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Hydrological Flow Health Assessment of the River Ganga

GRBMP: Ganga River Basin Management Plan

by

Indian Institutes of Technology

IIT Bombay | IIT Delhi | IIT Guwahati | IIT Kanpur | IIT Kharagpur | IIT Madras | IIT Roorkee

Preface

In exercise of the powers conferred by sub-sections (1) and (3) of Section 3 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government has constituted National Ganga River Basin Authority (NGRBA) as a planning, financing, monitoring and coordinating authority for strengthening the collective efforts of the Central and State Government for effective abatement of pollution and conservation of the river Ganga. One of the important functions of the NGRBA is to prepare and implement a Ganga River Basin Management Plan (GRBMP).

A Consortium of 7 Indian Institute of Technology (IIT) has been given the responsibility of preparing Ganga River Basin Management Plan (GRBMP) by the Ministry of Environment and Forests (MoEF), GOI, New Delhi. Memorandum of Agreement (MoA) has been signed between 7 IITs (Bombay, Delhi, Guwahati, Kanpur, Kharagpur, Madras and Roorkee) and MoEF for this purpose on July 6, 2010.

This report is one of the many reports prepared by IITs to describe the strategy, information, methodology, analysis and suggestions and recommendations in developing Ganga River Basin Management Plan (GRBMP). The overall Frame Work for documentation of GRBMP and Indexing of Reports is presented on the inside cover page.

There are two aspects to the development of GRBMP. Dedicated people spent hours discussing concerns, issues and potential solutions to problems. This dedication leads to the preparation of reports that hope to articulate the outcome of the dialog in a way that is useful. Many people contributed to the preparation of this report directly or indirectly. This report is therefore truly a collective effort that reflects the cooperation of many, particularly those who are members of the IIT Team. A list of persons who have contributed directly and names of those who have taken lead in preparing this report is given on the reverse side.

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Executive Summary

Continuity in flow is a basic concern in Ganga river basin; a number of water resources projects (irrigation and hydropower projects) have rendered the river dry in several stretches. Hence a hydrologic health assessment of the Ganga River basin was undertaken based exclusively on hydrologic flow regime. The scope of this study is limited to assessment of flow health purely based on the hydrologic flow regime. Estimation of flow (E-flow) for different habitat is beyond the scope of this study. Nevertheless, the hydrologic flow health assessment conducted in this study will be an essential precursor for the habitat based assessment of E-flow.

The hydrologic flow regime for the virgin state and the current managed state were obtained through calibrating the hydrologic model Soil and Water Assessment Tool (SWAT) (Refer to the hydrology report for details on hydrologic modelling). The Flow health assessment was made for four scenarios 1) Virgin scenario 2) Currently managed scenario 3) Flow health due to improved irrigation efficiency and 4) Flow health due to implementation of projects such as run of the river hydroelectric projects that are envisaged.

In the first part of the study, a tool called "Flow Health" developed by the International Water Centre was used (Gippel et al, 2012). "Flow Health" is an application to assist in the design and management of river flow regimes thereby providing a “flow health score” assigned for the river based on the magnitude and frequency of the flows. It is based on the concept of comparing the values of hydrological attributes of a river with the values in reference condition. This reference condition is actually a period of time where river was devoid of (or with minimum) human interventions (virgin condition).

In second part, look-up table methods based on low flow indices such as Q_{90}, $Q_{95\ etc.}$, were applied and checked for their feasibility for Ganga River Basin. Two approaches are used in it viz. Flow Duration Curve analysis and Mean Monthly Flow analysis. Low flow indices e.g. Q_{90}, Q_{95} or their predefined percentage as well as percentages of Mean flows are generally used as indicators of minimum flow requirements. Both of these approaches have been applied for flow health assessment of 146 observation sites.

In general, the study shows that the hydrologic flow health has been considerably affected at several stretches of the River Ganga due to the present state of water management. The impact due to implementation of future projects seems to have only marginal effect over the current state of flow health. However, other aspects of river health such as the functional needs of the ecosystem and habitat should be considered while implementation of future projects. This report could be a first step to start a meaningful and effective dialogue between various stakeholders of the basin and agree upon a desired flow health to achieve in the different stretches of Ganga. This along with a study on the functional needs

of the ecosystem along different stretches will help to arrive at an E-flow regime to be maintained along different stretches of Ganga during different times of the year. The hydrologic model in conjunction with the flow health tools could be used to look at the current levels of diversions and the amount of reductions in upstream diversions necessary to achieve the level of desired flow health.

1. Introduction

1.1. Significance of hydrological flow health in the context of the River Ganga

Continuity in flow is a basic concern in Ganga river basin; a number of water resources projects (irrigation and hydropower projects) have rendered the river dry in several stretches and polluted in other stretches. Further, several hydroelectric power projects in Baghirathi and Alaknanda are in various stages of planning and design. Some of the major hydraulic interventions in Ganga include the Upper Ganga Canal near Haridwar, Lower Ganga Canal near Narora, Tehri dam which was constructed on Bhagirathi, a tributary of Ganga, the Bansagar dam and Rihand dam which are built on the Son tributary and the Farrakka barrage on the Hooghly tributary of Ganga and. By the presence of these major interventions as well as due to the large number of minor hydraulic structures, the flow in Ganga has lost continuity and badly fragmented. The wholesomeness of all rivers of the Ganga basin should be ensured for sustaining the population growth, urbanization, industrial and agricultural activities in it. The Water Quality Analysis and Assessment done in 2007 has recommended that the E-flow of Himalayan Rivers should be greater than 2.5% of 75% dependable annual flow *(WQAA, 2007)*. However, a thorough scientific assessment of hydrological flow health and E-flow requirement for the entire Ganga basin has not been done yet. The health of a river could be readily assessed using a set of indicators derived based on hydrology, water quality and biological aspects. In this report, the hydrological river health of different stretches of Ganga would be assessed based on different indicators of flow. This report will serve as a precursor to a detailed assessment of E-flow requirement along different stretches of the River Ganga.

1.2. River Health

River health can be referred to as the degree of similarity in biological diversity and ecological functioning to a river without any interventions (*Schofield, 2007*). Due to the in stream, riparian and catchment modification practices, most rivers will be less biologically functional and of lower ecological value than its original state. Important river stresses include nutrient enrichment, water extraction, flow controls, loss of riparian vegetation and effluent discharge. An ecologically healthy river can sustain a diverse range of habitat and the animals and plants depending on them. That is, by providing sufficient amount of energy and nutrients to sustain the food chain so that the natural interactions between species such as predator – prey, host – parasite and competition relationships are maintained. An ecologically healthy river need not be a pristine river. Deviations from the natural state will be present; but there will be a balance between the human use and the ecology of the river (Fei *et al.,* 2011).

Environmental flows are very important for sustaining the health of the river. A healthy river supports local biota and plays a key role in process such as sediment transport, nutrient cycling and waste assimilation and usually it recovers after short-term natural disturbance.

1.3. Environmental Flows and Flow Health

Rivers and streams have a wide range of functions including irrigation, domestic water supply and biodiversity conservation despite the fact that the flows are varying for different seasons throughout the year. Environmental flows (E-flows) come into picture when the flow volume or natural flow patterns are affected by hydraulic structures like dams, abstractions, diversions or addition of flows (*ACT Government (2006), 2006 Environmental Flow Guidelines*). E-flows are the flows of water in rivers and streams that are necessary to maintain a healthy aquatic ecosystem and life in and out of a river.

The assessment of E-flow is based on the fact that some spare water can be maintained all throughout the year in the river. But it doesn't mean that E-flows are minimum flows; it can be a combination of high flows and low flows maintained at different frequencies. Hence, the E-flows mimic the natural condition in our rivers like transportation of water, self-purification, and sustenance of its cultural and livelihood activities. By providing a range of habitats, including river channels (vegetation cover, flood plains, estuaries, lakes etc.) between aquatic and land ecosystems, it supports an enormous diversity of life (*O'Keeffe and Le Quesne, 2009*).

The requirements for E-flow could be arrived at based on the consideration of hydrology and/or from the consideration of habitat (ecology and geomorphology) of few indicator species. Hydrology affects ecology and geomorphology and vice-versa. The fundamental assumption of the Hydrological Flow Health is that if we strive to maintain a similar hydrological flow regime as that in its virgin state (high and lows and frequency between floods etc.,) then the needs of ecology and geomorphology will be least affected due to development.

In the habitat based assessment we look at only few indicator species and it is possible that we may miss out on the requirements of the functioning of the other species which may not be vulnerable now, but could become vulnerable later. Other than the aquatic species some flora in the flood plain could also become vulnerable as well. E-flow requirements based on Geomorphological requirements could be riddled with large uncertainties.

It is in this regard that the assessment of "hydrological flow health" gains significance. The indicators of hydrological flow health evaluate the frequency and magnitude of high flows and low flows and compare them against flows that occur under a reference (or virgin) condition. This could be one of the important inputs to be used in subsequent studies and will be an essential precursor for the habitat based assessment of E-flow.

2. Hydrological Flow Health Assessment

This study involves two individual exercises undertaken to assess flow health of Ganga river basin. For this assessment, river flow regimes at 146 locations distributed over Ganga basin are used. These flow regimes are obtained from SWAT hydrological modelling under four different scenarios viz. a) in its virgin state (i.e. without any hydraulic structures, diversions or human interventions),b) in its present state of water diversion and management, c) with improved irrigation efficiency and d) due to implementation of future projects. Refer to hydrological modelling report by GRBEMP-WRM (2014) for details on hydrological modelling using SWAT.

In first part of the study, river health was analyzed using 'Flow Health Tool' developed by the International Water Centre. In second part, various hydrological indices like e.g. Q95, Q90, Q75, Q50, Mean Annual Flow, Mean Monthly Flow etc. were calculated for the four different scenarios simulated using SWAT. Worldwide, these indices and/or percentages of them are generally considered as first-cut estimates of minimum in-stream flow requirements in preliminary management decisions.

2.1. Flow Health Tool

Flow Health Tool, developed by the International Water Centre in 2009-2012 for the Australia China Environment Development Program (ACEDP) was used for assessing the River health and environmental flow in China (*Gippel et al, 2012*). It is an application to assist in the design and management of river flow regimes thereby providing a "flow health score" assigned for the river based on the magnitude and frequency of the flows. It is based on the concept of comparing the values of hydrological attributes of a river with the values in reference condition. This reference condition is actually a period of time where river was devoid of (or with minimum) human interventions (virgin condition).

Flow health was used for analysis of river health in different rivers of China by a project undertaken by International water centre. The result obtained from their study on major rivers Taizi and Gui are shown in figure 1 and figure 2. The flow regime was analyzed and the parametric variations contributing to the Flow health score formulation was analyzed in the study. (*Gippel et al, 2012*)

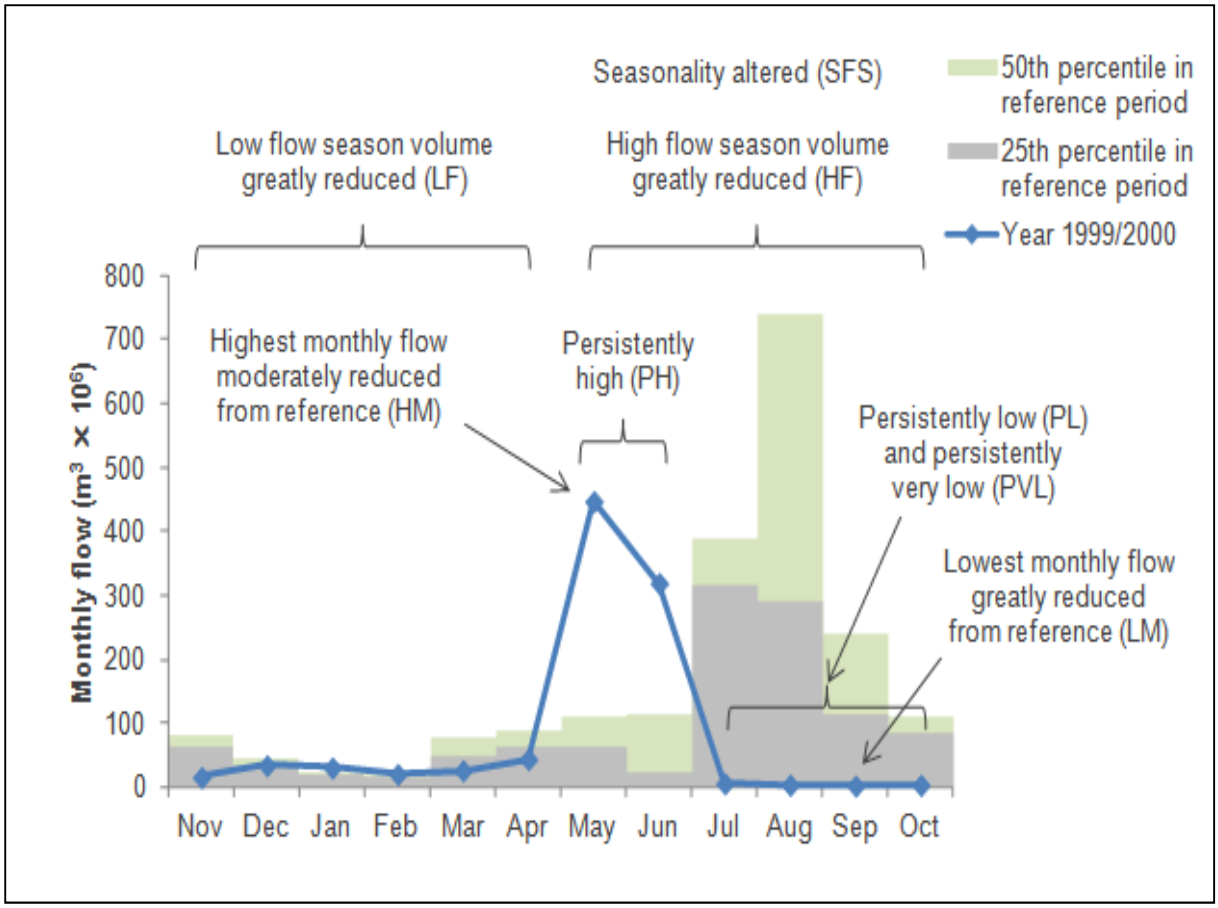

Figure 1: **Illustration of eight of the nine aspects of the flow regime characterized by the Flow Health Tool sub-indicators using a comparison of monthly flows for water year 1999/2000 at Liaoyang on the Taizi River, China with reference period median monthly flows and 25th percentile monthly flows (*Flow health User Manual, Gippel et al, 2012*).**

In the study conducted on Taizi River, it can be seen that eight parameters of the flow health tool are as shown in figure 1. It can be seen that during the period of November to March (low flow season period), flows have been reduced even less than that of 25 percentile flow and during the period of April to July (high flow season period), flows were lesser than the 50 percentile flow of reference period. Persistently very low flow was observed during the period of July to October; during this time, flows were found to be so negligible. Overall the flows were found to be unhealthy during the period 1999 - 2000.

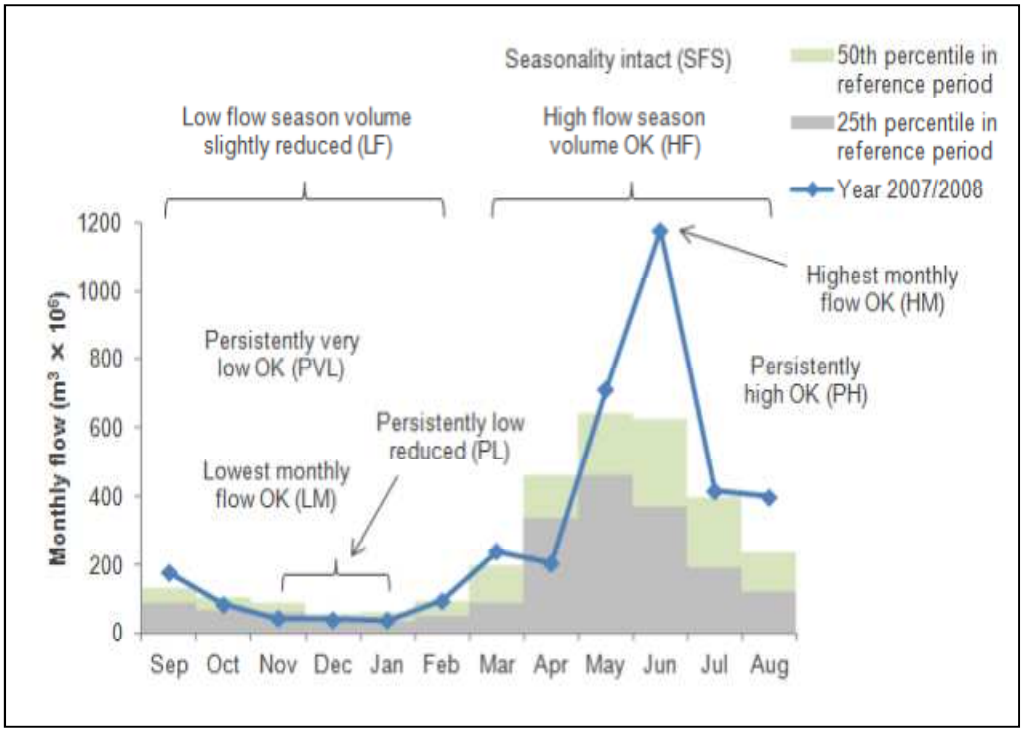

Figure 2: **Illustration of eight of the nine aspects of the flow regime characterized by the flow Health sub-indicators using a comparison of monthly flows for water year 2007/2008 at Guilin on the Gui River, China with reference period median monthly flows and 25th percentile monthly flows (*Flow health User Manual, Gippel et al, 2012*).**

In the study conducted on Gui River in China, the test period for flow was found to be more or less healthy because even during the low flow period, the flows were almost around 25 percentile of flows as that of the reference period. Moreover, in high flow season, flows were higher than 50 percentile of flows mostly touching 75 percentile of flows and hence the flows were found to be healthy during the period 2007 – 2008.

2.2. Look-up Table Methods

Look-up table methods are most simple and quick approach for obtaining the preliminary idea about varying river flow patterns. In this approach, river flow regimes are statistically analyzed to obtain various hydrological indices like e.g. Q_{95}, Q_{90}, Q_{75}, Q_{50}, Mean Annual Flow, Mean Monthly Flow etc. Worldwide, these indices and/or percentages of them are generally considered as minimum flow requirements in preliminary management decisions.

In the present study, four different flow regimes obtained through hydrological modelling are used to obtain these indices. Fate and feasibility of these indices are checked in reference to Ganga River basin. Using these indices, inferences about varying river flow patterns of Ganga can be drawn.

