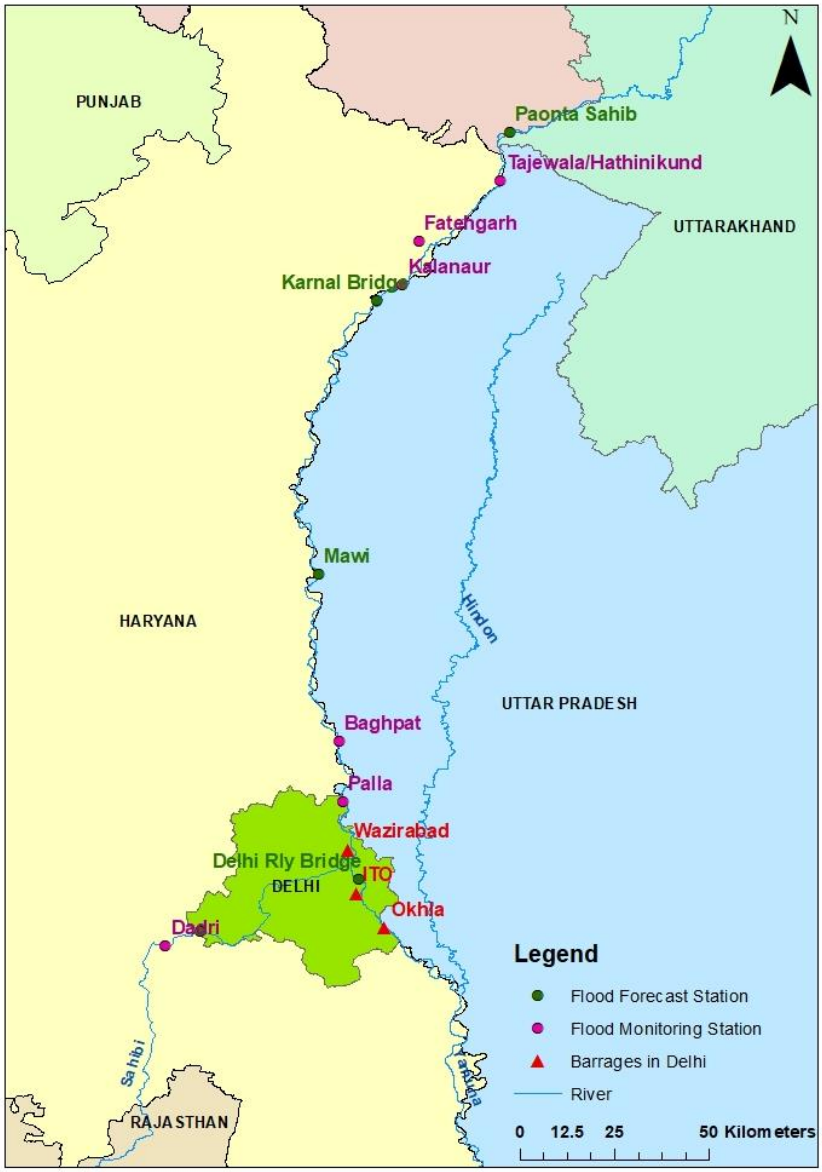
Interim Report of the Committee

On

"Joint Flood Management Study of River Yamuna for its reach between Hathnikund and Okhla Barrage"



January, 2024

Central Water Commission
Department of Water Resources,
River Development and Ganga Rejuvenation
Ministry of Jal Shakti

INTERIM REPORT

ON

JOINT FLOOD MANAGEMENT STUDY OF RIVER YAMUNA FOR ITS REACH BETWEEN HATHNIKUND AND OKHLA BARRAGE

Submitted To

MINISTRY OF JAL SHAKTI
DEPARTMENT OF WATER RESOURCES,
RIVER DEVELOPMENT AND GANGA REJUVENATION
MINISTRY OF JAL SHAKTI

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JOINT FLOOD MANAGEMENT STUDY OF RIVER YAMUNA FOR ITS REACH BETWEEN HATHNIKUND AND OKHLA BARRAGE

JANUARY 2024

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Executive Summary

Western Disturbances and south-west monsoon caused heavy rainfall during the period 09th to 13th July 2023, at different places in the States of Himachal Pradesh, Uttarakhand, Punjab, Delhi and Haryana in the catchment of river Yamuna. This wide spread heavy rainfall across catchment of the river Yamuna led to high runoff and huge discharge resulting in rapid rise of water level in the river Yamuna which led to extensive landslides and flooding in the hills and plains. This flooding event necessitated a fresh look at the river's flood management in its reach from Hathnikund Barrage up to Okhla Barrage. Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti, vide OM dated 6th August 2023, constituted a Committee for conducting a joint flood management study of river Yamuna for its reach between Hathnikund and Okhla Barrage. The Committee is headed by Chairman, Central Water Commission & Ex-Officio Secretary to Government of India has members from Haryana, Uttar Pradesh, NCT of Delhi and expert Organizations. The committee has been mandated to examine the meteorological aspects, return period of floods, discharging capacity of barrages, functional requirement of ITO barrage, etc.

The committee held meetings with the officials from Government of Haryana, Government of NCT of Delhi, Govt. of UP and other organizations who provided their inputs and shared their first-hand on ground experience in this regard. As a follow up of the discussions held during these meetings relevant data/information was collected from various departments and was analysed. The interim report of the committee summarizes this analysis and views of the committee on various aspects w.r.t. the term of Reference of the committee. The Interim Report of the committee broadly focusses on the cause of the event and measures for better on ground preparedness in case of such events in future. The major observations and recommendations of the committee are:

1) The rainfall analysis indicates that the excessive rainfall in the Yamuna catchment during 9th to 13th July, 2023 was the major causative factor of extreme flooding in Delhi and other locations along the reach of river Yamuna.
2) The committee recommended to operate ITO barrage with all gates open during floods in coordination with operation of Wazirabad barrage and Okhla barrage. It is also recommended that regular maintenance of all hydro-mechanical equipment of barrage to be conducted as per the operation and maintenance manual of the barrage/codal provisions.
3) The committee observed that the warning and danger levels of river Yamuna in Delhi need to be reviewed. Govt. of Delhi may conduct scientific study for the same, so that appropriate warning and danger levels can be decided which shall be presented in final report.
4) The committee recommended that any temporary structure made to facilitate construction within the right of way of river should be dismantled and muck should be properly disposed away from the river bed/bank as soon as possible.

Other important aspects like identification of sites for storage of flood water, locations for raising & strengthening of embankments, role of ITO barrage during floods, review of warning and danger levels of river Yamuna, etc. have been briefly included in the report. However, all these aspects would require further analysis supported by field data and would be addressed in detail in the final report of the committee.

1. Introduction

Floods constitute one of the major natural 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 may not be feasible.

River Yamuna, one of the largest tributaries of River Ganga, originates from Yamunotri Glacier on the south western slope of Bandarpunch peaks of the Lower Himalayas in Uttarakhand. The river basin lies in the states of Uttarakhand, Himachal Pradesh, Haryana, Uttar Pradesh, Rajasthan and Delhi. Before its confluence with River Ganga at Sangam in Prayagraj district of Uttar Pradesh, important tributaries such as Tons, Giri, Hindon, Chambal, Sindh, Betwa and Ken join the river along its way. The basin's huge population depends upon the water of the river Yamuna. Yamuna has six functional barrages and one proposed barrage. The functional barrages are Dakpathar Barrage, Hathnikund Barrage, Wazirabad Barrage, ITO Barrage, Okhla Barrage and Gokul (Mathura) Barrage. From Hathnikund Barrage, water is diverted to Eastern and Western Yamuna Canals. A line diagram of River Yamuna is shown in **Fig. 1**. The river water takes about 2-2.5 days to travel from Hathnikund to Delhi. Central Water Commission (CWC) started flood forecasting services in the year 1958 with its first forecasting station on Yamuna at Old Delhi Railway Bridge.

1.1 Background

Due to a combination of Western Disturbances and Southwest Monsoon, there was heavy rainfall in different places of Himachal Pradesh, Uttarakhand and Haryana during 09-13 July 2023, leading to extensive landslides and flooding in the hills and plains. The heavy rainfall in the catchment area of river Yamuna resulted in huge runoff in the river, due to which an earlier Highest Flood Level (HFL) of 207.49 m recorded at the CWC gauging site of old Delhi railway bridge on 6th September, 1978 got surpassed by a new HFL of 208.66 m observed on 13th July 2023. This necessitated a fresh look at the river's flood management in its reach from Hathnikund Barrage up to Okhla Barrage. In this regard, DoWR, RD&GR, Ministry of Jal Shakti, vide OM No. Z-15011 /1 /2020-FM Section-MOWR dated 6th August 2023, constituted a Committee for conducting a joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage. The Committee headed by Chairman CWC has members from Haryana, Uttar Pradesh, NCT of Delhi and expert Organizations. It will inter-alia examine the meteorological aspects, return period of floods, discharging capacity of barrages, functional requirement of ITO barrage, etc. Constitution of Committee and its terms of reference is attached as **Annexure-I**.

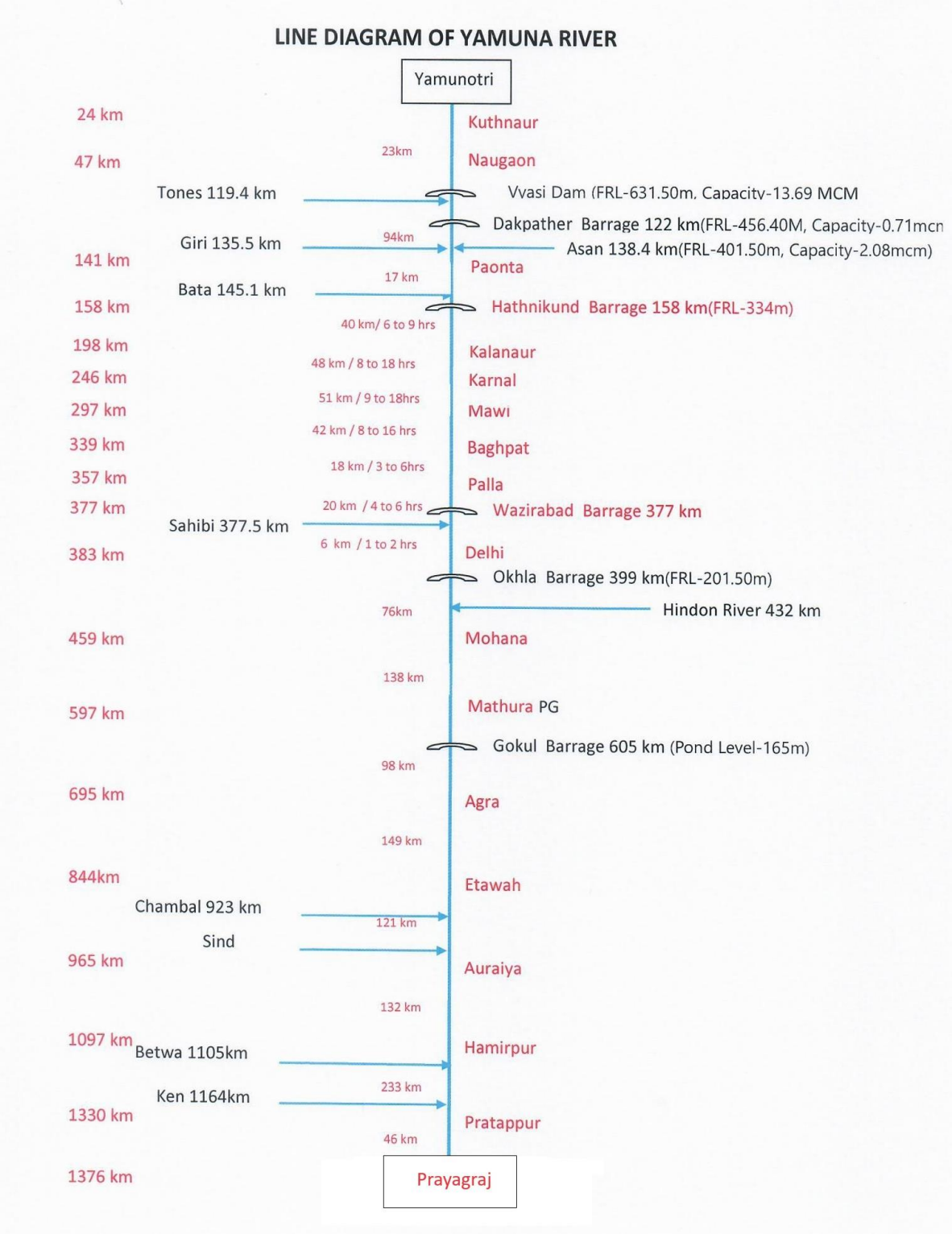


Fig. 1: Line Diagram of Yamuna River

The 1st meeting of the Committee was held on 4th September, 2023 at 1500 hrs in the Committee Room, CWC, 2nd Floor, Sewa Bhawan, R K Puram, New Delhi - 110066 under the chairmanship of Shri Kushvinder Vohra, Chairman, Central Water Commission and Ex-officio Secretary to the Govt of India. After detailed discussions, data requirements for the study assigned to Committee were identified for finalization of report.

- Data requirement

Sl. No.	Task/Assignment	Agency
a.	***Station RF in the catchment***	IMD
b.	***Annual Flood Peak (Discharge/ Water Level)***	
1.	Hathnikund Barrage	Govt of Haryana
2.	Wazirabad Barrage	Delhi Jal Board (Govt of NCT of Delhi will arrange the information)
3.	Delhi Railway Bridge site	CWC
4.	ITO Barrage	Govt of Haryana
5.	Okhla Barrage	Govt of Uttar Pradesh
c.	***DTM***	
1.	Hathnikund to u/s Shamli (1000 sqkm)	Survey of India
2.	U/s Shamli to Shamli (500 sqkm)	Survey of India
3.	Upto Okhla Barrage	Survey of India
d.	***X-section (with Lat/Long along the centre line)***	
1.	Haryana Reach embankment to embankment	Govt of Haryana
2.	Delhi reach upto Jaitpur (d/s of Okhla) embankment to embankment	Govt of NCT of Delhi
3.	Existing x-section of Yamuna (Delhi Reaches) surveyed during 2021	Govt of NCT of Delhi
e.	***Information/salient features of Structures including drawings***	
1.	Bridges	Govt of NCT of Delhi to coordinate and collect information from different agencies.
2.	Hathnikund Barrage	Govt of Haryana
3.	Wazirabad Barrage	Govt of NCT of Delhi
4.	ITO Barrage	Govt of Haryana
5.	Okhla Barrage	Govt of Uttar Pradesh
f.	***Review of Danger Level and Warning Level of Old Delhi Railway Bridge***	Govt of NCT of Delhi
g.	***Review of utility of ITO Barrage***	Govt of Haryana, Govt of NCT of Delhi
h.	***Details of Temporary structure/muck disposal clearance from the river bed/bank***	Govt of NCT of Delhi
i.	***Salient features/ layout of drains***	

1.	Level/sections/discharges and its functioning details of drains in Delhi	Govt of NCT of Delhi
2.	Level/sections/discharges and its functioning details of Jasola drains	Govt of Uttar Pradesh
j	**LULC map**	NRSC
k.	**Information for examining the feasibility of creation of underground reservoirs as well as storages in flood plain for surplus flood water.**	Govt of NCT of Delhi DDA

- X-section data available with IIT Roorkee/NIH need to be collected and utilized for this work.
- It has been decided that the report prepared on meteorological data (rainfall) analysis may be shared with IMD.
- Regular Inspection and maintenance schedule of drains need to be ensured by Government NCT of Delhi.

2. Yamuna Flood 2023 and Detailed Catchment Representative Rainfall Analysis

2.1 Observed Rainfall

The catchment area of river Yamuna at Old Delhi Railway Bridge is given in **Fig. 2**. The estimated catchment areas at Hathnikund barrage, Mawi G&D site and Old Delhi Railway Bridge is 11397, 15683 and 17882 sq. km., respectively. Due to combination of Western Disturbances and Monsoon, heavy rainfall occurred in Himachal Pradesh and Uttarakhand during 09-13 July 2023, as shown in **Fig. 3 to Fig. 10**, which led to extensive landslides and flooding in the hills and plains.

