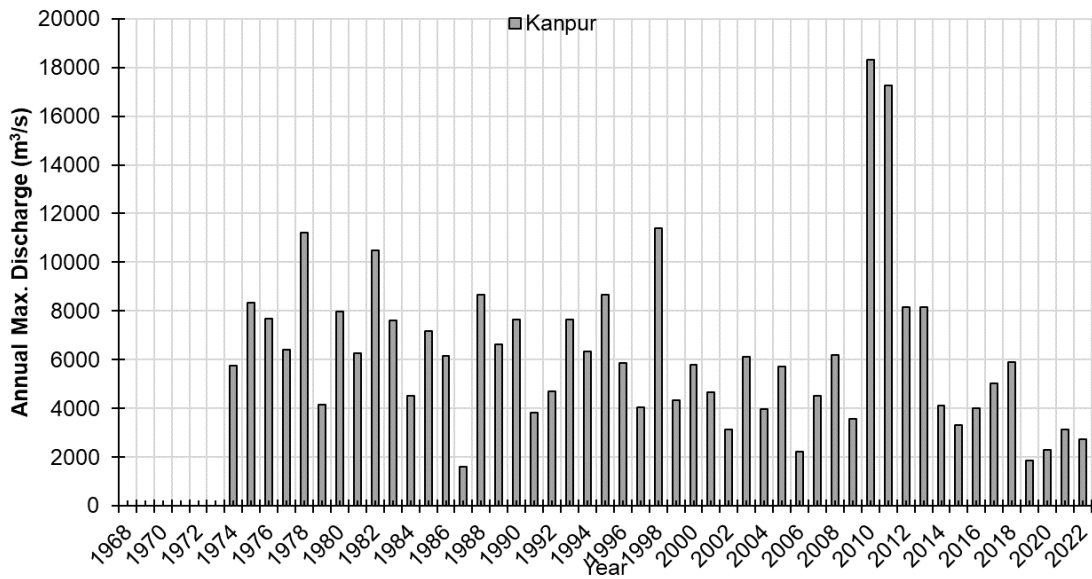
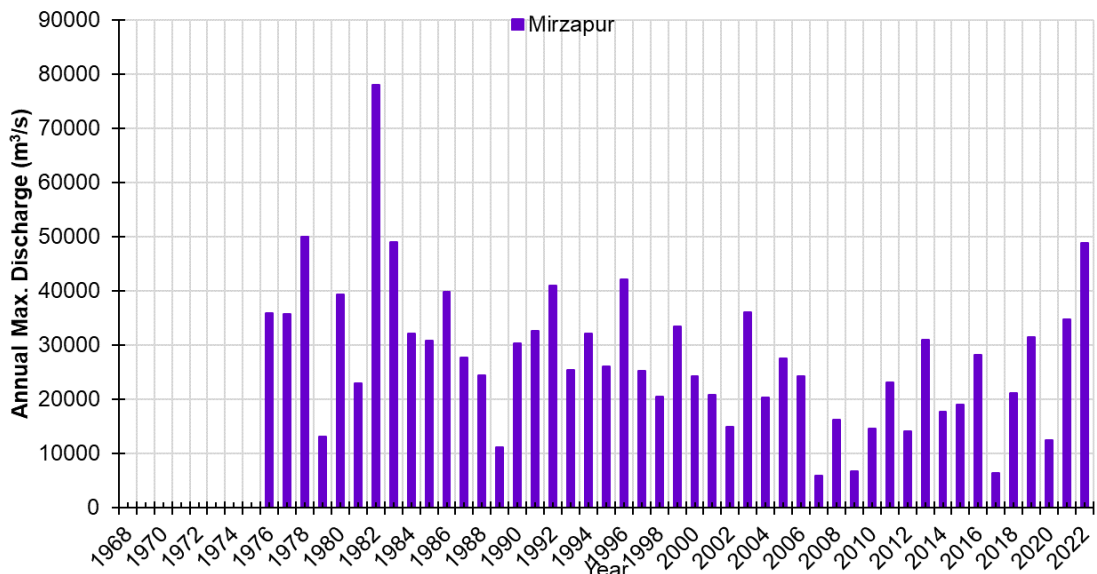
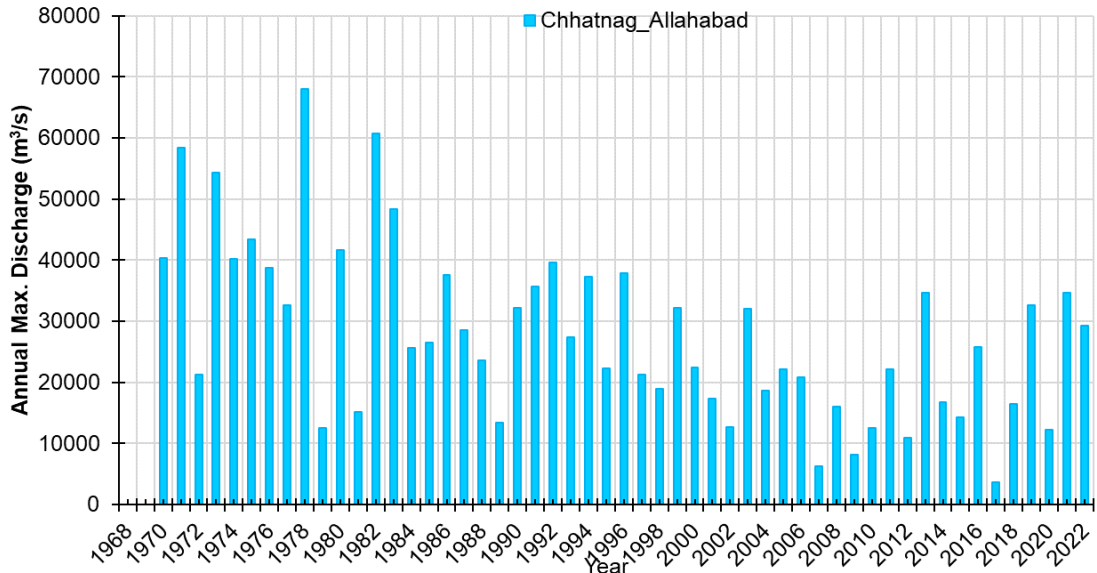
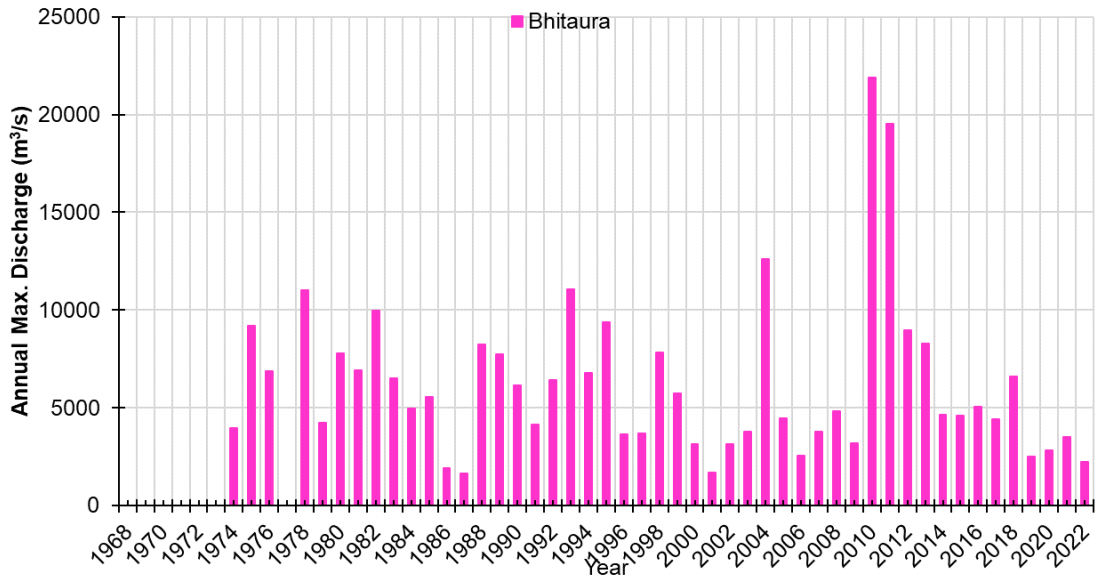