3. Objectives

The objectives of this report are:

1. to assess the hydrological flow health of river Ganga under four scenarios:
   a. in its virgin state (i.e. without any hydraulic structures, diversions or human interventions),
   b. in its present state of water diversion and management,
   c. with improved irrigation efficiency and
   d. due to implementation of future projects
2. to provide information for arriving at policy decisions for regulating current as well as future water diversions from the perspective of hydrologic flow health.

4. Scope

The scope of this study is limited to assessment of flow health purely based on the hydrologic flow regime. Estimation of E-flow or minimum in-stream flow for different habitat is beyond the scope of this study. Nevertheless, the hydrologic assessment conducted in this study will be essential for the habitat based assessment of E-flow. The hydrologic flow regime for the four different scenarios were obtained through calibrating the hydrologic model Soil and Water Assessment Tool (SWAT) (Refer to the hydrology report for details on hydrologic modelling). The hydrologic flow health was assessed using Flow Health, developed by the International Water Centre (*Gippel et al, 2012*) and using look-up table methods separately.

5. Methodology

5.1. Hydrologic Model Simulations for Flow Health Assessment

For hydrologic assessment of flow health, a long record of flow data encompassing both the natural as well as the managed state of the river is essential. As discharge stations having such a long history of flow data are available only at a few locations, a hydrologic model SWAT was used to simulate the long history of hydrology of the basin by calibrating the model with the limited flow data. For the purpose of hydrologic modelling, the entire Ganga river basin was subdivided in to 1045 subbasins, hence flow health could be potentially evaluated with hydrologic simulations made at 1045 locations spread across the basin. The calibrated hydrologic model was then used to simulate a long history of hydrology with hydraulic interventions and diversions (i.e. managed state) and without interventions (i.e. virgin state) for a long history (29 years) of similar weather data (1974 – 2002). Apart from that, long term flows were simulated for future condition where number of consumptive use projects are supposed to start operating. SWAT simulation with increased irrigation efficiency provided an additional scenario.

Among the flow simulations made at 1045 locations, the flow simulations made at 146 critical locations were used to assess the flow health (Fig. 4).Refer to hydrological modelling report by GRBEMP-WRM (2014) for details on hydrological modelling using SWAT.

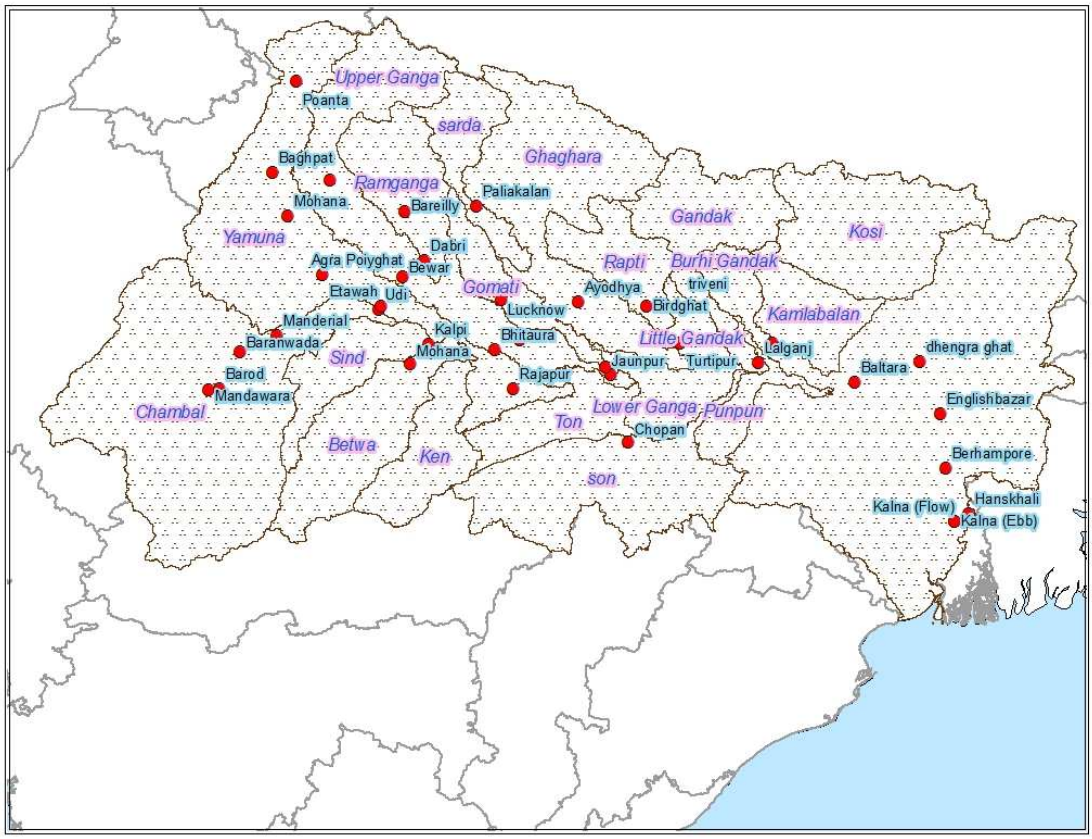

Figure 3: Critical Points along the Flow Network Where the Flow Health was Assessed

5.2. Flow Health Tool

In order to assess the hydrological health of Ganga, a tool called "Flow Health" was used which will help to analyze the flow over a long time period. Flow Health is an application to assist in the assessment, design and management of river flow regimes (*Gippel et al, 2012*). Its main purpose is to provide an annual score for hydrology in river health assessment, but it can also be used as a tool to assist environmental flow assessment. Flow Health Tool was used for this study as it is able to analyze the river flows in a more precise way and suggest flows to improve the hydrological health of the river. Further, the tool can be used to analyze the hydrologic data at different time scales (daily, monthly and yearly).

The major assumption of the flow health tool as with the other tools based on the hydrologic assessment is that the ecosystem will be restored to a greater extent when the flow magnitude and frequencies are made healthy. For that purpose, Flow Health tool was found to be more adaptive. Flow Health has four main functions (*Gippel et al, 2012*):

- To provide an annual score for the hydrology indicator in river health assessment

- To recommend a minimum monthly environmental flow regime
- To test the hydrological health of any monthly environmental flow regime
- To generate a synthetic monthly flow time series based on the designed environmental flow regime

The major inputs required for the Flow health tool is the monthly or daily flow hydrograph (observed or simulated) continuously available for a period of time. The flow health score is derived from nine different hydrological sub indicators: High Flow (HF), Low Flow (LF), Highest Monthly (HM), Lowest Monthly (LM), Persistently Higher (PH), Persistently Lower (PL), Persistently Very Low (PVL), Seasonality Flow Shift (SFS) and Flood Flow Interval (FFI) (*Gippel et al, 2012*). These nine indicators are closely related to the basic flow components of a natural flow regime (Fig. 3) such as ceae-to-flow, low flow period and high period baseflows, high flows and timing (seasonality).

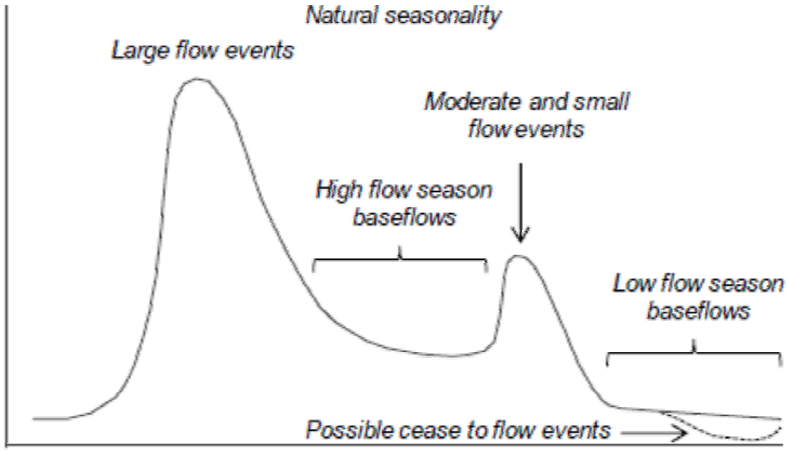

Figure 4: The Main Ecologically Relevant Flow Components (*Flow Health User Manual, Gippel et al, 2012*).

Flow health basically compares the time series data of test year flow data with a reference flow series. For assessing the change in flow health due to diversion, the virgin flow is assumed to be the healthy river flow and hence was taken as the reference flow and the present flow as the test condition flow. The flow health tool compares the monthly flow values, in test period with that of the reference period and assigns a score in such a way that the flow which is more or less the same as that of the virgin condition will have a flow health score close to 1, while the flow which deviate considerably from the virgin condition will be assigned a value close to zero.

The assessment of flow health starts by identifying natural low-flow and natural high-flow periods based on the flows from the reference period. The percentile ranking of different flow metrics were arrived at by comparing the current flow with the reference period to arrive at non-dimensional scoring system of different flow indices. The scoring system assumes that i) flow reductions are more detrimental to river health than flow increases and

ii) occasional increased flows in the high flow season were not detrimental to river health. Flow health adopts the inter-quartile range (25^{th} to 75^{th} percentile) for different flow metrics (hydrological attribute) as the range within which the hydrological health score is 1. Any deviations in an attribute outside this range could potentially affect the flow health and hence assigned a value less than 1.

High Flow (HF): HF is the sum of the monthly flows in the natural high flow period. The flow health score (FHS) is assigned a value of 1 when the cumulative flow during the high flow period is more than 25 percentile of the reference period cumulative flow for high flow period and assigned a value range of 0 to 1 linearly for the flow percentile varying from 0 to 25 percentile.

E.g.: >25%, FHS =1
0% - 25%, FHS = 0 to 1 linearly

Low Flow (LF): LF is the sum of the monthly flows in the natural low flow period. The FHS is assigned a value of 1 if the cumulative flow percentile is between 25 and 75 percentile of cumulative low flow volume during the reference period. The FHS is assigned a value range of 0 to 1 linearly for the flow percentile varying from 0 to 25 percentile. For the flow range above 75 percentile the FHS is linearly reduced in the range of 1 to 0.75 linearly as this higher than expected low flow in the year might negatively impact some biota.
E.g.: 0% - 25%, FHS = 0 to 1 linearly
25% - 75%, FHS =1
75% - 100%, FHS = 1 to 0.75linearly
Highest Monthly (HM): HM is the highest monthly flow in the year. It is assigned a value of 1 if any value in a test year is higher than the 25 percentile value in the reference year and if the max value in the test year is lesser than min value in the reference year, then the value is zero and when the test year maximum value percentile lies in between 0 and 25 percentile, the FHS is assigned a value range of 0 to 1 linearly.
E.g.: > 25%, FHS =1

0% - 25%, FHS = 0 to 1 linearly

Lowest Monthly (LM): LM is the lowest monthly flow in the year. FHS is assigned a value of 1 if any min value in a test year is between 25^{th} and 75^{th} percentile of the lowest flow value in the reference years. The FHS is linearly interpolated between 0 to 1 for percentile values between 0 and 25. For percentile values higher than 75, the FHS is reduced linearly between 1 and 0.75 as this higher than expected brief period of low flow in the year might negatively impact some biota.
E.g.: 0% - 25%, FHS = 0 to 1 linearly

25% - 75%, FHS =1
75% - 100%, FHS = 1 to 0.75 linearly

Persistently Higher (PH): PH is a measure of how many sequential months in the natural low flow season were the flows are higher than expected (95^{th} percentile). The number of consecutive months in the low flow period having a flow lying outside the upper range (95^{th} percentile) of flow in each month in a reference period is counted. If that total is greater than or equal to 6, then it is assigned a FHS of 0 and if that total is less than or equal to 1, it is assigned a FHS of 1.

E.g.: PH Count = 6, FHS = 0

PH Count <= 1, FHS = 1

6 > PH Count > 1, FHS = 0 to 1 linearly

Persistently Lower (PL): PL is a measure of how many sequential months were lower than expected (25^{th} percentile). It is assigned a FHS of 0 if the number (count) of consecutive months having a flow lower than the lower range of flow is 12 and assigned a FHS of 1 if the count is less than or equal to 1. In the values lying in between, FHS is assigned linearly in the range 0 to 1.

E.g.: PL Count <= 1, FHS = 1

PL Count >= 12, FHS = 0

12 < PL Count < 1, FHS = 0 to 1 linearly

Persistently Very Low (PVL): PVL is a measure of how many sequential months were much lower than expected flow occurs. The number of consecutive months where flow observed is less than 5 percentile of flow is counted in a test year. If that count is greater than or equal to 6, then FHS is assigned a value of 0 and if in any month, flow less than 5 percentile is not observed in the test year, FHS is assigned a value of 1. If the count ranges between 1 and 6, then linear interpolation of FHS from 0 to 1 is required.

E.g.: PVL Count >= 6, FHS = 0

PVL Count = 0, FHS = 1

0< PVL Count < 6, FHS = 0 to 1 linearly

Seasonality Flow Shift (SFS): SFS is a measure of the degree to which the seasonality of the monthly flows has been altered. It is applicable especially in the case of a dam operation. SFS measures the mean deviation in the ranking of the monthly flow values when compared to the deviation in ranks observed in the reference data. If mean monthly deviation of the flow ranking in the test data is lesser than 75 percentile of the deviation observed in the reference data, the FHS is assigned a value of 1 and if it is greater than 75 percentile, it is assigned values linearly from 1 to 0 for 75 percentile to 100 percentile

E.g.: SFS < 75%, FHS =1

SFS > 75%, FHS = 1 to 0 linearly

Flood Flow Interval (FFI): FFI is a measure of the time interval between the last significant flood month. In this a flood of magnitude with five year recurrence interval is considered. If this5 yr flood doesn't occur for continuously 10 years, then FHS is assigned a value of 0 and if it occurs within the 5 years, FHS is assigned a value of 1 and if the flood occurs in between 5 and 10 years, FFI is assigned a FHS value linearly between1 to 0.

E.g.: FFI <60 months, FHS =1

FFI >120 months, FHS = 0

60<Interval between 5-year floods<120, FHS = 1 to 0 linearly

Flow Health Index: Unlike the other metrics, the Persistently High (PH) flow metric rewards the absence of an undesirable condition and hence can technically have a score of 1 with no flow. But in fact the PH sub-indicator loses its meaning when the low flow period flows are depressed. This problem is resolved by using PH as a moderator of the Low Flow (LF) sub-indicator. The LF is multiplied by the PH score to get modified LF score. The overall Flow Health index score is then calculated as the average of this modified LF score and the other 7 individual metric scores. This gives a score within the range 0 – 1, with 1 representing a low degree of deviation from the reference hydrology.

Total Flow Health Score = Average FHS (LF*PH,HF, HM, LM, PL, PVL, SFS, FFI,)

In flow health analysis; two flow metrics, persistently higher (PH) and Seasonality flow shift (SFS) consistently show a very large deviation even during the virgin state itself. This was the case at all the 146 locations. This basically indicates that high flows closer to the upper ranges of monthly flows occur at least more than once within the year during the low flow season and the average deviation in the seasonal ranking of the flows within the year is also quite high. The deviation in the seasonal ranking of the flow is quite high because of the strong monsoonal influence, where the flows during the non-monsoon are more or less similar. Hence, these two flow metrics will not be considered further for health analysis.

5.3. Look-up Table Approach

5.3.1. Flow Duration Curve Analysis

In this method, simple statistical analyses of flow regimes were done to check feasibility of different hydrological indices established and followed worldwide as minimum flow requirements. For four different scenarios, using monthly discharges for 29 years (1975-2003) obtained from SWAT modelling, annual and long term Flow Duration Curves (FDC) are obtained. Different flow percentiles e.g. Q_{95}, Q_{90}, Q_{75} and Q_{50}obtained on long term basis for all four scenarios are tabulated in Table 5 and 6 respectively. Apart from these tables, on a representative basis, variation in Q_{90}over the years for all 146 stations along with long term

Q_{90} are plotted station wise in figures provided in Appendices. These figures show the variation in availability of long term Q_{90} over the years in all four scenarios.

5.3.2. Mean Monthly Flow Analysis

Another look-up table approach used is 'Mean Monthly Flow' (MMF) analysis. Mean monthly flows and long term means were obtained for identified 146 stations for all four scenarios. Generally some predefined percentages of Mean Annual Flow (MAF) are considered as minimum flow requirements e.g. Tennant Method-10% of MAF, 25% of MAF in Canada(Caissie and El-Jabi 1995) etc. In preliminary stage of this study, feasibility of percentages of MAF were checked for Ganga Basin at various stretches and tributaies. From the considerable failures in attaining those percentages of MAF on daily basis, it was observed that '% of MAF' approach does not suit well to Ganga basin. This is on account of high seasonal variability.

From this understanding, Mean Monthly Flow approach has been used in this study. Considering Virgin flow scenario as reference line, long term monthly means of this scenarios are obtained (for 29 years).Availability of different percentages of these long term means (e.g. 10%, 5% and 2%)was checked month wise for 29 year data sets of all four scenarios. Comparisons of these availabilities for four different scenarios are done as shown in figure 7 to figure 10.

6. Result and Discussion

6.1. Preamble

The results from the flow health analysis as well as look-up table analyses at all the 146 locations are presented in the appendices. For the sake of brevity and illustration, the results from only a few locations are discussed here in detail. The Flow health assessment was made for four scenarios

1) Virgin scenario
2) Currently managed scenario
3) Flow health due to improved irrigation efficiency and
4) Flow health due to implementation of projects such as run of the river hydroelectric projects that are envisaged.

In general hydrologic flow health has been considerably affected at several stretches of Ganga due to the present state of water management. The flow health due to improved irrigation efficiency as implemented in the current model run do not seem to have a large impact in improving the hydrologic flow health and needs further investigation. The impact due to implementation of future projects seems to have only marginal effect over the current flow health. However, other aspects of flow health such as the water quality, biological aspects and functional needs of the ecosystem need to be considered while implementation of future projects.

<u>Note:</u> The hydrologic modeling and flow health analysis carried out here are indicative of only the overall flow conditions in stretches. However, there could be some localized conditions such as immediately downstream of the run of the river projects where the flow conditions may not be adequate, however further downstream, it may become normal due to return flows of water used in the power production. Longitudinal and lateral connective of the river along such local stretches should be thoroughly investigated even though the overall flow health in these stretches may appear good.

6.2. Upper Ganga

6.2.1. Rishikesh

As depicted by the long-term monthly flow hydrographs, the mean monthly flows during the managed state as a percentage of mean monthly flows during the virgin state did not deviate considerably. Because of this, small deviation in the managed flows when compared to the virgin flows, the disturbance to the flow health ranged from small to moderate during most of the years. Further, this variation in the flow health score is well within the range of variability in the flow health score during the virgin state itself. Look-up table analyses; Q_{90}as well as % of MMF analyses testimony the results of flow health tool analysis. Yearly Q_{90} and long term FDC are faintly varying from virgin conditions. Hence, the hydrologic flow health at Rishikesh could be considered as good.