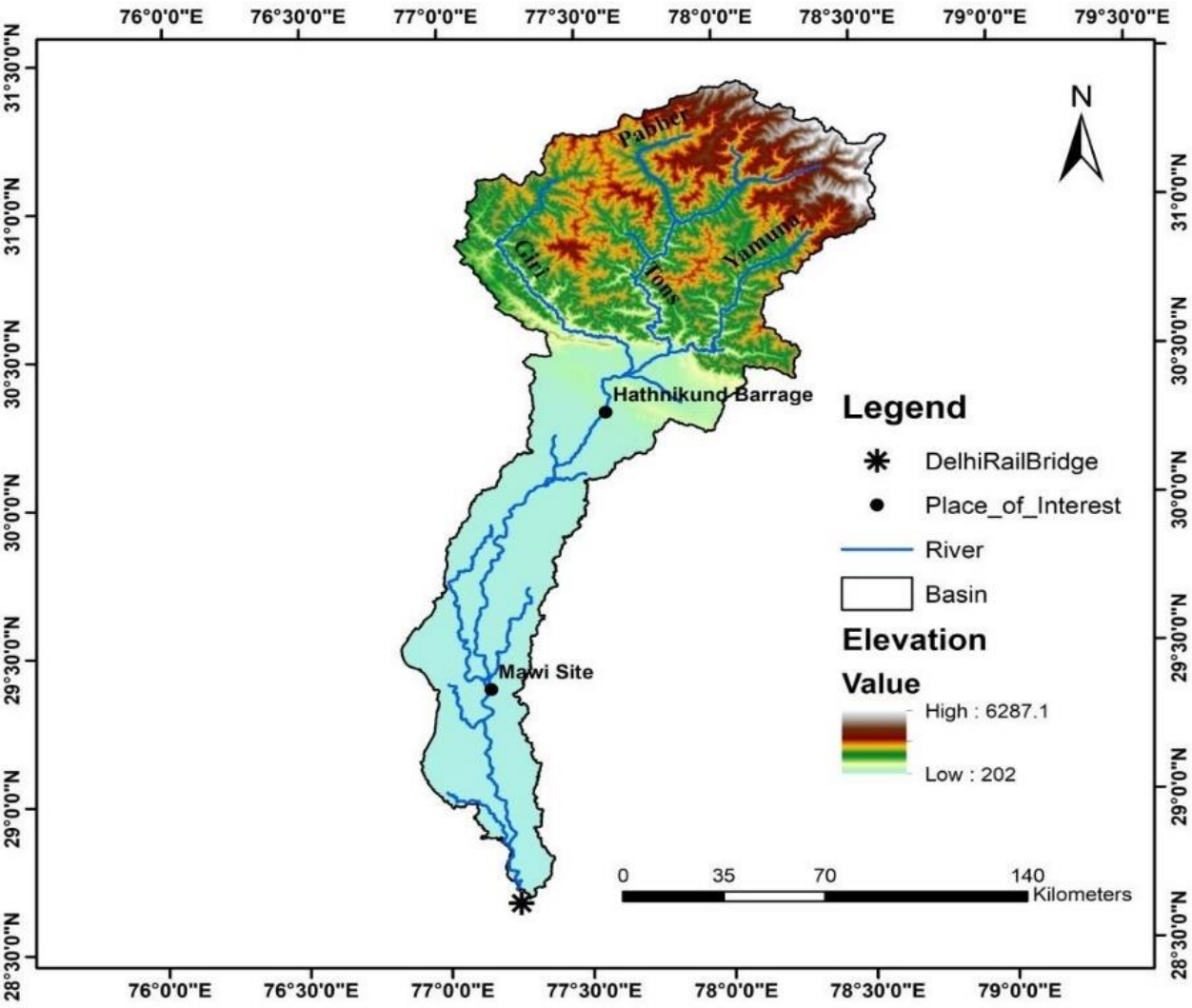
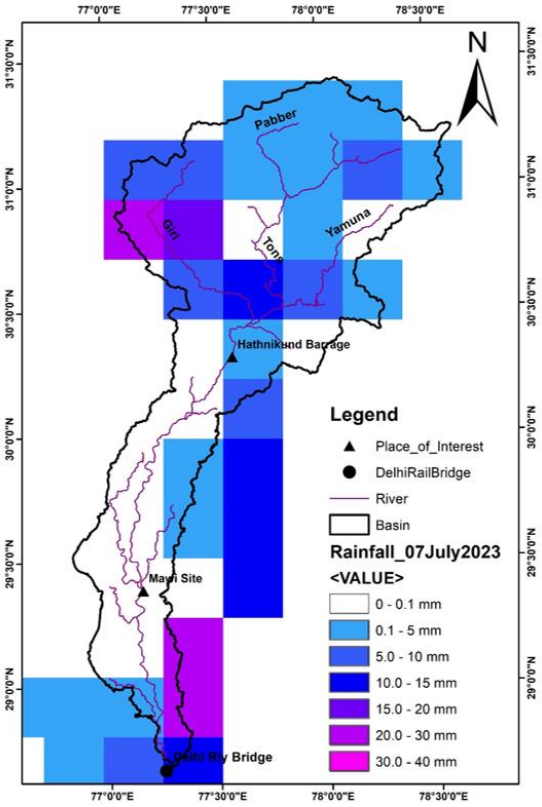


Fig. 2: Catchment of Yamuna (excluding Sahibi) River at Old Delhi Railway Bridge



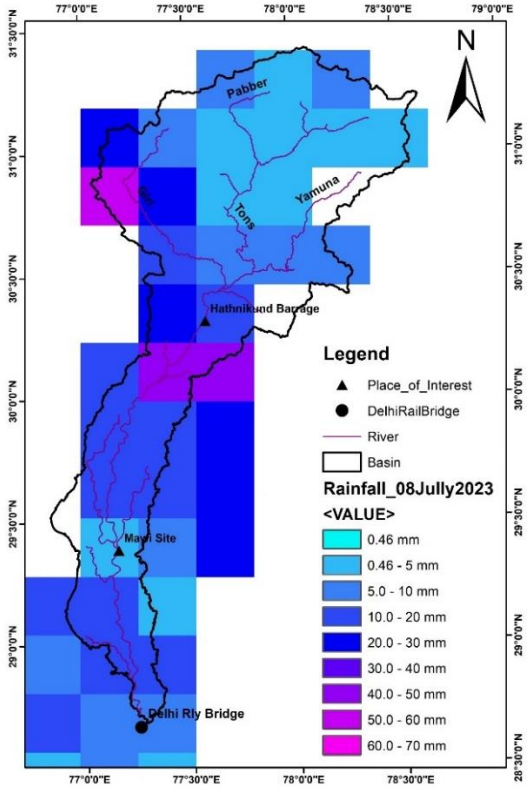
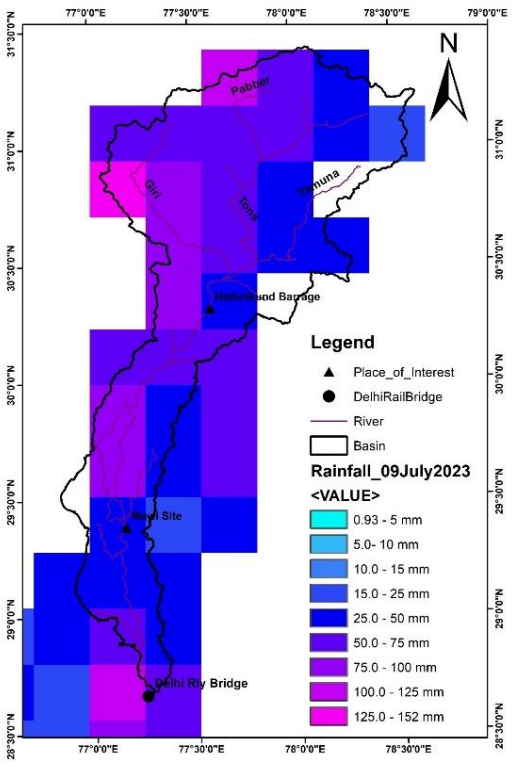


Fig. 3 & 4: Spatial Distribution of Rainfall on 07th & 8th July 2023



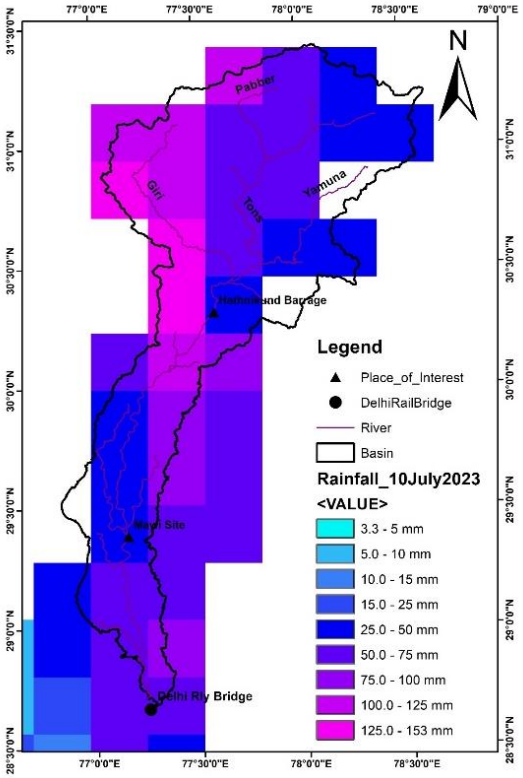
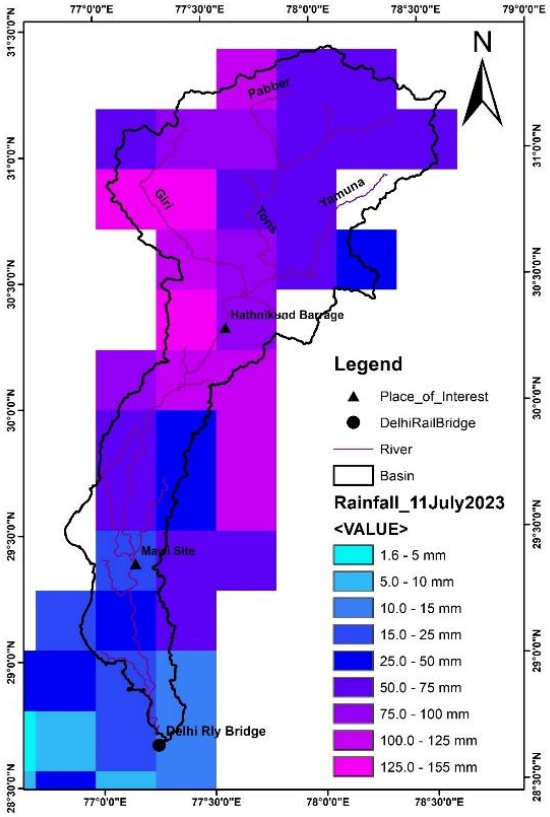


Fig. 5 & 6: Spatial Distribution of Rainfall on 09th & 10th July 2023



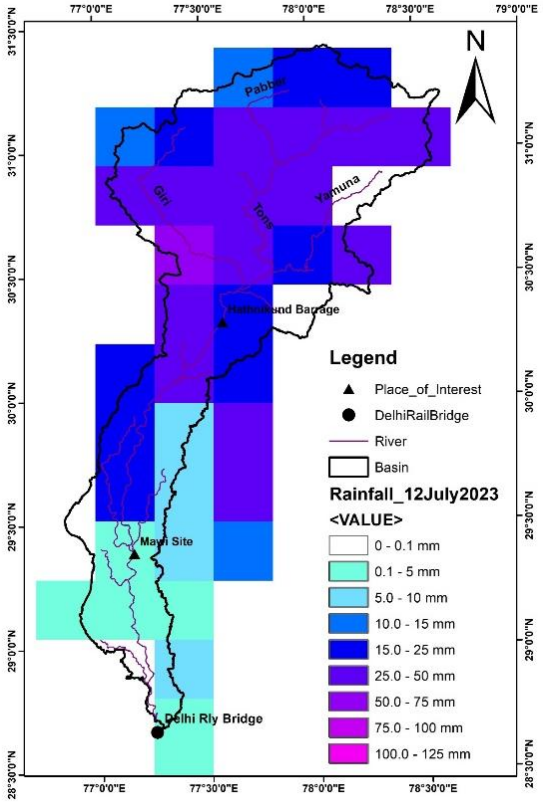
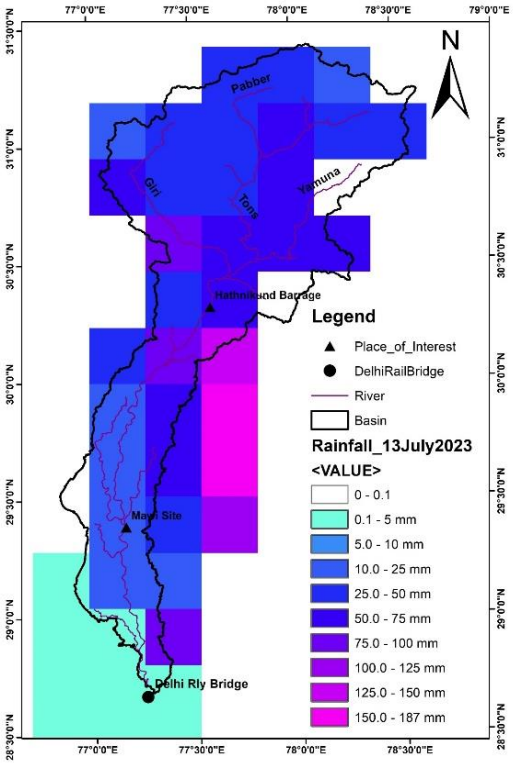


Fig. 7 & 8: Spatial Distribution of Rainfall on 11th & 12th July 2023



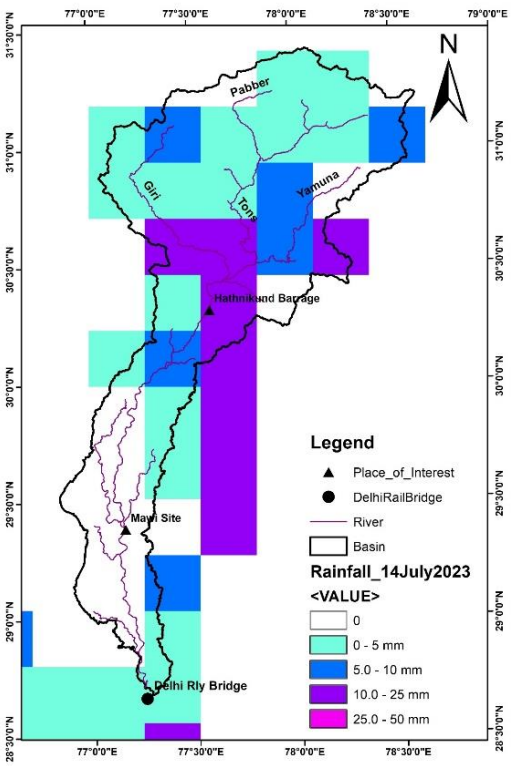


Fig. 9 & 10: Spatial Distribution of Rainfall on 13th & 14th July 2023

2.2 Methodology of Analysis of Rainfall

Gridded IMD Rainfall from 1970 to 2022, available on IMD website and rainfall for July 2023 (supplied by IMD) have been utilized to compute the catchment representative rainfall for the catchment upto Hathnikund and Mawi. The IMD Grids used for computation for catchment representative rainfall are given in **Fig. 11 and 14**. An Annual Maximum series for cumulative 5-day rainfall for Hathnikund and Mawi have been computed and frequency analysis has been conducted to determine the 5, 10, 25, 50, 100 year return period of rainfall.

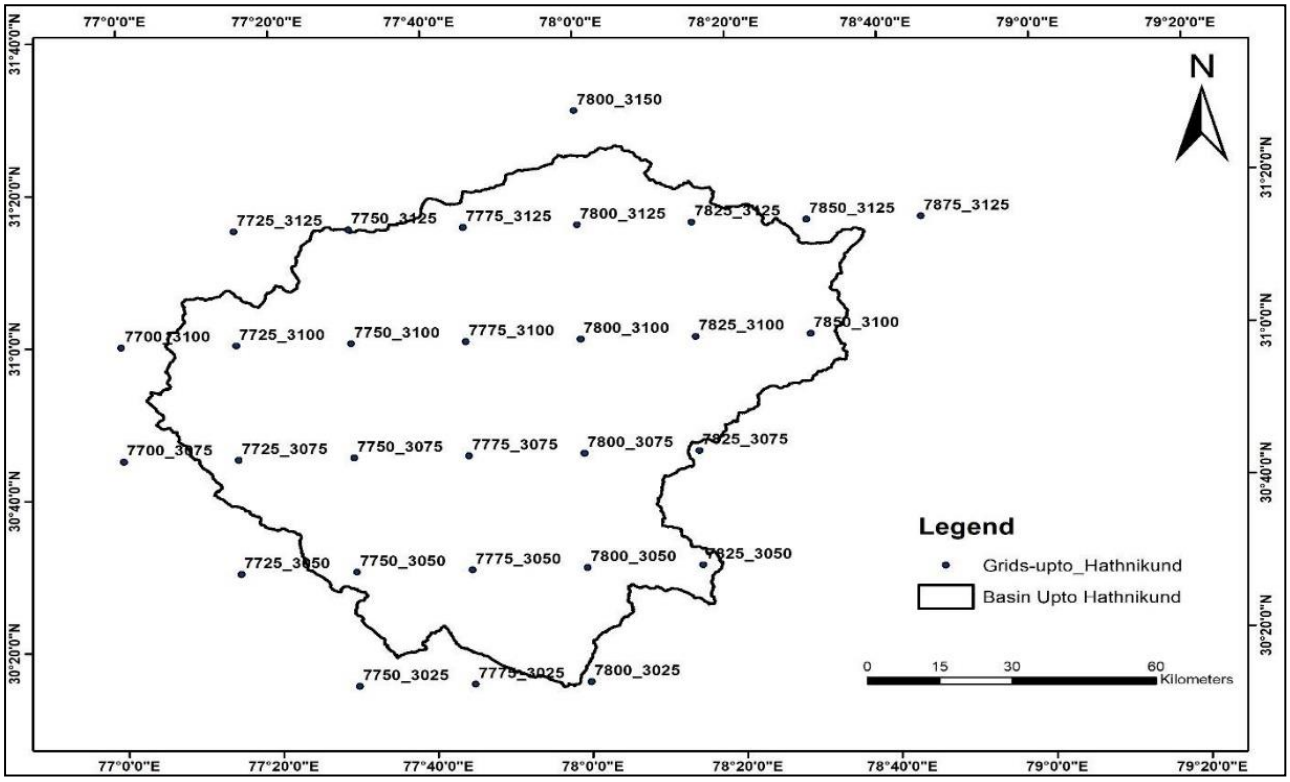


Fig. 11: Catchment Map of IMD Grids over Yamuna Catchment at Hathnikund

2.3 Catchment Representative Rainfall for Hathnikund Barrage

The catchment map of Yamuna River upto Hathnikund Barrage is presented in **Fig. 12**. Physiographic parameters of Yamuna catchment at Hathnikund barrage are given in **Table-1**. Elevation difference between highest and lowest point along the Longest Flow Path is 5385 m.