Figure 5: Annual maximum discharge series





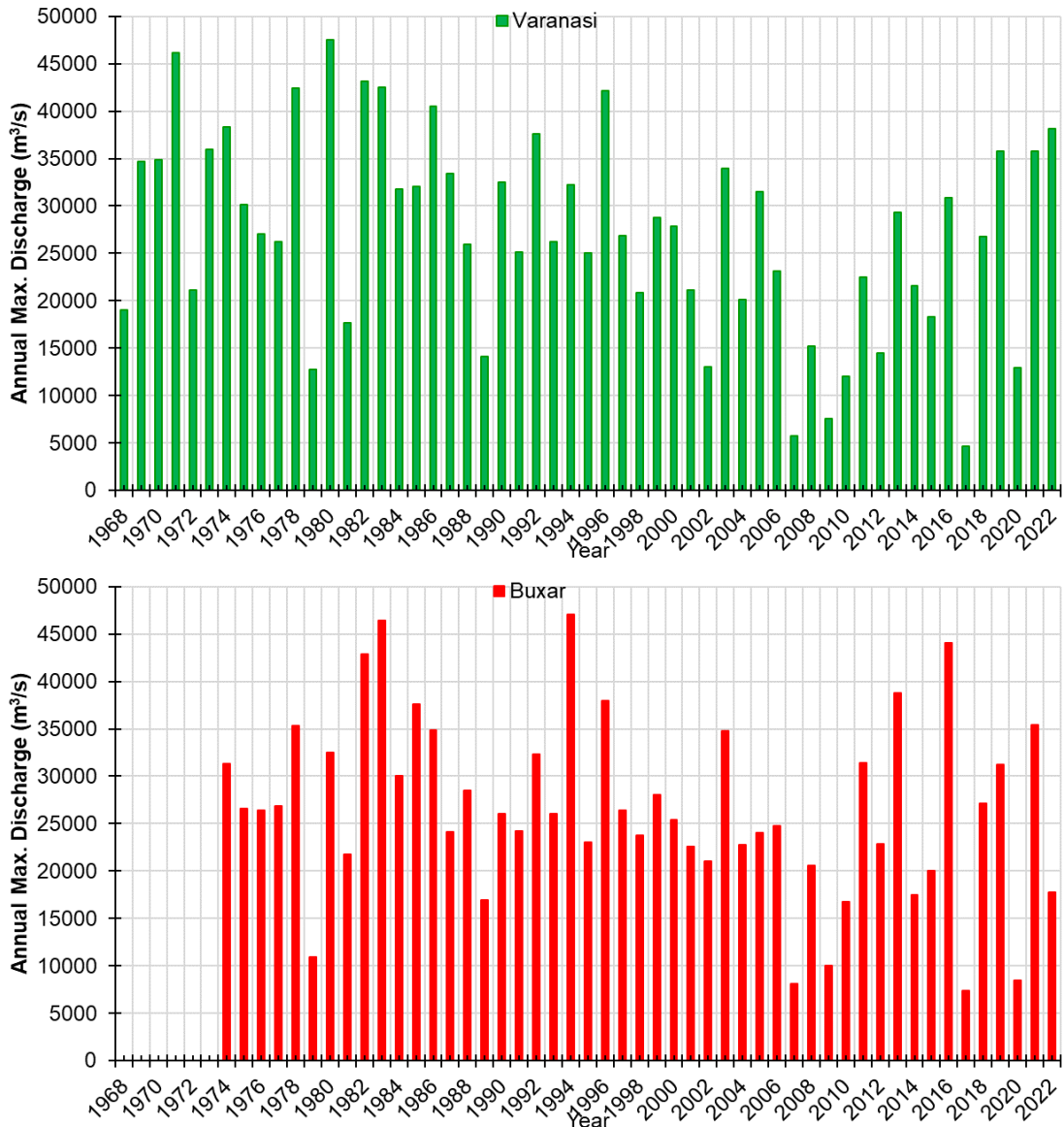


Figure 6: G&D site wise observed annual maximum discharge data.

Table 2: Estimated floods of various return periods

Return Period (Year)	Discharge (cumec)					
	Kanpur	Bhitaure	Chhatnag_Allahabad	Mirzapur	Varanasi	Buxar
2	5595.2	5216.7	25926.1	26291.2	27659.0	26364.9
5	<b>8174.7</b>	<b>8434.2</b>	<b>39098.5</b>	<b>36907.2</b>	<b>36697.2</b>	<b>33931.8</b>
10	10112.4	11002.0	47163.7	43956.8	40944.0	38445.5
20	12243.3	13850.9	54475.5	51061.8	44047.5	42693.6
25	<b>12991.0</b>	<b>14838.0</b>	<b>56708.1</b>	<b>53411.7</b>	<b>44864.2</b>	<b>44021.1</b>
50	15539.3	18192.9	63405.9	60986.7	47042.0	48163.0
100	<b>18492.7</b>	<b>22010.2</b>	<b>69824.7</b>	<b>69086.9</b>	<b>48702.7</b>	<b>52278.4</b>

## 5.2 Flood Plain Demarcation based on Satellite Data/Images

The Joint Research Centre- European Commission have analyzed Landsat multispectral Satellite images of past 37 years (1984-2021) for deriving frequency with which water returns from year to year i.e. recurrence interval. The maximum flood extent map is shown in Figure 7.