6.2.2. Garmukhteshwar and Fatehgarh

Unlike at Rishikesh, the flow at Garmukhteshwar and downstream is considerably affected due to human interventions as reflected by the long-term monthly flow hydrographs. The low flow metrics seem to be reasonable. However, the two high flow metrics that are considerably affected include the High Flow (HF) and the Highest Monthly (HM) flow. This indicates that the total flow volume during the high flow season as well the highest flow within a year have considerably reduced due to human intervention. Further, the metric on flood frequency (FFI) is also very low.

For both Garmukhteshwar as well as Fatehgarh, FDC analysis represents huge alteration in flow regime with high differences in high flows as well as low flows thereby severely affecting total flow volumes. Low flows e.g. Q90 flows are reduced by more than 50%. MMF analysis shows reduction in mean monthly flows from 10% of virgin MMF to less than 2%.

Hence, the overall hydrologic flow health of Upper Ganga downstream of Rishikesh could be considered as poor. The hydrologic flow health is predicted to deteriorate even further if the projects envisaged were implemented above this stretch without adequate provision to maintain a healthy flow regime.

6.2.3. Bewar

The flow at Bewar is that of a different tributary to Upper Ganga. Unlike at Rishikesh, this flow does not include flow from snow melt. The flow health at Bewar is also considerably affected due to human interventions. The low flow metrics seem to be reasonable. However, the two high flow metrics that are considerably affected include the High Flow (HF) and the Highest Monthly (HM) flow, although not to the same degree as that in Garmukteshwar or Fatehgrah. Further, the metric on flood frequency (FFI) is also very low. MMF analysis shows reasonable reduction in total flow volume and MMF analysis shows reduction in mean monthly flows from 5% of virgin MMF to less than 2%. Hence, the overall hydrologic flow health of Upper Ganga at Bewar could be considered as moderate.

6.3. Ramganga

6.3.1. Bareilly and Dabri

As depicted by the long-term monthly flow hydrographs, the flow is considerably affected due to human interventions as reflected by the long-term monthly flow hydrographs. The low flow metrics seem to be reasonable. However, the two high flow metrics that are considerably affected include the High Flow (HF) and the Highest Monthly (HM) flow. This indicates that the total flow volume during the high flow season as well the highest flow within a year have considerably reduced due to human intervention. Further, the metric on flood frequency (FFI) is also very low i.e. the desired 5-yr frequency flood is not occurring at regular intervals. FDC shows that low flows (e.g. long term Q_{90}) are slightly reduced whereas high flows are considerably reduced. Overall, the hydrologic flow health of Ramganga at Bareilly and Dabri could be considered as poor.

6.4. Middle Ganga

6.4.1. Bhitaura

The flow at Bhitaura is contributed from Upper Ganga as well as from Ramgamga and is considerably affected due to human interventions. The low flow metrics seem to be reasonable. However, the two high flow metrics that are considerably affected include the High Flow (HF) and the Highest Monthly (HM) flow. Further, the metric on flood frequency (FFI) is also very low. FDC indicates that reduction in high as well as low flows reflect in high reduction in total flow volume. Mean monthly flows reduced from 5% of virgin MMF to less than 2%. Hence, the overall hydrologic flow health of Middle Ganga at Bhitaura could be considered as Poor.

6.4.2. Allahabad (Chatnag)

This station falls just downstream of confluence of Yamuna with Ganga. As in Bhitaura on Ganga, the flow at Allahabad (Chatnag) is considerably affected due to human interventions. Two high flow metrics that are considerably affected include the High Flow (HF) and the Highest Monthly (HM) flow. Further, the metric on flood frequency (FFI) is also very low. Considerable reduction is observed in Q_{90} flow as well as total flow volume. Hence, the

overall hydrologic flow health of Middle Ganga at Allahabad (Chatnag) could be considered as poor.

6.5. Upper Yamuna

6.5.1. Poanta

Poanta is located in the upper reaches of the Yamuna. As depicted by the long-term monthly flow hydrographs, the mean monthly flows during the managed state as a percentage of mean monthly flows during the virgin state did not deviate considerably. The maximum deviation during the month of November is close to 70% of the virgin flow. Because of this small deviation in the managed flows when compared to the virgin flows, the disturbance to the flow health ranged from small to moderate during most of the years. Slight variation in FDCs is observed. Hence, the hydrologic flow health at Poanta could be considered as moderate. Improving the irrigation efficiency seem to improve the hydrologic flow health considerably.

6.6. Middle Yamuna

6.6.1. Baghpat, Mohana, Agra Poiyghat and Etawah

Unlike at Poanta, the flow at Baghpatand downstream is considerably affected due to human interventions as reflected by the long-term monthly flow hydrographs. The low flow metrics seem to be reasonable. However, the two high flow metrics that are considerably affected include the High Flow (HF) and the Highest Monthly (HM) flow. This indicates that the total flow volume during the high flow season as well the highest flow within a year have considerably reduced due to human intervention. FDCs testimony this finding. Mean monthly flows reduced from 5% to 2% of virgin long term mean. Hence, the overall hydrologic flow health of Yamuna downstream ofBaghpat could be considered as poor.

6.7. Chambal

6.7.1. Baranwada

The flow at Baranwada represents the contribution to Chambal from the tributary Banas. The long-term monthly hydrograph indicates that the flow in Banas is only seasonal (June to November) and it is considerably affected due to human interventions. However, the low flow metrics seem to be reasonable. The two high flow metrics that are slightly affected include the High Flow (HF) and the Highest Monthly (HM) flow. In other words, high flows e.g. Q1 to Q25 are reduced considerably. This indicates that the total flow volume during the high flow season as well the highest flow within a year have reasonably reduced due to human intervention. The metric on flood frequency (FFI) is very low indicating reduced frequency of floods. Hence, the overall hydrologic flow health of Chambal at Baranwada could be considered as moderate.

6.7.2. Mandawara

The flow at Mandawara represents the contribution to Chambal from one of the two limbs of Kali Sindh tributary. The long-term monthly hydrograph indicates that the flow in Kali Sindh is only seasonal (July to September) and is considerably affected due to human interventions. The low flow metrics seem to be reasonable and the two high flow metrics High Flow (HF) and the Highest Monthly (HM) flow are only slightly affected. The metric on flood frequency (FFI) although low, it is within the range of variability observed during the virgin condition as well. FDC shows significant reduction in flow volume with major reduction in Q10 to Q40.MMF analysis shows slight variations from virgin condition. Hence, the overall hydrologic flow health of Chambal at Mandawara could be considered to be moderate.

6.7.3. Barod

The flow at Barod represents the contribution from the other limb of Kali Sindh tributary to Chambal. The long-term monthly hydrograph indicates that the flow in Kali Sindh is only seasonal (July to December) and is considerably affected due to human interventions. Long term Q90 reduces from 55 m^3/s to $0m^3/s$. MMF analysis shows marginal reduction in mean monthly flows in comparison to virgin condition. Hence, the overall hydrologic flow health of Chambal at Barodcould be considered as moderate.

6.7.4. Manderial and Udi

The flow at Manderial and Udi represents the contribution from most of Chambal basin. The long-term monthly hydrograph indicates that the seasonal flows in Chambal are considerably affected due to human interventions. Long term Q_{90} reduces from >150 m^3/s to $0m^3/s$. FDCs testimony substantial reduction in flow volume.The overall hydrologic flow health of Chambal at Manderial and Udi could be considered as Moderate.

6.8. Lower Yamuna

6.8.1. Kalpi

The flow at Kalpi represents the contribution to Yamuna from Sind. The long-term monthly hydrograph indicates that the flows in Sind at Kalpi are considerably affected due to human interventions. The low flow metrics seem to be reasonable. However, the two high flow metrics that are considerably affected include the High Flow (HF) and the Highest Monthly (HM) flow. Long term Q_{90} reduces from >250 m^3/s to $0m^3/s$ and high flow e.g. Q_1 reduces from more than 15,000 m^3/s to less than 10,000 m^3/s. This indicates that the total flow volume during the high flow season as well the highest flow within a year have considerably reduced due to human intervention. The metric on flood frequency (FFI) is very low indicating reduction in frequency of floods post development. Hence, the overall hydrologic flow health of Sind at Kalpi could be considered as poor.

6.8.2. Mohana

The flow at Mohana represents the contribution to Yamuna from Betwa. The long-term monthly hydrograph indicates that the flow is only seasonal (July to September) and is considerably affected due to human interventions. Low flows seem to be reasonable but high flows are significantly reduced. Hence, the overall hydrologic flow health of Betwa at Mohana could be considered as poor. Future developments are seem be cascading this situation severely.

6.9. Gomati

6.9.1. Raibareli and Jalalpur

The flows at Raibareli and further downstream at Jalalpurare considerably affected due to human interventions. The flows during the monsoon season have reduced as much as 50% of the virgin condition flows. The low flow metrics seem to be reasonable. $Q_{90}$is consistent. However, the two high flow metrics that are moderately affected include the High Flow (HF) and the Highest Monthly (HM) flow. FDCs witness it reduced flow volumes. The metric on flood frequency (FFI) is also low indicating reduction in the frequency of floods. Hence, the overall hydrologic flow health of Gomati at Raibareli and Jalalpur could be considered as moderate.

6.9.2. Lucknow and Jaunpur

The flows at Lucknow and further downstream at Jaunpur are considerably affected due to human interventions. The flows during the monsoon season have reduced as much as 55% of the virgin condition flows. The low flow metrics seem to be reasonable. However, the two high flow metrics that are moderately affected include the High Flow (HF) and the Highest Monthly (HM) flow. The metric on flood frequency (FFI) is also low indicating reduction in the frequency of floods. Hence, the overall hydrologic flow health of Gomati at Lucknow and Jaunpur could be considered as moderate.

6.10. Sone

6.10.1. Chopan

The long-term monthly hydrograph indicates that the flows in Sone at Chopan are considerably affected due to human interventions. High flows are prominently representation of it. The overall hydrologic flow health of Sone at Chopan could be considered as poor. Additional future developments look to be worsening the situation.

6.11. Gaghra

6.11.1. Paliakalan

The flows at Paliakalan, indicates the most upstream conditions in Gaghra basin. The long-term monthly hydrograph indicates that the flows in Gaghra at Paliakalan are moderately affected due to human interventions. From the hydrological perspective, the low flow metrics and high flow metrics are affected only moderately. Hence, the overall hydrologic

flow health of Gaghra at Paliakalan could be considered as moderate. Increased irrigation efficiency scenario shows some betterment in the current situation in FDC.

6.11.2. Ayodhya

Ayodhya is downstream of Paliakalan and the flows indicates the conditions in the middle section of Gaghra basin. The long-term monthly hydrograph indicates that the flows in Gaghra at Ayodhya are only moderately affected due to human interventions. MMF analysis results prove this. From the hydrological perspective, the low flow metrics and high flow metrics are affected only moderately and so the flow volumes. Hence, the overall hydrologic flow health of Gaghra at Ayodhya could be considered as moderate.

6.11.3. Turtipur

The flows at Turtipur is indicative of the most downstream conditions at Gaghra basin. The long-term monthly hydrograph indicates that the flows in Gaghra at Turtipur are moderately affected due to human interventions. The overall hydrologic flow health of Gaghra at Turtipur could be considered as moderate.

6.12. Gandak

6.12.1. Triveni

The flow at Triveni represents the flow conditions in the most upstream reaches of Gandak. The long-term monthly hydrograph indicates that the flows in Gandak at Triveniare only moderately affected due to human interventions. The low flow metrics seem to be reasonable. However, the two high flow metrics that are considerably affected include the High Flow (HF) and the Highest Monthly (HM) flow. This indicates that the total flow volume during the high flow season as well the highest flow within a year have considerably reduced due to human intervention. The metric on flood frequency (FFI) is also very low indicating reduction in frequency of floods post development. Hence, the overall hydrologic flow health of Gandak at Triveni could be considered as moderate.

6.12.2. Lalganj

Lalganj is located in the most downstream portion of Gandak. As at Triveni,the long-term monthly hydrograph indicates that the flows in Gandak at Lalganjare also only moderately affected due to human interventions. FDCs show significant reduction in high as well as low flows. Two high flow metrics that are considerably affected include the High Flow (HF) and the Highest Monthly (HM) flow. This indicates that the total flow volume during the high flow season as well the highest flow within a year have considerably reduced due to human intervention. The metric on flood frequency (FFI) is also very low indicating reduction in frequency of floods post development. MMF analysis also shows the alterations. Hence, the overall hydrologic flow health of Gandak at Lalganjcould be considered as moderate.

6.13. Kosi

6.13.1. Baltara

Baltara is located in the most downstream section of Kosi. The long-term monthly hydrograph indicates that the flows in Kosi at Baltara are marginally affected due to human interventions. From the hydrological perspective, the low flow metrics and high flow metrics are affected moderately. Hence, the overall hydrologic flow health of Kosi at Baltara could be considered as moderate. Increased Irrigation efficiency scenarios seems to add some betterment.

6.14. Lower Ganga

6.14.1. Sikandarpur

The long-term monthly hydrograph indicates that the flows at Sikandarpurare only slightly affected due to human interventions. The low flow metrics seem to be reasonable. The two high flow metrics that are marginally affected include the High Flow (HF) and the Highest Monthly (HM) flow. However, the metric on flood frequency (FFI) is low indicating reduction in frequency of floods post development. Hence, the overall hydrologic flow health at Sikandarpur could be considered as moderate to good.

6.14.2. Sripalpur

The long-term monthly hydrograph indicates that the flows at Sripalpurare considerably affected due to human interventions. The low flow metrics seem to be reasonable. However, the two high flow metrics that are considerably affected include the High Flow (HF) and the Highest Monthly (HM) flow. This indicates that the total flow volume during the high flow season as well the highest flow within a year have considerably reduced due to human intervention. The metric on flood frequency (FFI) is also very low indicating reduction in frequency of floods post development. Hence, the overall hydrologic flow health of Sripalpur could be considered as moderate.

6.14.3. Dhengra Ghat, Patna and Farakka

The long-term monthly hydrograph indicates that the flows at Dhengra Ghat all the way to Patna, Farakka are considerably affected due to human interventions. The low flow metrics seem to be reasonable. However, the two high flow metrics that are considerably affected include the High Flow (HF) and the Highest Monthly (HM) flow. This indicates that the total flow volume during the high flow season as well the highest flow within a year have considerably reduced due to human intervention. The metric on flood frequency (FFI) is very low indicating reduction in frequency of floods post development. Hence, the overall hydrologic flow health downstream of Dhengra Ghat all the way to Farakka could be considered as poor. From FDCs it can be seen that, increased irrigation efficiency scenario can help in improvement of the situation.

Table 1: Median flow Health scores based on 29 years of simulation assuming virgin flow conditions

Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good	Good		Moderate		Poor		Worst	
Upper Ganga Basin								
Badrinath	1	1	0.75	0.75	1	1	0.89	0.7
Joshimath	1	1	0.75	0.75	1	1	0.88	0.69
Nandkeshri	1	1	0.75	0.75	1	1	0.5	0.62
Karanprayag	1	1	0.75	0.75	1	1	0.89	0.7
Chandrapuri	1	1	0.75	0.75	1	1	0.89	0.7
Rudraprayag Below Confluence	1	1	0.75	0.75	1	1	0.89	0.69
Uttarkashi	1	1	0.75	0.75	1	1	0.88	0.69
Tehri (Zero Point)	1	1	0.75	0.75	1	1	0.75	0.66
Deoprayag A-1	1	1	0.75	0.75	1	1	0.75	0.66
Deoprayag Z-9	1	1	0.75	0.75	1	1	0.89	0.69
Marora	1	1	0.75	0.75	1	1	0.88	0.67
Rishikesh	1	1	0.75	0.75	1	1	0.89	0.69
Garmukhteshwar	1	1	0.75	0.75	1	1	0.88	0.69
Kachlabridge	1	1	0.75	0.75	1	1	0.88	0.69
Fatehgarh	1	1	0.75	0.75	1	1	0.89	0.69
Bewar	1	1	0.75	0.75	1	1	0.88	0.69
Ramganga Basin								
Moradabad	1	1	0.75	0.75	1	1	0.89	0.69
Rampur	1	1	0.75	0.75	1	1	0.89	0.69
Gangan	1	1	0.75	0.75	1	1	0.88	0.67
Bareilly	1	1	0.75	0.75	1	1	0.89	0.68
Dabri	1	1	0.75	0.75	1	1	0.89	0.69
Middle Ganga Basin								
Ankinghat	1	1	0.75	0.75	1	1	0.89	0.68
Kanpur	1	1	0.75	0.75	1	1	0.89	0.68
Bhitaura	1	1	0.75	0.75	1	1	0.89	0.68
allahabad (chatnag)	1	1	0.75	0.75	1	1	0.88	0.69
Pratappur	1	1	0.75	0.75	1	1	0.88	0.68
Upper Yamuna basin								
Tuini (P)	1	1	0.75	0.75	1	1	0.88	0.69
Tuini (T)	1	1	0.75	0.75	1	1	0.88	0.69
Yashwant Nagar	1	1	0.75	0.75	1	1	0.88	0.67
Naugaon	1	1	0.75	0.75	1	1	0.89	0.7
Bausan	1	1	0.75	0.75	1	1	0.88	0.69
Haripur	1	1	0.75	0.75	1	1	0.88	0.68
Poanta	1	1	0.75	0.75	1	1	0.88	0.69
Kalanaur	1	1	0.75	0.75	1	1	0.88	0.69
Karnal	1	1	0.75	0.75	1	1	0.88	0.69
Mawi	1	1	0.75	0.75	1	1	0.88	0.69
Baghpat	1	1	0.75	0.75	1	1	0.88	0.69
Galeta	1	1	0.75	0.75	1	1	0.88	0.69