Table - 1: Physiographic parameters of catchment of river Yamuna at Hathnikund barrage

Catchment Area	Longest Flow Path	Centroidal Flow Path	Equivalent Stream Slope
11397 km^2	225 km	115 km	9.53 m/km

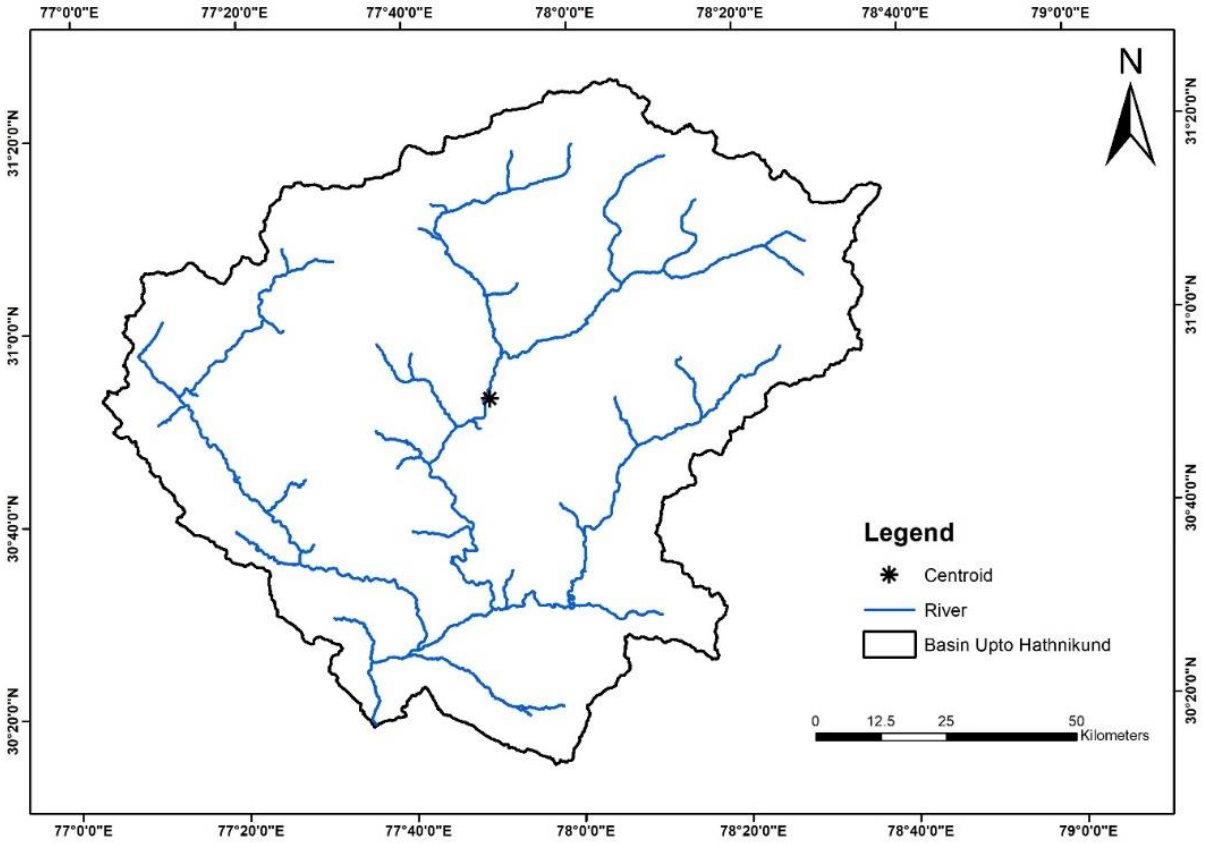


Fig. 12: Catchment Map Yamuna River upto Hathnikund Barrage

Based on the above physiographic parameters, it emerged that in general the entire catchment at Hathnikund barrage shall get activated in 3 days of continuous rainfall for generating the maximum runoff at Hathnikund barrage site. The Hathnikund barrage with a small pondage will be forced to release the flood water in case of rise of water upto a certain elevation and this water will travel downstream along the river. If the heavy rainfall sustains for more than the three days, then the water shall be released for a longer duration, resulting in less attenuation of flood peak in downstream reach of the river due to channel routing, resulting in higher flood peaks in the downstream reaches of the river. Considering the above aspects, the rainfall of 5 days duration has been analysed in the present study. The IMD Grids as shown in **Fig. 11** and **13** have been utilized for gridded rainfall to estimate the catchment representative rainfall from 1970-2022. The cumulative 5-day annual maximum rainfall series has been then computed from IMD Gridded Rainfall and in case of 2023, the rainfall has been considered from 09-13 July 2023 which is maximum for 2023 till 13th July. The 5-day series is shown in **Table - 2**.

Further, the frequency analysis of Annual Maximum values of 5-day rainfall has also been carried out to estimate the 5, 10, 25, 50, 100 year return period of rainfall for series from 1970-2022 and 5-day observed rainfall till July 2023 using the best fitting frequency distribution Log Pearson Type-III. The above estimated return period rainfalls are given in **Table - 3**.

Table - 2: Cumulative 5-day Annual Maximum Rainfall Series from 1970-2023 for catchment upto Hathnikund

Year	Annual Max of Sum of 5 days (mm)	Year	Annual Max of Sum of 5 days (mm)
1970	104.93	1997	131.25
1971	131.66	1998	142.97
1972	93.46	1999	134.39
1973	132.70	2000	134.67
1974	93.36	2001	90.83
1975	77.35	2002	150.49
1976	101.33	2003	97.85
1977	89.97	2004	80.17
1978	222.09	2005	117.62
1979	116.58	2006	117.05
1980	163.24	2007	121.41
1981	85.67	2008	125.00
1982	123.49	2009	181.59
1983	97.11	2010	143.46
1984	102.03	2011	152.77
1985	132.22	2012	115.16
1986	86.01	2013	306.63
1987	72.77	2014	120.31
1988	233.29	2015	110.37
1989	152.92	2016	117.07
1990	147.30	2017	102.46
1991	120.85	2018	158.00
1992	110.76	2019	125.48
1993	151.12	2020	73.77
1994	155.13	2021	107.25
1995	214.43	2022	114.54
1996	101.24	2023	316.94

Table - 3: Return Period Rainfall for Catchment upto Hathnikund

Return Period	Rainfall (mm)
5-year	160
10-year	192
25-year	238
50-year	278
100-year	324

2.4 Catchment Representative Rainfall for Catchment upto Mawi Site

IMD grids for Yamuna river catchment upto Mawi site is shows in **Fig 13** below:

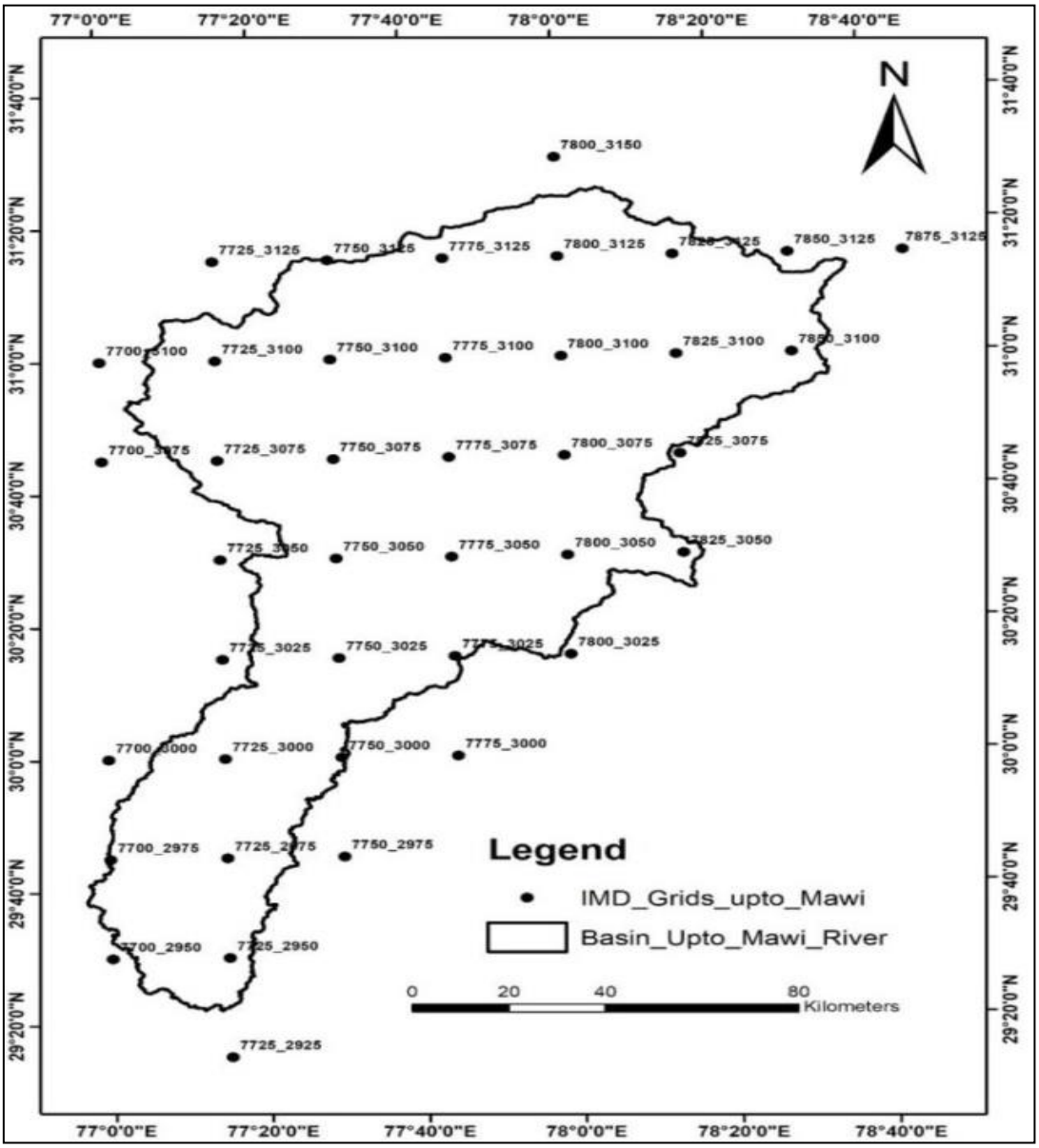


Fig. 13: Catchment Map of IMD Grids over Yamuna Catchment upto Mawi Base station

The catchment map of Yamuna River upto Mawi G & D Site of CWC (at $29^0$23'05"N and $77^0$09'20"E) is presented in **Fig. 14**.

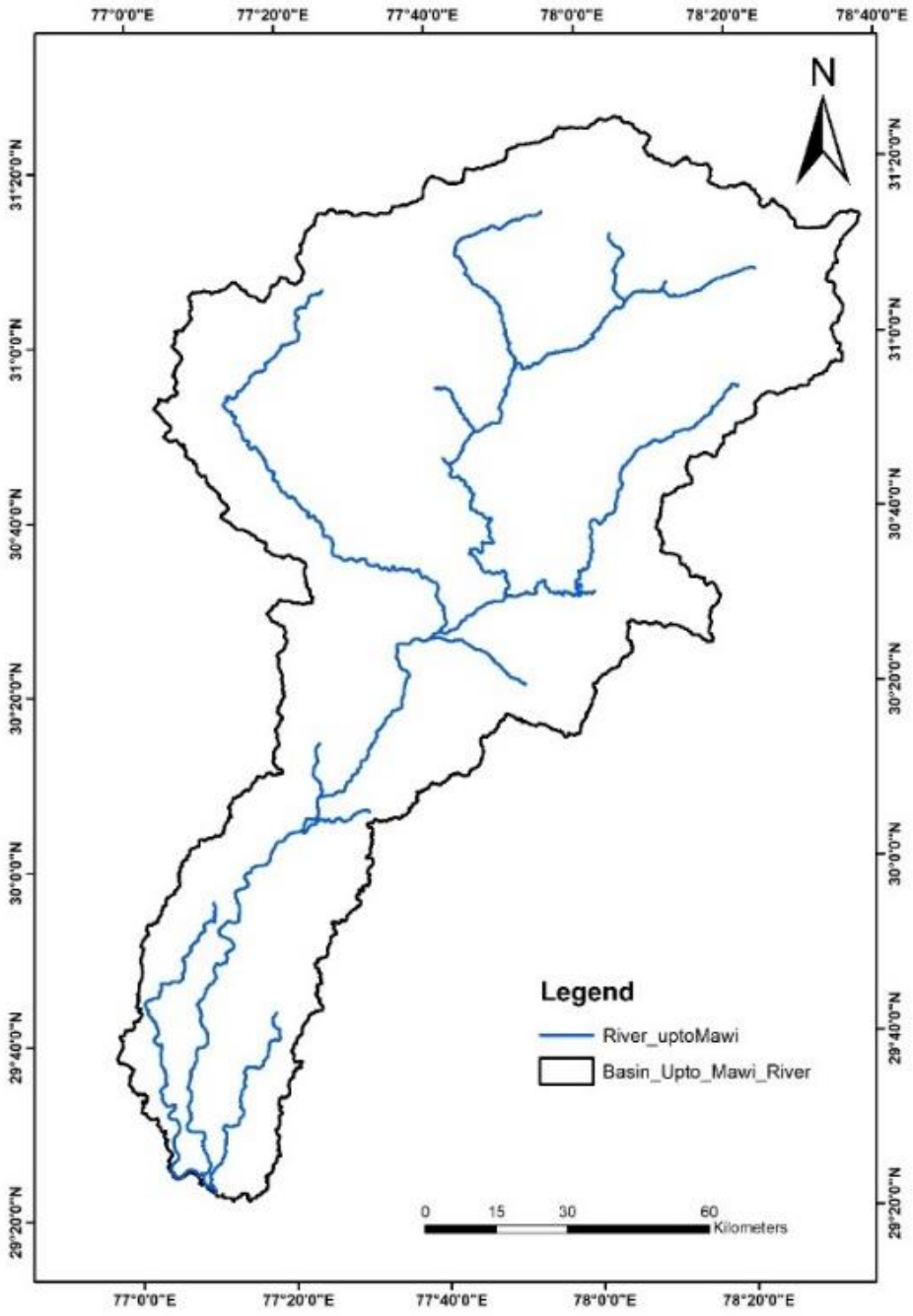


Fig. 14: Catchment Map of Yamuna River upto Mawi Site

The Physiographic parameters of river Yamuna catchment at Mawi are given in **Table - 4**. The Elevation difference between highest and lowest point along the Longest Flow Path is 5486 m.

Table - 4: Physiographic parameters of catchment of river Yamuna at Mawi Site

Catchment Area	Longest Flow Path	Centroidal Flow Path	Equivalent Stream Slope
15683 km^2	379.4 km	218.1 km	3.72 m/km

The IMD Grids as shown in **Fig. 21** have been utilized for gridded rainfall to estimate

the catchment representative rainfall from 1970-2022. The cumulative 5-day annual maximum series has been then prepared from IMD Gridded Rainfall. In case of 2023, rainfall has been considered from 09-13 July 2023 which is maximum for 2023. The 5-day series is shown in **Table - 5.**

The frequency analysis of annual maximum values of 5-day rainfall has been carried out to estimate the 2, 5, 10, 25, 50, 100 year return period of rainfall for series from 1970-2022 and 5-day observed rainfall till July 2023 using the best fitting frequency distribution Log Pearson Type-III. The above estimated return period rainfalls are given in **Table - 6**.

Table - 5: Cumulative 5-day Annual Maximum Rainfall Series from 1970-2023

Year	Annual Max of Sum of 5 days (mm)	Year	Annual Max of Sum of 5 days (mm)
1970	105.0	1997	123.7
1971	135.0	1998	130.4
1972	105.7	1999	120.7
1973	117.5	2000	134.8
1974	85.6	2001	102.7
1975	87.8	2002	158.0
1976	133.2	2003	89.0
1977	83.9	2004	88.8
1978	230.8	2005	112.9
1979	96.8	2006	95.9
1980	152.9	2007	103.9
1981	99.7	2008	105.2
1982	100.9	2009	186.1
1983	139.6	2010	143.3
1984	79.7	2011	146.7
1985	113.7	2012	113.7
1986	76.9	2013	255.9
1987	66.7	2014	116.1
1988	215.5	2015	115.1
1989	159.1	2016	121.4
1990	152.4	2017	99.7
1991	105.7	2018	158.4
1992	117.2	2019	120.1
1993	134.4	2020	71.2
1994	146.0	2021	103.9
1995	220.7	2022	118.5
1996	103.3	2023	303.6

Table 6: Return Period Rainfall for Catchment at Mawi G&D site

Return Period	Rainfall (mm)
5-year	155
10-year	184
25-year	226
50-year	261
100-year	300

2.5 Catchment Representative Rainfall for Catchment at Old Delhi Railway Bridge

CWC is maintaining a gauge site at Old Delhi Railway Bridge, where earlier HFL recorded as 207.49 m on 6th September 1978 was surpassed on 13th July 2023 and maximum water level recorded was 208.66 m. Hence, catchment representative 5-day cumulative rainfall at Old Delhi Railway Bridge has also been estimated and the same has been found as 223.12 mm during the period 31.08.1978 to 04.09.1978 and 276.25 mm during the period 9-14, July 2023.

2.6 Stage Hydrograph Analysis

Hydrological Observation (HO) network of CWC in Yamuna catchment (from Paonta to Delhi) is shown in **Fig. 15**. As per observations over the period up to 2023, travel time between various stations is given below in **Table 7.**

Table -7 Travel Time

Station	Gap (kms)	Travel Time (Hrs)
Hathnikund- Kalanaur	40	5-8
Kalanaur- Karnal	48	7-16
Karnal- Mawi	51	7-16
Mawi- Baghpat	54	7-16
Bagpat- Palla	18	4-9
Palla- Old Delhi Railway Bridge	26	5-10
Total	237	35-75

The water levels observed at HO sites from Paonta to Old Delhi Railway Bridge as evident from the **Figures 16 to 22** also establishes the travel time between different locations as given at **Table 7**. It is observed from **Figure 19,** showing the flood hydrographs at Hathnikund barrage and Okhla barrage that peak flood discharge of 3,59,760 cusecs occurred at Hathnikund barrage on 11.07.2023 at 11.07 Hrs followed by peak flood discharge of 3,72,225 cusecs at Okhla barrage on 14.07.2023 at 13.00 Hrs.

Flood hydrographs during the flooding event at different gauging stations starting from upstream are shown in **Fig. 16** to **22**. Graphs indicating discharge for Hathnikund and Okhla barrages during July 2023 are shown in **Fig. 23**.