The flood date wise and annual flood extent layer extracted from remotesensing data for the period 2009 to 2023 supplied by NRSC are also made available. The overlay of JRC inundation extent and NRSC data set is shown in Figure 8. However, these Satellite /remote sensing based flood inundation extent needs further classification and ground truthing for extraction of Riverine Flood (flooding due to over bank flood of the Ganga river). This will be jointly carried out by NIH and Irrigation and Water Resources Department, Govt. of UP.

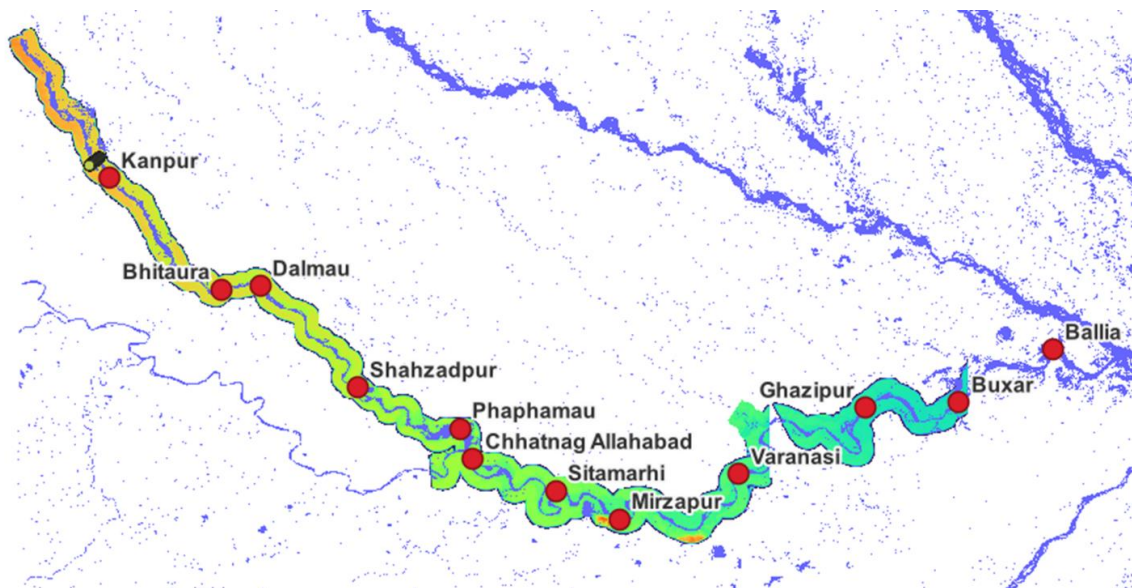


Figure 7: Maximum flood inundation extent map (JRC, 1984-2021)

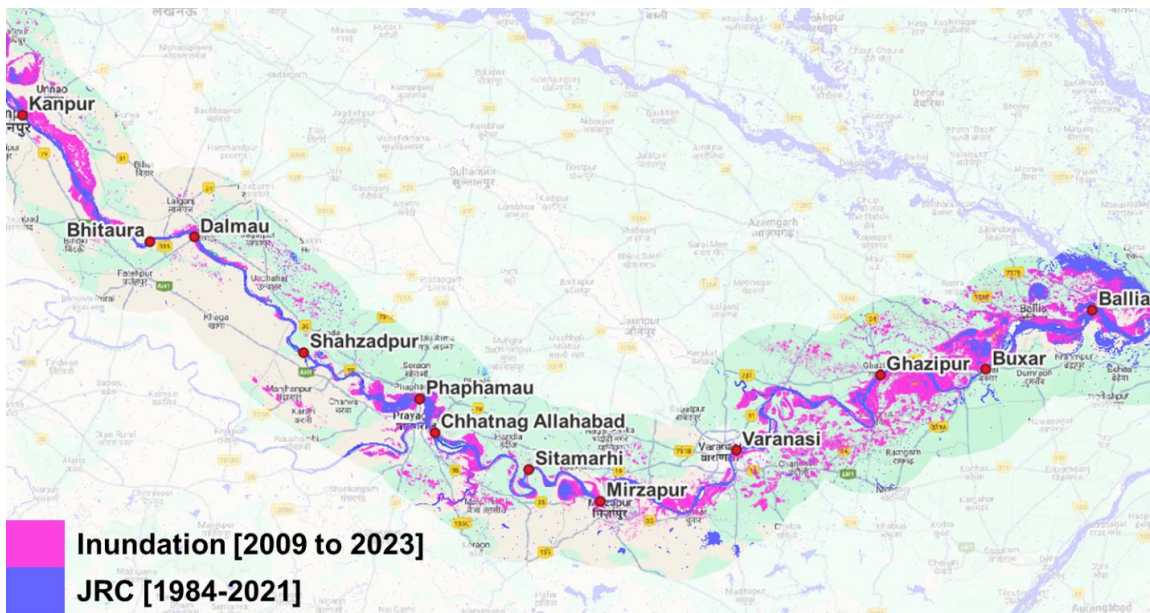


Figure 8: Overlay of maximum flood inundation extent of JRC and NRSC

### 5.3 Flood Plain Demarcation based on hydraulic modelling

In the previous study by CWC (2019), SRTM DEM (90 m) was used with correction of river profile below the water surface based on available cross-sections. Similarly in this study also the LiDAR DEM (SOI) is used. About 44 surveyed river cross-sections are being used for HEC-RAS model setup. The 1-D HEC-RAS model with extended river cross-section has been prepared. The model is being calibrated for past flood of 2010, 2013, 2016, 2019, 2022 etc.

Comparisons of longitudinal simulated water surface profile for 100-year return period flood and 2010 flood event are shown in Figure 9. The inundation extent for 100-year return period flood is shown in Figure 10. The discharge at Kanpur and Bhitaura in they year 2010 is maximum and near to 100 year return period.

The HEC-RAS model is still requires some recalibration based on recently obtained flood inundation extents from satellite data. Further, if the 1 m contour data from SOI is available, model will be updated with it.