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Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good	Good		Moderate		Poor		Worst	
Middle Yamuna basin								
Delhi Rly. Bridge	1	1	0.75	0.75	1	1	0.88	0.69
Mohana_UY	1	1	0.75	0.75	1	1	0.88	0.67
Mathura	1	1	0.75	0.75	1	1	0.88	0.67
Agra Poiyghat	1	1	0.75	0.75	1	1	0.88	0.67
Banas								
Chittorgarh	1	1	0.75	0.75	1	1	0.88	0.69
Bigod	1	1	0.75	0.75	1	1	0.88	0.68
Tonk	1	1	0.75	0.75	1	1	0.88	0.67
Kali sindh								
Salavad	1	1	0.75	0.75	1	1	0.88	0.69
Sarangpur	1	1	0.75	0.75	1	1	0.75	0.69
Aklera	1	1	0.75	0.75	1	1	0.88	0.69
Sangod	1	1	0.75	0.75	1	1	0.88	0.7
Chambal Upper								
Dhareri	1	1	0.75	0.75	1	1	0.76	0.67
tal	1	1	0.75	0.75	1	1	0.62	0.64
Ujjain	1	1	0.75	0.75	1	1	0.75	0.69
Mahidpur	1	1	0.75	0.75	1	1	0.75	0.66
Mandawara	1	1	0.75	0.75	1	1	0.75	0.66
Barod	1	1	0.75	0.75	1	1	0.88	0.69
Khatoli	1	1	0.75	0.75	1	1	0.89	0.69
Pali	1	1	0.75	0.75	1	1	0.88	0.67
Chambal Lower								
A. B. Road X-ing	1	1	0.75	0.75	1	1	0.88	0.69
Baranwada	1	1	0.75	0.75	1	1	0.75	0.67
Manderial	1	1	0.75	0.75	1	1	0.75	0.67
Dholpur	1	1	0.75	0.75	1	1	0.75	0.66
Lower Yamuna								
Pachauli	1	1	0.75	0.75	1	1	0.88	0.67
Seonda	1	1	0.75	0.75	1	1	0.88	0.69
Bhind	1	1	0.75	0.75	1	1	0.89	0.69
Udi	1	1	0.75	0.75	1	1	0.75	0.66
Etawah	1	1	0.75	0.75	1	1	0.88	0.67
Auraiya	1	1	0.75	0.75	1	1	0.75	0.67
Kalpi	1	1	0.75	0.75	1	1	0.75	0.67
Lalpur	1	1	0.75	0.75	1	1	0.89	0.7
Hamirpur	1	1	0.75	0.75	1	1	0.75	0.67
Shahjina	1	1	0.75	0.75	1	1	0.88	0.69
Basoda	1	1	0.75	0.75	1	1	0.88	0.68
Mohana_LY	1	1	0.75	0.75	1	1	0.88	0.69

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Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good	**Good**		**Moderate**		**Poor**		**Worst**	
Garrauli	1	1	0.75	0.75	1	1	0.88	0.69
Garhakota	1	1	0.75	0.75	1	1	0.88	0.7
Gaisabad	1	1	0.75	0.75	1	1	0.88	0.69
Madla	1	1	0.75	0.75	1	1	0.88	0.69
Banda	1	1	0.75	0.75	1	1	0.88	0.69
Rajapur	1	1	0.75	0.75	1	1	0.88	0.68
Gomati								
Neemsar	1	1	0.75	0.75	1	1	0.89	0.69
Lucknow	1	1	0.75	0.75	1	1	0.89	0.7
Jaunpur	1	1	0.75	0.75	1	1	0.88	0.69
Raibareli	1	1	0.75	0.75	1	1	0.89	0.66
Jalalpur	1	1	0.75	0.75	1	1	0.88	0.67
Sone								
Goverdheghat	1	1	0.75	0.75	1	1	0.88	0.69
Chopan	1	1	0.75	0.75	1	1	0.89	0.68
Duddhi	1	1	0.75	0.75	1	1	0.89	0.7
Ghaghra								
Tawaghat	1	1	0.75	0.75	1	1	0.75	0.67
Jauljibi	1	1	0.75	0.75	1	1	0.5	0.66
Ghat	1	1	0.75	0.75	1	1	0.5	0.62
Paliakalan	1	1	0.75	0.75	1	1	0.5	0.65
Elginbridge	1	1	0.75	0.75	1	1	0.89	0.69
Ayodhya	1	1	0.75	0.75	1	1	0.89	0.69
Bijalpur								
Gandak								
Basti	1	1	0.75	0.75	1	1	0.88	0.69
Bhinga	1	1	0.75	0.75	1	1	0.89	0.69
Balrampur	1	1	0.75	0.75	1	1	0.89	0.69
Kakrahi	1	1	0.75	0.75	1	1	0.88	0.69
Regauli	1	1	0.75	0.75	1	1	0.88	0.69
Birdghat	1	1	0.75	0.75	1	1	0.88	0.68
Turtipur	1	1	0.75	0.75	1	1	0.88	0.69
triveni	1	1	0.75	0.75	1	1	0.76	0.67
Dumariaghat	1	1	0.75	0.75	1	1	0.75	0.67
Lalganj	1	1	0.75	0.75	1	1	0.75	0.67
Gangajal								
Kosi								
Jainagar	1	1	0.75	0.75	1	1	0.88	0.68
Jhanjharpur	1	1	0.75	0.75	1	1	0.88	0.67

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Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good	Good		Moderate		Poor		Worst	
Lower Ganga								
Jamalpur	1	1	0.75	0.75	1	1	0.88	0.68
Ramchandipur	1	1	0.75	0.75	1	1	0.88	0.68
Ithara	1	1	0.75	0.75	1	1	0.88	0.69
Katesar	1	1	0.75	0.75	1	1	0.88	0.69
lalbegiaGhat	1	1	0.75	0.75	1	1	0.75	0.67
Sikandarpur	1	1	0.75	0.75	1	1	0.75	0.66
Sripalpur	1	1	0.75	0.75	1	1	0.88	0.7
Dheng Bridge	1	1	0.75	0.75	1	1	0.88	0.67
Benibad	1	1	0.75	0.75	1	1	0.75	0.67
Ekmighat	1	1	0.75	0.75	1	1	0.75	0.68
Hayaghat	1	1	0.75	0.75	1	1	0.88	0.67
Saulighat	1	1	0.75	0.75	1	1	0.75	0.66
Baltara	1	1	0.75	0.75	1	1	0.88	0.68
dhengraghat	1	1	0.75	0.75	1	1	0.88	0.68
Labha	1	1	0.75	0.75	1	1	0.88	0.69
Hanskhali	1	1	0.75	0.75	1	1	0.88	0.67
Kalna (Ebb)	1	1	0.75	0.75	1	1	0.88	0.69
Kalna (Flow)	1	1	0.75	0.75	1	1	0.88	0.69
Islampur	1	1	0.75	0.75	1	1	0.75	0.65
Palasipara	1	1	0.75	0.75	1	1	0.88	0.69
Chapra	1	1	0.75	0.75	1	1	0.88	0.69
Katwa	1	1	0.75	0.75	1	1	0.75	0.66
Bazarsau	1	1	0.75	0.75	1	1	0.5	0.62
Berhampore	1	1	0.75	0.75	1	1	0.64	0.65
GangbararJivpur	1	1	0.75	0.75	1	1	1	0.7
Birpur	1	1	0.75	0.75	1	1	0.89	0.7
Narainpur	1	1	0.75	0.75	1	1	0.88	0.67
Rudrapur	1	1	0.75	0.75	1	1	0.89	0.7
TolaBalaRai	1	1	0.75	0.75	1	1	0.89	0.68
Patna	1	1	0.75	0.75	1	1	0.89	0.69
HathidahBuzurg	1	1	0.75	0.75	1	1	1	0.7
Padma, Teesta and Jamuna								
Englishbazar	1	1	0.75	0.75	1	1	0.75	0.65
Rasalpur	1	1	0.75	0.75	1	1	1	0.7
Gangania	1	1	0.75	0.75	1	1	1	0.7
Bariarpur	1	1	0.75	0.75	1	1	1	0.7
Kamlakund	1	1	0.75	0.75	1	1	1	0.7
Mahespur	1	1	0.75	0.75	1	1	0.88	0.68
HR Farakka	1	1	0.75	0.75	1	1	0.88	0.68
Mirzapur	1	1	0.75	0.75	1	1	0.88	0.69

Table 2: Median flow Health scores based on 29 years of simulation with the current state of management

Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good / Good / Moderate / Poor / Worst								
Upper Ganga basin								
Badrinath	1	1	0.75	0.75	1	1	0.89	0.7
Joshimath	1	1	0.75	0.75	1	1	0.88	0.69
Nandkeshri	1	1	0.75	0.75	1	1	0.88	0.68
Karanprayag	1	1	0.75	0.75	1	1	0.75	0.66
Chandrapuri	1	1	0.75	0.75	1	1	0.89	0.7
Rudraprayag_Below Confluence	1	1	0.75	0.75	1	1	0.89	0.68
Uttarkashi	1	1	0.75	0.75	1	1	0.88	0.69
Tehri (Zero Point)	1	1	0.75	0.75	1	1	0.75	0.66
Deoprayag A-1	1	1	0.75	0.75	1	1	0.75	0.66
Deoprayag Z-9	1	1	0.75	0.75	1	1	0.75	0.64
Marora	1	1	0.75	0.75	1	1	0.75	0.66
Rishikesh	1	1	0.75	0.75	1	1	0.62	0.64
Garmukhteshwar	0	0	0.75	0.75	1	1	0	0.47
Kachlabridge	0	0	0.75	0.75	1	1	0	0.41
Fatehgarh	0	0	0.75	0.75	1	1	0	0.38
Bewar	0.27	0.27	0.75	0.75	1	1	0	0.48
Ramganga basin								
Moradabad	0	0	0.75	0.75	1	1	0	0.34
Rampur	0.19	0.19	0.75	0.75	1	1	0	0.41
Gangan	0.81	0.81	0.75	0.75	1	1	0.5	0.59
Bareilly	0.04	0.04	0.75	0.75	1	1	0	0.41
Dabri	0.06	0.06	0.75	0.75	1	1	0	0.4
Middle Ganga basin								
Ankinghat	0	0	0.75	0.75	1	1	0	0.36
Kanpur	0	0	0.75	0.75	1	1	0	0.36
Bhitaura	0	0	0.75	0.75	1	1	0	0.36
allahabad (chatnag)	0	0	0.75	0.75	1	1	0	0.34
Pratappur	0	0	0.75	0.75	1	1	0	0.34
Upper Yamuna basin								
Tuini (P)	1	1	0.75	0.75	1	1	0.88	0.69
Tuini (T)	1	1	0.75	0.75	1	1	0.88	0.69
Yashwant Nagar	1	1	0.75	0.75	1	1	0.88	0.67
Naugaon	1	1	0.75	0.75	1	1	0.89	0.7
Bausan	1	1	0.75	0.75	1	1	0.88	0.69
Haripur	1	1	0.75	0.75	1	1	0.88	0.68
Poanta	1	1	0.75	0.75	1	1	0	0.59
Kalanaur	0	0	0.75	0.75	1	1	0	0.34
Karnal	0	0	0.75	0.75	1	1	0	0.34
Mawi	0	0	0.75	0.75	1	1	0	0.34
Baghpat	0	0	0.75	0.75	1	1	0	0.34
Galeta	1	1	0.75	0.75	1	1	0.88	0.67

Table2 continued to next page … … …

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Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good	Good		Moderate		Poor		Worst	
Middle Yamuna basin								
Delhi Rly. Bridge	0	0	0.75	0.75	1	1	0	0.34
Mohana_UY	0	0	0.75	0.75	1	1	0	0.34
Mathura	0	0	0.75	0.75	1	1	0	0.34
Agra Poiyghat	0	0	0.75	0.75	1	1	0	0.34
Banas								
Chittorgarh	0	0	0.75	0.75	1	1	0	0.43
Bigod	0.22	0.22	0.75	0.75	1	1	0	0.44
Tonk	0.2	0.2	0.75	0.75	1	1	0	0.43
Kali sindh								
Salavad	0.26	0.26	0.75	0.75	1	1	0.25	0.45
Sarangpur	0	0	0.75	0.75	1	1	0	0.39
Aklera	0	0	0.75	0.75	1	1	0	0.34
Sangod	0	0	0.75	0.75	1	1	0	0.34
Chambal Upper								
Dhareri	0.34	0.34	0.75	0.75	1	1	0	0.47
tal	0.65	0.65	0.75	0.75	1	1	0	0.51
Ujjain	0	0	0.75	0.75	1	1	0	0.41
Mahidpur	0.12	0.12	0.75	0.75	1	1	0	0.41
Mandawara	0	0	0.75	0.75	1	1	0	0.38
Barod	0	0	0.75	0.75	1	1	0	0.38
Khatoli	0	0	0.75	0.75	1	1	0	0.34
Pali	0	0	0.75	0.75	1	1	0	0.34
Chambal Lower								
A. B. Road X-ing	0	0	0.75	0.75	1	1	0	0.34
Baranwada	0.24	0.24	0.75	0.75	1	1	0	0.42
Manderial	0	0	0.75	0.75	1	1	0	0.35
Dholpur	0	0	0.75	0.75	1	1	0	0.35
Lower Yamuna								
Pachauli	0.09	0.09	0.75	0.75	1	1	0	0.39
Seonda	0	0	0.75	0.75	1	1	0	0.39
Bhind	0	0	0.75	0.75	1	1	0	0.34
Udi	0	0	0.75	0.75	1	1	0	0.35
Etawah	0	0	0.75	0.75	1	1	0	0.36
Auraiya	0	0	0.75	0.75	1	1	0	0.34
Kalpi	0	0	0.75	0.75	1	1	0	0.34
Lalpur	0.29	0.29	0.75	0.75	1	1	0	0.44
Hamirpur	0	0	0.75	0.75	1	1	0	0.34
Shahjina	0.03	0.03	0.75	0.75	1	1	0	0.38
Basoda	0.04	0.04	0.75	0.75	1	1	0	0.37
Mohana_LY	0.05	0.05	0.75	0.75	1	1	0	0.38
Garrauli	0.31	0.31	0.75	0.75	1	1	0.62	0.53
Garhakota	0.14	0.14	0.75	0.75	1	1	0.62	0.45

Table2 continued to next page … … …

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Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good / Good / Moderate / Poor / Worst								
Gaisabad	0.11	0.11	0.75	0.75	1	1	0	0.44
Madla	0.11	0.11	0.75	0.75	1	1	0	0.41
Banda	0.11	0.11	0.75	0.75	1	1	0	0.41
Rajapur	0	0	0.75	0.75	1	1	0	0.34
Gomati								
Neemsar	0.24	0.24	0.75	0.75	1	1	0	0.48
Lucknow	0.59	0.59	0.75	0.75	1	1	0.12	0.54
Jaunpur	0.21	0.21	0.75	0.75	1	1	0	0.44
Raibareli	0.3	0.3	0.75	0.75	1	1	0	0.46
Jalalpur	0.24	0.24	0.75	0.75	1	1	0.62	0.49
Sone								
Goverdheghat	0	0	0.75	0.75	1	1	0	0.34
Chopan	0.03	0.03	0.75	0.75	1	1	0	0.36
Duddhi	0	0	0.75	0.75	1	1	0	0.38
Ghaghra								
Tawaghat	1	1	0.75	0.75	1	1	0.75	0.67
Jauljibi	1	1	0.75	0.75	1	1	0.5	0.64
Ghat	0.47	0.47	0.75	0.75	1	1	0	0.47
Paliakalan	0	0	0.75	0.75	1	1	0	0.46
Elginbridge	0.09	0.09	0.75	0.75	1	1	0	0.44
Ayodhya	0	0	0.75	0.75	1	1	0	0.41
Bijalpur								
Gandak								
Basti	0.24	0.24	0.75	0.75	1	1	0	0.49
Bhinga	0	0	0.75	0.75	1	1	0	0.36
Balrampur	0	0	0.75	0.75	1	1	0	0.35
Kakrahi	0.25	0.25	0.75	0.75	1	1	0	0.46
Regauli	0.09	0.09	0.75	0.75	1	1	0	0.41
Birdghat	0.1	0.1	0.75	0.75	1	1	0	0.41
Turtipur	0	0	0.75	0.75	1	1	0	0.37
triveni	0.22	0.22	0.75	0.75	1	1	0	0.41
Dumariaghat	0.08	0.08	0.75	0.75	1	1	0	0.38
Lalganj	0.05	0.05	0.75	0.75	1	1	0	0.37
Gangajal								
Kosi								
Jainagar	0	0	0.75	0.75	1	1	0	0.39
Jhanjharpur	0	0	0.75	0.75	1	1	0	0.36

Table2 continued to next page … … …

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Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good	Good		Moderate		Poor		Worst	
Lower Ganga								
Jamalpur	0	0	0.75	0.75	1	1	0	0.34
Ramchandipur	0	0	0.75	0.75	1	1	0	0.34
Ithara	0	0	0.75	0.75	1	1	0	0.34
Katesar	0	0	0.75	0.75	1	1	0	0.34
lalbegiaGhat	0.81	0.81	0.75	0.75	1	1	0	0.56
Sikandarpur	1	1	0.75	0.75	1	1	0.38	0.64
Sripalpur	0.02	0.02	0.75	0.75	1	1	0	0.39
Dheng Bridge	0	0	0.75	0.75	1	1	0	0.34
Benibad	0.14	0.14	0.75	0.75	1	1	0	0.41
Ekmighat	0.44	0.44	0.75	0.75	1	1	0	0.49
Hayaghat	0	0	0.75	0.75	1	1	0	0.34
Saulighat	0.03	0.03	0.75	0.75	1	1	0	0.39
Baltara	0.1	0.1	0.75	0.75	1	1	0	0.4
dhengraghat	0	0	0.75	0.75	1	1	0	0.34
Labha	0	0	0.75	0.75	1	1	0	0.34
Hanskhali	0	0	0.75	0.75	1	1	0	0.34
Kalna (Ebb)	0	0	0.75	0.75	1	1	0	0.36
Kalna (Flow)	0	0	0.75	0.75	1	1	0	0.36
Islampur	0.06	0.06	0.75	0.75	1	1	0	0.38
Palasipara	0.01	0.01	0.75	0.75	1	1	0	0.38
Chapra	0	0	0.75	0.75	1	1	0	0.36
Katwa	0.09	0.09	0.75	0.75	1	1	0	0.41
Bazarsau	0.71	0.71	0.75	0.75	1	1	0	0.52
Berhampore	0.43	0.43	0.75	0.75	1	1	0	0.46
GangbararJivpur	0	0	0.75	0.75	1	1	0	0.34
Birpur	0	0	0.75	0.75	1	1	0	0.34
Narainpur	0	0	0.75	0.75	1	1	0	0.34
Rudrapur	0	0	0.75	0.75	1	1	0	0.34
TolaBalaRai	0	0	0.75	0.75	1	1	0	0.34
Patna	0	0	0.75	0.75	1	1	0	0.34
HathidahBuzurg	0	0	0.75	0.75	1	1	0	0.34
Padma, Teesta and Jamuna								
Englishbazar	0	0	0.75	0.75	1	1	0	0.34
Rasalpur	0	0	0.75	0.75	1	1	0	0.34
Gangania	0	0	0.75	0.75	1	1	0	0.34
Bariarpur	0	0	0.75	0.75	1	1	0	0.34
Kamlakund	0	0	0.75	0.75	1	1	0	0.34
Mahespur	0	0	0.75	0.75	1	1	0	0.34
HR Farakka	0	0	0.75	0.75	1	1	0	0.34
Mirzapur	0	0	0.75	0.75	1	1	0	0.34

Table 3: Median flow Health scores based on 29 years of simulation with the current state of management but with increased irrigation efficiency

Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good	Good		Moderate		Poor		Worst	
Upper Ganga basin								
Badrinath	1	1	0.75	0.75	1	1	0.89	0.7
Joshimath	1	1	0.75	0.75	1	1	0.88	0.69
Nandkeshri	1	1	0.75	0.75	1	1	0.88	0.68
Karanprayag	1	1	0.75	0.75	1	1	0.75	0.67
Chandrapuri	1	1	0.75	0.75	1	1	0.89	0.7
Rudraprayag_Below Confluence	1	1	0.75	0.75	1	1	0.89	0.69
Uttarkashi	1	1	0.75	0.75	1	1	0.88	0.69
Tehri (Zero Point)	1	1	0.75	0.75	1	1	0.75	0.66
Deoprayag A-1	1	1	0.75	0.75	1	1	0.75	0.66
Deoprayag Z-9	1	1	0.75	0.75	1	1	0.88	0.67
Marora	1	1	0.75	0.75	1	1	0.75	0.66
Rishikesh	1	1	0.75	0.75	1	1	0.88	0.67
Garmukhteshwar	0	0	0.75	0.75	1	1	0	0.47
Kachlabridge	0	0	0.75	0.75	1	1	0	0.47
Fatehgarh	0	0	0.75	0.75	1	1	0	0.41
Bewar	0.31	0.31	0.75	0.75	1	1	0.5	0.51
Ramganga basin								
Moradabad	0	0	0.75	0.75	1	1	0	0.34
Rampur	0.47	0.47	0.75	0.75	1	1	0	0.46
Gangan	0.83	0.83	0.75	0.75	1	1	0.5	0.59
Bareilly	0.06	0.06	0.75	0.75	1	1	0	0.41
Dabri	0.09	0.09	0.75	0.75	1	1	0	0.41
Middle Ganga basin								
Ankinghat	0	0	0.75	0.75	1	1	0	0.38
Kanpur	0	0	0.75	0.75	1	1	0	0.36
Bhitaura	0	0	0.75	0.75	1	1	0	0.36
allahabad (chatnag)	0	0	0.75	0.75	1	1	0	0.34
Pratappur	0	0	0.75	0.75	1	1	0	0.34
Upper Yamuna basin								
Tuini (P)	1	1	0.75	0.75	1	1	0.88	0.69
Tuini (T)	1	1	0.75	0.75	1	1	0.88	0.69
Yashwant Nagar	1	1	0.75	0.75	1	1	0.88	0.67
Naugaon	1	1	0.75	0.75	1	1	0.89	0.7
Bausan	1	1	0.75	0.75	1	1	0.88	0.69
Haripur	1	1	0.75	0.75	1	1	0.88	0.68
Poanta	1	1	0.75	0.75	1	1	0.88	0.69
Kalanaur	0	0	0.75	0.75	1	1	0	0.34
Karnal	0	0	0.75	0.75	1	1	0	0.34
Mawi	0	0	0.75	0.75	1	1	0	0.34
Baghpat	0	0	0.75	0.75	1	1	0	0.34
Galeta	1	1	0.75	0.75	1	1	0.88	0.67

Table3 continued to next page … … …

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Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good	Good		Moderate		Poor		Worst	
Middle Yamuna basin								
Delhi Rly. Bridge	0	0	0.75	0.75	1	1	0	0.34
Mohana_UY	0	0	0.75	0.75	1	1	0	0.34
Mathura	0	0	0.75	0.75	1	1	0	0.34
Agra Poiyghat	0	0	0.75	0.75	1	1	0	0.34
Banas								
Chittorgarh	0.02	0.02	0.75	0.75	1	1	0	0.44
Bigod	0.22	0.22	0.75	0.75	1	1	0	0.45
Tonk	0.24	0.24	0.75	0.75	1	1	0	0.43
Kali sindh								
Salavad	0.21	0.21	0.75	0.75	1	1	0.25	0.45
Sarangpur	0	0	0.75	0.75	1	1	0	0.39
Aklera	0	0	0.75	0.75	1	1	0.25	0.41
Sangod	0	0	0.75	0.75	1	1	0	0.34
Chambal Upper								
Dhareri	0.35	0.35	0.75	0.75	1	1	0	0.48
tal	0.67	0.67	0.75	0.75	1	1	0	0.52
Ujjain	0	0	0.75	0.75	1	1	0	0.41
Mahidpur	0.16	0.16	0.75	0.75	1	1	0	0.42
Mandawara	0	0	0.75	0.75	1	1	0	0.39
Barod	0	0	0.75	0.75	1	1	0	0.38
Khatoli	0	0	0.75	0.75	1	1	0	0.34
Pali	0	0	0.75	0.75	1	1	0	0.34
Chambal Lower								
A. B. Road X-ing	0	0	0.75	0.75	1	1	0	0.34
Baranwada	0.24	0.24	0.75	0.75	1	1	0	0.42
Manderial	0	0	0.75	0.75	1	1	0	0.35
Dholpur	0	0	0.75	0.75	1	1	0	0.35
Lower Yamuna								
Pachauli	0.1	0.1	0.75	0.75	1	1	0	0.39
Seonda	0	0	0.75	0.75	1	1	0	0.39
Bhind	0	0	0.75	0.75	1	1	0	0.34
Udi	0	0	0.75	0.75	1	1	0	0.35
Etawah	0	0	0.75	0.75	1	1	0	0.36
Auraiya	0	0	0.75	0.75	1	1	0	0.34
Kalpi	0	0	0.75	0.75	1	1	0	0.34
Lalpur	0.32	0.32	0.75	0.75	1	1	0	0.45
Hamirpur	0	0	0.75	0.75	1	1	0	0.34
Shahjina	0.06	0.06	0.75	0.75	1	1	0	0.38
Basoda	0.04	0.04	0.75	0.75	1	1	0	0.37
Mohana_LY	0.07	0.07	0.75	0.75	1	1	0	0.39
Garrauli	0.41	0.41	0.75	0.75	1	1	0.62	0.53
Garhakota	0.15	0.15	0.75	0.75	1	1	0.62	0.45

Table3 continued to next page … … …

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Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good	Good		Moderate		Poor		Worst	
Gaisabad	0.12	0.12	0.75	0.75	1	1	0	0.44
Madla	0.12	0.12	0.75	0.75	1	1	0	0.41
Banda	0.13	0.13	0.75	0.75	1	1	0	0.41
Rajapur	0	0	0.75	0.75	1	1	0	0.34
Gomati								
Neemsar	0.26	0.26	0.75	0.75	1	1	0	0.51
Lucknow	0.61	0.61	0.75	0.75	1	1	0.12	0.55
Jaunpur	0.24	0.24	0.75	0.75	1	1	0	0.44
Raibareli	0.38	0.38	0.75	0.75	1	1	0	0.47
Jalalpur	0.57	0.57	0.75	0.75	1	1	0.62	0.5
Sone								
Goverdheghat	0	0	0.75	0.75	1	1	0	0.34
Chopan	0.05	0.05	0.75	0.75	1	1	0	0.36
Duddhi	0.02	0.02	0.75	0.75	1	1	0	0.41
Ghaghra								
Tawaghat	1	1	0.75	0.75	1	1	0.75	0.67
Jauljibi	1	1	0.75	0.75	1	1	0.5	0.65
Ghat	1	1	0.75	0.75	1	1	0	0.59
Paliakalan	0.45	0.45	0.75	0.75	1	1	0	0.47
Elginbridge	0.37	0.37	0.75	0.75	1	1	0	0.46
Ayodhya	0.25	0.25	0.75	0.75	1	1	0	0.47
Bijalpur								
Gandak								
Basti	0.26	0.26	0.75	0.75	1	1	0	0.49
Bhinga	0	0	0.75	0.75	1	1	0	0.36
Balrampur	0	0	0.75	0.75	1	1	0	0.36
Kakrahi	0.31	0.31	0.75	0.75	1	1	0	0.47
Regauli	0.11	0.11	0.75	0.75	1	1	0	0.42
Birdghat	0.12	0.12	0.75	0.75	1	1	0	0.42
Turtipur	0	0	0.75	0.75	1	1	0	0.44
triveni	0.23	0.23	0.75	0.75	1	1	0	0.41
Dumariaghat	0.12	0.12	0.75	0.75	1	1	0	0.39
Lalganj	0.1	0.1	0.75	0.75	1	1	0	0.38
Gangajal								
Kosi								
Jainagar	0.03	0.03	0.75	0.75	1	1	0	0.4
Jhanjharpur	0	0	0.75	0.75	1	1	0	0.36

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Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good	Good		Moderate		Poor		Worst	
Lower Ganga								
Jamalpur	0	0	0.75	0.75	1	1	0	0.34
Ramchandipur	0	0	0.75	0.75	1	1	0	0.34
Ithara	0	0	0.75	0.75	1	1	0	0.34
Katesar	0	0	0.75	0.75	1	1	0	0.34
lalbegiaGhat	0.82	0.82	0.75	0.75	1	1	0	0.58
Sikandarpur	1	1	0.75	0.75	1	1	0.38	0.64
Sripalpur	0.04	0.04	0.75	0.75	1	1	0	0.39
Dheng Bridge	0	0	0.75	0.75	1	1	0	0.34
Benibad	0.16	0.16	0.75	0.75	1	1	0	0.42
Ekmighat	0.47	0.47	0.75	0.75	1	1	0	0.49
Hayaghat	0	0	0.75	0.75	1	1	0	0.34
Saulighat	0.05	0.05	0.75	0.75	1	1	0	0.41
Baltara	0.14	0.14	0.75	0.75	1	1	0	0.42
dhengraghat	0	0	0.75	0.75	1	1	0	0.34
Labha	0	0	0.75	0.75	1	1	0	0.34
Hanskhali	0	0	0.75	0.75	1	1	0	0.34
Kalna (Ebb)	0.01	0.01	0.75	0.75	1	1	0	0.37
Kalna (Flow)	0.01	0.01	0.75	0.75	1	1	0	0.37
Islampur	0.09	0.09	0.75	0.75	1	1	0	0.42
Palasipara	0.03	0.03	0.75	0.75	1	1	0	0.38
Chapra	0	0	0.75	0.75	1	1	0	0.36
Katwa	0.13	0.13	0.75	0.75	1	1	0	0.41
Bazarsau	0.71	0.71	0.75	0.75	1	1	0	0.54
Berhampore	0.44	0.44	0.75	0.75	1	1	0	0.47
GangbararJivpur	0	0	0.75	0.75	1	1	0	0.34
Birpur	0	0	0.75	0.75	1	1	0	0.34
Narainpur	0	0	0.75	0.75	1	1	0	0.34
Rudrapur	0	0	0.75	0.75	1	1	0	0.34
TolaBalaRai	0	0	0.75	0.75	1	1	0	0.34
Patna	0	0	0.75	0.75	1	1	0	0.34
HathidahBuzurg	0	0	0.75	0.75	1	1	0	0.34
Padma, Teesta and Jamuna								
Englishbazar	0	0	0.75	0.75	1	1	0	0.34
Rasalpur	0	0	0.75	0.75	1	1	0	0.34
Gangania	0	0	0.75	0.75	1	1	0	0.34
Bariarpur	0	0	0.75	0.75	1	1	0	0.34
Kamlakund	0	0	0.75	0.75	1	1	0	0.34
Mahespur	0	0	0.75	0.75	1	1	0	0.34
HR Farakka	0	0	0.75	0.75	1	1	0	0.34
Mirzapur	0	0	0.75	0.75	1	1	0	0.34

Table 4: **Median flow Health scores based on 29 years of simulation with the implementation of future projects**

Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good / Good / Moderate / Poor / Worst								
Upper Ganga basin								
Badrinath	1	1	0.75	0.75	1	1	0.89	0.7
Joshimath	1	1	0.75	0.75	1	1	0.88	0.69
Nandkeshri	1	1	0.75	0.75	1	1	0.88	0.68
Karanprayag	1	1	0.75	0.75	1	1	0.75	0.66
Chandrapuri	1	1	0.75	0.75	1	1	0.89	0.7
Rudraprayag_Below Confluence	1	1	0.75	0.75	1	1	0.89	0.68
Uttarkashi	1	1	0.75	0.75	1	1	0.88	0.69
Tehri (Zero Point)	1	1	0.75	0.75	1	1	0.75	0.66
Deoprayag A-1	1	1	0.75	0.75	1	1	0.75	0.66
Deoprayag Z-9	1	1	0.75	0.75	1	1	0.75	0.64
Marora	1	1	0.75	0.75	1	1	0.75	0.66
Rishikesh	1	1	0.75	0.75	1	1	0.62	0.64
Garmukhteshwar	0.04	0.04	0.75	0.75	1	1	0	0.47
Kachlabridge	0	0	0.75	0.75	1	1	0	0.47
Fatehgarh	0	0	0.75	0.75	1	1	0	0.42
Bewar	0.27	0.27	0.75	0.75	1	1	0	0.48
Ramganga basin								
Moradabad	0	0	0.75	0.75	1	1	0	0.34
Rampur	0.19	0.19	0.75	0.75	1	1	0	0.41
Gangan	0.81	0.81	0.75	0.75	1	1	0.5	0.59
Bareilly	0.04	0.04	0.75	0.75	1	1	0	0.41
Dabri	0.06	0.06	0.75	0.75	1	1	0	0.4
Middle Ganga basin								
Ankinghat	0	0	0.75	0.75	1	1	0	0.39
Kanpur	0	0	0.75	0.75	1	1	0	0.37
Bhitaura	0	0	0.75	0.75	1	1	0	0.37
allahabad (chatnag)	0	0	0.75	0.75	1	1	0	0.34
Pratappur	0	0	0.75	0.75	1	1	0	0.34
Upper Yamuna basin								
Tuini (P)	1	1	0.75	0.75	1	1	0.88	0.69
Tuini (T)	1	1	0.75	0.75	1	1	0.88	0.69
Yashwant Nagar	1	1	0.75	0.75	1	1	0.88	0.67
Naugaon	1	1	0.75	0.75	1	1	0.89	0.7
Bausan	1	1	0.75	0.75	1	1	0.88	0.69
Haripur	1	1	0.75	0.75	1	1	0.88	0.68
Poanta	1	1	0.75	0.75	1	1	0	0.59
Kalanaur	0	0	0.75	0.75	1	1	0	0.34
Karnal	0	0	0.75	0.75	1	1	0	0.34
Mawi	0	0	0.75	0.75	1	1	0	0.34
Baghpat	0	0	0.75	0.75	1	1	0	0.34
Galeta	1	1	0.75	0.75	1	1	0.88	0.67

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Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good	Good		Moderate		Poor		Worst	
Middle Yamuna basin								
Delhi Rly. Bridge	0	0	0.75	0.75	1	1	0	0.34
Mohana_UY	0	0	0.75	0.75	1	1	0	0.34
Mathura	0	0	0.75	0.75	1	1	0	0.34
Agra Poiyghat	0	0	0.75	0.75	1	1	0	0.34
Banas								
Chittorgarh	0	0	0.75	0.75	1	1	0	0.43
Bigod	0.22	0.22	0.75	0.75	1	1	0	0.44
Tonk	0.2	0.2	0.75	0.75	1	1	0	0.43
Kali sindh								
Salavad	0.26	0.26	0.75	0.75	1	1	0.25	0.45
Sarangpur	0	0	0.75	0.75	1	1	0	0.39
Aklera	0	0	0.75	0.75	1	1	0	0.34
Sangod	0	0	0.75	0.75	1	1	0	0.34
Chambal Upper								
Dhareri	0.34	0.34	0.75	0.75	1	1	0	0.47
tal	0.65	0.65	0.75	0.75	1	1	0	0.51
Ujjain	0	0	0.75	0.75	1	1	0	0.41
Mahidpur	0.12	0.12	0.75	0.75	1	1	0	0.41
Mandawara	0	0	0.75	0.75	1	1	0	0.38
Barod	0	0	0.75	0.75	1	1	0	0.38
Khatoli	0	0	0.75	0.75	1	1	0	0.34
Pali	0	0	0.75	0.75	1	1	0	0.34
Chambal Lower								
A. B. Road X-ing	0	0	0.75	0.75	1	1	0	0.34
Baranwada	0.24	0.24	0.75	0.75	1	1	0	0.42
Manderial	0	0	0.75	0.75	1	1	0	0.35
Dholpur	0	0	0.75	0.75	1	1	0	0.35
Lower Yamuna								
Pachauli	0.09	0.09	0.75	0.75	1	1	0	0.39
Seonda	0	0	0.75	0.75	1	1	0	0.39
Bhind	0	0	0.75	0.75	1	1	0	0.34
Udi	0	0	0.75	0.75	1	1	0	0.35
Etawah	0	0	0.75	0.75	1	1	0	0.36
Auraiya	0	0	0.75	0.75	1	1	0	0.34
Kalpi	0	0	0.75	0.75	1	1	0	0.34
Lalpur	0.29	0.29	0.75	0.75	1	1	0	0.44
Hamirpur	0	0	0.75	0.75	1	1	0	0.34
Shahjina	0	0	0.75	0.75	1	1	0	0.34
Basoda	0.04	0.04	0.75	0.75	1	1	0	0.37
Mohana_LY	0	0	0.75	0.75	1	1	0	0.35
Garrauli	0.22	0.22	0.75	0.75	1	1	0.25	0.46
Garhakota	0.14	0.14	0.75	0.75	1	1	0.62	0.45

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Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good / Good / Moderate / Poor / Worst								
Gaisabad	0.11	0.11	0.75	0.75	1	1	0	0.44
Madla	0.09	0.09	0.75	0.75	1	1	0	0.41
Banda	0.08	0.08	0.75	0.75	1	1	0	0.4
Rajapur	0	0	0.75	0.75	1	1	0	0.34
Gomati								
Neemsar	0.24	0.24	0.75	0.75	1	1	0	0.48
Lucknow	0.59	0.59	0.75	0.75	1	1	0.12	0.54
Jaunpur	0.21	0.21	0.75	0.75	1	1	0	0.44
Raibareli	0.3	0.3	0.75	0.75	1	1	0	0.46
Jalalpur	0.24	0.24	0.75	0.75	1	1	0.62	0.49
Sone								
Goverdheghat	0	0	0.75	0.75	1	1	0	0.34
Chopan	0.01	0.01	0.75	0.75	1	1	0	0.35
Duddhi	0	0	0.75	0.75	1	1	0	0.38
Ghaghra								
Tawaghat	1	1	0.75	0.75	1	1	0.75	0.67
Jauljibi	1	1	0.75	0.75	1	1	0.5	0.64
Ghat	0.47	0.47	0.75	0.75	1	1	0	0.47
Paliakalan	0	0	0.75	0.75	1	1	0	0.43
Elginbridge	0.04	0.04	0.75	0.75	1	1	0	0.44
Ayodhya	0	0	0.75	0.75	1	1	0	0.4
Bijalpur								
Gandak								
Basti	0.24	0.24	0.75	0.75	1	1	0	0.49
Bhinga	0	0	0.75	0.75	1	1	0	0.36
Balrampur	0	0	0.75	0.75	1	1	0	0.35
Kakrahi	0.25	0.25	0.75	0.75	1	1	0	0.46
Regauli	0.09	0.09	0.75	0.75	1	1	0	0.41
Birdghat	0.1	0.1	0.75	0.75	1	1	0	0.41
Turtipur	0	0	0.75	0.75	1	1	0	0.36
triveni	0.22	0.22	0.75	0.75	1	1	0	0.41
Dumariaghat	0.08	0.08	0.75	0.75	1	1	0	0.38
Lalganj	0.06	0.06	0.75	0.75	1	1	0	0.37
Gangajal								
Kosi								
Jainagar	0	0	0.75	0.75	1	1	0	0.34
Jhanjharpur	0	0	0.75	0.75	1	1	0	0.34