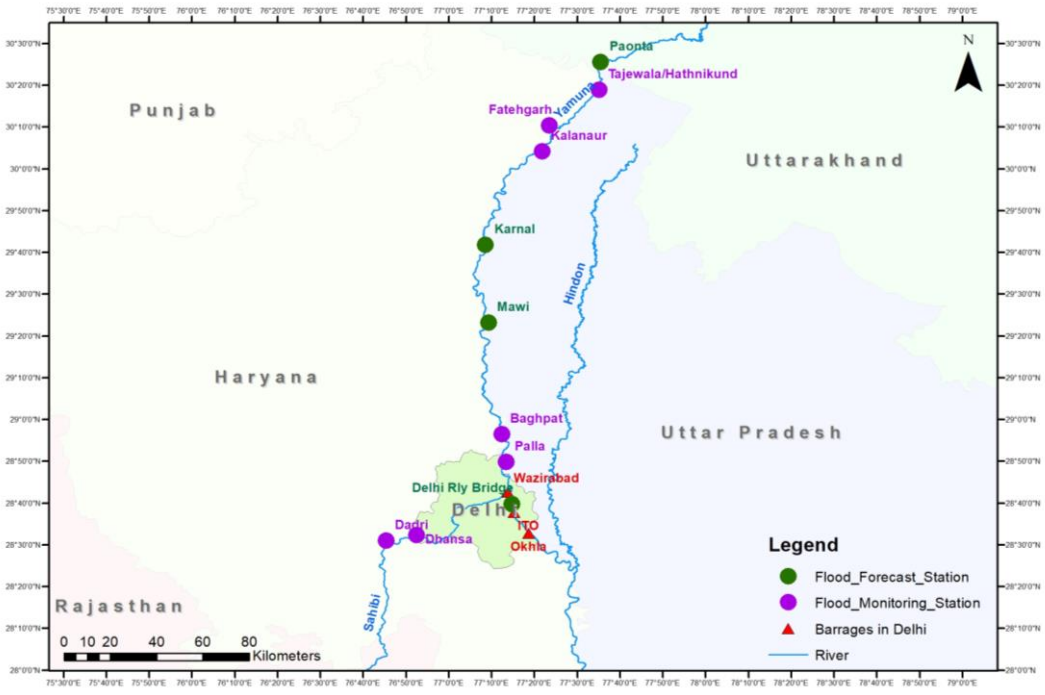


Fig: 15 a) HO network of CWC from Paonta to Delhi

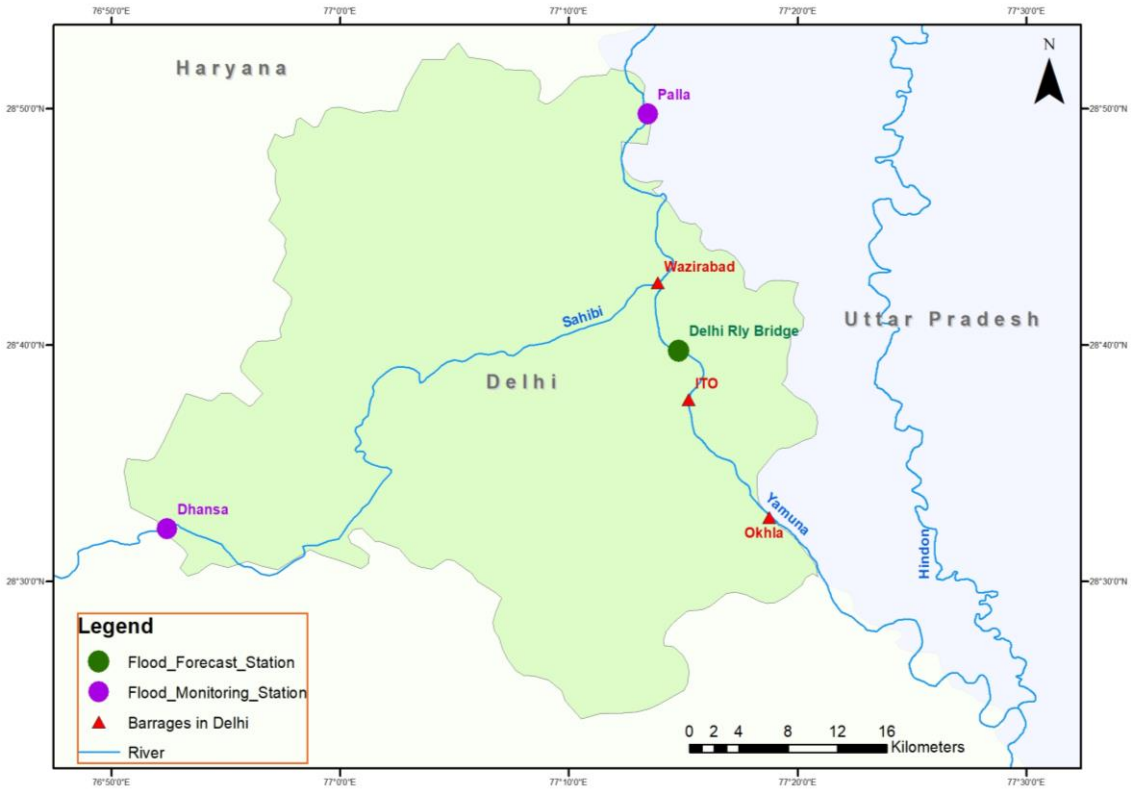
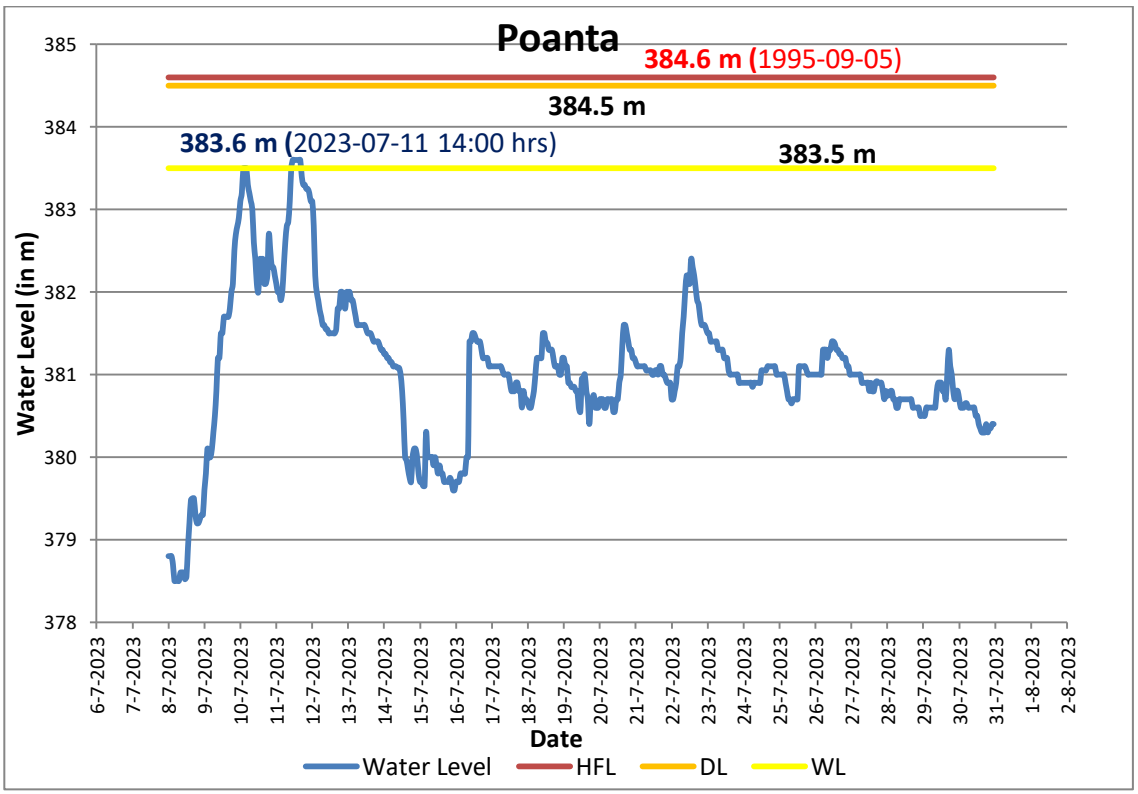


Fig. 15: b) HO Network within Delhi i.e. from Palla to Okhla



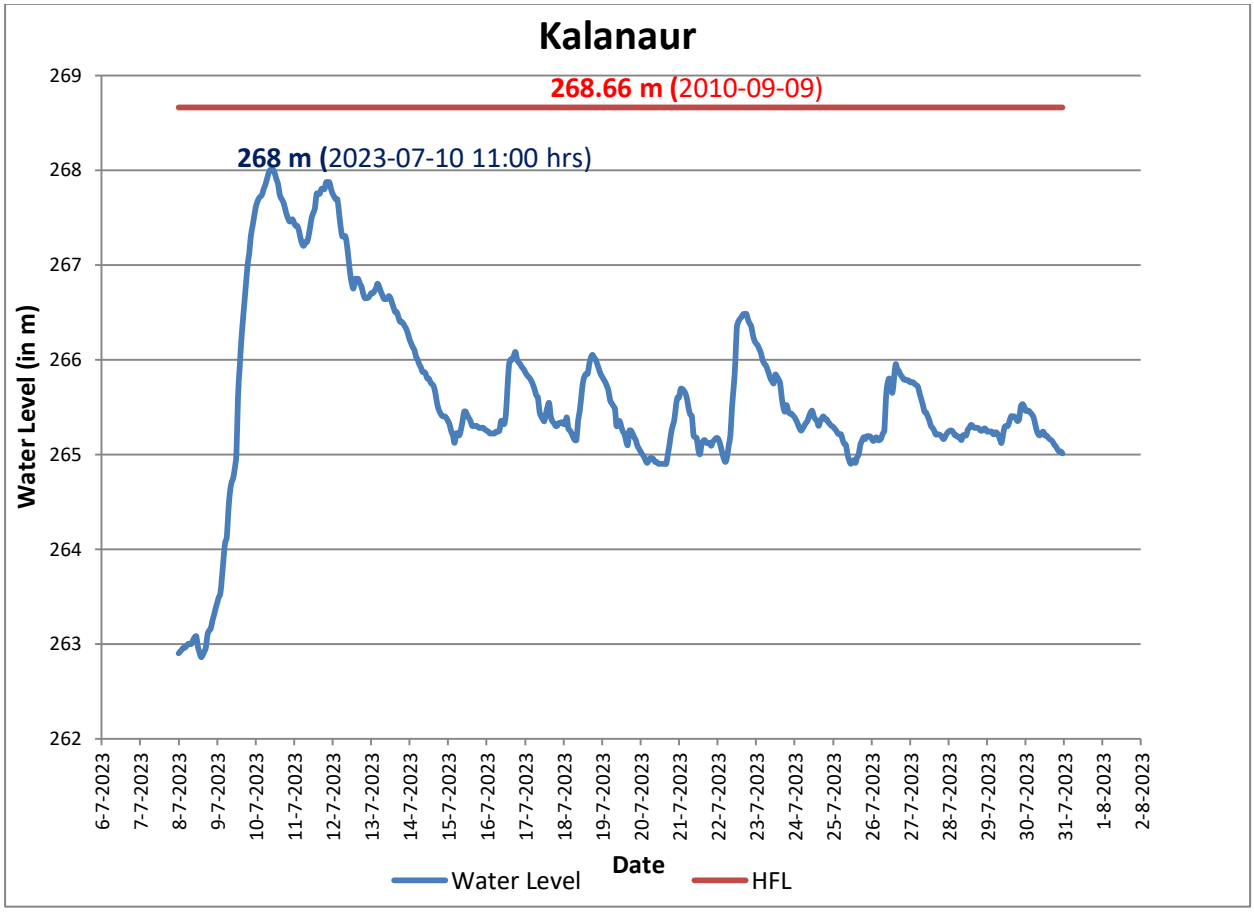
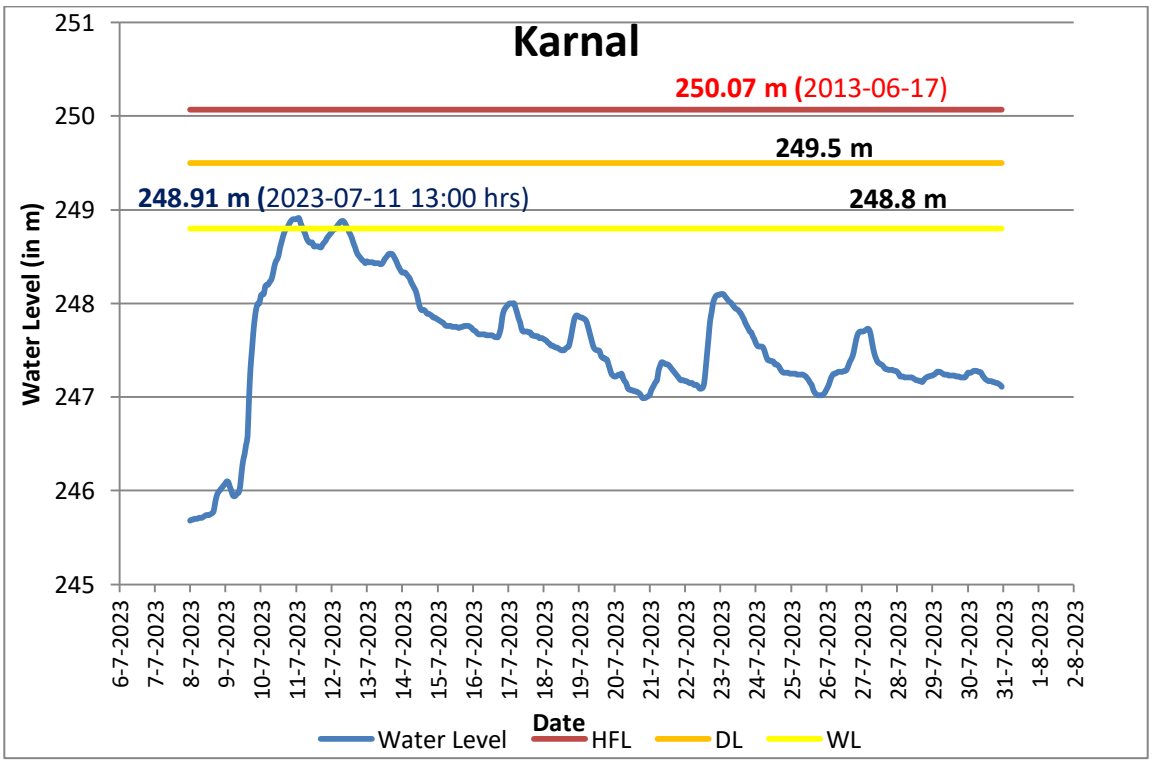


Fig. 16 to 17: Stage (WL) hydrograph at Paonta and Kalanaur during July 2023



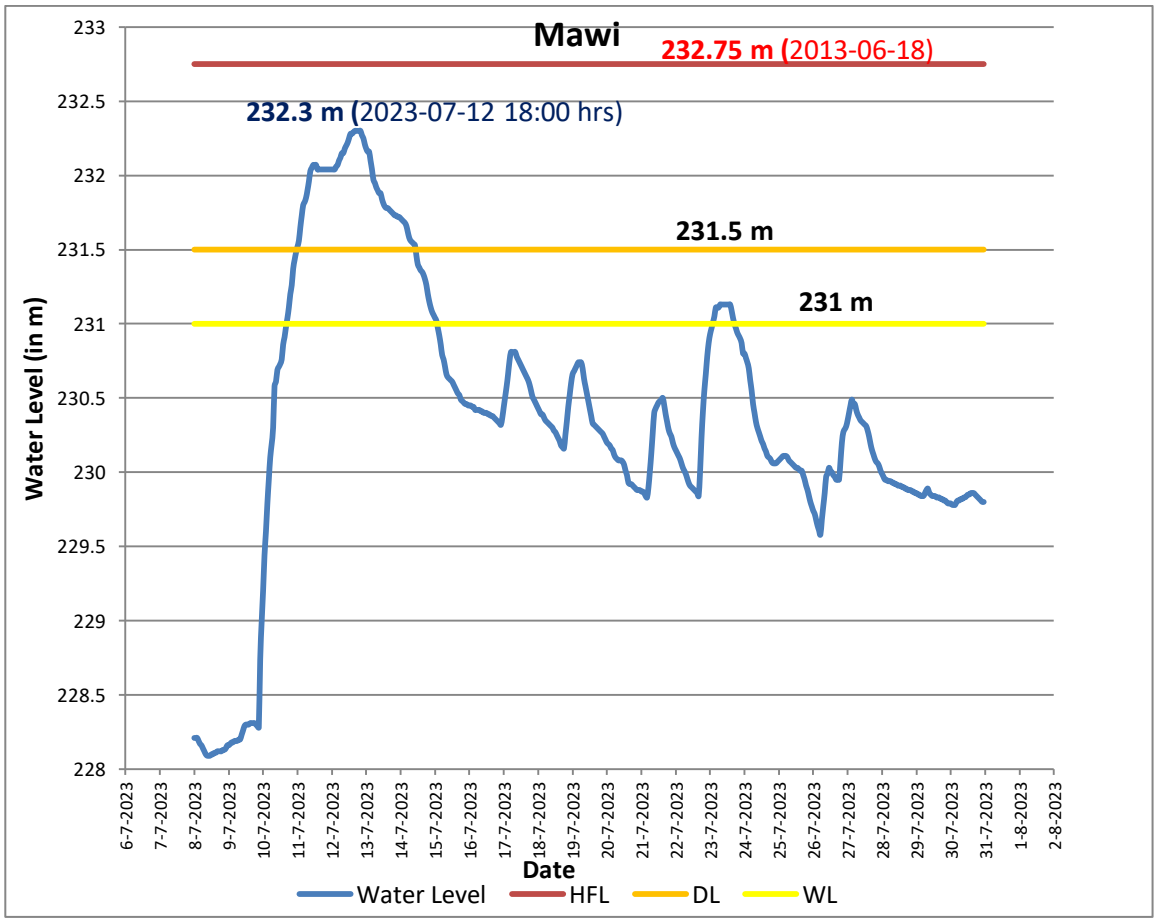
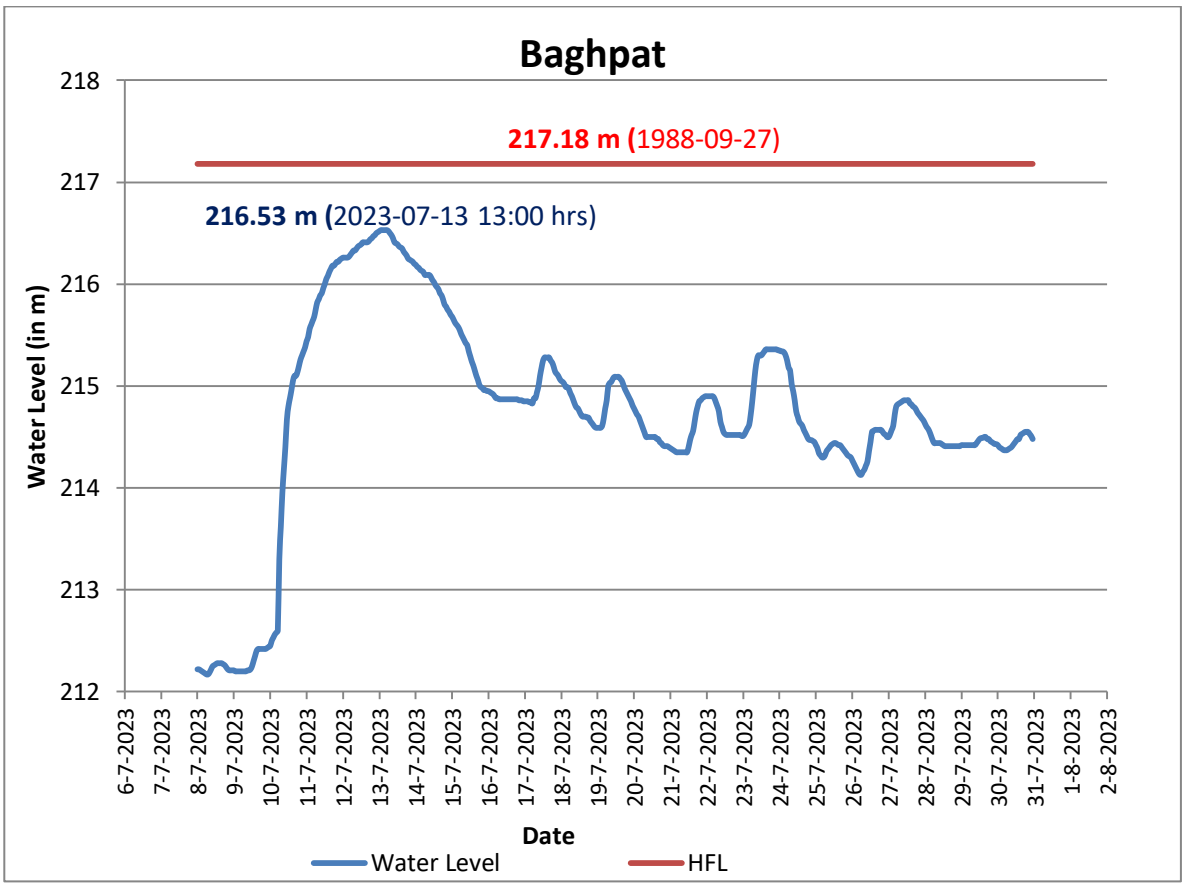