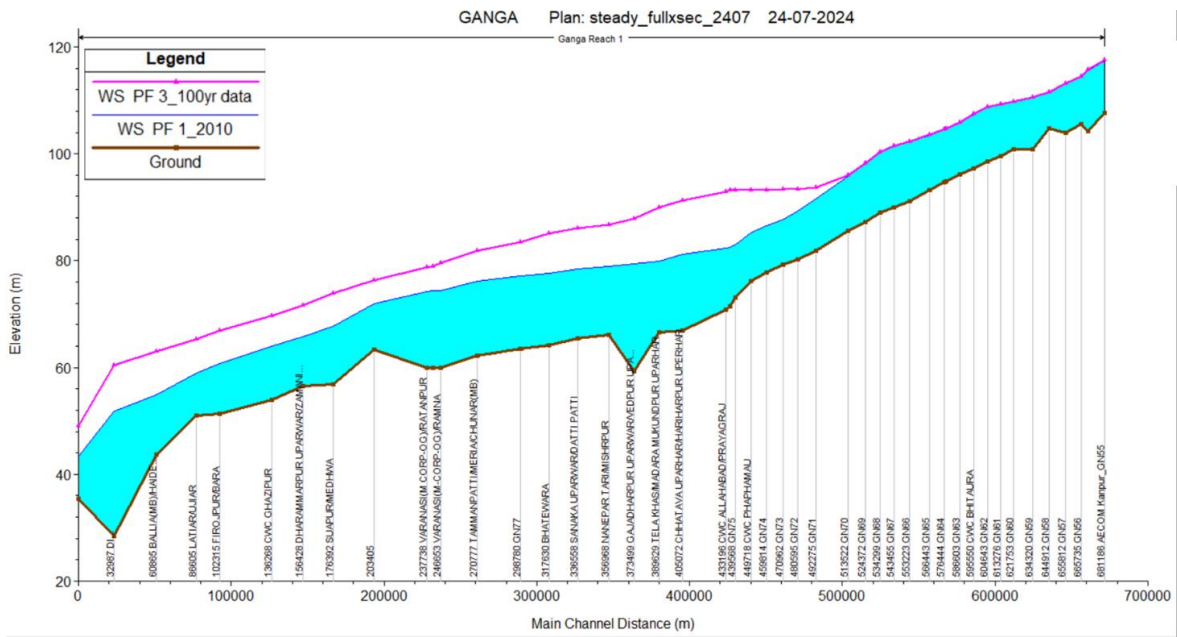


Figure 9: Longitudinal simulated water surface profile for 100 year return period flood and 2010 flood

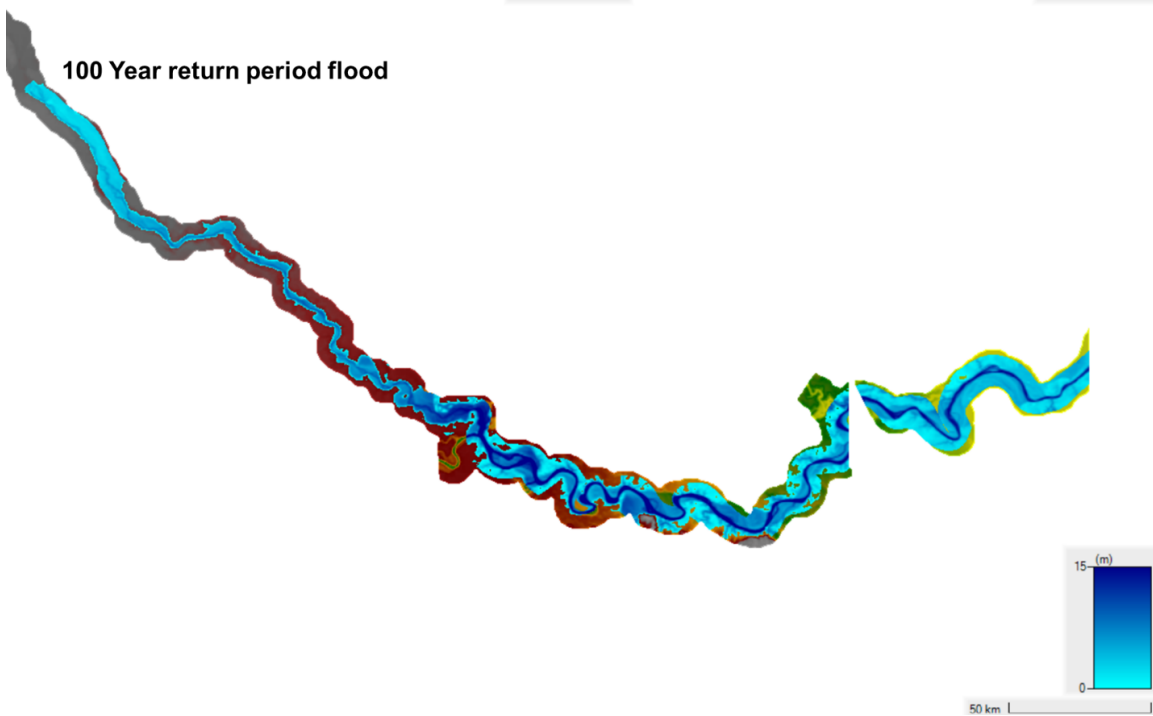


Figure 10: Flood Inundation extent for 100-year return period flood

## 6 Future Work Plan

The major time line of activities of this study are given below. As mentioned at section 5.2 the satellite /remote sensing-based flood inundation extent needs further classification and ground truthing for extraction of riverine Flood (flooding due to over bank flood of the Ganga river) and this will be jointly carried out by NIH and Irrigation and Water Resources Department, Govt. of UP. Moreover, attempts are being made to obtain 1 m contour data of the area from SOI on direction of Hon'ble NGT. The hydraulic modelling approach based inundation map will be redeveloped using these data as per availability. After this, in hybrid approach both the results will be combined by taking union of the flood inundation areas obtained these approach to make final flood plain boundary for 100 year return period flood. The flood plain boundary will be provided as georeferenced GIS layer (shape file) so that it can be super imposed over any other layer as per requirement. The coordinates (Lat, Long) at regular interval will also be provided, so that it can be marked on the ground when required.

SN	Task/ Component	Month		
		Aug	Sep	Oct
1	Inception Report	Completed		
2	Data collection and Processing	Under progress (1m contour data from SOI is under progress)		
3	Flood frequency analysis	Completed		
4	Flood plain zoning based on the JRC Satellite images of past 37 years (1984-2021)	Completed		
5	Flood Plain Demarcation based on Satellite Data/Images	■	■	
6	HEC RAS model setup (Calibration/validation)	■	■	
7	Finalization of hydraulic model results		■	■
8	Submission of interim findings discussion, ground truthing/ result verification			■
9	Demarcation of flood plain based on <i>hybrid approach</i>			■
10	Submission of draft Report			■
11	Submission of final Report	*		

\*Final report will be submitted after incorporating the comments received from the sponsoring agency.

## Bibliography

Hosking, J.R.M., and Wallis, J.R. (1997). *Regional frequency analysis: an approach based on L-moments*. Cambridge University Press, Cambridge.