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Stream flow station	High flow (HF)	Highest monthly (HM)	Low flow (LF)	Lowest monthly (LM)	Persistently lower (PL)	Persistently very low (PVL)	Flood flow interval (FFI)	Flow health score (FH)
Very Good	Good		Moderate		Poor		Worst	
Lower Ganga								
Jamalpur	0	0	0.75	0.75	1	1	0	0.34
Ramchandipur	0	0	0.75	0.75	1	1	0	0.34
Ithara	0	0	0.75	0.75	1	1	0	0.34
Katesar	0	0	0.75	0.75	1	1	0	0.34
lalbegiaGhat	0.81	0.81	0.75	0.75	1	1	0	0.56
Sikandarpur	1	1	0.75	0.75	1	1	0.38	0.64
Sripalpur	0.02	0.02	0.75	0.75	1	1	0	0.39
Dheng Bridge	0	0	0.75	0.75	1	1	0	0.34
Benibad	0.14	0.14	0.75	0.75	1	1	0	0.41
Ekmighat	0.44	0.44	0.75	0.75	1	1	0	0.49
Hayaghat	0	0	0.75	0.75	1	1	0	0.34
Saulighat	0.03	0.03	0.75	0.75	1	1	0	0.39
Baltara	0.08	0.08	0.75	0.75	1	1	0	0.4
dhengraghat	0	0	0.75	0.75	1	1	0	0.34
Labha	0	0	0.75	0.75	1	1	0	0.34
Hanskhali	0	0	0.75	0.75	1	1	0	0.34
Kalna (Ebb)	0	0	0.75	0.75	1	1	0	0.36
Kalna (Flow)	0	0	0.75	0.75	1	1	0	0.36
Islampur	0.06	0.06	0.75	0.75	1	1	0	0.38
Palasipara	0.01	0.01	0.75	0.75	1	1	0	0.38
Chapra	0	0	0.75	0.75	1	1	0	0.36
Katwa	0.09	0.09	0.75	0.75	1	1	0	0.41
Bazarsau	0.71	0.71	0.75	0.75	1	1	0	0.52
Berhampore	0.43	0.43	0.75	0.75	1	1	0	0.46
GangbararJivpur	0	0	0.75	0.75	1	1	0	0.34
Birpur	0	0	0.75	0.75	1	1	0	0.34
Narainpur	0	0	0.75	0.75	1	1	0	0.34
Rudrapur	0	0	0.75	0.75	1	1	0	0.34
TolaBalaRai	0	0	0.75	0.75	1	1	0	0.34
Patna	0	0	0.75	0.75	1	1	0	0.34
HathidahBuzurg	0	0	0.75	0.75	1	1	0	0.34
Padma, Teesta and Jamuna								
Englishbazar	0	0	0.75	0.75	1	1	0	0.34
Rasalpur	0	0	0.75	0.75	1	1	0	0.34
Gangania	0	0	0.75	0.75	1	1	0	0.34
Bariarpur	0	0	0.75	0.75	1	1	0	0.34
Kamlakund	0	0	0.75	0.75	1	1	0	0.34
Mahespur	0	0	0.75	0.75	1	1	0	0.34
HR Farakka	0	0	0.75	0.75	1	1	0	0.34
Mirzapur	0	0	0.75	0.75	1	1	0	0.34

Table 5: Q_{95} and Q_{90} flows for four scenarios for 146 stations in Ganga Basin

Stream flow station	Q95				Q90			
	Virgin	Present	Future	Increased. Eff.	Virgin	Present	Future	Increased. Eff.
'Tuini (P)'	1.77	1.76	1.76	1.76	2.34	2.34	2.34	2.34
'Tuini (T)'	10.05	9.86	9.86	9.95	13.52	13.56	13.56	13.56
'Yashwant Nagar'	0.81	0.80	0.80	0.80	1.17	1.12	1.12	1.12
'Naugaon'	0.60	0.61	0.61	0.61	0.77	0.77	0.77	0.77
'Badrinath'	0.50	0.49	0.49	0.49	0.60	0.58	0.58	0.58
'Uttarkashi'	16.37	16.32	16.46	16.32	23.16	23.13	23.18	23.13
'Haripur'	0.11	0.08	0.08	0.08	0.16	0.12	0.12	0.12
'Bausan'	2.80	2.76	2.76	2.76	3.66	3.63	3.63	3.63
'Chandrapuri'	9.39	9.34	9.34	9.34	12.49	12.48	12.48	12.48
'Poanta'	22.50	20.50	18.41	20.74	28.13	26.77	24.94	27.01
'Joshimath'	15.69	15.70	15.70	15.70	19.85	19.68	19.68	19.68
'Tehri (Zero Point)'	27.58	27.52	27.69	27.52	35.80	35.74	35.63	35.74
'Rudraprayag_ Below Confluence'	67.50	69.62	69.53	71.65	90.03	92.68	92.67	92.67
'Karanprayag'	19.66	22.21	22.21	22.52	29.38	29.44	29.44	30.52
'Deoprayag A-1-Bhagirathi'	32.26	32.30	33.02	32.30	41.98	41.92	41.87	41.92
'Deoprayag Z-9-Ganga'	115.30	118.70	118.10	118.70	137.80	140.50	140.70	140.60
'Kalanaur'	21.51	0.00	0.00	0.00	26.81	0.00	0.00	0.00
'Rishikesh'	125.70	124.60	121.70	124.60	149.30	152.20	153.20	153.00
'Nandkeshri'	12.89	12.92	12.92	12.92	16.32	16.36	16.36	16.36
'Marora'	2.38	2.39	2.39	2.39	3.16	3.23	3.23	3.23
'Tawaghat'	14.88	14.86	14.86	14.86	18.88	18.84	18.84	18.84
'Karnal'	20.91	0.00	0.00	0.00	26.15	0.00	0.00	0.00
'Jauljibi'	28.36	26.86	26.86	27.61	36.80	37.01	37.01	38.29
'Ghat'	8.51	0.00	0.00	1.28	13.72	1.69	1.69	6.37
'Mawi'	20.38	0.00	0.00	0.00	25.82	0.00	0.00	0.00
'Galeta'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Baghpat'	19.39	0.00	0.00	0.00	25.61	0.00	0.00	0.00
'Moradabad'	3.25	0.00	0.00	0.00	7.18	0.00	0.00	0.00
‘Garmukhteswar	124.50	21.42	33.21	20.14	166.00	47.17	63.53	50.73
'Gangan'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Rampur'	0.00	0.00	0.00	0.00	0.56	0.00	0.00	0.00
'Delhi Rly. Bridge'	18.76	0.00	0.00	0.00	27.06	0.00	0.00	0.00
'Paliakalan'	63.69	1.84	0.23	8.04	87.58	17.61	2.03	45.87
'Bareilly'	4.85	0.00	0.00	0.00	12.55	0.00	0.00	0.00
'Mohana_UY'	16.97	0.00	0.00	0.00	25.27	0.00	0.00	0.00

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Stream flow station	Q95				Q90			
	Virgin	Present	Future	Increased. Eff.	Virgin	Present	Future	Increased. Eff.
'Kachlabridge'	117.60	4.29	3.87	6.65	161.10	21.50	29.20	27.32
'Bhinga'	6.81	0.00	0.00	0.00	12.17	0.00	0.00	0.00
'Mathura'	13.25	0.00	0.00	0.00	20.03	0.00	0.00	0.00
'Dabri'	4.09	0.00	0.00	0.00	10.51	0.00	0.00	0.00
'Balrampur'	6.42	0.00	0.00	0.00	11.22	0.00	0.00	0.00
'Fatehgarh'	115.80	0.00	0.00	0.00	171.30	0.00	2.73	2.30
'Triveni'	250.80	213.80	209.60	220.20	329.70	282.10	278.70	289.90
'Neemsar'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Agra Poiyghat'	10.84	0.00	0.00	0.00	18.00	0.00	0.00	0.00
'Bewar'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Kakrahi'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Elginbridge'	356.60	72.46	66.30	131.90	444.70	152.60	137.10	213.40
'Ankinghat'	171.90	0.00	0.00	0.00	230.10	0.00	0.01	0.10
'Lucknow'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Ayodhya'	359.50	44.64	38.72	80.90	438.80	108.90	89.15	176.10
'Etawah'	6.78	0.00	0.00	0.00	13.68	0.00	0.00	0.00
'Basti'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Dheng Bridge'	10.82	0.05	0.05	0.24	16.39	0.20	0.20	0.79
'Regauli'	5.35	0.00	0.00	0.00	12.46	0.00	0.00	0.00
'Birdghat'	6.37	0.00	0.00	0.00	12.79	0.00	0.00	0.00
'Lalbegia Ghat'	11.63	6.04	6.04	8.86	17.82	9.50	9.50	11.26
'Udi'	102.50	0.00	0.00	0.00	156.90	0.00	0.00	0.00
'Bhind'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Jainagar'	0.93	0.00	0.00	0.00	2.13	0.00	0.00	0.00
'Kanpur'	176.30	0.00	0.00	0.00	233.90	0.00	0.00	0.00
'Dholpur'	119.80	0.00	0.00	0.00	170.40	0.00	0.00	0.00
'Saulighat'	1.76	0.00	0.00	0.00	2.80	0.00	0.00	0.00
'Auraiya'	207.70	0.00	0.00	0.00	285.20	0.00	0.00	0.00
'Manderial'	125.40	0.00	0.00	0.00	179.40	0.00	0.00	0.00
'Tonk'	0.74	0.00	0.00	0.00	8.52	0.00	0.00	0.00
'Jhanjharpur'	3.28	0.00	0.00	0.00	5.61	0.00	0.00	0.00
'Lalpur'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Benibad'	0.59	0.00	0.00	0.00	1.12	0.00	0.00	0.00
'Raibareli'	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
'Sikandarpur'	12.57	58.82	58.82	58.91	22.41	61.48	61.48	61.57
'Ekmighat'	0.01	0.00	0.00	0.00	0.07	0.00	0.00	0.00
'Turtipur'	352.90	0.00	0.00	0.00	511.80	0.00	0.00	0.00

Table 5 continued to next page … … …

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Stream flow station	Q95				Q90			
	Virgin	Present	Future	Increased. Eff.	Virgin	Present	Future	Increased. Eff.
'Kalpi'	192.60	0.00	0.00	0.00	270.00	0.00	0.00	0.00
'Baranwada'	2.37	0.00	0.00	0.00	12.84	0.00	0.00	0.00
'Seonda'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Hayaghat'	19.51	0.00	0.00	0.00	25.79	0.00	0.00	0.00
'Bhitaura'	183.70	0.00	0.00	0.00	242.00	0.00	0.00	0.00
'Dumariaghat'	272.00	72.70	68.16	98.73	359.50	117.40	117.80	154.50
'Hamirpur'	182.90	0.00	0.00	0.00	262.60	0.00	0.00	0.00
'dhengra ghat'	24.98	0.00	0.00	0.00	33.51	0.00	0.00	0.00
'Shahjina'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Pali'	105.60	0.00	0.00	0.00	144.20	0.00	0.00	0.00
'Lalganj'	272.40	55.62	49.83	81.53	360.50	101.70	94.78	135.20
'Mohana_LY'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Rudrapur'	0.00	0.00	0.00	0.00	622.00	0.00	0.00	0.00
'Tola Bala Rai '	852.20	0.00	0.00	0.00	1504.00	0.00	0.00	0.00
'Khatoli'	19.85	0.00	0.00	0.00	27.65	0.00	0.00	0.00
'Jaunpur'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Gangajal'	876.60	0.00	0.00	0.00	1522.0	0.00	0.00	3.49
'Bijalpur'	172.00	0.00	0.00	0.00	626.70	0.00	0.00	0.00
'Patna '	1512.0	43.47	44.19	89.41	2254.0	97.10	88.75	167.90
'Jalalpur'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Baltara'	236.00	94.01	79.38	111.20	296.00	124.40	119.30	146.70
'Narainpur'	160.80	0.00	0.00	0.00	626.90	0.00	0.00	0.00
'Labha'	54.29	0.00	0.00	0.00	61.72	0.00	0.00	0.00
'Birpur'	148.60	0.00	0.00	0.00	627.00	0.00	0.00	0.00
'Jamalpur'	328.00	0.00	0.00	0.00	669.00	0.00	0.00	0.00
'Barod'	38.91	0.00	0.00	0.00	55.25	0.00	0.00	0.00
'Gangbarar Jivpur'	323.00	0.00	0.00	0.00	668.40	0.00	0.00	0.00
'Mandawara'	42.03	0.02	0.02	0.11	57.94	0.12	0.12	0.27
'Hathidah Buzurg'	1480.0	22.74	24.64	66.57	2225.0	71.41	57.97	145.10
'Sripalpur'	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
'Bigod'	5.11	0.00	0.00	0.00	9.08	0.00	0.00	0.00
'Mahespur'	1811.0	100.50	71.93	187.20	2574.0	187.70	174.70	305.50
'Rajapur'	127.00	0.00	0.00	0.00	237.40	0.00	0.00	0.00
'Rasalpur'	1485.0	6.87	7.73	44.31	2209.0	37.17	31.48	115.70
'Allahabad (Chatnag)'	507.10	0.00	0.00	0.00	708.40	0.00	0.00	0.00
'Bariarpur'	1568.0	2.78	2.11	25.93	2220.0	19.42	14.05	100.60
'Pratappur'	67.17	0.00	0.00	0.00	181.50	0.00	0.00	0.00

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Stream flow station	Q95				Q90			
	Virgin	Present	Future	Increased. Eff.	Virgin	Present	Future	Increased. Eff.
'Kamlakund'	1560.0	0.00	0.00	15.95	2215.0	10.55	7.40	85.05
'Gangania'	1572.0	1.62	1.14	24.96	2223.0	16.41	13.31	100.80
'Ramchandipur'	447.90	0.00	0.00	0.00	643.80	0.00	0.00	0.00
'Banda'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Katesar'	450.60	0.00	0.00	0.00	644.00	0.00	0.00	0.00
'Pachauli'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'HR Farakka'	1920.0	53.34	44.23	135.40	2719.0	133.70	118.20	251.40
'Ithara'	455.60	0.00	0.00	0.00	651.30	0.00	0.00	0.00
'Mirzapur'	456.10	0.00	0.00	0.00	646.10	0.00	0.00	0.00
'Englishbazar'	0.44	0.00	0.00	0.00	1.25	0.00	0.00	0.00
'Sangod'	14.66	0.00	0.00	0.00	20.02	0.00	0.00	0.00
'Chittorgarh'	1.16	0.00	0.00	0.00	1.88	0.00	0.00	0.00
'Garrauli'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Madla'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Chopan'	0.11	0.00	0.00	0.00	4.19	0.00	0.00	1.28
'Aklera'	10.44	0.00	0.00	0.00	14.59	0.00	0.00	0.00
'Salavad'	9.82	0.00	0.00	0.00	15.05	0.13	0.13	0.03
'A. B. Road X-ing'	7.82	0.00	0.00	0.00	12.73	0.00	0.00	0.00
'Islampur'	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
'Gaisabad'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Berhampore'	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00
'Duddhi'	0.00	0.30	0.30	0.31	0.00	0.35	0.35	0.35
'Bazarsau'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Palasipara'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Basoda'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Garhakota'	0.03	0.00	0.00	0.00	0.12	0.00	0.00	0.00
'Katwa'	0.54	0.00	0.00	0.00	2.26	0.00	0.00	0.00
'Goverdheghat'	0.54	0.00	0.00	0.00	2.79	0.00	0.00	0.00
'Chapra'	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
'Sarangpur'	2.49	0.00	0.00	0.00	3.96	0.00	0.00	0.00
'Tal'	5.93	0.00	0.00	0.00	8.43	0.00	0.00	0.00
'Mahidpur'	8.04	0.00	0.00	0.00	10.13	0.00	0.00	0.00
'Hanskhali'	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00
'Kalna (Ebb)'	0.27	0.00	0.00	0.00	1.94	0.00	0.00	0.00
'Kalna (Flow)'	0.27	0.00	0.00	0.00	1.94	0.00	0.00	0.00
'Ujjain'	3.80	0.00	0.00	0.00	5.38	0.00	0.00	0.00
'Dhareri'	1.43	0.00	0.00	0.00	2.38	0.00	0.00	0.00

Table 6: Q_{75} and Q_{50} flows for four scenarios for 146 stations in Ganga Basin

Stream flow station	Q_{75}				Q_{50}			
	Virgin	Present	Future	Increased. Eff.	Virgin	Present	Future	Increased. Eff.
'Tuini (P)'	5.90	5.91	5.91	5.91	22.49	22.80	22.80	22.80
'Tuini (T)'	23.74	23.98	23.98	23.98	57.59	57.55	57.55	57.55
'Yashwant Nagar'	3.00	3.05	3.05	3.05	18.12	17.68	17.68	17.68
'Naugaon'	2.09	2.09	2.09	2.09	7.91	7.91	7.91	7.91
'Badrinath'	1.23	1.21	1.21	1.21	8.30	8.28	8.28	8.28
'Uttarkashi'	44.80	44.86	44.90	44.86	158.60	157.40	157.00	157.90
'Haripur'	0.32	0.29	0.29	0.29	1.55	1.51	1.51	1.51
'Bausan'	9.22	9.20	9.20	9.20	34.01	34.16	34.16	34.16
'Chandrapuri'	21.08	21.06	21.06	21.06	46.08	46.03	46.03	46.03
'Poanta'	51.00	46.90	45.20	47.73	158.20	138.60	135.80	141.50
'Joshimath'	40.70	41.16	41.16	41.16	119.50	119.40	119.40	119.40
'Tehri (Zero Point)'	81.26	81.26	81.24	81.26	263.60	263.50	263.50	263.50
'Rudraprayag_Below Confluence'	152.00	147.50	147.40	151.50	347.50	341.80	341.80	344.50
'Karanprayag'	43.59	43.91	43.91	44.52	96.06	91.28	91.28	95.34
'Deoprayag A-1-Bhagirathi'	90.40	90.41	90.48	90.41	274.30	274.20	273.90	274.30
'Deoprayag Z-9-Ganga'	235.70	233.70	237.30	235.90	642.40	621.50	622.90	630.20
'Kalanaur'	50.35	0.00	0.00	0.00	154.50	18.71	16.39	19.47
'Rishikesh'	246.50	247.50	248.40	250.40	697.50	673.20	673.50	680.20
'Nandkeshri'	26.02	26.11	26.11	26.11	64.15	64.15	64.15	64.15
'Marora'	6.83	6.88	6.88	6.88	26.47	26.28	26.28	26.27
'Tawaghat'	33.42	33.39	33.39	33.39	70.15	70.16	70.16	70.16
'Karnal'	50.76	0.00	0.00	0.00	153.00	6.39	6.38	8.01
'Jauljibi'	68.47	63.02	63.02	66.63	135.20	128.40	128.40	132.70
'Ghat'	29.40	15.12	15.12	23.75	66.79	41.10	41.10	53.70
'Mawi'	50.73	0.00	0.00	0.00	152.50	4.27	4.27	6.95
'Galeta'	0.01	0.00	0.00	0.00	0.79	0.00	0.00	0.00
'Baghpat'	51.13	0.00	0.00	0.00	151.80	0.00	0.00	0.00
'Moradabad'	13.98	0.00	0.00	0.00	35.51	0.21	0.21	0.28
'Garmukhteswar	271.10	134.60	165.20	137.50	735.50	427.80	494.50	463.50