Fig. 18 to 19: Stage (WL) hydrograph at Karnal and Mawi during July 2023



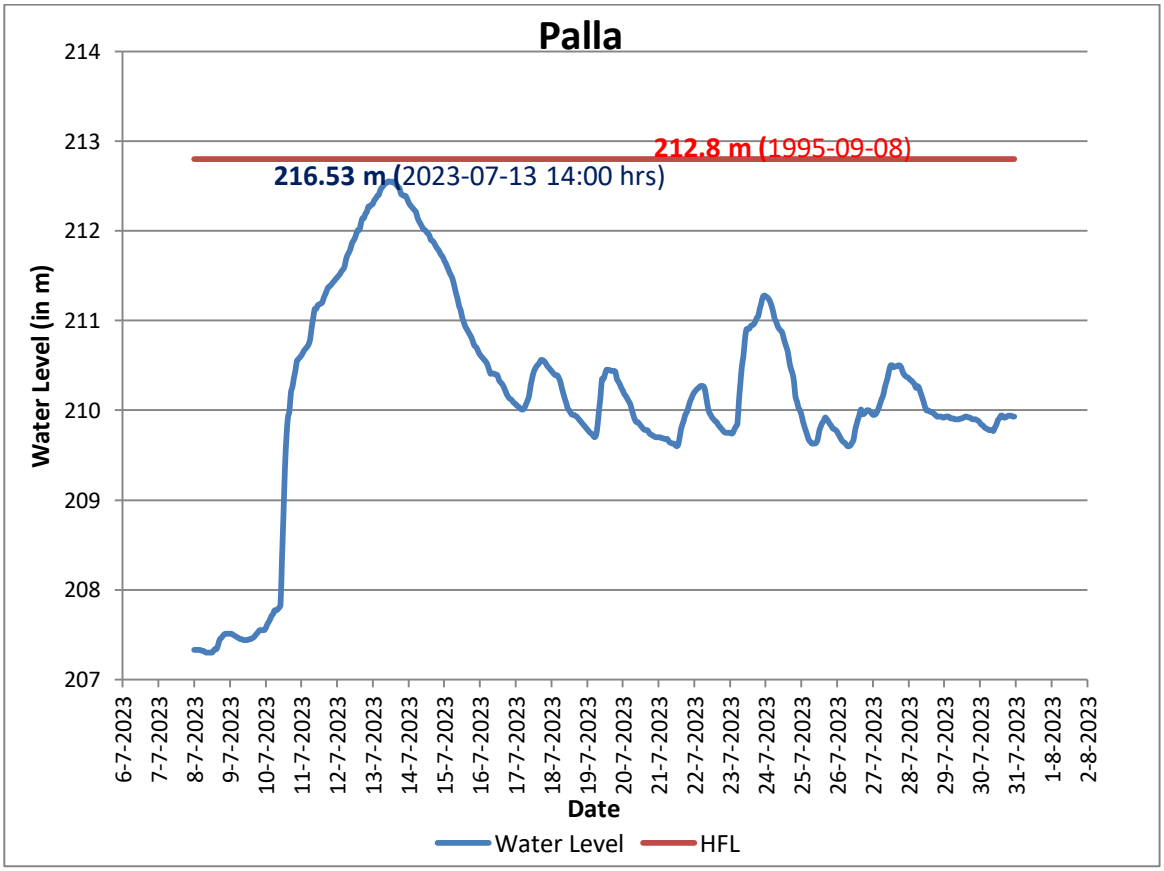


Fig. 20 to 21: Stage (WL) hydrograph at Baghpat & Palla during July 2023

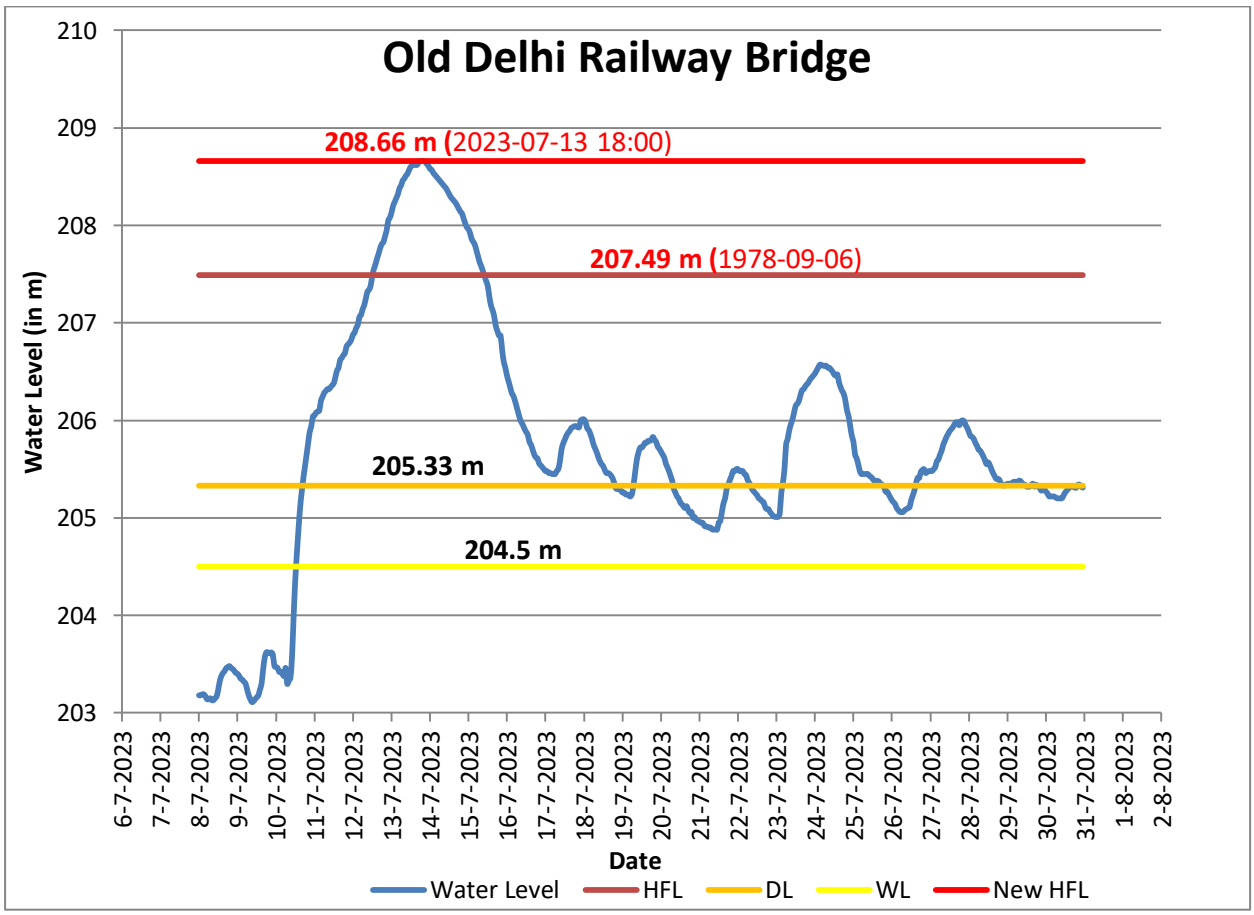


Fig. 22: Stage (WL) hydrograph at Old Delhi Railway Bridge

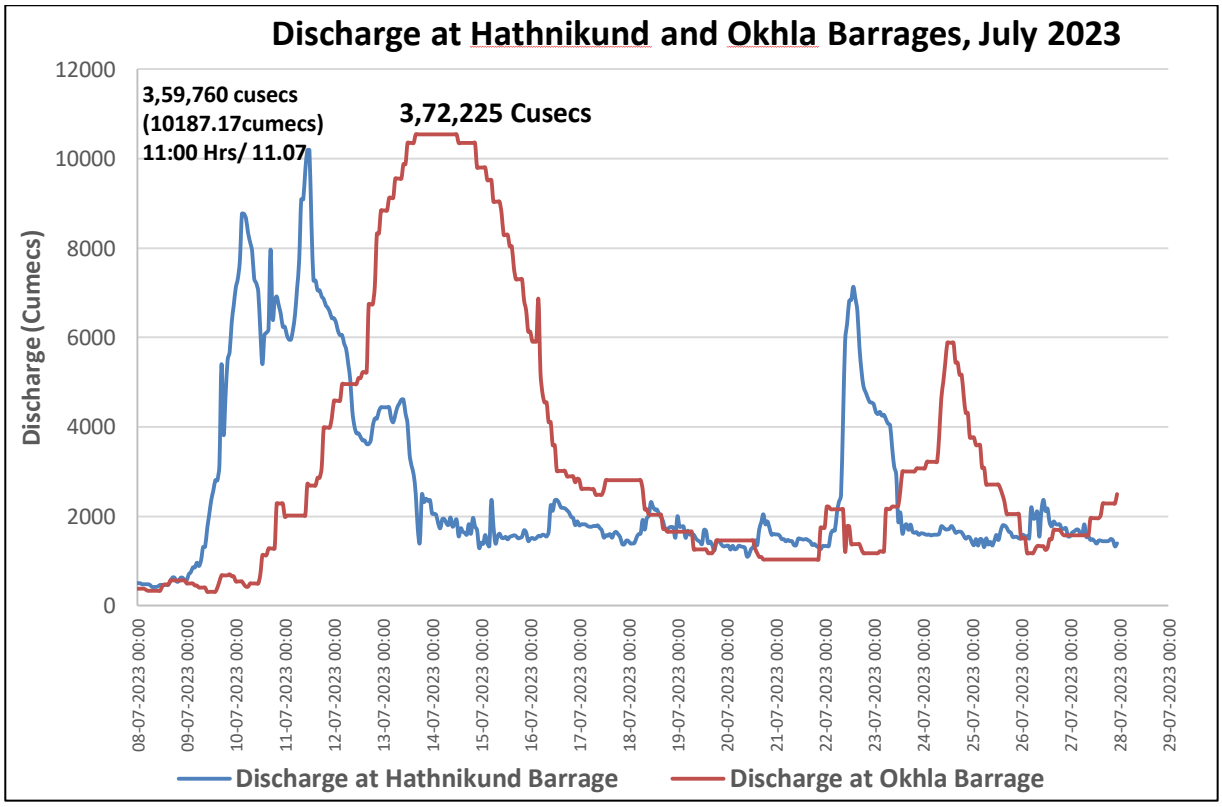


Fig. 23: Discharge from Hathnikund and Okhla barrages during July 2023

2.7 Findings of the present study

The rainfall data of 1978 is as per the IMD Gridded Rainfall records. Further, daily data of rainfall as supplied by IMD from 09th-13th July 2023 to CWC has been used for the year 2023. Based upon that, the following conclusions are made:

Table 8: Analysis of the rainfall data for floods during the year 1978 and 2023.

S. No.	Event	In 1978	In 2023	% Increase in 2023 w.r.t 1978
1	Annual maximum Sum of 5 days Rainfall in Catchment upto Hathnikund (mm) Catchment Area- 11397 sq km	222.09 mm (31.08.1978 to 04.09.1978)	316.94 mm (09-13, July 2023)	+42.7%
2	Annual maximum Sum of 5 days Rainfall in Catchment upto Mawi G&D site (mm) Catchment Area- 15683 sq km	230.8 mm (31.08.1978 to 04.09.1978)	303.6 mm (09-13, July 2023)	+31.5%
3.	Annual maximum Sum of 5 days Rainfall in entire catchment upto Delhi old railway bridge (mm) Catchment Area- 17882 sq km	223.12 mm (31.08.1978 to 04.09.1978)	276.25 mm (09-13, July 2023)	+23.8%
4.	Water Levels at Delhi old railway bridge (m)	207.49 m 06 Sep 1978	208.66 m 13 July 2023	+ 1.17 m

From the analysis of catchment representative 5-day cumulative rainfall data as given above, it has been found that the catchment representative rainfall at old Delhi railway bridge in 2023 is 23.8% more in comparison to rainfall of year 1978. The catchment representative rainfall in year 2023 at Mawi G&D site is about 31.5% more in comparison to rainfall of year 1978. The catchment representative rainfall in year 2023 at Hathnikund barrage site is about 42.7% more in comparison to rainfall of year 1978. The cumulative 5-day catchment representative rainfall during July 2023 at Hathnikund barrage and Mawi G&D site corresponds to rainfall of about 100 year return period.

From the Stage Hydrograph analysis at various Hydrological Observations (HO) sites on river Yamuna as well as from rainfall analysis in Yamuna catchment, it can be concluded that rainfall during 9th July, to 13th July, 2023 period was one of the major causative factor for extreme flooding in Delhi and other locations along the reach of river Yamuna.

Some other factors which resulted in certain afflux along the reach of river Yamuna around Delhi are as under:

a. During the peak flow, out of 32 gates of ITO Barrage, which is downstream of old Delhi Railway Bridge, some of the gates were reportedly non-operational till 13th July 2023 (as per media reporting). During this time, the peak flood was passing through old Delhi Railway Bridge & ITO barrage, leading to higher afflux and subsequent water levels.

b. During 09-13, July 2023 the rainfall in the catchment area upto Hathnikund was about 42.7% more in comparison to 5 days cumulative rainfall of year 1978. The excess rainfall in Hathnikund Catchment resulted release of flood water from Hathnikund barrage for a longer duration. The longer duration release of discharge from Hathnikund resulted in lesser attenuation of flood peak in downstream river reach and subsequent crossing of HFL at Old Delhi Railway Bridge.

c. Between 1978 and 2023, construction of embankments for flood protection in Delhi areas led to reduced cross-sections for the flow of flood water, resulting in some afflux upstream. Several new bridges constructed in the reach of river Yamuna in Delhi, also caused some afflux.

3. Review of the utility of ITO Barrage

Views of Government of Haryana:

The Yamuna Barrage near ITO, Delhi across River Yamuna was constructed by the Haryana Irrigation Department during the year 1966-67 as a Deposit Work for the then Delhi Electric Supply Undertaking (DESU) for meeting cooling water requirement of Indraprastha Power Station and Rajghat Power House of Delhi Thermal Power Control Board (DTPCB). After construction of ITO barrage, its operation & maintenance was entrusted to Haryana Irrigation Department. Indraprastha Power Station was decommissioned on 31.12.2009 and Rajghat Power House also ceased operation in May 2015. The Barrage is a water diversion structure with limited pondage and is not designed as storage reservoir. The function of ITO Barrage is not for regulation of flood water. Presently, there is no purpose of the barrage. All the gates should be kept open during floods for passing of flood water in the river. Haryana Govt. has informed that Indraprastha Power Generation Company Limited (IPGCL) has refused to pay for capital expenditure w.e.f. 2015 and for O&M w.e.f. 2018 which hampered O&M of ITO Barrage and functioning of gates. Further, they have informed that Delhi Govt. has failed to honor the interstate agreement signed between Haryana and Delhi for ITO Barrage. In 2022, NCT of Delhi disconnected the electric connection at ITO Barrage thus endangering the lives of people in Delhi. Haryana Govt. then reinstalled the electric connection from its funds in and is still maintaining the same. Further, there is always probability of error/discrepancy in measurement of available inflows at Okhla Barrage due to inclusion of Hindon Cut Canal discharge (Ganga water) into river Yamuna inflows. To avoid any such Inter-state dispute regarding actual availability and distribution of water at Okhla, an important decision was taken in the meeting of Chief Secretary, Haryana and Principal Secretary Irrigation Department, Uttar Pradesh held on 02.04.2015, wherein it was decided that supplies available at Barrage at ITO, Delhi be considered for further distribution amongst U.P. Haryana and Rajasthan at Okhla**.** Hence, it was considered not feasible for Haryana to transfer the control of Barrage to Delhi.