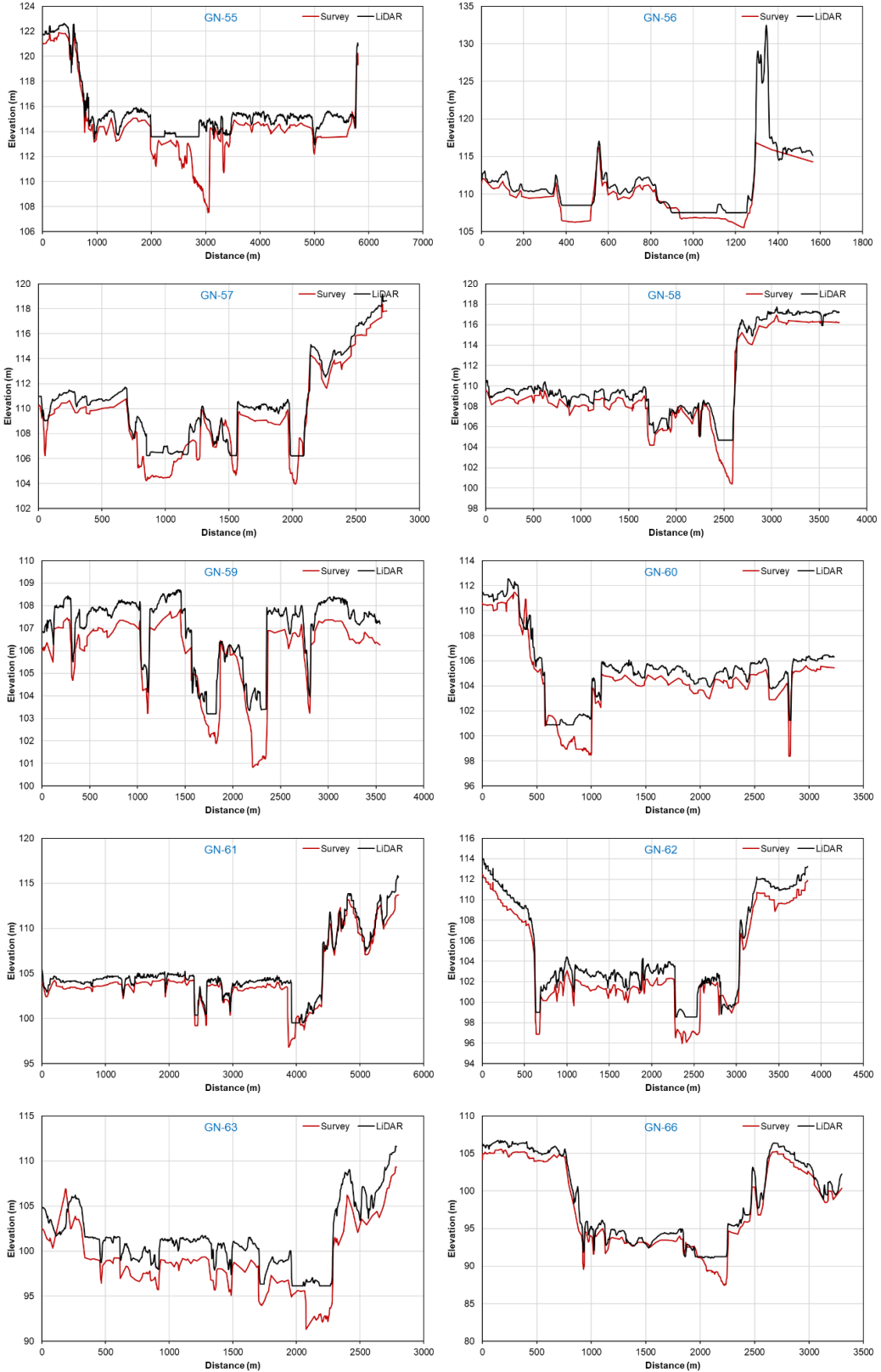
Kumar, R., and Chatterjee, C. (2005). Regional flood frequency analysis using L-moments for North Brahmaputra Region of India. *Journal of Hydrologic Engineering, American Society of Civil Engineers*, 10(1), 1–7.

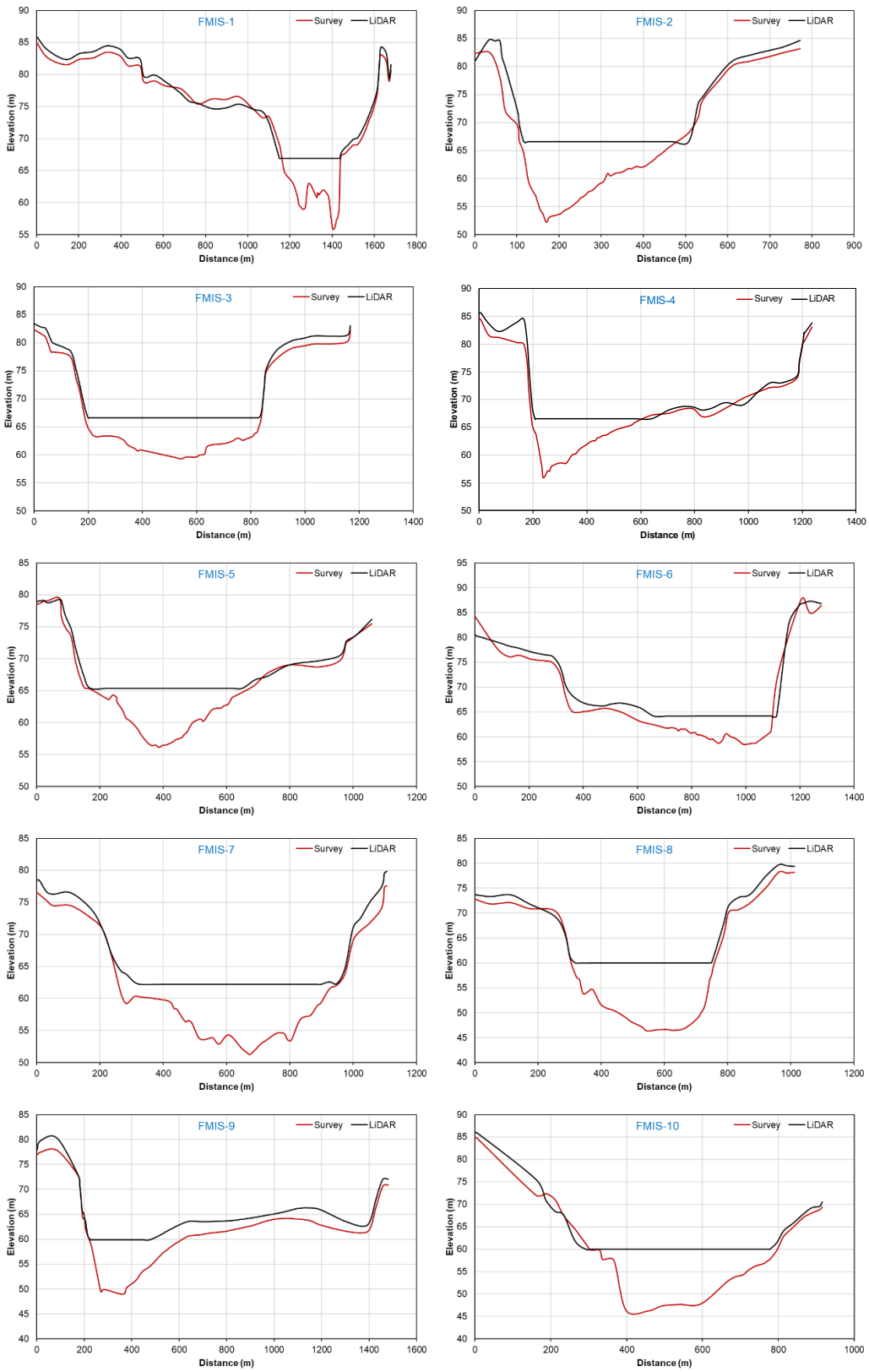
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[https://nmcg.nic.in/writereaddata/fileupload/47\\_AuthorityNotification.pdf](https://nmcg.nic.in/writereaddata/fileupload/47_AuthorityNotification.pdf)