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Stream flow station	Q_{75}				Q_{50}			
	Virgin	Present	Future	Increased. Eff.	Virgin	Present	Future	Increased. Eff.
'Gangan'	0.21	0.00	0.00	0.00	2.15	0.00	0.00	0.00
'Rampur'	5.48	0.00	0.00	0.00	22.73	0.00	0.00	6.22
'Delhi Rly. Bridge'	53.25	0.00	0.00	0.00	150.80	0.00	0.00	0.00
'Paliakalan'	144.20	64.54	38.44	95.46	305.30	159.30	141.20	184.30
'Bareilly'	33.78	0.00	0.00	0.00	90.19	0.69	0.69	3.42
'Mohana_UY'	52.72	0.00	0.00	0.00	147.10	0.00	0.00	0.00
'Kachlabridge'	272.20	103.50	120.20	113.20	679.60	413.50	479.20	431.90
'Bhinga'	23.39	0.00	0.00	0.52	67.68	12.17	12.17	15.17
'Mathura'	48.52	0.00	0.00	0.00	139.20	0.00	0.00	0.00
'Dabri'	33.41	0.00	0.00	0.00	94.86	0.00	0.00	0.00
'Balrampur'	23.15	0.00	0.00	0.00	68.34	3.73	3.73	7.22
'Fatehgarh'	287.60	42.11	69.57	56.47	703.60	303.00	411.50	345.40
'Triveni'	607.10	498.70	494.20	522.30	1230.0	1046.0	1043.0	1051.00
'Neemsar'	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.00
'Agra Poiyghat'	46.22	0.00	0.00	0.00	133.70	0.00	0.00	0.00
'Bewar'	0.04	0.00	0.00	0.00	13.85	0.00	0.00	0.00
'Kakrahi'	0.06	0.00	0.00	0.00	2.23	0.00	0.00	0.00
'Elginbridge'	732.60	387.00	362.90	445.30	1459.0	950.40	943.10	1025.00
'Ankinghat'	387.60	17.86	49.21	31.97	942.00	252.80	377.50	287.70
'Lucknow'	0.00	0.00	0.00	0.00	1.37	0.00	0.00	0.00
'Ayodhya'	732.50	364.10	321.40	419.30	1480.0	922.90	904.00	1005.00
'Etawah'	48.43	0.00	0.00	0.00	149.40	0.00	0.00	0.00
'Basti'	0.18	0.00	0.00	0.00	4.68	0.00	0.00	0.00
'Dheng Bridge'	26.90	0.95	0.95	1.59	90.44	6.90	6.90	7.64
'Regauli'	32.23	0.00	0.00	0.00	108.20	0.00	0.00	0.00
'Birdghat'	35.35	0.00	0.00	0.00	115.20	0.00	0.00	0.00
'Lalbegia Ghat'	44.76	12.76	12.76	13.12	104.50	17.27	17.27	17.54
'Udi'	367.00	0.00	0.00	0.00	1019.0	0.00	0.00	0.00
'Bhind'	0.13	0.00	0.00	0.00	14.75	0.00	0.00	0.00
'Jainagar'	7.27	0.00	0.00	0.00	30.54	5.77	0.00	6.06
'Kanpur'	408.70	1.27	26.31	13.02	960.40	205.60	345.20	224.60
'Dholpur'	380.00	0.00	0.00	0.00	1043.0	0.00	0.00	0.00
'Saulighat'	7.80	0.00	0.00	0.00	37.58	0.00	0.00	0.00
'Auraiya'	523.40	0.00	0.00	0.00	1243.0	0.00	0.00	0.00

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Stream flow station	Q_{75}				Q_{50}			
	Virgin	Present	Future	Increased. Eff.	Virgin	Present	Future	Increased. Eff.
'Manderial'	384.70	0.00	0.00	0.00	1042.0	0.00	0.00	0.00
'Tonk'	36.22	0.00	0.00	0.00	130.40	0.01	0.01	0.02
'Jhanjharpur'	14.23	0.00	0.00	0.00	56.51	1.62	0.00	2.77
'Lalpur'	0.21	0.00	0.00	0.00	12.59	0.00	0.00	0.00
'Benibad'	3.41	0.00	0.00	0.00	16.72	0.00	0.00	0.00
'Raibareli'	1.86	0.00	0.00	0.00	16.63	0.00	0.00	0.00
'Sikandarpur'	57.46	69.74	69.74	70.51	139.90	84.90	84.90	85.94
'Ekmighat'	0.44	0.00	0.00	0.00	3.52	0.00	0.00	0.00
'Turtipur'	911.70	142.50	132.10	249.80	1764.0	1037.00	1050.00	1119.00
'Kalpi'	523.90	0.00	0.00	0.00	1263.0	0.00	0.00	0.00
'Baranwada'	50.89	0.00	0.00	0.00	176.50	0.00	0.00	0.00
'Seonda'	1.51	0.00	0.00	0.00	37.52	0.00	0.00	0.00
'Hayaghat'	47.81	0.00	0.00	0.00	166.30	0.00	0.00	0.20
'Bhitaura'	428.10	0.16	22.13	6.93	966.00	186.00	332.50	222.50
'Dumariaghat'	643.50	291.80	284.30	347.80	1231.0	834.90	841.50	886.40
'Hamirpur'	519.90	0.00	0.00	0.00	1289.0	0.00	0.00	0.00
'dhengra ghat'	68.64	0.00	0.00	0.00	256.70	2.02	0.52	2.99
'Shahjina'	0.74	0.00	0.00	0.00	78.37	0.00	0.00	0.00
'Pali'	284.10	0.00	0.00	0.00	720.00	0.00	0.00	0.00
'Lalganj'	643.20	251.60	248.20	317.30	1230.0	792.30	776.30	856.10
'Mohana_LY'	0.70	0.00	0.00	0.00	74.42	0.00	0.00	0.00
'Rudrapur'	1177.0	0.00	0.00	0.00	2492.0	0.00	0.00	0.00
'Tola Bala Rai '	2352.0	27.41	44.01	206.20	4229.0	1146.0	1244.0	1207.00
'Khatoli'	53.16	0.00	0.00	0.00	137.60	1.67	1.67	1.78
'Jaunpur'	4.11	0.00	0.00	0.00	45.12	0.00	0.00	0.00
'Gangajal'	2475.0	54.45	72.54	212.40	4612.0	1168.0	1277.0	1256.00
'Bijalpur'	1179.0	0.00	0.00	0.00	2543.0	0.00	0.00	0.00
'Patna '	3279.0	524.40	481.10	725.40	5704.0	1829.0	1938.0	1985.00
'Jalalpur'	1.62	0.00	0.00	0.00	30.30	0.00	0.00	0.00
'Baltara'	466.00	244.10	215.70	260.50	1129.0	617.60	596.70	638.00
'Narainpur'	1171.0	0.00	0.00	0.00	2481.0	0.00	0.00	0.00
'Labha'	127.50	0.00	0.00	0.00	404.00	1.21	0.92	3.69
'Birpur'	1133.0	0.00	0.00	0.00	2457.0	0.00	0.00	0.00

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Stream flow station	Q_{75}				Q_{50}			
	Virgin	Present	Future	Increased. Eff.	Virgin	Present	Future	Increased. Eff.
'Jamalpur'	1175.0	0.00	0.00	0.00	2446.0	0.00	1.10	0.00
'Barod'	100.50	0.00	0.00	0.00	259.70	0.00	0.00	0.00
'Gangbarar Jivpur'	1171.0	0.00	0.00	0.00	2457.0	0.00	0.76	0.00
'Mandawara'	105.90	0.89	0.89	1.35	282.80	4.65	4.65	5.90
'Hathidah Buzurg'	3292.0	476.00	436.80	707.90	5673.0	1787.0	1898.0	1951.00
'Sripalpur'	1.22	0.00	0.00	0.00	11.37	0.00	0.00	0.00
'Bigod'	22.02	0.00	0.00	0.00	60.60	0.00	0.00	0.00
'Mahespur'	3863.0	654.30	592.70	946.10	6906.0	2138.0	2152.0	2399.00
'Rajapur'	482.20	0.00	0.00	0.00	1564.00	0.00	0.00	0.00
'Rasalpur'	3328.0	454.70	406.80	656.60	5777.0	1820.0	1848.0	1909.00
'Allahabad (Chatnag)'	1106.0	0.00	0.00	0.00	2291.0	142.80	330.20	206.10
'Bariarpur'	3355.0	418.10	371.80	611.90	5873.0	1740.0	1805.0	1967.00
'Pratappur'	429.50	0.00	0.00	0.00	1558.0	0.00	0.00	0.00
'Kamlakund'	3347.0	396.60	387.60	594.90	5876.0	1716.0	1775.0	1932.00
'Gangania'	3358.0	414.10	367.90	616.20	5857.0	1740.0	1809.0	1966.00
'Ramchandipur'	1118.0	0.00	0.00	0.00	2370.0	2.30	11.30	3.19
'Banda'	0.07	0.00	0.00	0.00	61.63	0.00	0.00	0.00
'Katesar'	1122.0	0.00	0.00	0.00	2370.0	0.01	0.74	0.04
'Pachauli'	0.57	0.00	0.00	0.00	11.35	0.00	0.00	0.00
'HR Farakka'	3960.0	608.20	545.20	892.40	7360.0	2065.0	2104.0	2347.00
'Ithara'	1143.0	0.00	0.00	0.00	2370.0	40.90	211.10	139.70
'Mirzapur'	1129.0	0.00	0.00	0.00	2370.0	21.25	201.20	132.80
'Englishbazar'	6.91	0.00	0.00	0.00	40.62	0.00	0.00	0.00
'Sangod'	37.95	0.00	0.00	0.00	94.99	0.00	0.00	0.00
'Chittorgarh'	3.64	0.00	0.00	0.00	9.22	0.00	0.00	0.00
'Garrauli'	0.22	0.00	0.00	0.00	11.27	0.00	0.00	0.00
'Madla'	1.08	0.00	0.00	0.00	57.47	0.00	0.22	0.00
'Chopan'	52.18	114.80	61.73	219.90	296.60	259.90	249.50	270.60
'Aklera'	27.19	0.00	0.00	0.00	64.21	0.00	0.00	0.00
'Salavad'	29.85	3.87	3.87	3.19	75.42	16.88	16.88	14.85
'A. B. Road X-ing'	23.30	0.00	0.00	0.00	57.40	0.39	0.39	1.07
'Islampur'	0.05	0.00	0.00	0.00	0.56	0.00	0.00	0.00

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Stream flow station	Q_{75}				Q_{50}			
	Virgin	Present	Future	Increased. Eff.	Virgin	Present	Future	Increased. Eff.
'Gaisabad'	0.07	0.00	0.00	0.00	17.90	0.33	0.33	0.33
'Berhampore'	2.90	0.00	0.00	0.00	19.13	0.00	0.00	0.00
'Duddhi'	1.08	0.51	0.51	0.52	30.18	1.06	1.06	1.33
'Bazarsau'	0.01	0.00	0.00	0.00	0.38	0.40	0.40	0.52
'Palasipara'	0.42	0.00	0.00	0.00	5.32	0.00	0.00	0.00
'Basoda'	1.37	0.00	0.00	0.00	27.16	0.00	0.00	0.00
'Garhakota'	0.66	0.00	0.00	0.00	8.07	0.00	0.00	0.00
'Katwa'	14.60	0.00	0.00	0.00	98.63	0.00	0.00	0.34
'Goverdheghat'	19.97	0.00	0.00	0.00	93.24	3.84	3.84	7.69
'Chapra'	0.46	0.00	0.00	0.00	6.77	0.00	0.00	0.00
'Sarangpur'	8.40	0.09	0.09	0.17	24.93	1.60	1.60	1.93
'Tal'	15.15	0.32	0.32	0.61	37.77	4.73	4.73	5.67
'Mahidpur'	18.31	0.01	0.01	0.07	45.28	3.35	3.35	3.72
'Hanskhali'	0.09	0.00	0.00	0.00	1.10	0.00	0.00	0.00
'Kalna (Ebb)'	18.70	0.00	0.00	0.00	123.40	0.00	0.00	0.00
'Kalna (Flow)'	18.70	0.00	0.00	0.00	123.40	0.00	0.00	0.00
'Ujjain'	9.60	0.00	0.00	0.00	20.85	0.00	0.00	0.00
'Dhareri'	4.98	0.00	0.00	0.00	13.20	0.00	0.00	0.00

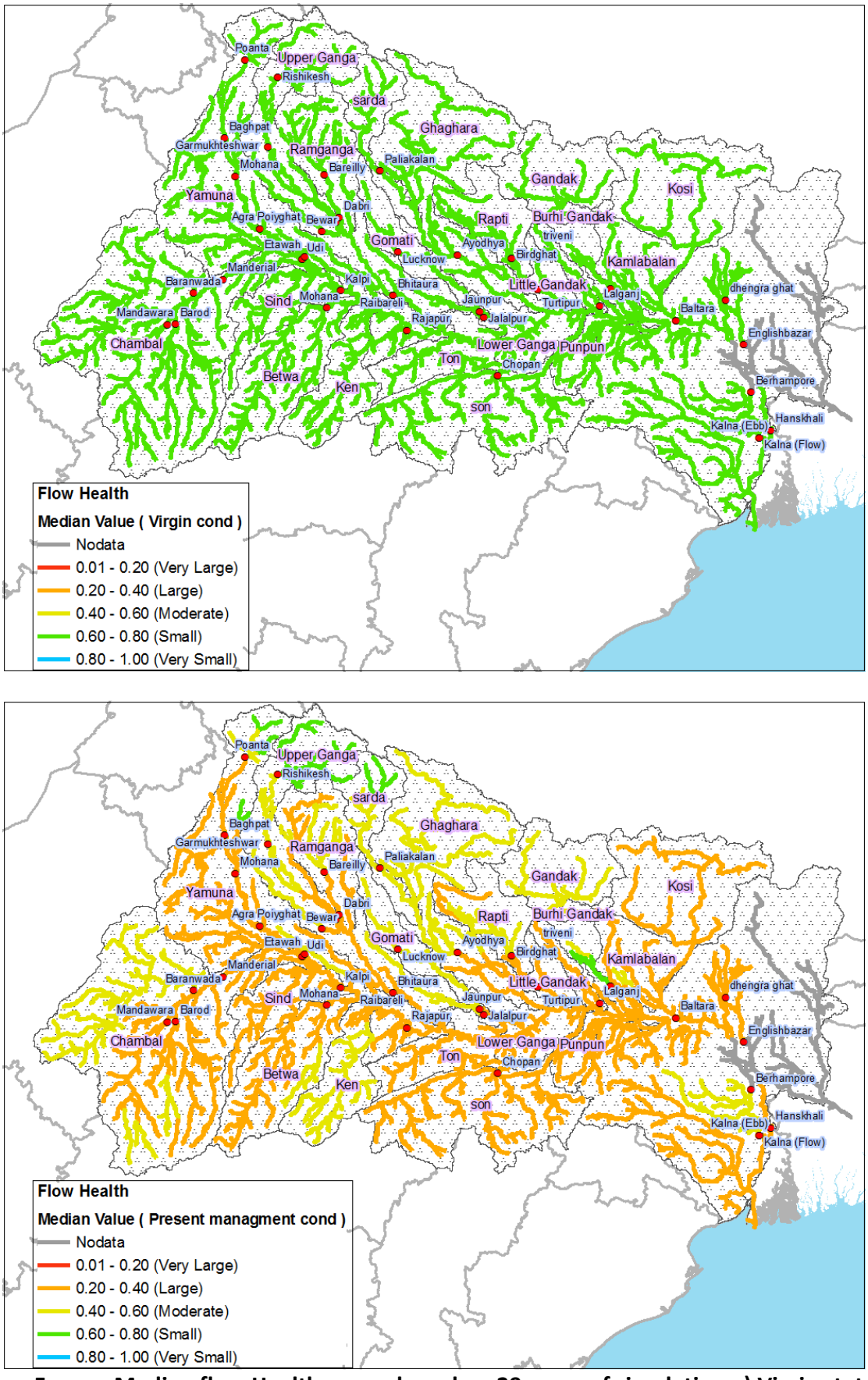
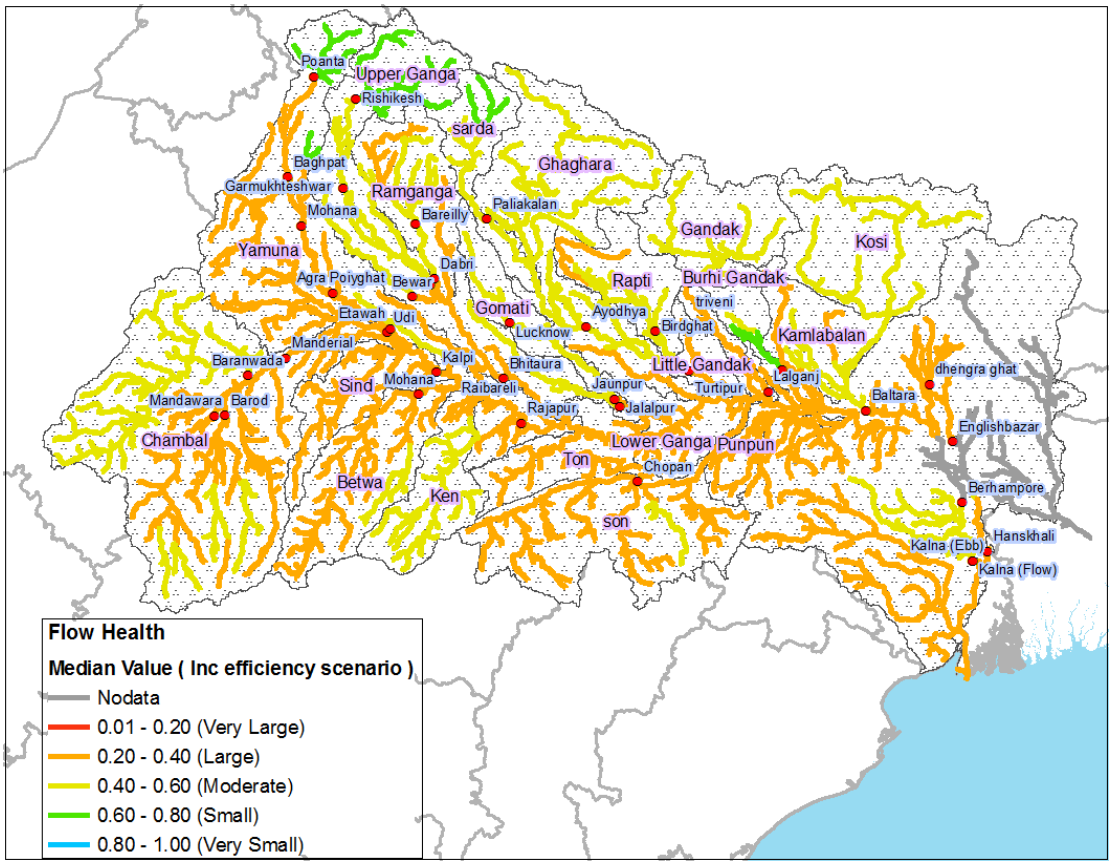