View of Government of NCT of Delhi:

a. Barrage is useful for storage of water during lean season.
b. Barrage is useful for creating pondage for recharge purpose.
c. Communication and resolution of direction are easy as the Head Quarter of I&FC/ Delhi Government is within few meter away from ITO Barrage where as the Head Quarter of Haryana Irrigation Department is located at Chandigarh.
d. Impact of Operation and maintenance of ITO barrage is directly linked with the resident of Delhi as the same is located amidst the heart of the National Capital City whereas Haryana public is not affected at all. Inundation even in a small way directly impacts the National Image as vital National Institute of International repute like Hon'ble Supreme Court, Rajghat, WHO, Vikas Minar, etc., are located in the vicinity and also results into huge loss of exchequer in

Delhi being highly urbanized and densely populated and has serious implications for human lives as well in Delhi.

Hence, operation of ITO barrage may be better handled by Delhi Government. Further, Govt. of NCT of Delhi, has opined that they have technical capability to operate and maintain ITO Barrage at present and can operate it in a better way as per requirement during the flood in Delhi territory. They have also informed that request has been made to Govt. of Haryana and their authorities to hand over the ITO barrage.

Views of the Committee:

The basic structure of ITO barrage comprising of piers with gate grooves and deck slab is in place. The gates of the barrages are kept open during flood period so that the original condition of river is maintained and the barrage structure has a minimum impact on river flow during floods.

Further, the barrage is linked with road bridge. Therefore, the only matter to be considered is whether gates are to be dismantled or not. It is observed that in lean season, the gates could be useful to impound some water for various purposes including recreational activities.

Hence, it is recommended to operate ITO barrage with all gates open during floods in coordination with operation of Wazirabad barrage and Okhla barrage. It is also recommended that regular maintenance of all hydro-mechanical equipment of barrage be conducted as per the operation and maintenance manual of the barrage/codal provisions.

The matter of handing over of the ITO barrage to Government of Delhi can be taken up separately by appropriate authority.

4. Review of Warning levels and Danger levels in Delhi

Danger level and warning level are important parameters utilized for flood forecasting services. These levels are fixed in consultation with State Govt. and depends upon the threat perception in the area corresponding to those levels. The danger level considered presently at Old Delhi Railway Bridge needs to be re-ascertained as this level is attained even at a very low discharge/flood, thereby, causing panic to citizens of NCT of Delhi. Earlier, warning & danger levels at Old Railway Bridge were 204.00 m & 204.83 m, respectively. However, in the year 2019, the warning & danger levels were raised by 0.5 m which is 204.50 m & 205.33 m, respectively. Delhi Govt. officials informed that they are contemplating to change warning & danger levels further to 205.00 m and 205.75 m, respectively.

Views of the Committee:

The committee observed that there is a need to review the warning and danger level of river Yamuna in Delhi. In this respect, Govt. of Delhi was requested to carry out a detailed analysis to review and suggest appropriate warning and danger levels. On the basis of studies/rational by Govt. of Delhi, the issue of finalizing the warning and danger levels will further be taken up in the final report on the basis of rationality suggested by Govt. of Delhi supported by detailed analysis.

5. Operation schedules of barrages

There are 06 barrages across Yamuna River. The details of barrages (as per various sources) are summarised in **table 8** below:

Table 8: Details of the barrages on river Yamuna

	Dakpathar	Hathnikund	Wazirabad	ITO	Okhla	Gokul
Year of Construction	1965	1999	1959	1965-66	1982	2001
Owner	UJVN, Uttarakhand	I&WRD, Haryana	DJB, Delhi	I&WRD, Haryana	I&WRD, UP	I&WRD, UP
River Bed Level (m)	449.43	329	NA	NA	195.85	NA
Design Flood (cumec)	11620 (1 in 50 yr)	22000 (1 in 100 yr)	7840	8490	9911.4	-
HFL (m)		342.35	208.178	206.289	202.17	
PL (m)	456.4	334.32	205.6	202.23	201.35	165
PL, normal/min (m)	454.152	-	-	201.777	-	-
Width (m)	516.92	363.8	454	552	552.09	435
Catchment Area (km2)	7340	-	-	-	17950	-
Gates (Nos.)	25	18	29	32	27	21
Under-sluice(Nos.)	6	8	12	10	5	4
US Width (m)	18.288	18	8	8.38	18.3	18.3
US Crest (m)	449.43	329	201.473	199.217		
Spillways (Nos.)	19	10	17	22	22	17
SP Width (m)	18.288	18	17.5	18.3	18.3	-
SP Crest (m)	450.6	330	202.692	200.131	-	-

Note: It was reported during a meeting that there is perhaps one more Okhla weir upstream of Okhla barrage. However, concerned officials did not have any information on the same. Therefore, it was decided that its details, if any, shall be included in the final report.

A layout depicting the existing and planned structures in Yamuna Basin is presented below:

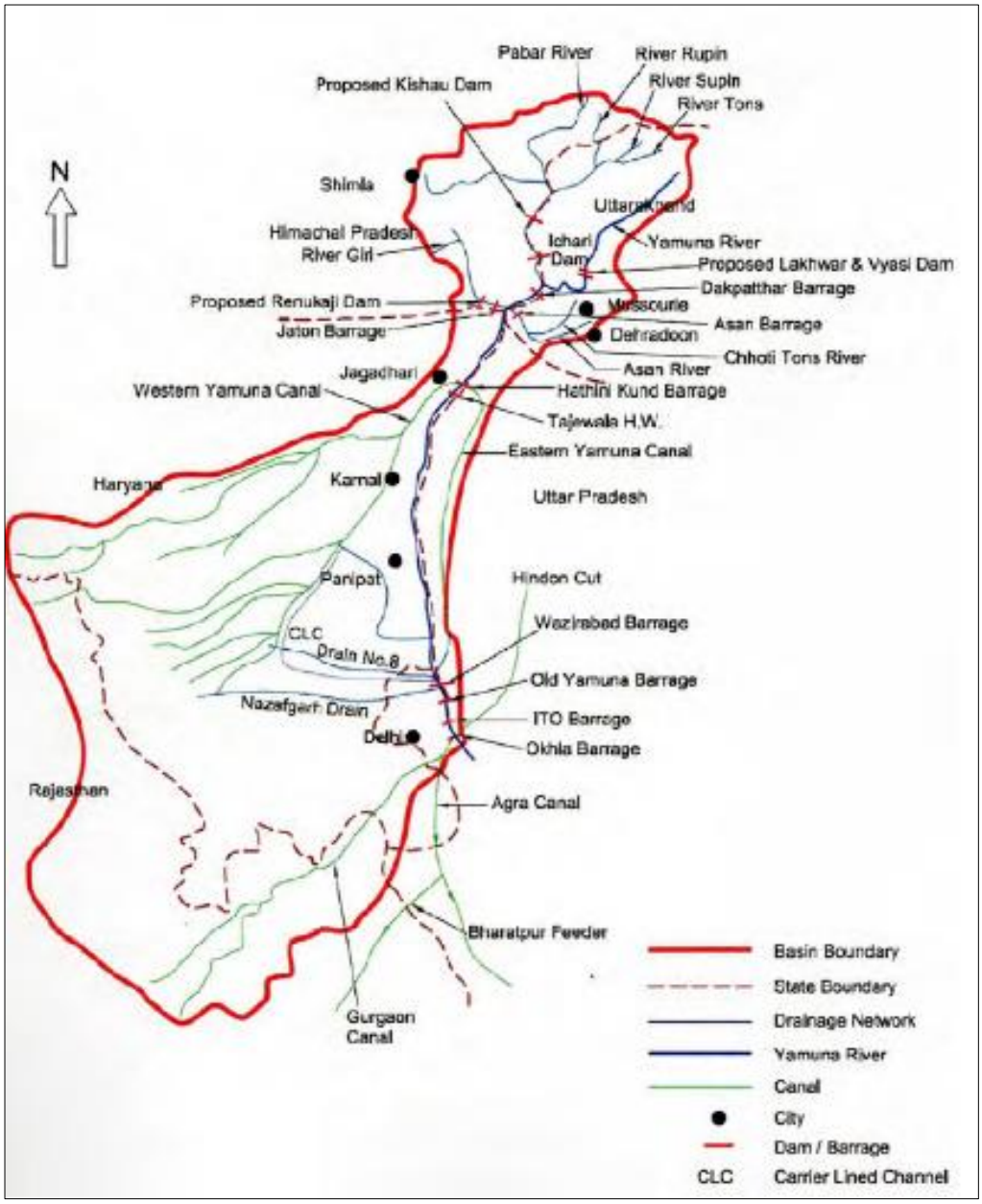


Fig 24: Map depicting the existing and planned structures on Yamuna Basin

5.1 Gate Operation/Tail Water Rating Curves

Gate Operation Manual has already been obtained from the project authorities. As a general practice, the gates of barrages are operated during the lean season as per Gate Operation Schedule to maintain the desired pond level and allow abstractions through intakes/canals. During flood seasons, the gates are operated to pass the inflow discharge and then closed as the flood recedes as per the gate operation manual.

5.1.1 Hathnikund Barrage

Based on the data already available in office records, the gate operation of Hathnikund Barrage is summarised below:

Non Monsoon (November – May)	• Required canal discharge for Eastern Yamuna Canal (EYC) and Western Yamuna Canal (WYC) are diverted through head regulators • Balance river flow, if any, is to be discharged through spillway. • Flushing as and when the inflow exceeds 1982 cumecs (70000 cusecs) through under sluice bays by closure of head regulator gates
Monsoon Season (June – October)	• Only spillway bays are operated till the inflow is 1982 cumecs (70000 cusecs) • Once the inflow exceeds 1982 cumecs, undersluice gates are partially opened and water may be drawn through both the HRs (WYC:EYC in 2:1). • Once the silt concentration in the canal water reaches 2500 ppm (2.5 gm/L), both the head regulators are closed. • At inflow magnitude of 6094 cumecs (215400 cusecs) and above, all the gates of the barrage i.e. undersluice and spillway bays shall be fully opened.
Receding Flood	Reverse Operation

The Tail Water Rating Curve during design of Hathnikund Barrage as per CWPRS Model Study Report 2018 is presented in **Fig 25**.

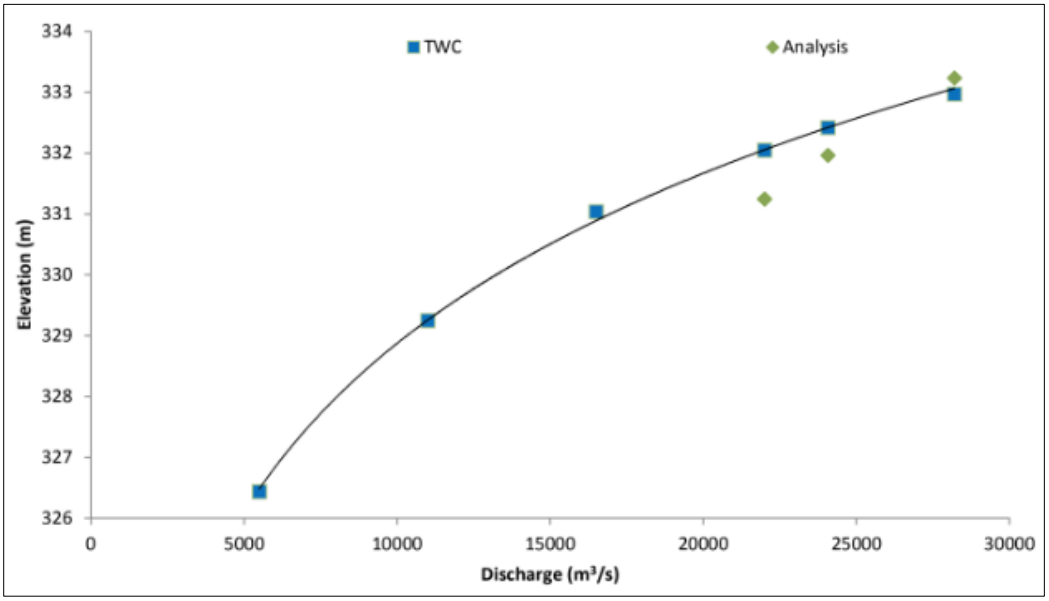


Fig 25: Tail water rating curves during design of Hathnikund Barrage

5.1.2 Okhla Barrage

i. Operations and Maintenance Manual of Okhla Barrage has been shared by the project authority.
ii. As per the Clause 10 of above manual, 'Various conditions for regulation' of the barrage have been described for different conditions of flow. The same is summarized below:

Normal Condition (Inflow = Main Canal Discharge)	• The normal PL of 201.35 m in upstream of the barrage shall be maintained throughout so long the river supply is in excess of the requirement. • In case river supply is deficient to run the canal with full supply, It is desirable to lower the Pond Level suitably to save on evaporation losses (But not below 201.00 m to prevent weed growth in reservoir area).
Commencement of flood	• Gauge of river may start to rise rapidly and river supply may be in excess of requirement. • Promptness to be exercised in order that the authorized supply to canal is not exceeded. • It is advisable that the Head regulator gate regulation should be little ahead of the rate of rise.
Low Flood Condition	• Regular and frequent inspections by SDO & JE (Headworks) and gate openings to be recorded in the flood register. • The JE(Head works) shall remain in the vicinity of the barrage site whether day and night and supervise regulation)
Medium Flood Condition	• SDO shall also remain at the barrage site whether day and night and supervise regulation.
High Flood Condition	• When the discharge is so much that the gauge near Head Regulator tends to rise above the Pond Level 201.35 m, with all the barrage gates fully open, the distribution of discharge may not be regulated. • The canal may be required to remain closed and flood passed through the barrage bays and under sluices to avoid entry of excessive bed load into the canal. • It is essential to resort to flushing operation by closure of canal whenever required to keep down the bed load however it has to be carried out keeping in view the safety of the barrage, canal lining and berms, which may be affected due to sudden drawdown. • In case of supply in excess of 500 cumecs (17,585 cusecs) the discharged passed should be distributed between under sluice and barrage bays. The distribution of discharge between under sluices and gate openings during various conditions of river supplies and corresponding gauges is given in the O&M Manual. • Every gate in turn shall be operated and checked every day by JE (Mechanical).
Receding flood	• The receding flood shall be passed through the under sluices and the first compartment of the barrage only to avoid the tendency of shoaling.

It has also been stated that in the case found best suited to:

a) Minimize the action on divide walls
b) Prevent cross flows
c) To suit the cutting of shoal formation upstream and downstream of the barrage

Views of the Committee:

The committee observed that there was discrepancy in the observed discharge data during floods which needs to be looked into. The detailed analysis of operation of barrages and updation of tail water rating curves is required and shall be presented in the final report.

6. Details of Temporary structure/muck disposal clearance from the river bed/bank

I&FC Department, Govt. of NCT Delhi has indicated the following encroachments & obstructions in the bed of river Yamuna between Wazirabad Barrage and Signature Bridge:

- A pucca room between Wazirabad Barrage & Signature Bridge of Yamuna.
- A temple between Wazirabad Barrage and Signature Bridge on the left bank of river Yamuna.
- Two temples & Huts just Downstream of Wazirabad Barrage on right bank of river Yamuna.
- A Mazaar and Masjid near outfall point of N.G. Drain on right bank of river Yamuna.
- A Kabristan between N.G. Drain & Signature Bridge on right bank of river Yamuna.
- Earthen Bund construction by DMRC.
- DMRC precast RCC Girders are lying in the river flood plains of river Yamuna.
- Debris and other construction waste material left under Signature Bridge by the bridge construction agency of DTDC.