ANNEXURE-I

Comparison of River cross-section river Surveyed vs LiDAR DEM (SOI)





**Progress report on Flood Plain Zone, delineation and demarcation of river Ganga (Segment B, Phase II) from Unnao to Ballia till August, 2024**

1. As per the direction of Hon'ble NGT, the DEM data of 1m contour interval from SOI has been provided to NIH on August 08, 2024, the total volume of data received by NIH is 835 GB which are in 1X1 km tile. To use this data for HEC-RAS modelling, merging of all these tiles are required. As the complete data set are in large number of tiles, merging is taking huge time. Therefore, processing of 1m contour interval data is under progress.
2. The flood frequency analysis of available Six Gauge sites discharge data has been completed and 100-year return period flood has been computed.
3. Flood plain zoning based on the JRC Satellite images of past 37 years (1984-2021) has been completed (because only 37 years satellite data is available).
4. Under the satellite-based approach method, flood plain demarcation based on satellite data/images received from NRSC, Hyderabad (from 2017 to 2023) and inundation data received from RSAC-UP, Lucknow (from 2009 to 2016) have been completed.
5. Under Hydraulic Model, HEC RAS method, for delineation of FPZ, the river cross sections data provided to NIH have been utilized for 1-D modelling. After processing of SOI 1m DEM the same will be incorporated in the HEC RAS model for FPZ.



Head, Surface Water Hydrology Division  
National Institute of Hydrology  
Roorkee

## 4 METHODOLOGY

The study will be carried out with the same methodology as used by Central Water Commission (CWC) in the study for river Ganga from Haridwar to Unnao (Phase-I). Three Types of Approaches will be used for flood plain zoning viz.

- a. Satellite
- b. Hydraulic Model - HEC RAS
- c. Hybrid

First, the flood frequency analysis will be carried out for various gauging sites in the study reach using various frequency distributions to estimate floods of various return periods up to 100-year return period.

### 4.1 Satellite base approach

The Joint Research Centre-European Commission has analyzed Landsat multispectral satellite images of the past 37 years (1984-2021) for deriving the frequency with which water returns from year to year i.e. recurrence interval. The same will be used in the study through the Google Earth engine platform. The flood inundation Extent of recent years as per availability (RSAC-UP/ NRSC) will be analyzed with reference to return period floods.

### 4.2 Hydraulic Model approach

HEC-RAS, a hydraulic model developed by the USACE, is extensively applied in calculating the hydraulic characteristics of rivers. HEC-RAS model needs details of river cross sections (for 1-D modelling) and DEM (for 2-D modelling and flood inundation mapping) apart from boundary conditions (discharge, water level etc.). The latest update on the program, HEC-RAS 6.5 includes capabilities to model the hydraulics both one and two dimensionally is used for this study. The HEC-RAS model is setup using:

- Upstream branch to provide constant flood magnitude equal to the given return period at upstream boundary (Unnao).
- Downstream boundary as normal depth at downstream of Balia.
- Flood plain bathymetry (DEM), River cross-section for routing the flows between Unnao and Balia.
- Different locations (G&D sites) flow is added to match the estimated flood of

corresponding return period at the intermediate gauging sites (Bhitora, Chhatnag\_Allahabad, Mirzapur, Varanasi, Buxar).

The HEC-RAS model will provide inundation extent for various return periods (corresponding to discharge)

### 4.3 Hybrid approach

The results of satellite analysis and modelling have their own limitation. Satellite may not cover the full flood event and model results are subjected to DEM quality. Therefore, hybrid approach will combine both the results by taking union of the areas obtained from both the results.

## 5 RESULTS AND DISCUSSIONS

### 5.1 Flood Frequency Analysis

The annual maximum discharge series of available six G&D sites are shown in Figure 5. The G&D site wise observed annual maximum discharge data are shown in Figure 6. Flood frequency analysis of annual maximum discharge series of available has been carried out using the L-moments approach as described elsewhere (Hosking and Wallis, 1997; Kumar and Chatterjee, 2005). Twelve frequency distributions viz. extreme value (EV1), general extreme value (GEV), logistic (LOS), generalized logistic (GLO), normal (NOR), generalized pareto (GPA), generalized normal (GNO), uniform (UNF), exponential (EXP), pearson Type-III (PT3), kappa (KAP) and wakeby (WAK) have been used to identify robust distribution based on the L-moment ratio diagrams and the  $Z_i^{dist}$ -statistic criteria. The Estimated floods of various return periods at six G&D sites are shown in Table 2.