Figure 5: Median flow Health scores based on 29 years of simulation a) Virgin state and b) current state of management



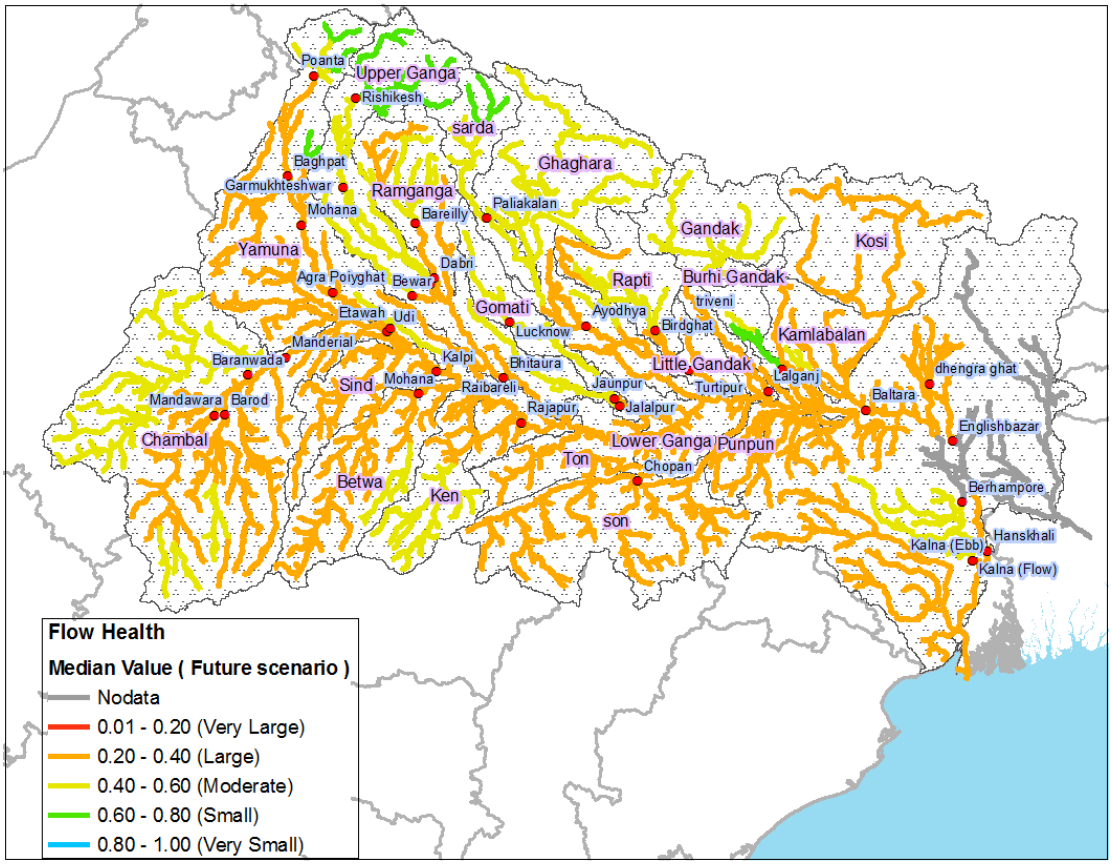


Figure 6 : Median flow Health scores based on 29 years of simulation a) Increase irrigation efficiency scenario and b) Implementation of future projects

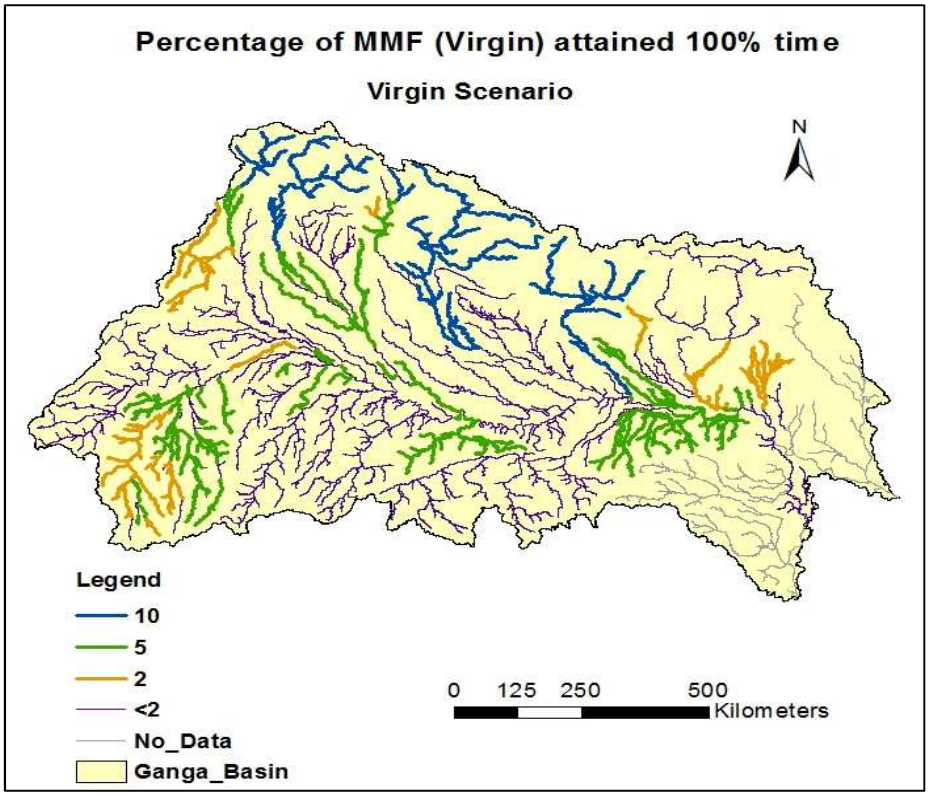


Figure 7: **Percentages of MMF attained 100% time on monthly basis-Virgin Scenario**

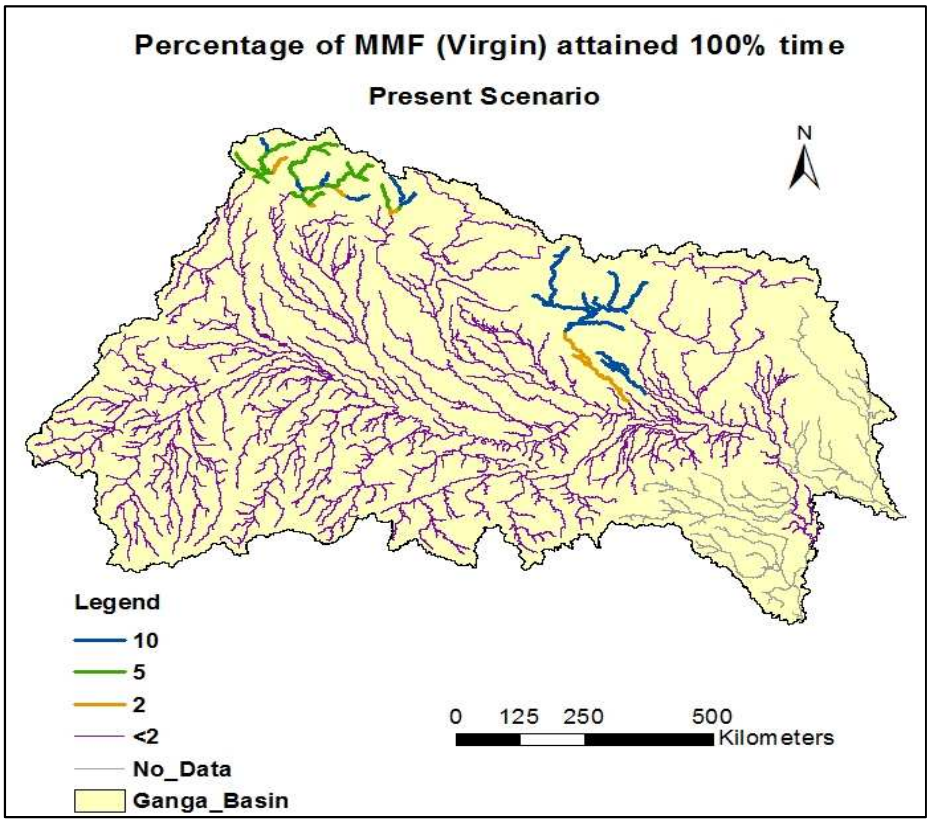


Figure 8: **Percentages of MMF attained 100% time on monthly basis-Present Scenario**

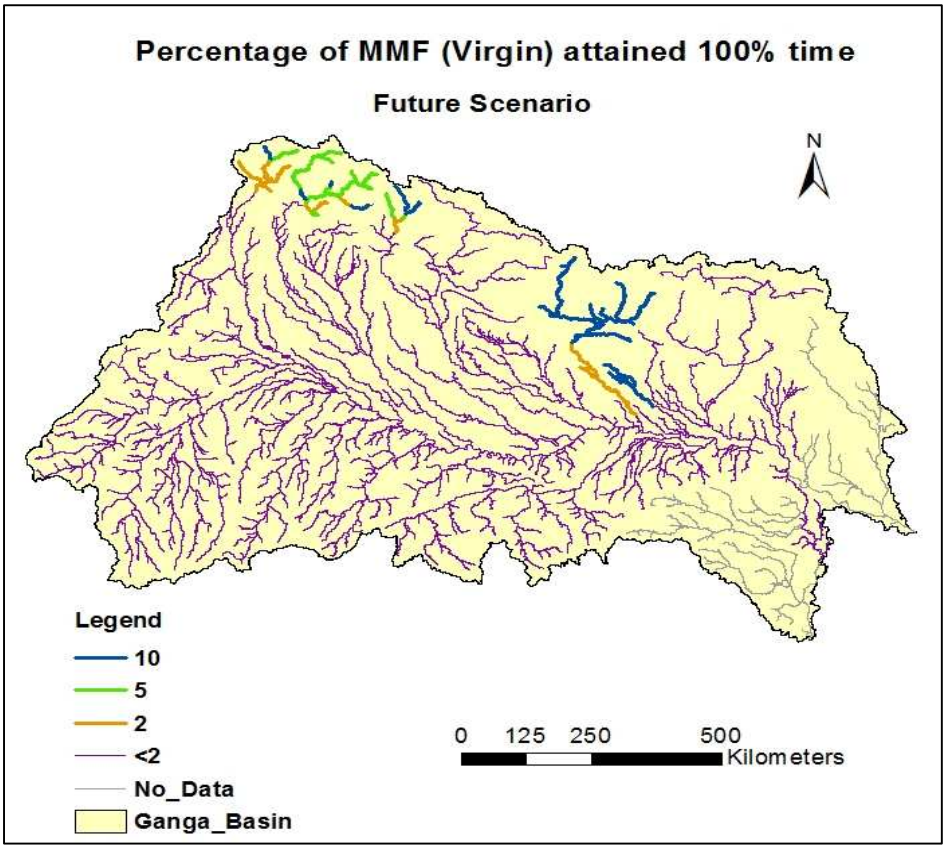


Figure 9: **Percentages of MMF attained 100% time on monthly basis-Future Scenario**

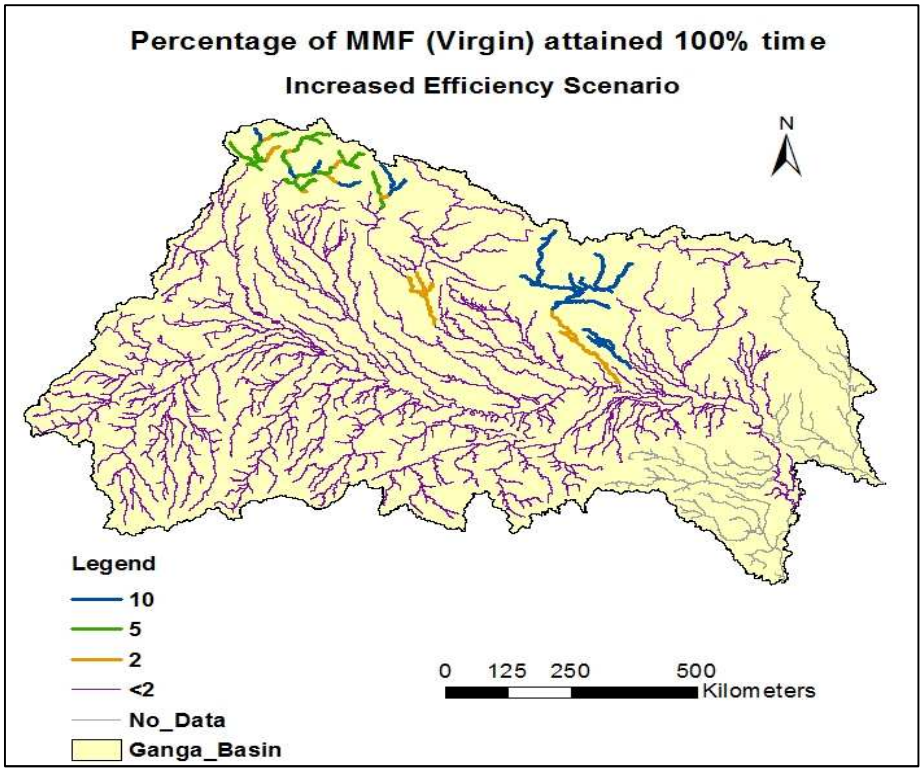


Figure 10: **Percentages of MMF attained 100% time on monthly basis-Increased Irrigation efficiency Scenario**

7. Recommendations

1. Based on the hydrologic flow health analysis, the health of the river in terms of low flows at the main stem of the river is mostly moderate to good. Hence, the problems in terms of water quality during the low flows are not due to hydrologic conditions, but are due to overloading of pollutants beyond the assimilation capacity of the river. Therefore the water quality problems in Ganga cannot be addressed by improving the low flow conditions only beyond the current levels. The water quality problems should be addressed by reducing the pollution loading.
2. Low flows (for example Q_{90}) are seen to be less violated in Upper Ganga Basin up to Rishikesh and in Upper Yamuna Basin up to Poanta. Middle to lower Ganga region ranging from Garhmukteshwar to upstream of Farakka Barrage shows considerable variations in Q_{90} compared with Virgin conditions. Lower Chambal and Lower Yamuna region also show similar trend but with comparatively smaller differences. These reduced low flows show the altered river hydrology and so the river health. More detailed investigation of these reduces low flows will provide a way forward to find its causes and solutions. Flow Duration Curves testimony the above mentioned observations.
3. The hydrologic flow health during high flows is affected significantly and is poor in few stretches across the basin, especially from Gomukteshwar to Fategarh in Upper Ganga and from Mohana to Etawah in Middle Yamuna. This can have an effect on the in stream ecology (flora and fauna) and geomorphology. Therefore, it is recommended that the present diversions upstream of these stretches may be reduced to the extent possible in order to improve the river health.
4. The hydrologic flow health during high flows is moderate at present in several stretches across the basin. For e.g. the flow health is only moderate in the stretch between Bhitaura to Allahabad on Ganga. Also the flow health in entire Chambal, Sind Gomati and Gandak basins is moderate. Therefore, we recommend no more additional diversions of water in the upstream stretches in order to maintain the flow health at the moderate level. For example, further diversions of water in Ganga basin upto Allahabad could impair the river health.

5. The hydrologic flow health in the rest of the stretches is good especially upstream of Rishikesh, Kosi and Sone basins. However, any further diversions in these basins could have a cascading effect on the main steam of Ganga at Allahabad and downstream. Hence, we recommend thorough scientific investigations to be carried out before permitting any further development in these basins.
6. Mean Monthly flows analysis suggested that considerable variation in flow regime has occurred from virgin to present situation. This study also suggests that, hydrological indices suggested and used worldwide as minimum flow requirements needs to be tested thoroughly and cannot be simply accepted as thumb rules for Ganga River basin. Just like '% of MAF' test '% of MMF' test also fails even under Virgin conditions. In this situation, instead of suggesting unique percentage of MMF for whole basin, distributed suitable percentages can be suggested for different sub-basins.
7. While finalizing the habitat based E-flow requirement for different stretches, we propose that one may check the hydrological flow health along different stretches and see if it is at least 0.6 or higher.
    a. Even with the recommended level of habitat based E-flow, if the hydrological flow health score falls below 0.6, then we need to make interventions on the diversions upstream to augment this flow further to achieve a hydrological flow health target of at least 0.6. This higher flow to maintain the hydrological flow health could be the recommended E-flow. Prescription of this higher flow will not be detrimental to the ecosystem or the geomorphology.
    b. On the other hand, if the recommended level of habitat based E-flow itself achieves a hydrological flow health score of 0.6 or higher, then the same flows could be used as the recommended E-flow.

Note: The hydrologic modeling and flow health analysis carried out here are indicative of only the overall flow conditions in stretches. However, there could be some localized conditions such as immediately downstream of the run of the river projects where the flow conditions may not be adequate, however further downstream, it may become normal due to return flows of water used in the power production. Longitudinal and lateral connective of the river along such local stretches should be thoroughly investigated even though the overall flow health in these stretches may appear good.

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