The photographs of encroachment & obstructions are shown below.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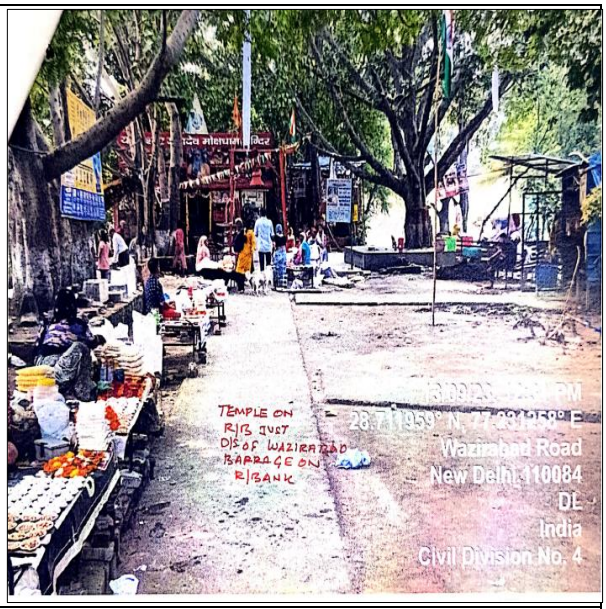
Civil Division No IV


TEMPLE ON R/B JUST D/S OF WAZIRABAD BARRAGE ON R/BANK
Wazirabad Road
New Delhi 110084
DL
India
Civil Division No. 4


TEMPLE ON R/BANK JUST D/S OF WAZIRABAD BARRAGE
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DL
India
Civil Division No. 4


HUTS NEAR TEMPLE ON R/BANK
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New Delhi 110084
DL
India
Civil Division No. 4


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New Delhi 110084
DL
India


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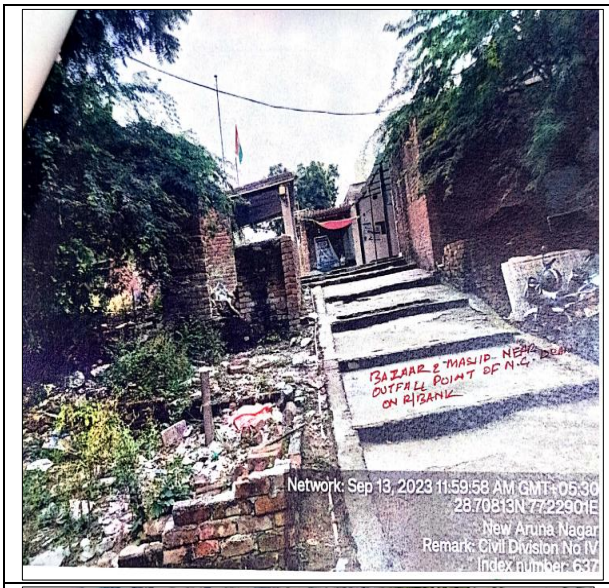
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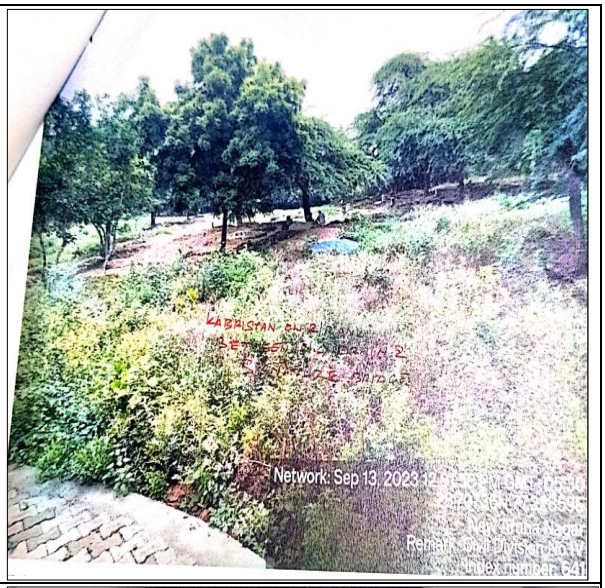
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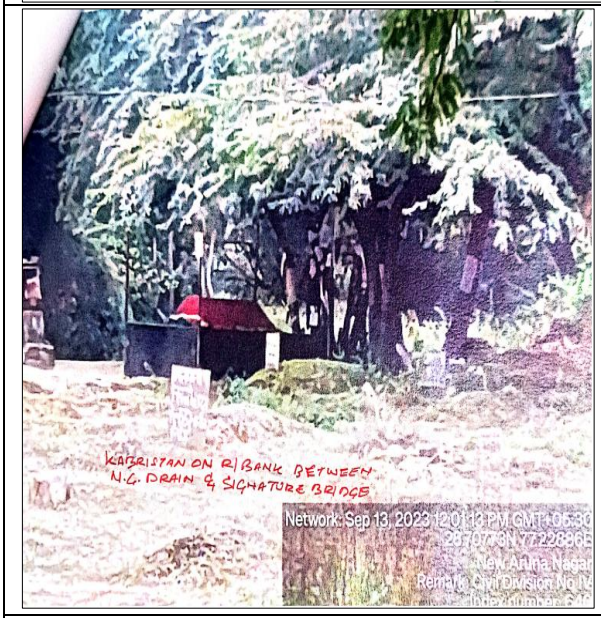
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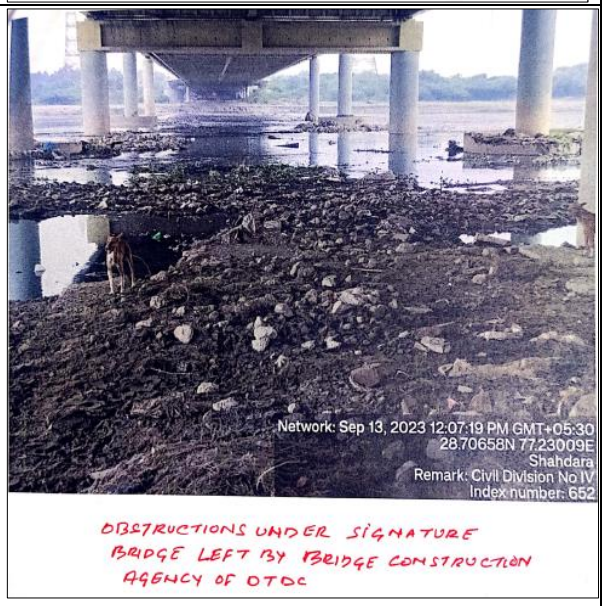
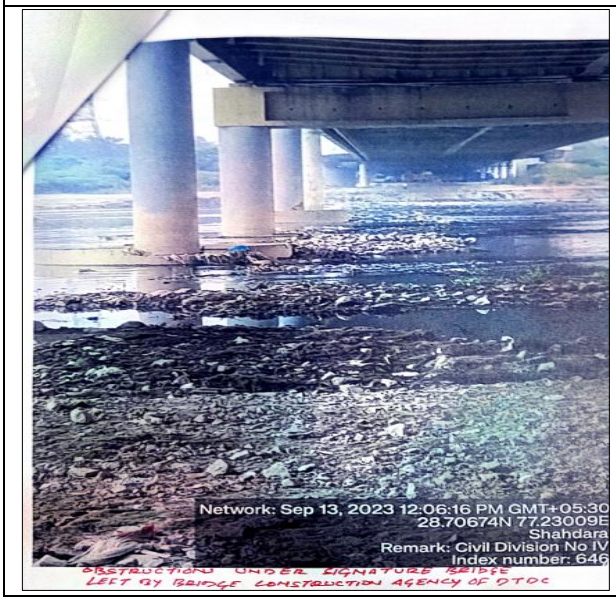

OBSTRUCTIONS UNDER SIGNATURE BRIDGE LEFT BY BRIDGE CONSTRUCTION AGENCY OF OTDC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OBSTRUCTIONS UNDER SIGNATURE BRIDGE LEFT BY BRIDGE CONSTRUCTION AGENCY OF OTDC


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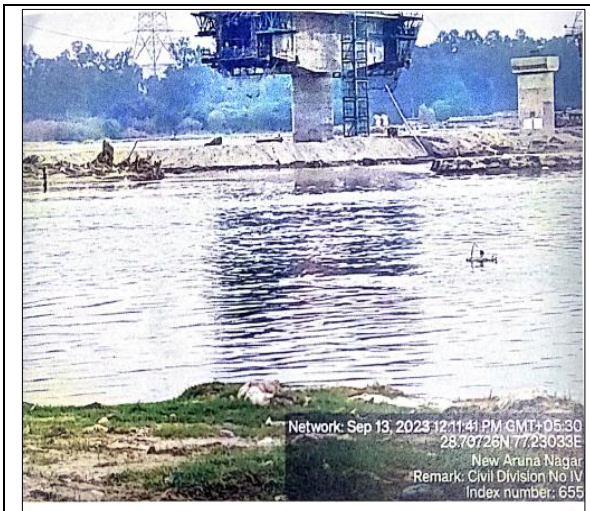

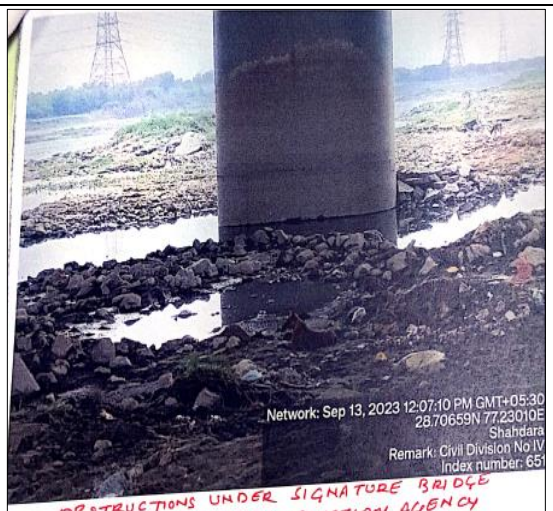

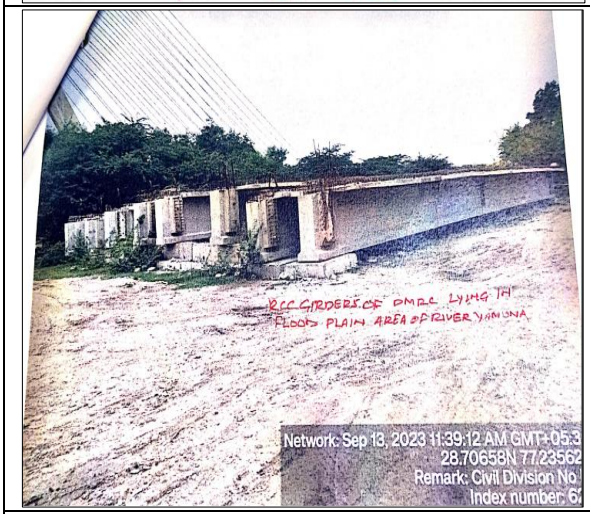

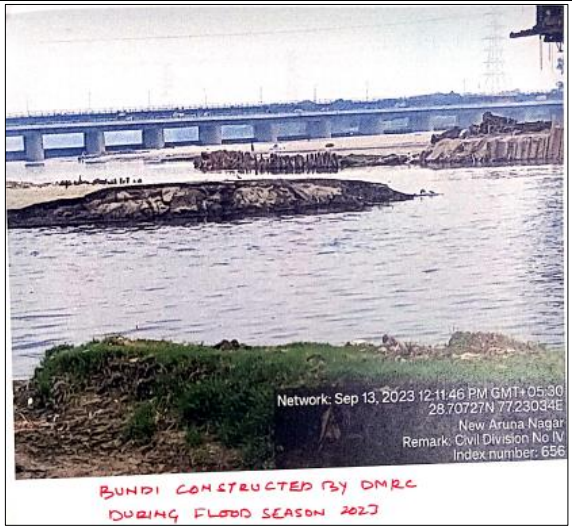

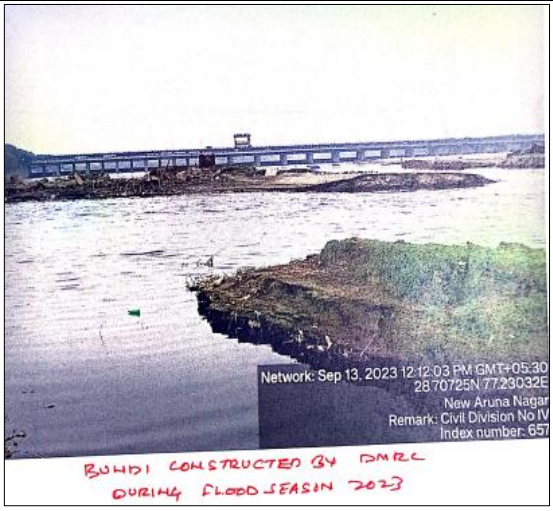

Views of the Committee:

It is observed, that construction of temporary structures and muck disposal in the right of way of river during the construction led to the increased afflux during a flooding event. Hence, after construction the temporary structures should be properly dismantled and muck should be properly disposed away from the river bed/bank.

7. Examining the feasibility of creation of underground reservoirs as well as storages in flood plain for surplus flood water

There are examples of underground reservoirs created for flood moderation purpose in Japan. The **Metropolitan Area Outer Underground Discharge Channel** is an underground water infrastructure project in Kasukabe, Saitama, Japan. It is the world's so called largest underground flood water diversion facility, built to mitigate overflowing of the city's major waterways and rivers during rain and typhoon seasons. It is located between Showa in Tokyo and Kasukabe in Saitama prefecture, on the outskirts of the city of Tokyo in the Greater Tokyo Area, Japan. Work on the project started in 1992 and was completed by early 2006 at an approximate cost of 2.6 billion US$ (2006). It consists of five concrete containment silos/ shafts with heights of 65 m and diameters of 32 m, connected by 6.4 km of tunnels, 50 m beneath the surface, as well as a large water tank with a height of 25.4 m, with a length of 177 m, with a width of 78 m, and with 59 massive pillars each weighing 500 ton connected to 7810 MW (13,000 hp) pumps that can pump up to 200 tons of water into the Edo River per second. These shafts and underground tunnel will divert the flood water in the rivers Oootoshifurutene, Koumatsu, Kuramatsu, Naka and No 18 Channel to the Edo River. The capacity of this arrangement is 6,70,000 cubic meter. The tank adjusts the water pressure for the pumps to operate smoothly in order to pump the water into Edo River.

The flood water diversion facility described above seems to be technically feasible. However, the following issues need to be considered:

a. **Magnitude of flooding**- The last flood sustained for about 2 days with discharge of about 3.7 lakh cusecs which is quite high.

b. **Siltation**- There are issues of heavy silt load in Indian rivers. Hence, handling silt load for an underground storage will pose a major challenge.

c. **Financial considerations**- Japanese experts themselves claim that the work began on the facility here in Kasukabe in the early 1990s, at a time when Japan was pouring funds, and concrete, into huge public works projects. But now, the country is less able to muster the resources to fund such ambitious projects. They consider now it as a one time feat, not to be repeated.

I&FC Department, Govt. of NCT Delhi has conducted a study where 6 probable locations have been identified in river Yamuna flood plains for recharging using flood water.

The physical parameters of the proposed reservoirs are given in **Table 10** below.

Sl. No.	Location	Surface Area (Sq.m)	Average Depth (m)	Storage Volume (Cubic.m)
1	Right Bank, north of Old	9,00,000	1.5	1,350,000

	Bawana Escape [Sheet No. 33]			
2	Right Bank, south of Old Bawana Escape [Sheet No. 33]	1,170,000	1.5	1,755,000
3	Left Bank, west of Sabapur, [Sheet No. 33]	8,40,000	1.5	1,260,000
4	Left Bank, south of Wazirabad Barrage [Sheet No. 34]	2,500,000	1.5	3,750,000
5	Left Bank, between Railway Bridge and ITO Bridge [Sheet No. 41]	6,05,000	1.5	9,07,500
6	Left Bank, opp. Mayur Vihar [Sheet No. 41]	3,120,000	1.5	4,680,000
	Total			13,707,500

The locations of probable reservoirs are highlighted in Maps given at **Fig 26 (a), (b) and (c)** below:

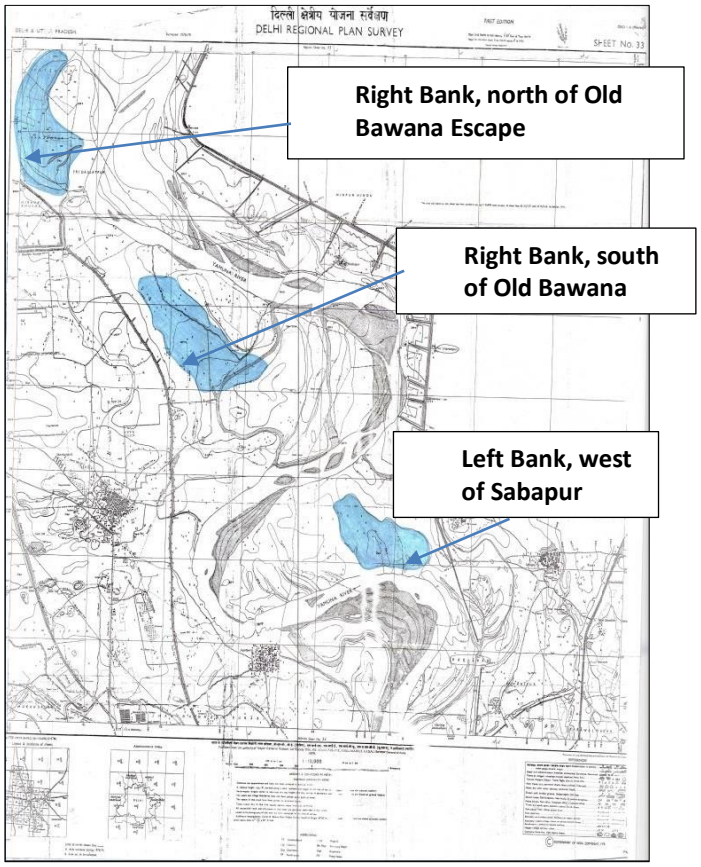

Fig 26 (a)

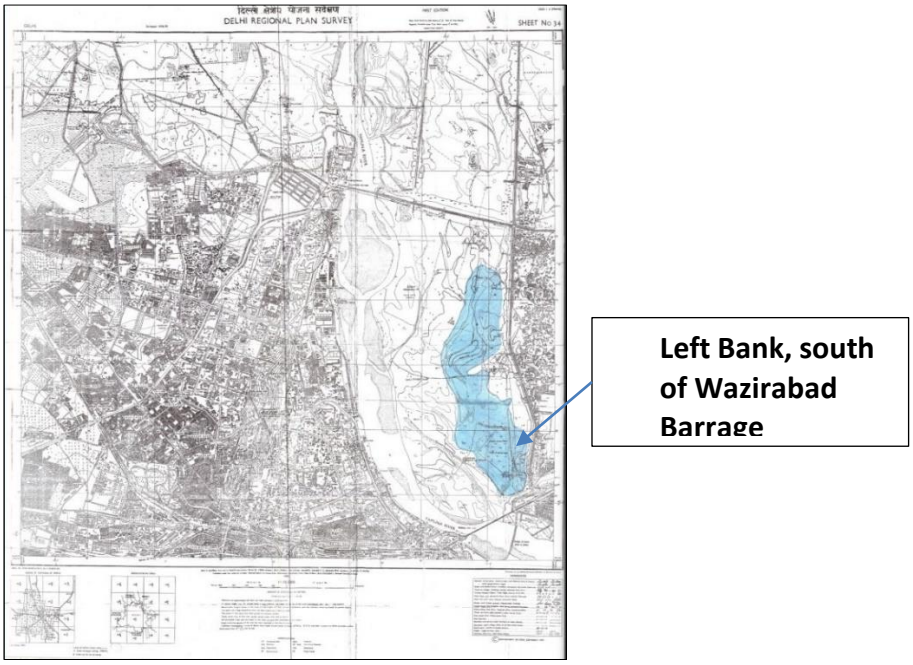

Fig 26 (b)