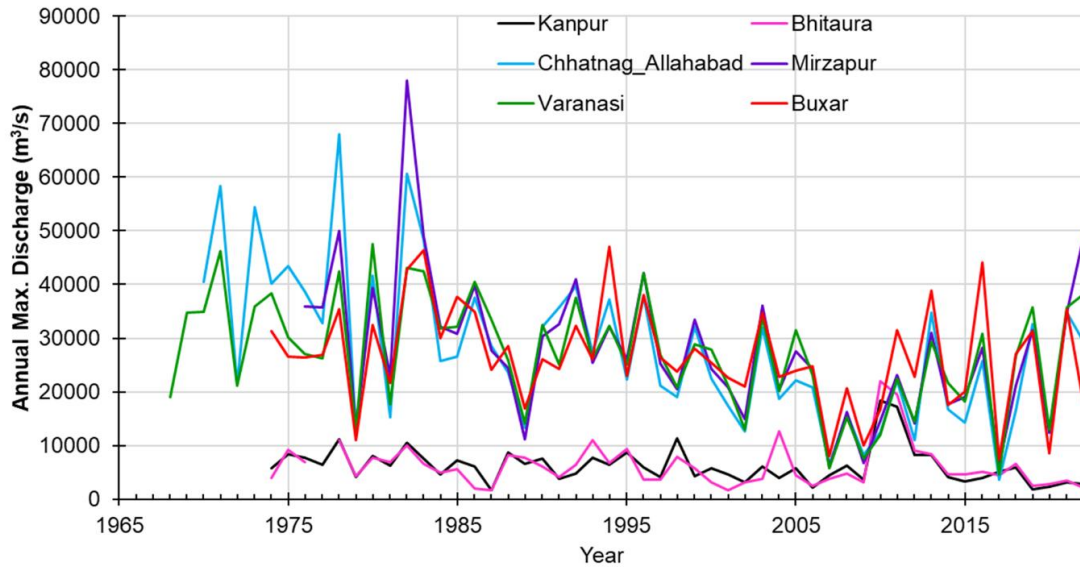
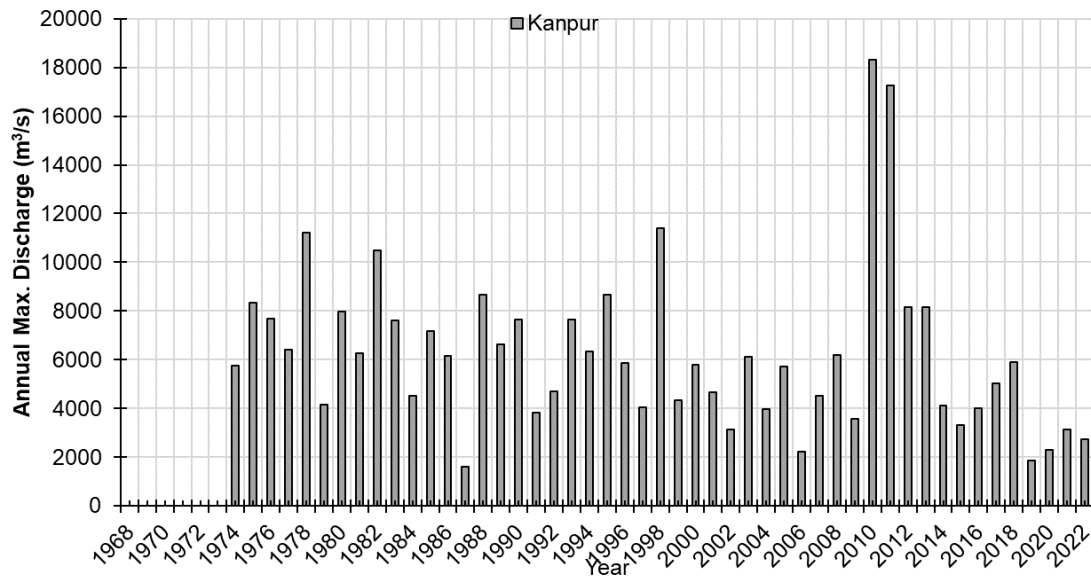
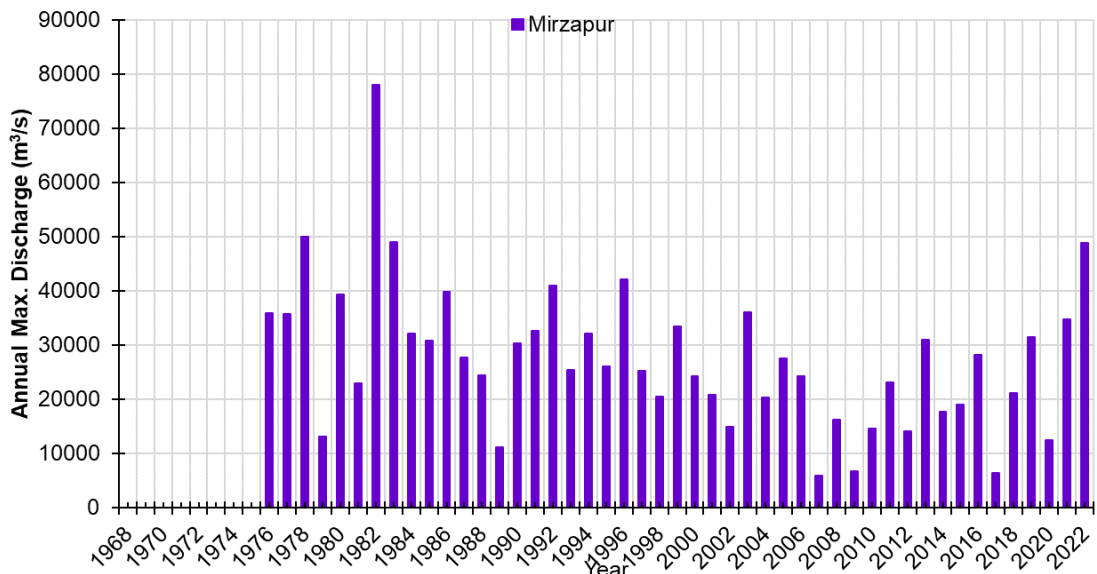
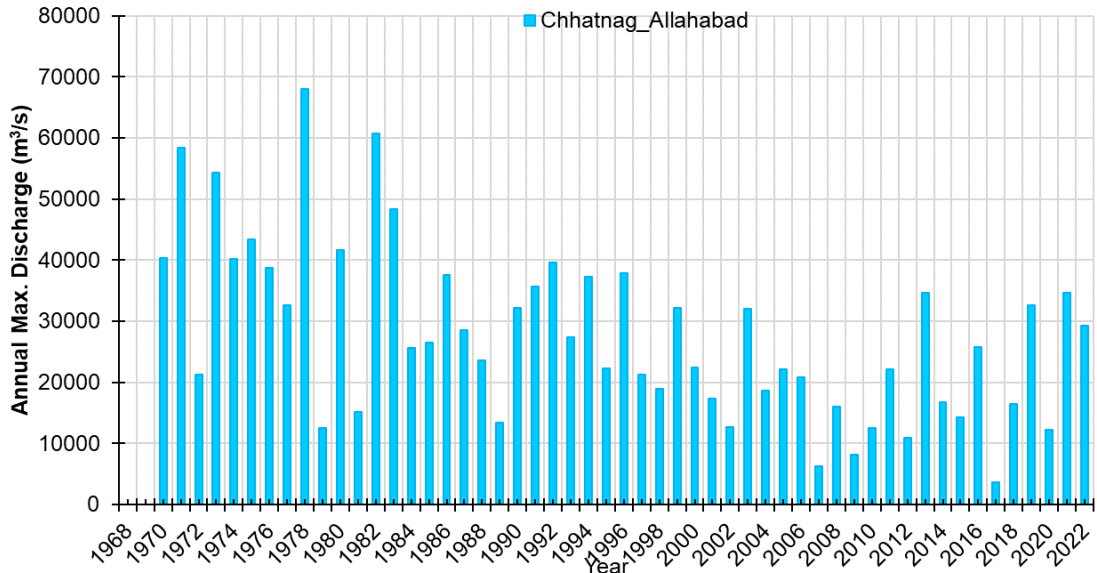
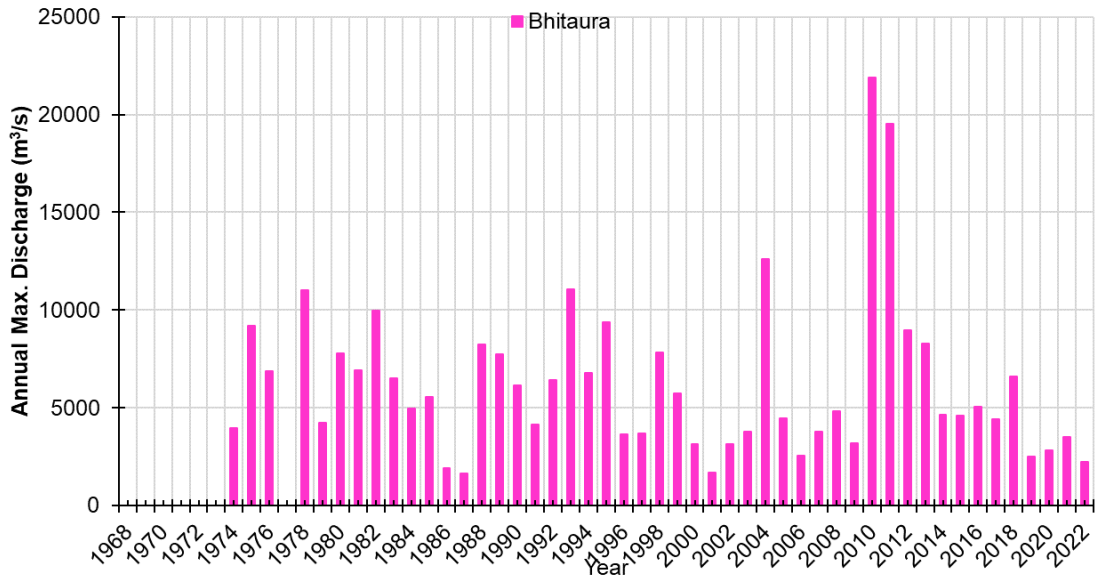


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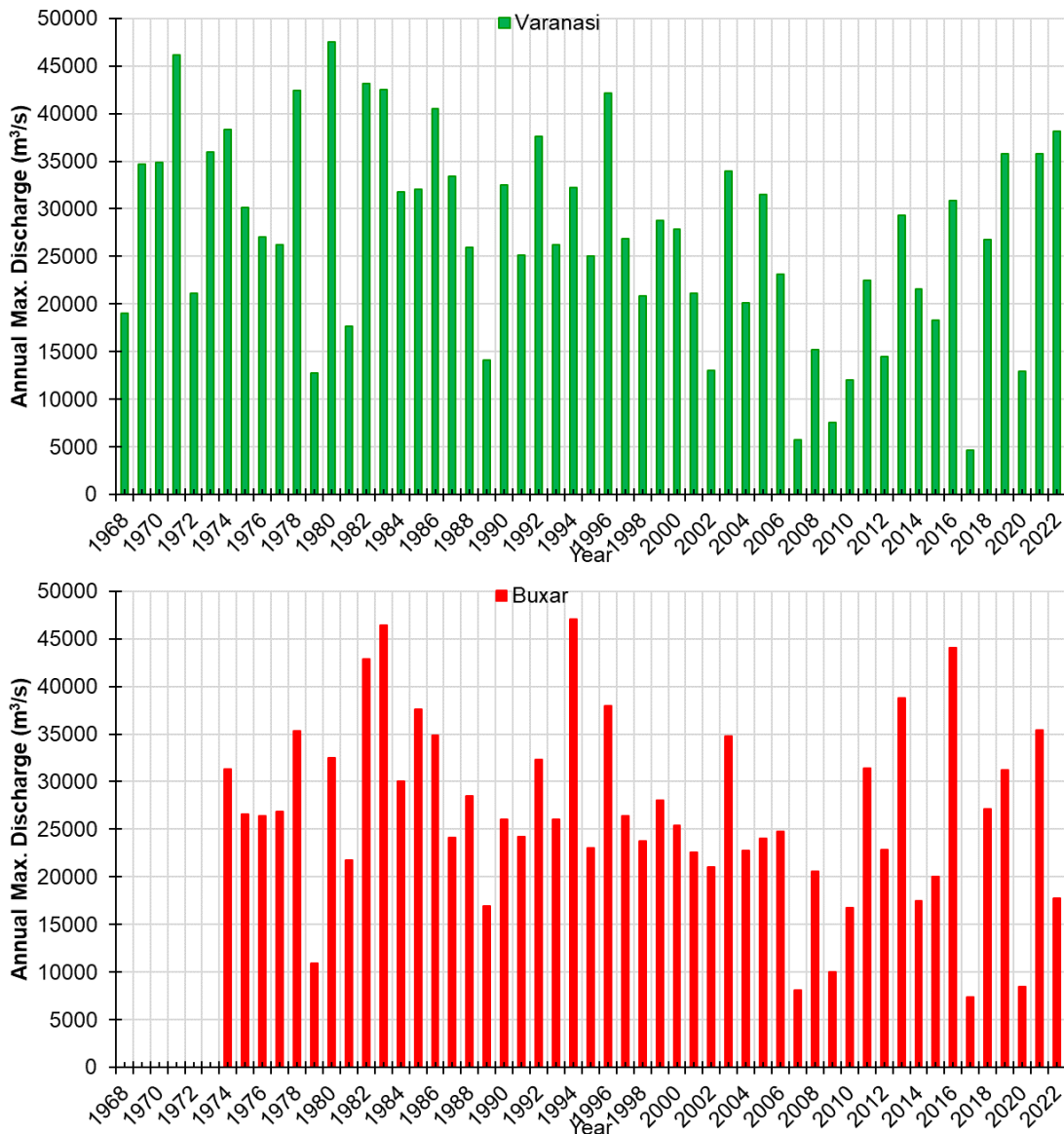


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