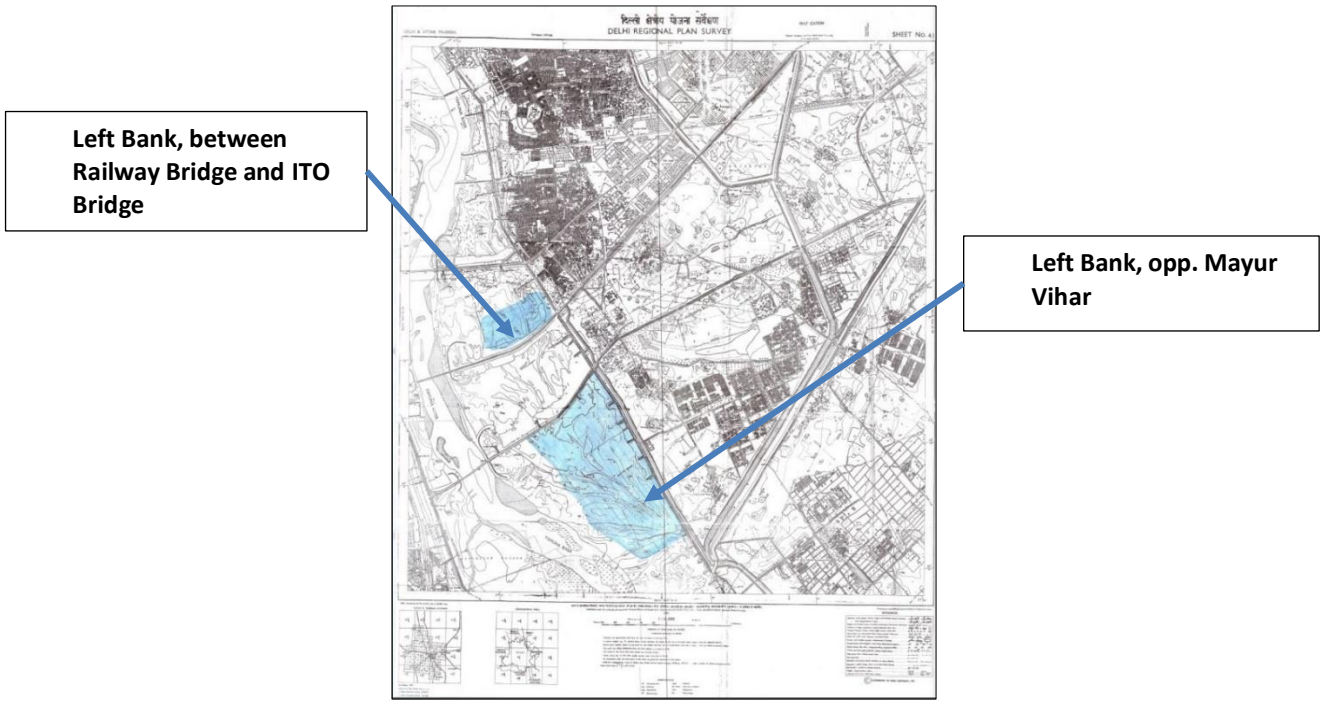

Fig 26 (c)

Govt. of Delhi has identified Bhatti Mines area to store floodwaters in the pits of Bhatti Mines and to recharge the groundwater table in the area.

Views of the Committee:

Prima facie, the above sites may not be adequate to accommodate high flows during flood period. However, further study may be conducted by Govt. of NCT of Delhi for suggesting any further potential location for detention of flood waters in Delhi region and this aspect will be discussed in the final report.

8. Analysis of Flood Embankments along Yamuna River in Delhi

A two dimensional (2D) hydrodynamic model of the reach of the river Yamuna from Palla to Okhla barrage has been developed on HEC-RAS utilizing ALOS DSM and Copernicus DTM along with surveyed cross sections of river Yamuna supplied by the State Govt. of Delhi. The details of existing embankments along the river Yamuna have also been simulated in the model to identify potential overtopping zones during floods with different return period. Preliminary simulations of 2D hydrodynamic model for Delhi reach of River Yamuna shows following potential overtopping zones based on 100-year return period flood (8636 Cumec). The identified locations in 14 zones are listed **in Table 11** below. The identified locations in **Table 11** are also shown in the map in **Fig 27** below:

Table 11: Identified Locations

ZONE	Long. (^{o}E)	Lat. (^{o}N)	EMBANKMENT	Location
1	77.249328	28.654831	RIGHT	MG Marg, Near Raj Ghat, Vijay Ghat
2	77.254095	28.647295	RIGHT	MG Marg, Near Raj Ghat
3	77.264990	28.654292	LEFT	Geeta colony Shamshan ghat
4	77.236482	28.886787	LEFT	Alipur Bandh, Mavikala
5	77.236959	28.888090	LEFT	Alipur Bandh, Mavi Kala
6	77.237171°	28.831976	LEFT	Near Allipur
7	77.234262	28.825883	LEFT	Near Allipur
8	77.229920	28.821415	LEFT	Near Allipur
9	77.228268	28.819780	LEFT	Near Allipur
10	77.215168	28.806133	LEFT	Near Pachayara Police chowki
11	77.243285	28.776001	LEFT	Tronica City Road
12	77.243389	28.776901	LEFT	Tronica City Road
13	77.206890	28.771060	RIGHT	Bund Road, near SCADA center DJB
14	77.209419	28.740487	RIGHT	Raj Marg, Milan Vihar

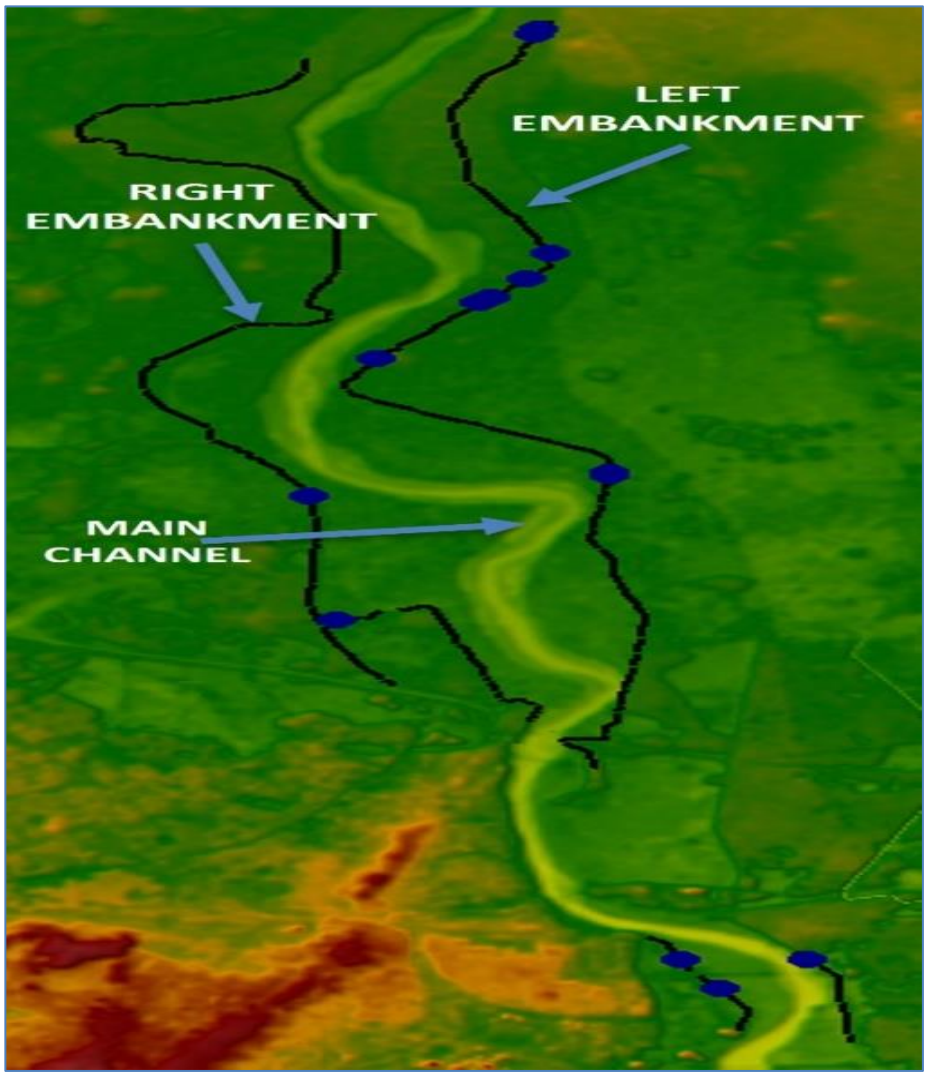

Fig 27: Potential overtopping zones.

Views of the Committee:

Prima facie there is a need to raise the left and right embankment at above locations. However, Govt. of NCT of Delhi may undertake ground verification in this regard to identify the exact such locations.

9. Conclusions

a) The rainfall analysis indicates that the excessive rainfall in the Yamuna catchment during 9th to 13th July, 2023 was the major causative factor of extreme flooding in Delhi and other locations along the reach of river Yamuna. During this period the rainfall in the catchment area upto Hathnikund was about 42.7% more in comparison to 5 days cumulative rainfall of year 1978. Besides above, non-operational gates of ITO barrage, construction of several bridges in the reach of river Yamuna in Delhi and construction/raising of embankments has led to reduced cross-sections for the flow of flood water, resulting in afflux upstream.

b) The basic structure of ITO barrage comprising of piers with gate grooves and deck slab is in place. The gates of the barrages are kept open during flood period so that the original condition of river is maintained and the barrage structure has a minimum impact on river flow during floods.

Further, barrage has linkage with road bridge. Therefore, the only matter to be considered is whether gates are to be dismantled or not. It is observed that in lean season gates could be useful to impound some water for various purposes including recreational activities.

Hence, it is recommended to operate ITO barrage with all gates open during floods in coordination with operation of Wazirabad barrage and Okhla barrage. It is also recommended that regular maintenance of all hydro-mechanical equipment of barrage to be conducted as per the operation and maintenance manual of the barrage/codal provisions.

The matter of handing over of the ITO barrage to Government of Delhi can be taken up separately by appropriate authority.

c) Delhi Govt. officials informed that they are contemplating to change warning & danger levels to 205.00 m and 205.75 m, respectively. After detailed discussions, the committee observed that the warning and danger levels of river Yamuna in Delhi need to be reviewed. However, Govt. of Delhi may conduct scientific study for the same, so that appropriate warning and danger levels can be decided which shall be presented in final report.

d) The committee observed that there was discrepancy in the observed discharge data during floods which needs to be looked into. The detailed analysis of operation of barrages and updation of tail water rating curves is required and shall be presented in the final report.

e) Any temporary structure made to facilitate construction within the right of way of river should be dismantled and muck should be properly disposed away from the river bed/bank as soon as possible.

f) Prima facie, the sites identified by Govt. of NCT of Delhi may not be adequate to accommodate high flows during flood period. However, further study may be conducted by Govt. of NCT of Delhi for suggesting any further potential location for detention of flood waters in Delhi region and this aspect will be discussed in the final report.

g) Prima facie there is a need to raise the left and right embankment at locations identified by model study. However, Govt. of NCT of Delhi may conduct ground verification in this regard to identify the exact such locations.

****

Annexure-I: Office memorandum for Constitution of the Committee

Z-15011/1/2020-FM Section-MOWR

I/86850/2023

Government of India
Ministry of Jal Shakti
Department of Water Resources, RD&GR
(Flood Management Wing)
Block-11, 8th Floor, CGO Complex,
Lodhi Road, New Delhi-110003.
Dated 06 August 2023

Office Memorandum

Subject: Constitution of a Committee for joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage

The extensive flooding in river Yamuna during July 2023 necessitated giving a fresh look for flood management of the river in its reach between Hathnikund and Okhla barrage. In this regard, the undersigned is directed to convey that, with the approval of the Competent Authority of DoWR, RD&GR, Ministry of Jal Shakti, a Committee is constituted for conducting a ***joint flood management study of river Yamuna for its reach between Hathnikund and Okhla barrage***, as per the following details:

2. **Composition of the Committee:**

1.	Chairman, Central Water Commission	Chairman
2.	Member (D&R), Central Water Commission	Member
3.	Member (RM), Central Water Commission	Member
4.	Commissioner (FM), DoWR, RD&GR, MoJS	Member
5.	Commissioner and Secretary, Irrigation and WRD, Government of Haryana	Member
6.	Engineer in Chief, Irrigation and WRD, Government of Haryana	Member
7.	Principal Secretary, Irrigation and WRD, Government of Uttar Pradesh	Member
8.	Engineer in Chief and HoD, Irrigation and WRD, Government of Uttar Pradesh	Member
9.	Principal Secretary, Irrigation and Flood Control Department, Government of NCT	Member
10.	Chief Engineer-Zone-1, Irrigation and Flood Control Department, Government of NCT	Member
11.	Director, Central Water & Power Research Station, Pune	Member
12.	Representative of National Remote Sensing Centre, Hyderabad	Member
13.	Representative of IMD	Member

I/86850/2023

14.	Chief Engineer(FMO), Central Water Commission,	Member-Secretary

The Committee shall review and advice the study as per Terms of Reference given at Annexure-I.

3. The Committee will submit its final report within a period of six months from the date of its constitution. However, an interim report regarding meteorological aspects, return period floods, discharging capacity of barrages, functional requirement of ITO barrage etc along with interim measures to be taken shall be submitted within two months. The Committee may co-opt other members, if required, and may invite any officer from expert organizations to present the outcome of related technical studies carried out by them, if any.

4. The expenditure on TA/DA etc. of the officials for participating in meetings/visits shall be borne by the respective Organizations.

6/8/2023

(Rajesh Kumar)
Sr. Joint Commissioner-II, FM
Ph.No. 9650550015
E-mai: sjcer2-mowr@nic.in

To,
The Members of the Committee

Copy to:

1. Chief Secretary, Government of Uttar Pradesh
2. Chief Secretary, Government of Haryana
3. Chief Secretary, Government GNCDT
4. Director General, IMD, New Delhi
5. Director, NRSC, Hyderabad.

Copy for kind information to:

1. PS to Hon'ble Minister Jal Shakti
2. Sr.PPS to Secretary (WR,RD&GR), Ministry of Jal Shakti
3. Sr. PPS to Special Secretary (WR,RD&GR), Ministry of Jal Shakti

Annexure-I

TERMS OF REFERENCE

FOR

FLOOD MANAGEMENT STUDY OF RIVER YAMUNA FOR ITS REACH BETWEEN HATHNIKUND AND OKHLA BARRAGE

1.0 Background

River Yamuna, one of the largest tributaries of River Ganga, originates from Yamunotri Glacier on the southwestern slope of Bandarpunch peaks of the Lower Himalayas in Uttarakhand. The Yamuna River basin lies in Uttarakhand, Himachal Pradesh, Haryana, Delhi and Uttar Pradesh. Before its confluence with River Ganga at Sangam in Prayagraj district of Uttar Pradesh, important tributaries such as Hindon, Tons, Pabbar, Chambal, Sindh, Betwa and Kenjoin the river. The country's huge population depends upon the water of the river Yamuna. There are six barrages constructed on the main course of the river. These barrages are Dakpathar Barrage, Hathnikund Barrage, Wazirabad Barrage, ITO Barrage, Okhla Barrage and Mathura Barrage. From Hathnikund Barrage, water is diverted to Eastern and Western Yamuna Canals. The river water takes about 2-2.5 days to travel from Hathnikund to Delhi. Central Water Commission started flood forecasting services in 1958 with its first forecasting station on Yamuna at Delhi's old railway bridge.

Due to a combination of Western Disturbances and Southwest Monsoon, heavy rainfall in different places of Himachal Pradesh, Uttrakhand and Haryana occurred during 09-13 July 2023, leading to extensive landslides and flooding in the hills and plains. The heavy rainfall in the catchment area of river Yamuna resulted in huge runoff in the river, due to which an earlier HFL of 207.49 m recorded at the CWC gauging site of Delhi's old railway bridge on 6th September 1978 surpassed and a new HFL of 208.66 m was observed on 13th July 2023. This necessitated giving a fresh look at the river's flood management in its reach from Hathnikund Barrage up to Okhla Barrage.

2.0 Scope of the Study

For any flood management intervention by structural or non-structural measures, an in-depth understanding of the hydrological and hydro-dynamic aspects of the river/stream is essential. Hence, for the reach of river Yamuna from Hathnikund barrage up to Okhla barrages, the following studies are proposed:

i. Detailed catchment representative rainfall analysis to compare the floods of the year 1978 and 2023 and other years as decided

ii. Estimation of 5, 10, 25, 50, 100 and 500-year return period floods at Hathnikund Barrage, Wazirabad Barrage, Delhi old railway bridge and Okhla Barrage

iii. Carrying capacity of the river between Hathnikund barrage and Okhla barrage

iv. Maximum water level at salient locations of the study river reach for 5, 10, 25, 50, and 100-year return period floods

v. Afflux of barrages, bridges, flood protection dykes and other structures in the study reach of the river

vi. 2D modelling and submergence area estimation for the reach of river Yamuna from 10 km upstream of Wazirabad barrage and up to 10 km downstream of Okhla barrage.

vii. Identification of possible drainage congestion in Delhi in case of high spate of river Yamuna.

viii. To review the utility of ITO barrage in present context.

ix. Examine the feasibility of some innovative measures like creating underground reservoirs for flood moderation in line with Tokyo model.

x. Examine the feasibility of creation of storages for surplus flood water in the flood plains of Yamuna and thereafter identification of such sites.

3.0. Tasks to be performed

a. Review of Data availability, Data Collection and Compilation

b. Collection and compilation of all the requisite information/data for the study as suggested

c. Delineation of river catchment and estimation of physiographic parameters

d. Preparation of DTM up to 200 m on either side of the river from river banks using a combination of Drone and hydrographic survey and merging this DTM with other available DTM/DEM for the study purpose

e. Catchment representative rainfall analysis using IMD gridded rainfall data to estimate 1-day, 3-day and 5-day maximum rainfall depths from the year 1970 to Year 2023.

d. Estimation of 5, 10, 25, 50, 100 and 500-year return period floods at Hathnikund barrage, Wazirabad Barrage, Delhi old railway bridge and Okhla barrage

e. Development of a 1-D mathematical model of the study river reach to estimate water level at salient locations for 5, 10, 25, 50 and100-year return period

floods and channel carrying capacity

f. Development of a 2-D mathematical model for the reach of river Yamuna from 10 km upstream of Wazirabad barrage and up to10 km downstream of Okhla barrage for submergence area estimation.

g. Identification of drainage congestion in Delhi in case of high spate of river Yamuna